LITHUANIAN ENERGY INSTITUTE

ANNUAL REPORT 2013

LITHUANIAN ENERGY INSTITUTE in 2013

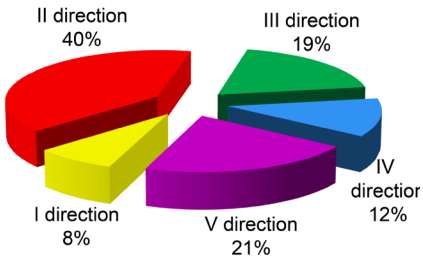
*Participants of anniversary conference **CYSENI 2013** organized by Lithuanian Energy Institute*

MISSION OF THE INSTITUTE

Perform research and develop innovative technologies in the fields of energy engineering, thermal engineering, measurement engineering, material science and economics, conduct fundamental and applied research, participate in studies' processes, apply the results of applied research to industry and business, as well as provide consultations to the 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 RESEARCH ACTIVITY OF THE INSTITUTE

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



Distribution of researchers according to the research directions

THE OBJECTIVES OF THE INSTITUTE:

- perform permanent fundamental and applied research at international level, experimental development activities, which is a must for sustainable development of Lithuanian energy and other Lithuanian economy branches and for the integration to the European energy systems and European Research Area;
- while cooperating with business, governmental and public subjects, transfer scientific knowledge to technically and commercially beneficial processes and facilities, ensuring the development of innovative energy technologies, cost-effectiveness and safety of energy objects and systems, efficient use of energy resources, reduction of environmental pollution and deceleration of global warming;
- provide accessible state-of-the-art scientific information to the society, promote the Lithuanian economy development based on innovations and knowledge;
- actively participate in the EU programmes and international projects, co-operate with other world research centres.

STRATEGIC OBJECTIVES

1. The establishment of the *National Open Access Scientific Center for Future Energy Technologies*;
2. The development of research, education and business co-operation;
3. To train top quality specialists able to deal with energy issues;
4. To maintain and develop the experimental basis.

*Dr. Dainius Pavalkis, the Minister of Education and Science of the Republic of Lithuania, paid visit to the **National Open Access Center for Future Energy Technologies** (at LEI)*

MEMBERSHIP AND COOPERATION WITH NATIONAL AND INTERNATIONAL ORGANIZATIONS

LEI belongs to the following associations:

Nuclear Energy Association **(BEA),** Lithuanian Electricity Association **(LEEA),** Lithuanian Energy Consultants Association **(LEKA),** Engineering Industries Association of Lithuania **(LINPRA),** Lithuanian Research Library Consortium **(LMBA),** Confederation of Lithuanian Industrialists **(LPK),** Lithuanian Thermotechnical Engineers Association **(LIŠTIA),** National Space Association of Lithuania, Lithuanian Gas Association **(DŪA),** Association for Energy Economics, Building Product Testing Laboratory Association **(SPBL),** Hydrogen Energy Association, European Technical Support Organisations Network **(ETSON)**, European Network of Freshwater Research Organisations **(EurAqua)**, The European Association of National Metrology Institutes **(EURAMET)**, Euro-Asian Cooperation of National Metrological Institutions **(COOMET)**, European Nuclear Safety Training and Tutoring Institute **(ENSTTI)**, International Energy Agency Hydrogen 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 technology platforms: Sustainable Nuclear Energy Technology Platform **(SNETP)** and Implementing Geological Disposal of Radioactive Waste Technology Platform **(IGD-TP)** and national technological platforms of Hydrogen and fuel cells **(H2/FC)**, Future production, National heat energy, National biomass and biofuel production and employment.

YEAR 2013 WAS FILLED WITH SIGNIFICANT EVENTS AND VISITS

In *January*, member of the EU Parliament Mr. Zigmantas Balčytis visited the Institute. He had a direct opportunity to get acquainted with the establishments of the Institute, available experimental base and activities. Meeting of ETSON (European Technical Safety Organisation Network) members also took place at the Institute. The State Patent Bureau of the Republic

of Lithuania on the 25th of January, 2013 issued LR patent No. 5895 *Method of hydrogen extraction from water* (founders – Dr. Darius Milčius and Dr. Liudas Pranevičius) to Lithuanian Energy Institute and Vytautas Magnus University.

Representatives from FP7 project SARNET2 visited the Institute in *February*.

In *March* the Institute was visited by the representatives from the Ministry of Education and Science of the Republic of Lithuania, representative of Physical-Technical Institute of the National Academy of Sciences of Belarus.

Young researchers of the Institute actively participated in the *Career Days* organized by Kaunas University of Technology, where they presented to the students the activities, studies and job opportunities at Lithuanian Energy Institute.

In *April* a great number of students from École Polytechnique Fédérale de Lausanne (Switzerland) visited the Institute. Employees of the Institute were granted rewards: Dr. Habil. Algirdas Kaliatka was granted the award of Algirdas Žukauskas (thermal physic and energy); Prof. Dr. Habil. Vaclovas Miškinis was granted the *Sign of Honour of Lithuanian Energy Men*; Dr. Arvydas Galinis was granted an honorable gratitude from the Prime Minister of the Republic of Lithuania and the Chairman of the Seimas of the Republic of Lithuania; Dr. Egidijus Urbonavičius was granted an honorable gratitude from the Prime Minister of the Republic of Lithuania. The FameLab International competition semi-final was organized by the British Council in the same month at the Institute.

LEI director Eugenijus Ušpuras at joint ***FISA and EURADWASTE 2013 conference***

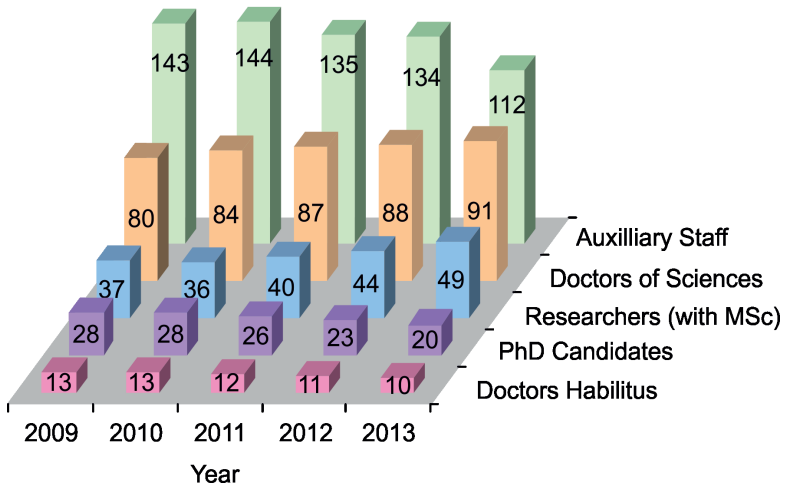
In *May* the Minister of Education and Science of the Republic of Lithuania Dr. Dainius Pavalkis also visited the Institute. FP7 project FIBCEM meeting took place as well as Seventh Framework Programme projects' preparation and administration training courses, which were organized by the colleagues from Estonia, Italy and Germany. In May, the last week, the anniversary **10th international conference CYSENI 2013** took place, where the lecture was given by professor Raymond Viskanta (Purdue University, USA), who also granted nominal awards to young researchers of the Institute.

In *June* Prof. Brunonas Gailiušis was granted the gratitude from the Klaipeda State Seaport Authority.

Year 2013 were exceptional due to Lithuanian Presidency of the Council of the European Union. It should be mentioned that the employees of the Institute not only participated in the events but also greatly contributed to organizing them.

In *July* a conference ***Science role in ensuring energy security: challenges and solutions in the Baltic region and behind its borders*** took place, where Prof. Dr. Habil. Eugenijus Ušpuras gave the presentation *Lithuanian Research Activities in Energy Security*.

In *August* the Institute was visited by the representatives from Brandenburg Economic Development Board and TSB In-



Variation of staff number

novationsagentur Berlin GmbH (Germany). For the first time ETSON JSP summer workshop was organized at the Institute.

In *September* the Institute was visited by GE-Hitachi Nuclear Energy representative Mr. Ziemowit Iwanski. Young researchers participated in science festival **Spaceship *Earth*** and **Researcher's Night 2013.**

In *October* the following guests visited the Institute: Prof. Pavel Krukovskyi from Engineering Thermal Physics Institute (Ukraine), Prof. V. Volkov from Oil Chemistry and Synthesis Institute (Russia), Prof. S. Leonovich from the Belarusian National Technical University, Prof. K. Dobrego from the Belarus A. V. Luikov Heat and Mass Transfer Institute, Norwegian Scientific Council special adviser Dr. Dag Høvik.

Joint **FISA and EURADWASTE 2013 conferences** took place in the same month. This was a special joined conference on research and training in reactor systems as well as radioactive waste management. Institute's researchers greatly contributed to organizing the conference.

In *November* deputy director Dr. Gunta Šlichta from Latvian Physical Energy Institute and the representatives from Norwegian company *Thor Energy* visited the Institute. As each year completed state funded projects were defended at the Institute.

In *December* the representative from Napier University (UK) Dr. Elene Prokofieva and researchers from Ukraine National Academy of Sciences Gas Institute visited the Institute.

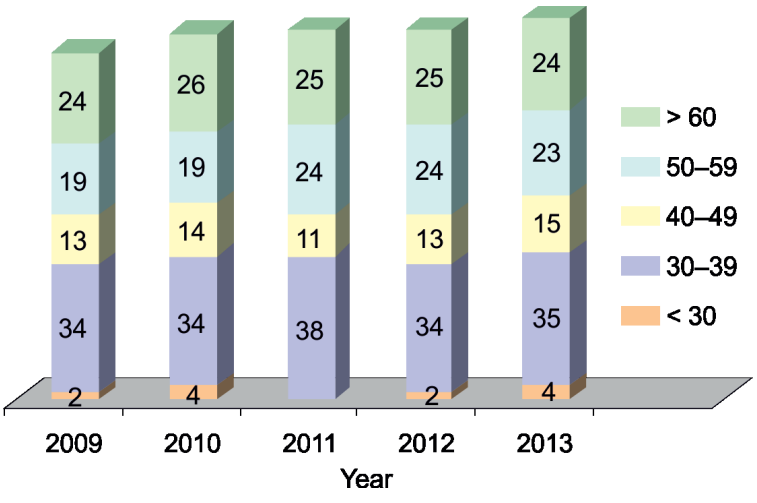
LEI was granted a silver medal in the competition ***Lithuanian product of the year 2013***, organized by Lithuanian Confederation of Industrialists for the developed service *Identification of thermal isolated tube thermal conduction.*

*The president of the Lithuanian Confederation of Industrialists R. Dagys and the Prime Minister of the Republic of Lithuania granted the award **Lithuanian product of the year 2013** to Dr. J. Čėsnienė*

On the 30th of December, 2013 under the **Decree No. 1K-1686 of the President of the Republic of Lithuania** *Regarding award with the sign of memory* – Director of the Institute Prof. Dr. Habil. **Eugenijus UŠPURAS** was granted the sign of Memory for personal input in contributing to the Lithuanian Presidency of the Council of the European Union in 2013.

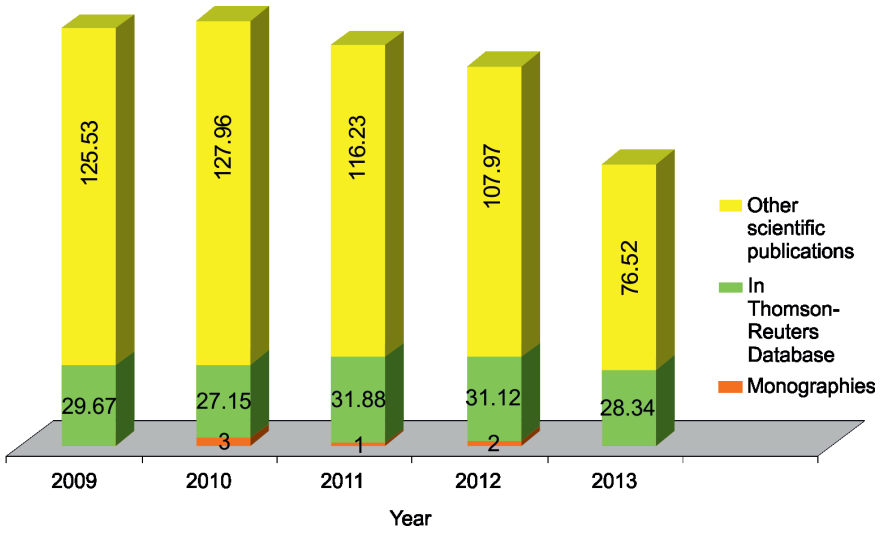
Lithuanian Energy Institute a great deal of attention devoted to educational activities. This is also revealed by a great number of visits of students, pupils and other interested persons who visited the Institute laboratories.

The Institute may be proud of high achievements in the Seventh Framework Programme. LEI participated in submitting 64 proposals (EURATOM-LEI is a special project of thermonuclear fusion associations), out of which 38 passed the threshold (~59.4%), 23 projects were to be financed (~35.9%).



Dynamics of age of scientists

In 2013, the Institute together with partners submitted 12 proposals, out of which 10 passed the threshold and 8 proposals were to be financed. It should be emphasized that besides the Seventh Framework Programme, researchers of the Institute implement projects of such programmes as Intelligent Energy-Europe, the Baltic Sea Region 2007–2013, South Baltic Cross-border Cooperation 2007–2013, Lithuania-Latvia Cross-border Cooperation programme, IAEA, COST, and EUREKA.



Variation of publication number (authors' contribution evaluated)

VALLEY *SANTAKA*

On the 31st of October, 2013 the agreement was signed with Kaunas University of Technology and Lithuanian University of Health Sciences regarding cooperation in implementing valley *Santaka* further development programme and the foreseen task – to provide favourable conditions for cooperation of business enterprises and science institutions, to promote transfer of new technologies and implementation of innovations.

Main objective of the project implemented by the Institute – to establish a **National Open Access Center for Future Energy Technologies**, purchasing the most essential experimental equipment and numerical analysis software. The activity of the center was registered on 8 March 2013. The main objective of the center – become the European level scientific research and experimental development center, cooperating with business, education and science institutions, conducting fundamental and applied research.

During project implementation in the period 2010–2013 22.5 million Litas from EU and Republic of Lithuania budget assets were applied, i.e. 67 pcs of experimental facility and 49 pcs of software codes were purchased. The purchased equipment enabled to update the research base in 10 research subdivisions of the Institute, out of which two are target research centers: Center for Hydrogen Energy Technologies and Alternative and Renewable Energy Centre; the centers were provided with newest worldwide level experimental and numerical facility.

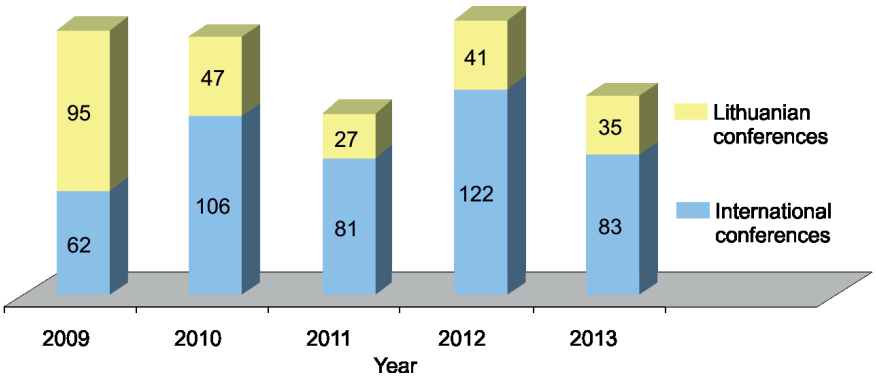
Over hundred representatives from Lithuanian and foreign science, studies and business institutions as well as society have already visited national open access Alternative and Renewable Energy Centre. Visitors are admired with infrastructure and conducted research and quality of studies of Center for Hydrogen Energy Technologies. Every day one can meet students from Kaunas University of Technology and Vytautas Magnus University at the Center for Hydrogen Energy Technologies conducting laboratory works and research.

In 2013 a young researcher from Serbia, the Vinča Institute of Nuclear Sciences from Belgrad made his traineeship at Center for Hydrogen Energy Technologies. In this center 4 technologies have been developed and defended by patents in the field of hydrogen energy and storage. MITA support was received to establish "spin-off" company – JSC *Inovatas*.

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** (project duration 2012–2016), project leader Prof. Dr. Habil. Povilas Poškas.
2. **Research on environmental impact and efficient use of renewable energy sources for energy production** (project duration 2012–2016), project leader Prof. Dr. Habil. Vladislovas Katinas.
3. **Scientific research of safety important processes in nuclear and thermal-nuclear equipment** (project duration 2012–2016), project leader Prof. Dr. Habil. Eugenijus Ušpuras.
4. **Experimental and numerical research of combustion and plasma processes for improvement of energy generation technologies from renewable biofuel and reduction of environmental pollution** (project



Number of papers in scientific conferences

duration 2012–2016), project leaders – Dr. Nerijus Striūgas, Dr. Vitas Valinčius.

5. **Economy and sustainability analysis of energy sector** (project duration 2012–2016), project leader Prof. Dr. Habil. Vaclovas Miškinis.
6. **Investigation of single-phase and two-phase flow dynamics, heat and mass transfer processes** (project duration 2012–2016), project leader Dr. Robertas Poškas.

In 2013, 13 state funded projects were implemented and 3 of them had been completed and defended, namely:

1. **Impact of modifying additives and nano-fillers on the structure and properties of constructional composite materials** (project leader Dr. I. Lukošiūtė).
2. **Experimental and theoretical research of combustion and gasification processes for wider use of renewable fuel sources and pollution reduction** (project leaders Dr. N. Striūgas and Dr. A. Džiugys).
3. **Assessment of regions' energy sustainable development implementation measures from technological, economical and social aspects** (project leader Dr. V. Kveselis).

INTERNATIONAL PROJECTS

In 2013, **32** international programme projects were conducted, out of which **1**6 projects are of the 7th Framework Programme:

1. ***European Fusion Development Agreement*** (EURATOM-LEI association). Lithuanian representative – E. Ušpuras.
2. ***Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology***, ***SARNET2.*** Institute's representative – A. Kaliatka.
3. ***MATerials TEsting and Rules (MATTER)***. Institute's representative – G. Dundulis.
4. ***Fate of Repository Gases, FORGE***. Institute's representative – P. Poškas.
5. ***New Member States Linking for an Advanced Cohesion in Euratom Research, NEWLANCER***. Institute's representative – A. Šmaižys.
6. ***Proposal for a harmonized European methodology for the safety assessment of innovative reactors with fast neutron spectrum planned to be built in Europe, SARGEN_IV***. Institute's representative – A. Kaliatka.
7. ***Sustainable network of Independent Technical Expertise for radioactive waste disposal, SITEX***. Institute's representative – A. Narkūnienė.
8. ***Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement Based Environmentally Friendly Sandwich Material for Building Applications, FIBCEM***. Institute's representative – J. Česnienė.
9. ***Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations (DEMI***). Institute's representative – R. Škėma.
10. ***Advanced Multiphysics Simulation Technologies (AMST***). Institute's representative – A. Džiugys.
11. ***Code for European Severe Accident Management, CESAM***. Institute's representative – V. Vileiniškis.
12. ***CArbon-14 Source Term, CAST***. Institute's representative – P. Poškas.
13. ***Advanced Safety Assessment: Extended PAS, ASAMPSA_E.*** Institute's representative – R. Alzbutas.
14. ***Building a platform for enhanced societal research related to nuclear energy in Central and Eastern Europe, PLATENSO***. Institute's representative – P. Poškas.
15. ***Nuclear Cogeneration Industrial Initiative – Research and Development Coordination, NC2I-R***. Institute's representative – S. Rimkevičius.
16. ***Assessment of Regional Capabilities for new reactors Development through an Integrated Approach, ARCADIA***. Institute's representative – E. Urbonavičius.

EUROPEAN RESEARCH AREA

In 2007–2013 LEI researchers successfully implemented the following international programme projects:

- The 6th Framework Programme – 12;
- The 7th Framework Programme – 23;
- Intelligent Energy Europe – 28;
- IAEA – 10;
- COST – 11;
- EUREKA – 3;
- Nordic Energy Research Programme – 2;
- Baltic Sea Region 2007–2013 – 3;
- South Baltic Cross-border Cooperation programme 2007–2013 – 1;
- Lithuania-Latvia Cross-border Cooperation programme – 1;
- Leonardo da Vinci – 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.

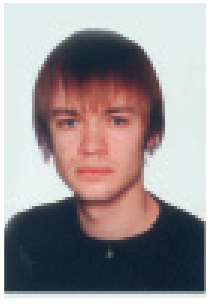
In the period 1992–2013 PhD studies were completed by 88 PhD students (out of 101), the dissertations were defended by 58. In 2013 6 PhD students were accepted to the studies, thus, total 20 PhD students studied.

In 2013 the following PhD theses were defended:

- 8 January. – Investigation of Efficient *Use of Biofuel for Sustainable Development of Energy Sector* (06T) **Eugenija Farida Dzenajavičienė** (Laboratory of Regional Energy Development). Scientific supervisor – Dr. V. Kveselis;
- 21 January. – *Changes of Water Balance Elements of the Curonian Lagoon and their Forecast Due to Anthropogenic and Natural Factors* (04T) **Darius Jakimavičius** (Laboratory of Hydrology). Scientific supervisor Dr. J. Kriaučiūnienė;
- 28 June – *Investigation of Heat Transfer from the Inclined Flat Surface to the Two-phase Foam Flow* (06T) **Martynas Gylys** (Laboratory of Nuclear Installation Safety). Scientific supervisor – Prof. Dr. T. Ždankus;
- 25 October – *Research on Numerical Solution of Markov Chain Reliability Models of Power Systems* (Physical Sciences, Informatics (09P) **Mindaugas Šnipas** (Laboratory of Systems Control and Automation). Scientific supervisor – Assoc. Prof. Dr. E. Valakevičius;
- 22 November. – *The Numerical Study of Aerosol and Radionuclide Transport in the Containments of Nuclear Power Plants* (06T) **Aurimas Kontautas** (Laboratory of Nuclear Installation Safety). Scientific supervisor – Dr. E. Urbonavičius;
- 6 December. – *Modelling the Impact of Changes in Energy Supply on the National Economy* (04S) **Vidas Lekavičius** (Laboratory of Energy Systems Research). Scientific supervisor – Dr. A. Galinis;

Dr. E.F. Dzenajavičienė

Dr. D. Jakimavičius



Dr. M. Gylys

Dr. M. Šnipas

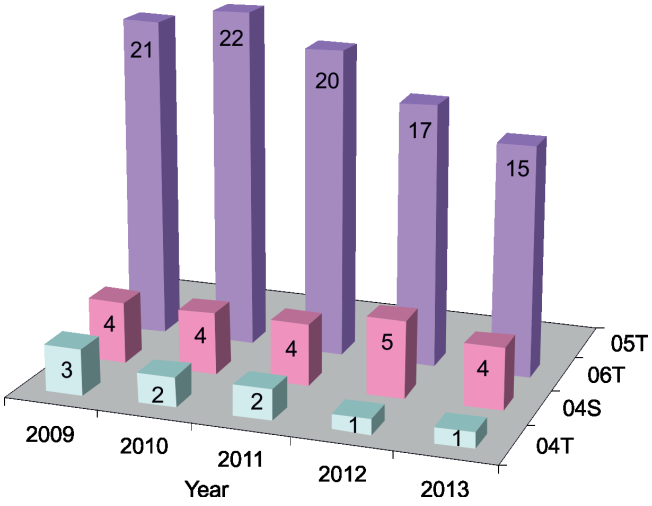
Dr. A. Kontautas

Dr. V. Lekavičius

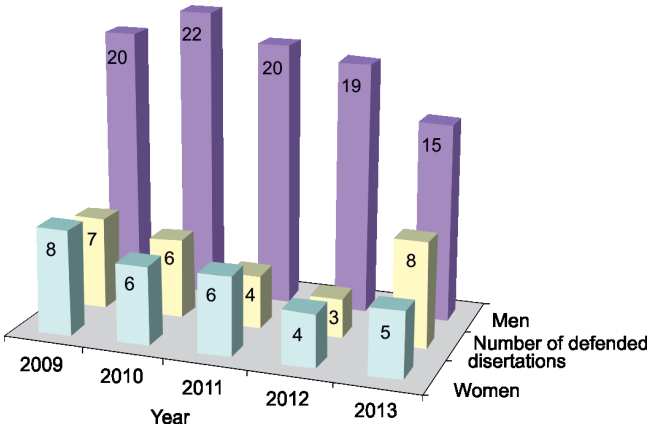
Dr. S. Tučkutė

Dr. M. Povilaitis

– 19 December. – *Investigation of Simultaneous Oxidation and Hydriding of Titanium Films in Water Vapour* (Physical Science, Physics (02P), Vytautas Magnus University **Simona Tučkutė** (Center for Hydrogen Energy Technologies). Scientific supervisor – Prof. Dr. L. Pranevičius;
– 20 December. – *Study of the Steam and Gas Mixing Processes in the Containments of Nuclear Power Plants* (06T) **Mantas Povilaitis** (Laboratory of Nuclear Installation Safety). Scientific supervisor – Dr. S. Rimkevičius.



Arrangement of PhD students according to science directions



Number of PhD students and defended theses

PhD students Andrius Tamošiūnas and Tadas Kaliatka were granted a nominal award of Professor Raymond Viskanta (USA), which was granted to them by the professor himself

Acceptance to LEI PhD studies takes place in July, when there are spare places, the acceptance is continued in September. During PhD studies there is a possibility to participate in international projects, take traineeships in foreign scientific centers, 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
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E-mail: Jolanta.Kazakeviciene@lei.lt

LABORATORY of HEAT-EQUIPMENT RESEARCH AND TESTING

MAIN DIRECTIONS OF SCIENTIFIC RESEARCH OF THE LABORATORY:

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

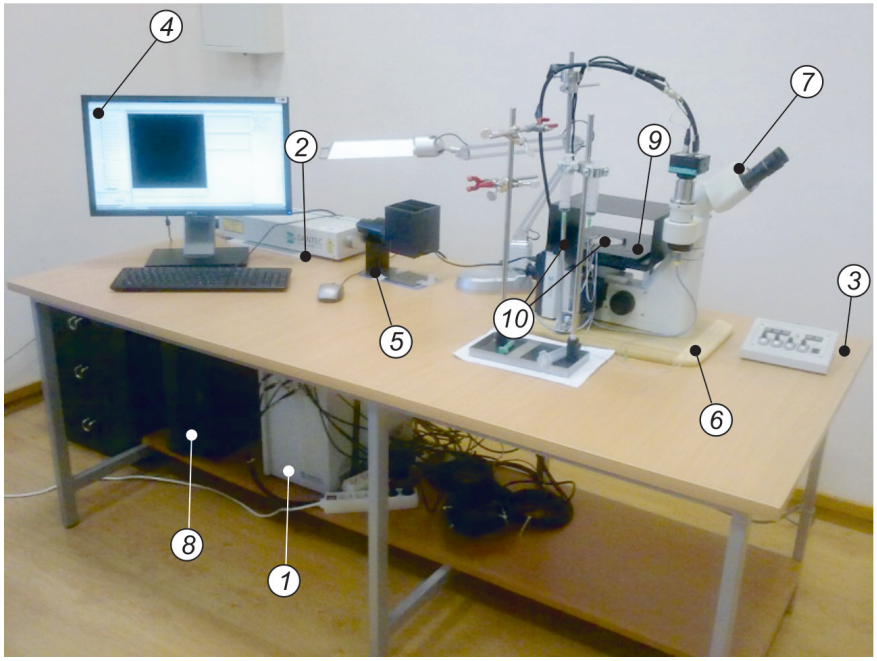
In 2013 basic research and applied activities significant for Lithuanian industry, and science were performed. The Laboratory actively cooperated with Lithuanian customers, taking into account general trends of further expanded in European countries, developed national liquid and gas flow standards as well as measurement services for Lithuanian customers and further expanded research, created experimental basis for perspective biofuel research and its practical application development.

SCIENTIFIC RESEARCH

The most important event should be considered the direction of R & D to solve the tasks formulated in new topic 2013–2015 ***Research of gas flow mixture and its interaction with structurized surfaces aiming to efficiently and least polluting environment to 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 the combustibility properties of biofuel and recovered fuel or to retrieve new materials applying thermal processing technologies;

– to investigate the processes of solid particles and noncombustible components separation from combustion gas an gas obtained by gasifying biofuel applying perspective technologies;
– to expand the application of the developed equipment and mastered methods designed to investigate various materials' permeability and visualize flows' structure for dealing with scientific and applied tasks of other fields.

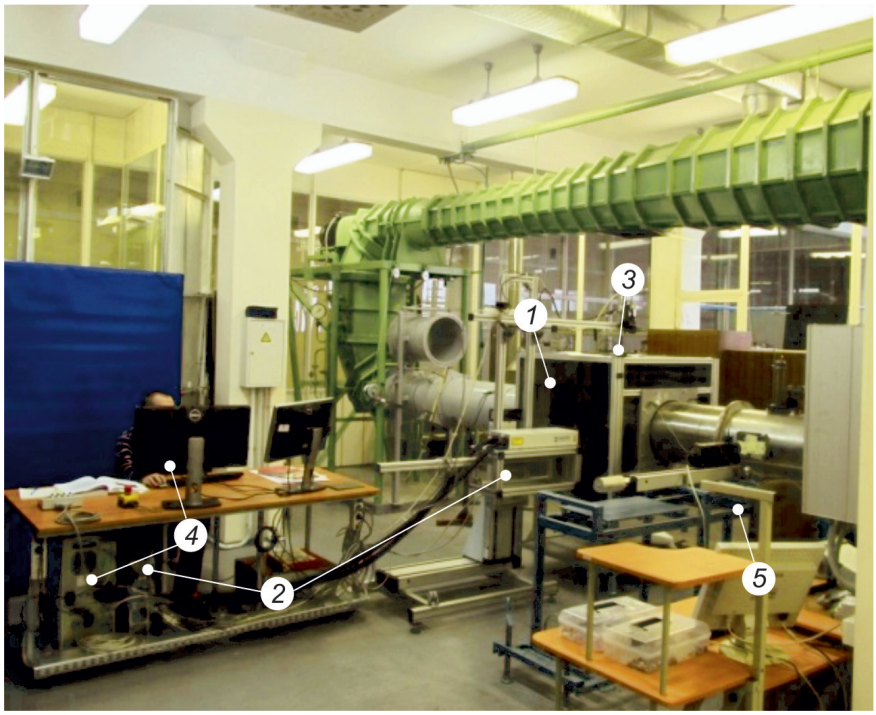


MicroPIV system: 1 – laser control system LPU 450; 2 – laser (Nano S 65 – 15 PIV); 3 – manual laser system (LPU 450) control; 4 – computer laser system control; 5 – artificial light source; 6 – microscope; 7 – chamber (FlowSenseEO groups); 8 – data processing and image reflection system computer; 9 – experimental channel; 10 –capacities of distil water and particles mixture

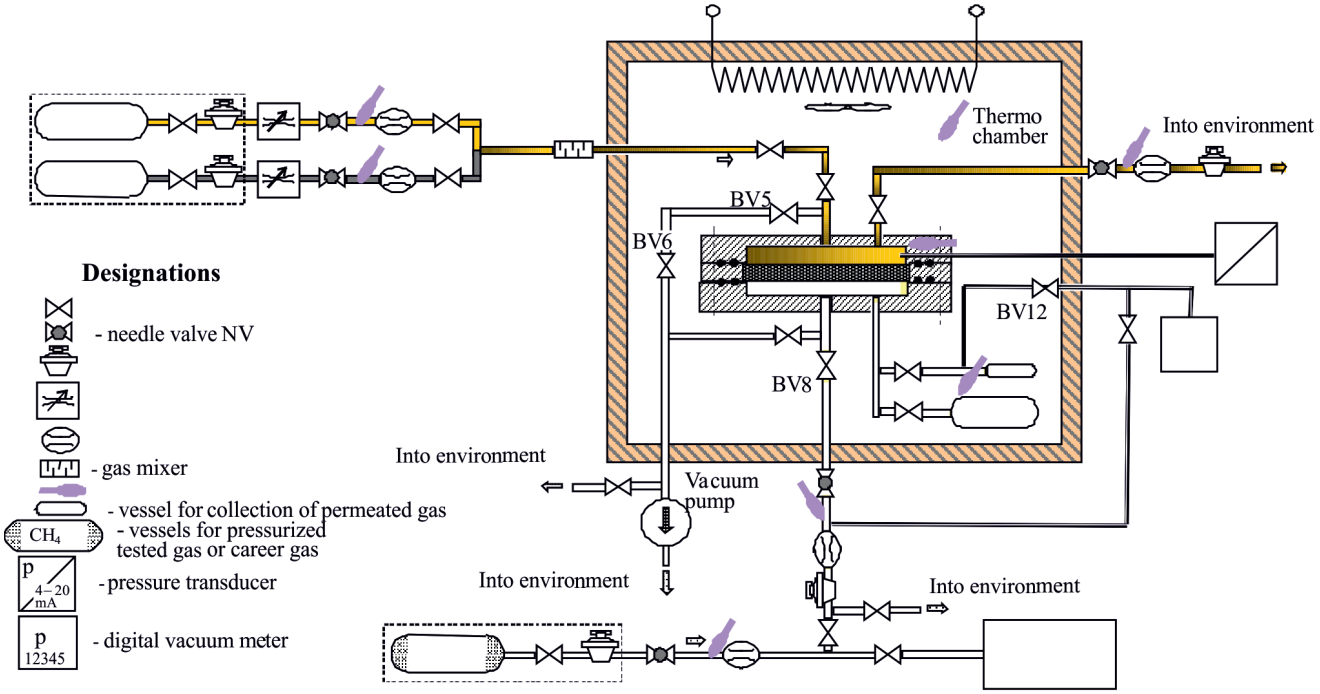
This is a basic guidance of research towards solution of relevant task which was preconditioned by up-to-date flows structure and transfer processes research equipment, purchased within framework of valley programme *Santaka*, and installed new experimental facilities.

Conducting the tasks foreseen in this topic in 2013 the following was achieved:

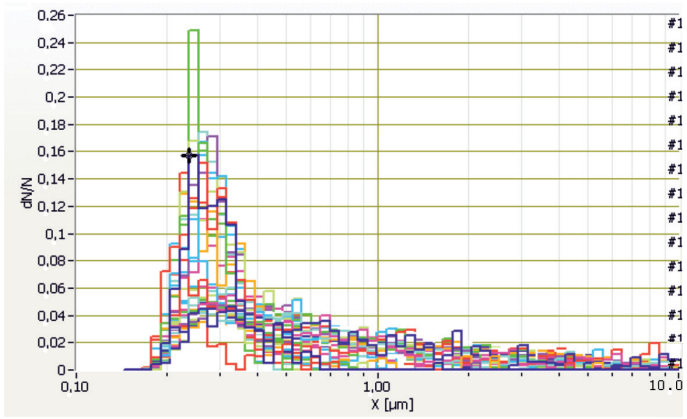
– *macro*PIV system was acquired and it was tested by analysing flow around cylinder placed in aerodynamic facility chamber being part of experimental channel. An aerodynamic facility designed for air flow mixture in the models of combustion chambers by applying *macro*PIV system was constructed and tested. Efficiency of the system was confirmed;
– hydrodynamic facility designed for investigating flows mixture in various form chambers and channels applying macroPIV and LDA systems was constructed and tested;
– numerical simulation schemes intended for analysing the processes of secondary air supply to combustion chambers and flows mixtures were prepared using Fluent Ansys software. Initial calculations and comparison were carried out;
– a compartment was prepared where microPIV systems was installed to investigate flows in micro-system and effectiveness of this system was acquired and



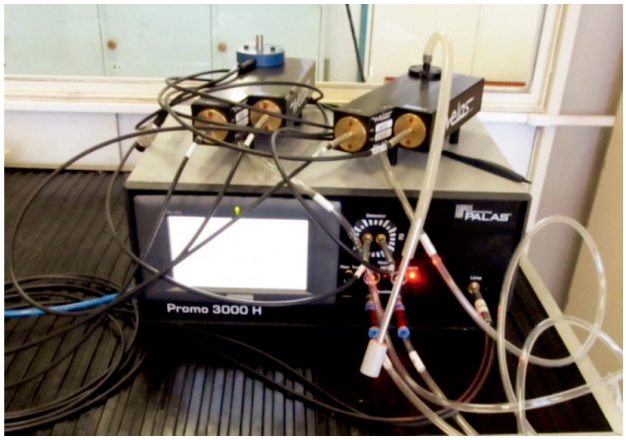
Basic image of aerodynamic facility with macroPIV system: 1 – chamber of experimental channel with cylinder in cross flow ; 2 – systems of laser beam generation and control; 3 – CCD chamber; 4 – data collection and processing system; 5 – laser velocity meter in a channel



Block diagram of the facility for testing membranes permeation



Distribution of relative amount according size of solid particles in smoke gas from water heating boiler, heated by biofuel



Solid particles spectrometer Promo 3000

tested;

– membrane permeability facility designed for determining regularity patterns of incombustible components' separation from gas obtained by gasifying biofuel was constructed;
– a spectrometer designed for investigating solid particles' emissions to the environment was mastered;

APPLIED RESEARCH

Applied research were continued in accordance with previously initiated projects:

Bioenergy Promotion

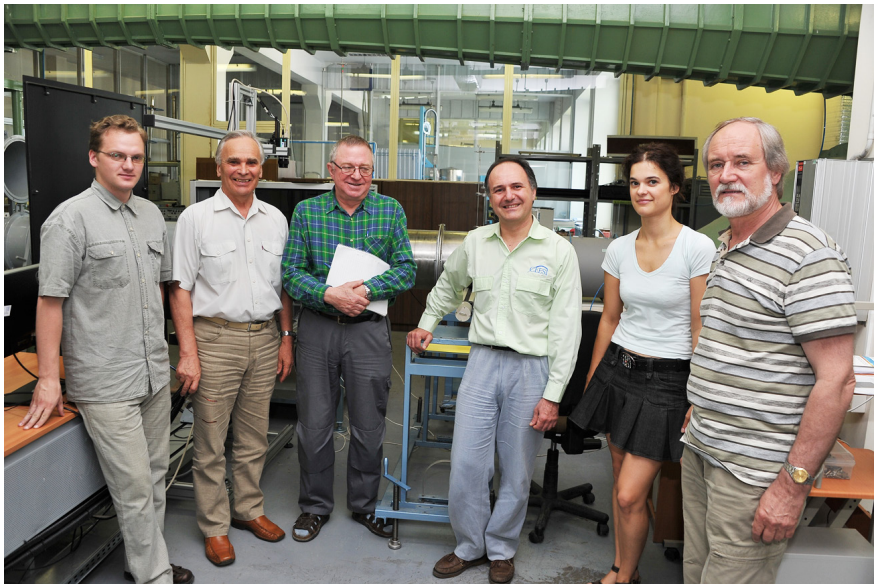
- The Baltic Sea Region **INTERREG III B** Neighbourhood Programme partially funded by the EU. The aim of the project was to strengthen a stable, competitive and territorially integrated development of Baltic Sea region in the field of stable bioenergy usage.

Research Council of Lithuania

- Research Council of Lithuania project ***Research of local fuel thermal decomposition processes by developing efficient and ecological***

technologies (**BIOKONVERS**), the duration 2012–2014, involvement – 3 Institute laboratories;

- European Social Fund Agency projects: ***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. VP1-3.1-ŠMM-10-V-02-011.



Experts Krister Stolt and Pier Giorgio Spazzini (in the middle) with Laboratory researchers

LONG-TERM PROGRAMMES 2012–2016

In 2013 together with other laboratories the activities were initiated in accordance with long-term programs: ***Research of dynamics, heat and mass transfer processes of single phase and two-phase flows***, 3 tasks were completed; ***Research of renewable energy sources' usage for efficient energy production and environmental impact***, 2 tasks were completed.

Activities in accordance with programme Economy development and increase of competitive ability

This program covers annual scientific R&D activities in accordance with authorization of Government of Republic of Lithuania to maintain a base of four state standards for liquids and gas volume, volume flow rate and velocity units, and to ensure its relevant 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 international exchange.

In 2013 the group of national institutes' experts (Krister Stolt, SP, Sweden, Pier Giorgio Spazzini, INRIM, Italy) performed assessment of Laboratory activity in the measurement liquids and gas flows in accordance with EURAMET TC Quality provisions and EURAMET TC Flow project No. 1276. In general, the Laboratory activity in this field was estimated positively, however proposals were made to improve installation and operation conditions of reference equipment as well as supply with up-to-date measurement means and data collection and processing systems.

Improving standard base equipment in 2013, the reconstruction of standard equipment of liquids (oil and oil products) was initiated; the facility of critical nozzles designed to reproduce air (gas) volume and flow rate units values was reconstructed; laminar elements purchased, the nominal flow rate of which 0.2 dm^3/min and 2 dm^3/min, will enable to reliably measure low air (gas) flow rates from 0.3 dm^3/h to 500 dm^3/h.

Most important applied works and services

In 2013 the laboratory performed the following large scope applied activities:

- Prepared and verified two sampling procedures ((DPS-01, (SC *Kauno energija* and RIS, AB *Axis Industries*) to conduct periodic verifications of remote data transmission systems.
- Under the contract with SC *Klaipėdos nafta* a study was concluded, where the most relevant supplier of liquefied natural gas was chosen for designed SkGD terminal.
- Research and testing as well as its installation of the reference 3 m^3 volumemeasure, designed at the Laboratory and produced by SC *Astra*, to periodically control and calibrate measurement systems of ethyl alcohol produced by JSC *Biofuture*, were carried out.
- Type approval tests of several modification sewage flow meter SNU-100 (AB *Axis Industries*) with electromagnetic or ultrasound flow sensor and ultrasonisc liquid level sensor or air type sensor of liquid level were carried out.
- 2 type approval certificates (module B) as well as 107 certificates of conformity assessment to type (module F) were issued for flow meters, produced

in Lithuania.

- Common verification procedure BPM 111955219-146:2013 *Rotameters* was prepared and validated.
- The Laboratory continued activities by providing services to customers as complementary unit of the *Open Access Center for Renewable and Alternative Energy*. The activities were related with biofuel application towards scientific and applied research. The scope of services provided to customers expanded greatly.

The incomes from performed projects, applied activities and services in 2013 approached 2.5 million Litas.

ACTIVITY IN INTERNATIONAL ORGANIZATIONS

Implementing national standard laboratory functions, the Laboratory participated in the activity of technical committees *Flows* of international organizations EURAMET and COOMET in 2013. Submitted information on quality management system functioning indicators EURAMET TK Quality.

During this cooperation period preparatory actions were particularly important for international flows measurement comparisons. The contacts were held with the laboratories executing international comparison: UME, Turkey according EURAMET Project No 1233 and BEV, Austria according EURAMET Project No. 1225. The Project meetings were organized to participate in the comparisons, initiated by European countries national laboratories MIKES (Finland) – gas flow rate from 0.1 mg/s to 630 mg/s and CMI (Czech Republic) gas flow rate from 20 m^3/h to 1000 m^3/h and in COOMET member's Ivan-Frankivskstandart (Ukraine) project No. 585/UA/12.

Dr. A. Bertašienė and dr. A. Stankevičius were appointed to work groups of gas velocity and volume/flow measurements in the EURAMET technical committee *Flows*.

PUBLICATION OF SCIENTIFIC RESULTS AND ACKNOWLEDGEMENT

The following seminars organized:

- ***Sustainable development aspects preparing expansion action plans for renewable resources energy usage of municipalities.*** Bioenergy promotion, project 2. 31/01/2013, LEI, Kaunas;
- ***Use of biofuel in Kaunas region – the present situation, issues and perspectives***. Bioenergy promotion, project 2. 19/11/2013. LEI, Kaunas.

Along with other project participants the publication was prepared: Dzenajavičienė E. F., Pedišius N., Škėma R., Vrubliauskas S. ***Review of biomass and solid biofuel certification systems*** 2013. LEI, Kaunas. P. 109, which continues the dissemination of international project ***Bioenergy promotion*** results, previously published in the publication Dzenajavičienė E. F., Pedišius N., Škėma R. ***Sustainable bioenergetics***. 2011. LEI, Kaunas. P. 136,

4 papers were prepared and read in international conferences, 2 articles were published in journals ***Energy and Mechanics***, 2 articles submitted to ISI journal.

In 2013 Dr. N. Pedišius was awarded the Sign of Honour for personal accomplishments and input in developing Lithuanian engineering industry and strengthening its international competitiveness by Lithuanian Engineering Industry Association LINPRA.

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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 high-calorie 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 field of fuel saving, environmental pollution reduction and materials thermal decontamination.

REDUCTION OF NOX CONCENTRATIONS IN FLUE GASES BY ADJUSTMENT OF PRIMARY AND SECONDARY FUEL TO THE BURNERS

Researchers of the Laboratory of Combustion Processes for many years have been working on improvement of combustion process efficiency, development and improvement of liquid and gaseous fuel burners, thermal destruction of waste material, gasification and pyrolysis. After the Directive of European Parliament and Council of 24 November 2010 came into force, stating that from year 2016 NOx concentration in the exhaust gases of larger than 50 MW capacity boilers shall not exceed 100 mg/nm^3, energy companies got worried how to achieve this objective with least expenses. One of the largest Lithuanian energy companies JSC *Vilniaus energija*, which operates the above discussed water heating boiler KVGM-100 with D-30 burners, conducted experimental research for additional NOx reduction by flue gas recirculation. Since NOx concentration in the exhaust gas of this boiler does not exceed 150 mg/nm^3 at maximum load, then after introducing additional amount of smoke into air flow it would be possible to meet the requirements indicated in the EU directive. After conducting experiments and receiving positive result, it was possible to escape extra investments for NOx reduction using carbamide.

The burning process was simulated by *Fluent* software in the furnace at the Laboratory of Combustion Processes with the objective to estimate NOx reduction effect. Additional amount of CO_2, H_2O and N_2 was injected to the combustion air, resulting the recirculation balance 10–20% of flue gas. After comparing the composition of exhaust gas for cases without recirculation and with recirculation it was found that 10% of recirculation reduces NO_x 15%, whereas 20% of recirculation up to 20% NOx. If we compare these results with the data presented in literature sources as well as with the results obtained at SC *Lietuvos elektrinė* it was determined that NOx may be reduced even by 30% with introduction of 20% recirculation in case of natural gas burning.

It should be emphasized that recirculation gas should be supplied evenly, into the streams along air channel cross-section and into the air flow supplied for combustion, and should also be mixed before entering the burners.

According to the smoke recirculation

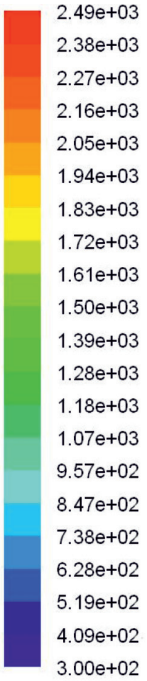
channel project, prepared by the researchers of the Laboratory of Combustion Processes, design modifications were conducted in smoke and air channels of heating boiler KVGM-100 operated by JSC *Vilniaus energija*.

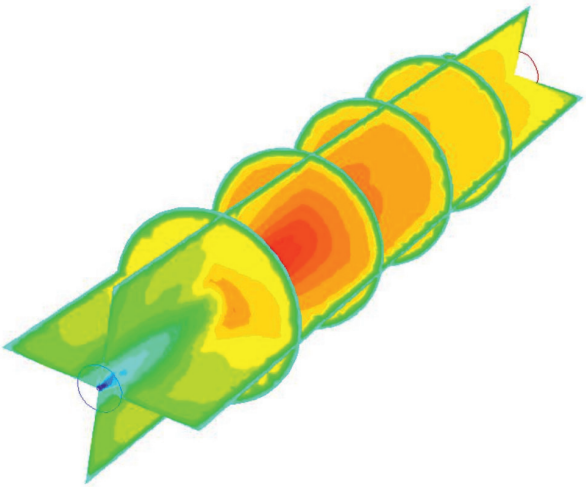
According experimental research it was determined that in case of correct adjustment of burners having fine natural gas current decomposition to heating boiler KVGM-100 geometry and introducing smoke recirculation, the NOx concentration in the exhaust smoke may be reduced from 150 mg/nm^3 to 95–100 mg/nm^3 and thus it is possible to meet the regulations of European Parliament and Council directive 2010/75/ES. The know-how discovered in the project provides basis to improve NOx reduction by rather cheap burning process improvement measures, i.e. to reduce the temperature of the hottest zone using smoke recirculation. This may be achieved by reducing furnace loads or improving furnace form, arrangement of burners and their number.

Burner No. 3 *Burner No. 2* *Burner No. 1*

Arrangement of boiler KVGM-100 burners' central and peripheral air currents and natural gas

RESEARCH OF BIOMASS GASIFICATION





Fluent CFD model of small NOx burner

In 2013 EUREKA 5840 Replace NG ***Development of heat recovery and combustion equipment for optimal replacement the natural gas by low-calorific gases*** was continued. A three year duration project was initiated in 2011. Partners from Ukraine, Hungary and Lithuania participated in the Replace NG project, the value of which is 0.47 million EUR.

Main objective of the project is to develop a new type waste heat recuperation technology designed for reduction

of natural gas consumption in industrial enterprises' technological furnaces. The project results are:

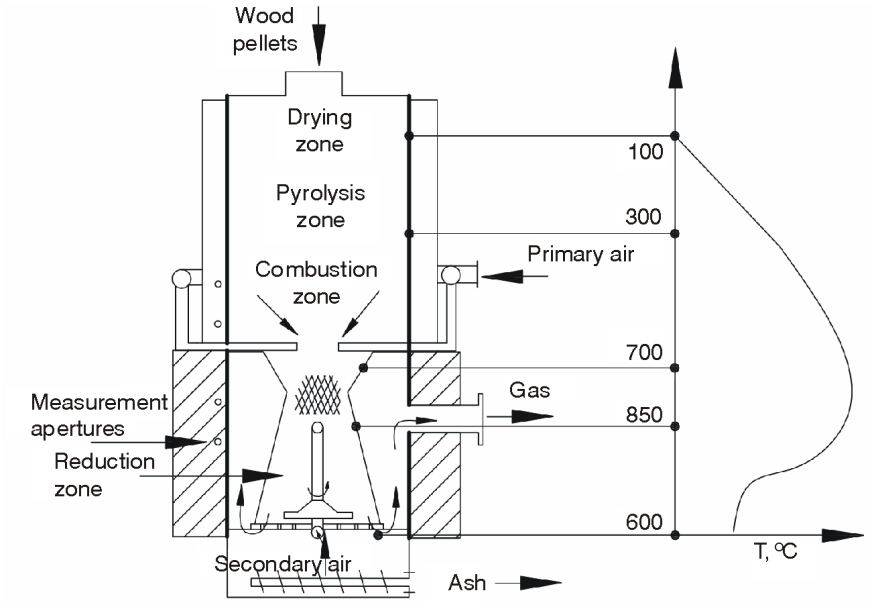
- Prototypes of advanced waste heat application equipment, high temperature tube recuperator and gas generator;
- High temperature recuperator designed to heat up the required air and combustible gas up to 800–1000 °C using high temperature waste gas released from production;
- Gasification facility designed for production of low calorific combustible gas from waste heat and biomass suitable to be burned in technological furnaces.

Originality:

- Integrated heat recuperation and biomass gasification system, designed to produce low calorie combustible gas, relevant to be burned in technological furnaces;
- A tube recuperator operating at high temperature and in aggressive environment was developed, it is distinguished for high heat exchange and low hydraulic resistance ratios.

Short description of the project

Wood gasification system comprised of reactor, particles' separator, gas recuperator, fuel feeding system and automatic control facility was designed and manufactured. Heat required for gasification is obtained by supplying air to the reactors and by maintaining combustion process at stoichiometric ratio 0.25. The composition of generated gas was investigated using gas chromatographic method, its determined calorific value varied within the range 4.5 to 5.5 kJ/nm^3. Thermal capacity of the facility is up to 200 kW. The obtained gas is combusted in water heating boiler VK-21.



Scheme of experimental downwards moving layer type wood gasification reactor

Cooperating with the Ukrainian Gas Institute a recuperator designed for heating gas up to temperature of 800°C was produced and tested.

The gasification facility developed together with Lithuanian partner JSC ***SynGas Tech*** was tested in practical application when gasifying henhouse waste in the mixture with wood sawdust and peat. During the project new know-how was received on biomass and gasification of calorific waste, kinetics of chemical changes occurring in the reactor, measurement practice and improvement of technology for bigger capacities were determined.

On the basis of performed experimental research results the following conclusions were made:

1. Work performed in a new field, which realizes gas generation from biomass;
2. New information was obtained on generated gas composition, calorific value and physical properties. A scientific input was revealed by investigated biomass carbon intensive oxidation velocity according chemical kinetics patterns;

Automated experimental wood gasification reactor

3. Technology construction features, control properties and proposals were made to develop a higher capacity facility;
4. Cooperating with partners a high temperature calorimeter was developed and investigated;
5. The application possibilities of the developed facility for business need was investigated;
6. The project gave stimulus for further improvements of the facility aiming to apply it for energy generation from specific waste.

Meaning for scientific progress:

1. Knowledge acquired on mass exchange processes in multimedia of different materials: solid and gas mass and physical transformations;
2. Tasks were solved on carbon oxidation intensification with the objective to transform into CO gas;
3. Kinetics of carbon reactions was mastered as well as results summary by *Arrhenius* equation method.

Importance for technological progress:

1. Gasification reactors are necessary for wood processing enterprises for electricity and heat production as well as specific construction materials production industry, such as lime burning, hothouses, etc.;
2. Generation of processing of organic waste of poultry manure into heat and electricity and collection of hazardous materials with ashes;
3. Combustion of dried sewage sludge collected from small towns, utilization of metals and hazardous materials which are present in the ashes.

CATALYTIC TAR DECOMPOSITION RESEARCH

In nowadays world gasification of biomass and various waste is considered one of the most perspective methods in heat and electricity production. If compared with direct biofuel combustion, gasification process is more efficient and environmentally friendly, less amount of hazardous CO_2 and (NO_x, SO_x, VOC's) atmospheric emissions are formed. Derived synthetic gas may further be used as fuel in internal combustion engines, gas turbines, hydrogen production industry, production of synthetic diesel.

The biggest obstacle preventing from expansion of gasification processes is the occurrence of tars and solid particles (mostly smoke and volatile metals) in synthesis gas. Currently synthesis gas are cleaned by physical methods: the solid particles are caught in electrostatic filters, whereas tars are condensed in scrubbers. These cleaning methods are rather efficient, however they are hazardous to our environment – after cleaning facilities there remain water polluted with tar, sulphur, chlorine and other hazardous compounds. New methods are sought for elimination of tars from gas in order to optimize gasification processes. One of such methods is catalytic thermal decomposition of tars, during which hydrocarbons composing tars are additionally gasified to final reaction products, such as CO and H_2.

Catalytic thermal tar decomposition research was carried out at the Laboratory of Combustion processes aiming to estimate two catalyst - dolomite, which in Lithuania is found as a natural resource, and char, as a residue from used tyre pyrolysis process. The efficiency of these catalysts at high temperature when decomposing real hydrocarbons was investigated, the optimum process conditions, which may be used as basis in developing new functional materials and technological solutions, were determined. The process of dry reforming with used tyre carbon as catalyst was investigated and research results were presented.

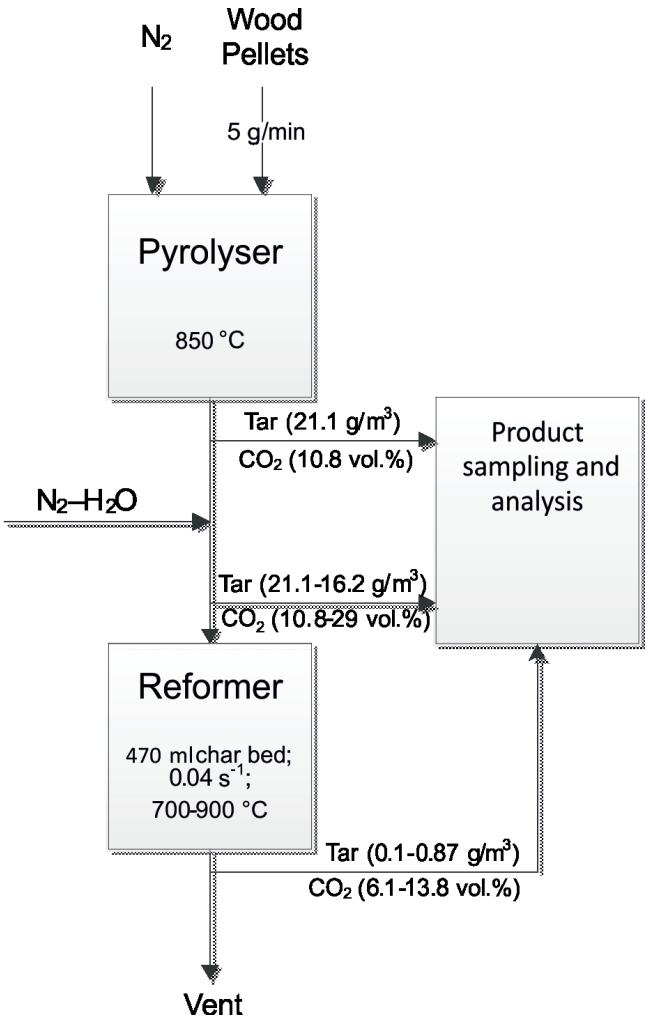


Diagram of the experiment

Basic factors influencing the destruction of tars is temperature, time and atmosphere in which tars are decomposed. Tars may be decomposed on catalyst surface down to CO and H_2, by the so called dry reforming method. Additional oxidiser is required aiming to speed up the conversion of tar composing compounds in gasification process. Continuing with the activities in the field of tar decomposition applying used activated tar pyrolysis residual carbon, CO_2 as oxidiser was analysed as well, its impact on tar destruction, its efficiency, reforming hydrocarbons, was compared to other processes: thermal destruction, water vapour reforming and partial oxidation. Carbon catalyst is prepared from granulated tyres, gasifying them and after that activating the residual carbon. The analysis of non-activated, activated and used catalyst surface was carried out using *Quantachrome Autosorb iQ* device. Research of catalytic tar removal was carried out in the experimental facility, which is comprised of the following parts: biomass pyrolysis reactor, catalyst constant layer reactor and tar condensers.

Commercially available biomass pellets, produced from coniferous wood, were used as raw material in the experiments. Analysis of wood pellets was performed using IKA C5000 calorimeter and *Flash 2000* analyser in accordance with standards (EN 14918:2009, CEN/TS 15104:2005, EN 14775:2009 ir EN 14774-1:2009). The tar compounds obtained in the samples were identified using *Agilent 7890A* gas chromatograph with *Agilent 5975C* mass spectrometer and NIST mass software v2.0. 18 tar composing compounds were calibrated and analysed during investigations. The concentration of tars in samples was determined using *Varian GC-3800* gas chromatograph with a flame ionization detector.

The unknown tar compounds obtained in samples were identified using *Agilent 7890A* gas chromatograph with *Agilent 5975C* mass spectrometer and NIST mass software v2.0. 18 tar composing compounds were calibrated and analysed during investigations. The analysis of gaseous samples was performed using *Agilent 7890A* gas chromatograph with two thermal conductivity detectors and va*l*ve system.

It was determined that CO_2 conversion into CO is most intensive at 900°C. At this temperature CO_2 concentration reduces from 21 to 10.8%. After introducing extra amount of carbon dioxide, the remaining tar concentration in gas increases. CO gas output increases in gaseous products, however, CnHm-H_2O and C-H_2O reactions are blocked. After performing research of catalyst efficiency from time perspective, catalyst volume reduction was determined, due to which free gas leakage occurs and space velocity in catalyst layer increases. With increase of space velocity, the efficiency of tars and CO_2 conversion decreases.

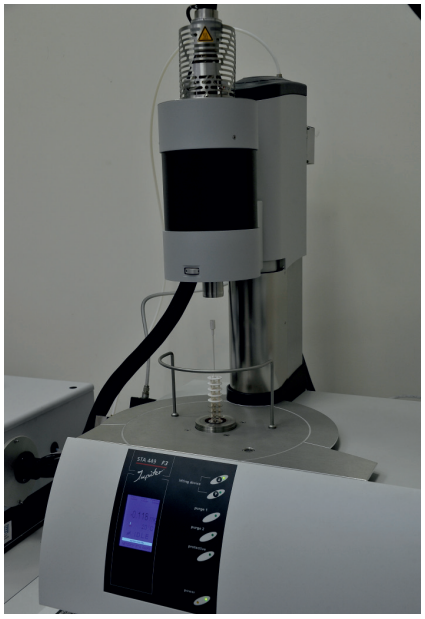
INTENSIFICATION OF CARBON RESIDUAL GASIFICATION

One of the cheapest and environmentally non-hazardous raw materials is wood burning. Lithuanian forest cleaning waste is one of the most perspective local fuel types. Lithuanian enterprises are not big and their energy demands as well, thus low capacity (1–4 MW) gas generators should be developed. When conducting wood gasification experiments, high-calorie gas of 6 MJ/m^3 are derived, which may be used in technological furnaces of local natural gal enterprises. However, in order to promote application of such reactors, complete conversion of gasification material into gas should be insured. Wood contains ~80% of volatile materials, the remaining part consists of carbon and humidity. In wood gasification reactor, after evaporation of vaporous materials from the wood remains ~ 10% of carbon from the initial raw material amount. In further process the carbon decomposes, due to this reason gas intrusion via a layer is more complicated. Under such condition reactor operation becomes unst[a]ble. Aiming to reduce hydraulic resistance of the layer, the rotation rate of grate is intensified and greater amount of carbon is removed. However, such non-decomposed carbon removal is ineffective. Aiming at more efficient granule fuel gaseous process, it is expedient to reduce the amount of residual carbon by intensifying its thermal decomposition.

The carbon layer is necessary for tar decomposition in gas up to lighter gas compounds. In order to decompose the residual carbon higher temperature and time is required. Carbon decomposition is possible using three oxidators, namely, oxygen, water and CO_2 gas. In the developed producer gas there is approximately 10% of CO_2, which reacting with carbon, according Boudouard reaction, CO gas is comprised, which increase caloric content of producer gas. Work objective was to determine optimal decomposition temperature of carbon residual.

Experimentally using a thermal analysis device (thermogravimeter) *Netzsch STA 449 F3*, the optimal temperature for CO generation from time respect was determined. According carbon concentration change in time the constants of reaction velocities are calculated. During experiments 0.2–0.3 mm fraction wood pyrolysis carbon was used in thermal analysis device furnace pot.

The sample weight varied around 12 ± 0.5 mg. The prepared carbon is placed into crucible and then into the thermogravimeter. Primary carbon gasification experiments were performed with CO_2 and N_2 atmosphere at different temperatures. The dependence of Boudouard reaction velocity from CO_2 oxidator concentration



Thermal analyser ***Netzsch STA 449 F3 Jupiter***

Sample holder designed for thermal analysis inside the furnace of the ***Netzsch STA 449 F3 Jupiter***

and temperature was analysed. It was determined that at 1100°C at gas flow ratio CO_2 : N_2 60 : 20 ml/min carbon is gasified into CO in 12 min. Smaller amount of CO_2 24 : 56 ml/min is gasified in 20.6 min, whereas after reaching ratio 16 : 64 in gas mixture, the reaction time prolongs up to 32 min. Wood carbon gasification with carbon dioxide reaction velocity constants were determined. Depending on CO_2 gas concentration and temperature, reaction velocity constants change respectively: they reduce with the reduction of temperature and partial CO_2 pressure in gas mixture.

RELEASE OF LOCALIZED PARTICLE GROUPS IN GRANULAR MEDIA

Modelling granular fuel combustion and other processes in granular media, most accurate results are achieved using discrete element methods – DEM/DPM. The basics of these models is the observation of processes of each particle movement, its interaction with other particles and other system elements. Modelling in such way the parameters of each separate particle are identified; the set of these parameters may be called a "micro-condition" of multi-particle system. In practice, more important are generalized system parameters, for example, distribution of temperature or corresponding chemical compounds in the charge of particles ("macro-condition"). One of such examples, important for analyzing solid fuel combustion is a formation of hot and cold zones in the charge of particles. Such generalized parameters are identified more easily. Thus aiming at comparing modelling and experiment results and to identify pattern regularities of multiparticle systems a methodology is required which would enable to investigate the formation of structures of larger scope in such systems knowing the parameters of individual particles from DEM/DPM modelling results. Aiming to develop a methodology devoted to community detection of particles with similar parameters, using available parameters of separate particles, the algorithms were analyzed which are designed for community detection of graph nodes. This is the task which is devoted a lot of attention in statistical mechanics. The macroscopic system parameters are influenced by the interactions among particles. Such interactions are depicted as a graph, the nodes of which depict corresponding particles, whereas the interactions and connections among particles are depicted as edges connecting corresponding nodes.

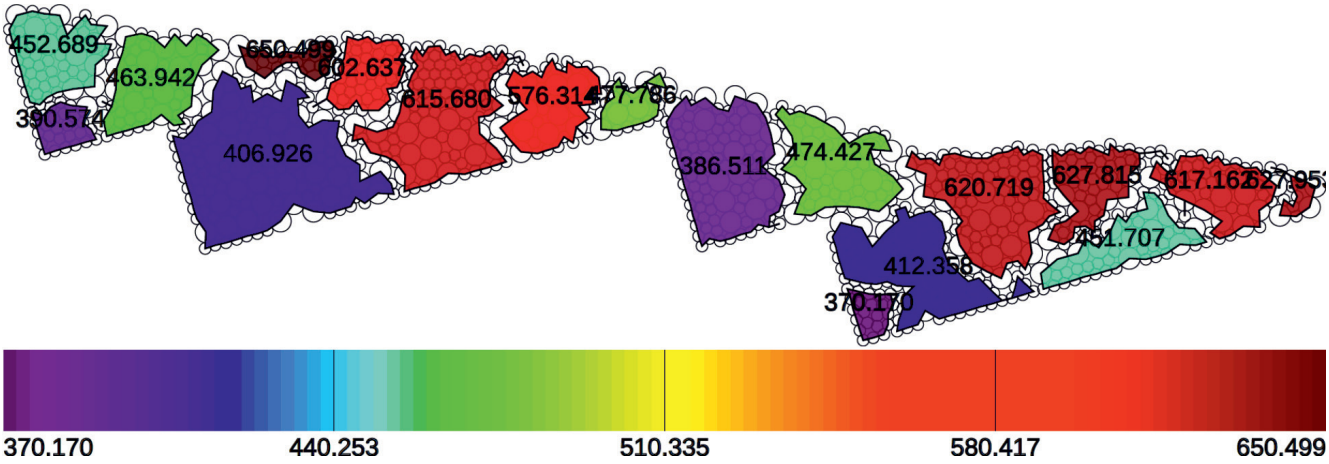
The weights of edges are proportional to the intensity of interactions or connections among particles. The detection of hot and cold zones in particles present on the moving grate was analysed as an example of this method application. The analysed particle parameter in this case is their temperature, but further discusses methodology is relevant in the case when particle groups should be detected according different parameters, for example, amount of humidity, corresponding chemical compound concentrations, etc. In the case of particle distribution according temperatures, "the group of particles" is assumed as a localized group of particles, the values of temperatures among which differ less than from the particle temperatures which do not belong to the group.

The task was to divide the particles into the groups in such way that the particles touching each other and having similar temperatures are connected with larger weight edges. In such way, the task of arranging the particles into groups according temperatures becomes equivalent to the task of detecting graph node groups and thus already known algorithms of detecting groups in graphs may be applied. For the same objective *igraph* software library was applied. Also two different algorithms, not related with graph node group detection, but designed for detecting localized particle groups, were used:

1) classification of particles into temperature intervals;

2) connection according particle parameter similarity.

Though particle groups differ, statistical patterns may be distinguished



Different temperature particle zones obtained simulating by DPM (discrete particle method) burning of particles on the grate. Numbers indicate temperatures in Kelvins

when analyzing a set of different particle configurations.

Other two mentioned algorithms – classification according parameter intervals and linkage according parameter similarity may develop "better" classifications, i.e. such where exist larger and indiscrete groups, however, the parameters are used which should be properly selected. On the other side, the results which are provided by algorithms designed for distinguishing particle groups, could be used as pattern, comparing with the results provided by "standard" algorithms designed for distinguishing graph node groups.

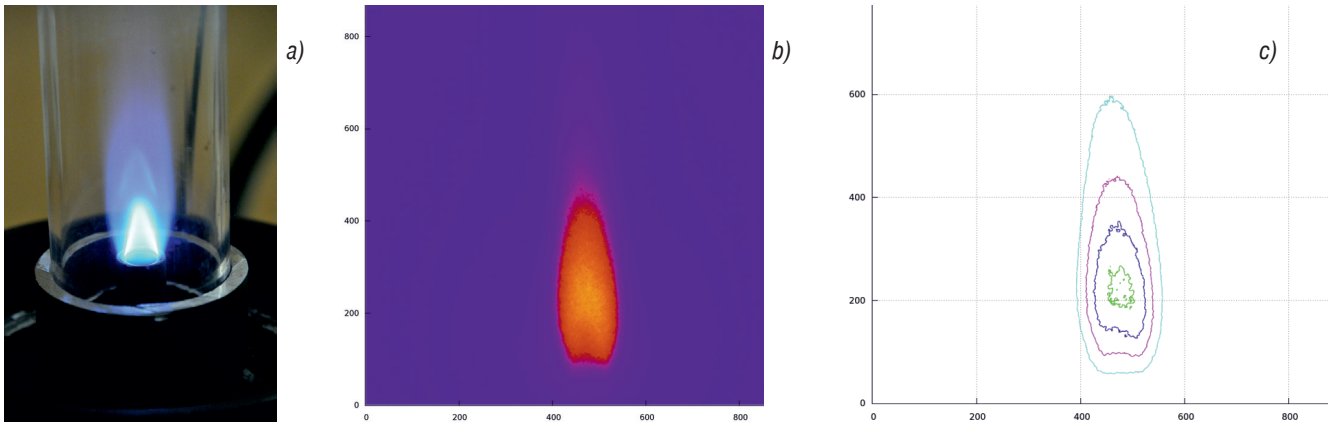
OPTICAL CHARACTERISATION RESEARCH OF FLAME (PROJECT GO-SMART – VP1-3.1-ŠMM-08-K-01-015)

Project ***Go-Smart Microsensors, microactuators and controllers for mechatronic systems*** was continued in 2013. A two year duration project was initiated in 2012. Its value is 1.83 million Litas, 5 Lithuanian universities and institutes participate in this project.

The objective of the project is to investigated the dependence of chemiluminescence flame properties on air-fuel ration aiming to develop micromechanical sensors of small NO burners parameters which operate with respect to data obtained from optical flame characterisation sensors.

The tasks are the following:

1. Using atomic spectroscopy method and high sensitivity CCD camera to investigate basic chemiluminescence radiation patterns of radicals present in the flame with respect to combustion conditions and burner parameters;
2. To determine the intensity levels of radical emission in the flame aiming to estimate probable combustion process control limits, in which a combustion



Experimental burner for spectroscoptic analysis of flame (a) and processed image of flame obtained by CCD camera (b, c)

process would be optimal with minimum amounts of pollutants;

3. According the obtained research data to propose a control algorithm for small NO burners according flame's optical micro sensors characterization data.

Combustion is a complicated process during which a great amount of interim chemical compounds disappear. It is beneficial to perform their research using optical and spectroscoptic measures since in such way their distribution in the flame is identified without disturbing the flame itself. Spectroscope *Andor Shamrock 303* and camera *Andor iStar ICCD* are used for optical research. The distribution of radicals OH*, CH*, C_2* in the flame are being investigated using the above devices. Laboratory burner was manufactured on the basis of *Bunsen* burner, where additionally air supply and gas composition control were installed. Using this data it is planned in the future to develop automatic combustion control systems based on flame optical sensors.

In 2013, the Laboratory researchers published 1 chapter of Monograph, 1 scientific article in the journal listed in Thomson-Reuters database, 1 scientific article, presented 4 papers in international and 2 papers in Lithuanian conferences.

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LABORATORY of MATERIALS RESEARCH AND TESTING

MAIN RESEARCH AREAS OF THE LABORATORY:

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

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

The Laboratory carries out research related to the investigation of the processes of ageing of metal alloys that are used as the constructional elements of power plants and to solve issues of their service life and aging control. Applying mechanical tests, X-ray Diffraction (XRD) and elemental composition analysis, as well as optic and scanning electron microscopy, structural and property changes of steel and non-ferrous metal alloys 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 is focussed 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 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)**.

Research Council of Lithuania

In 2013 researchers of the Laboratory participated in the Research Council of Lithuania funded programme *Energy for the Future* project ***Reliability and Risk Research of Lithuanian Energy Systems***. In this project the analysis of gas-main pipeline failure causes and ageing processes was carried out as well as research of tube metal properties after long term operation.

GEOTERMA

The work, initiated in 2010, under the agreement with JSC *GEOTERMA* on ***Analysis and control of Absorption Heat Pump (AHP) operating parameters*** was continued. The main tasks of the project are to analyse and identify the factors which influence corrosion process and material costs in the geothermal power plant; to give recommendations for the minimisation of corrosion process and material consumption costs as well for

ensuring stable parameters of lithium-bromide solution used in heat pumps. The work includes the analysis of AHP monitoring data, control and maintaining of LiBr solution parameters.

The methods of cleaning LiBr solution from corrosion products in operating absorption pumps were proposed by selecting optimum parameters of relevant equipment.

Alkalinity and corrosion inhibitor expenditure analysis was carried out, regularity patterns of expenditure variation were identified. The performed research enabled to optimize the amount of materials necessary to supplement LiBr solution, to reduce their expenditure and intensity of corrosion processes.

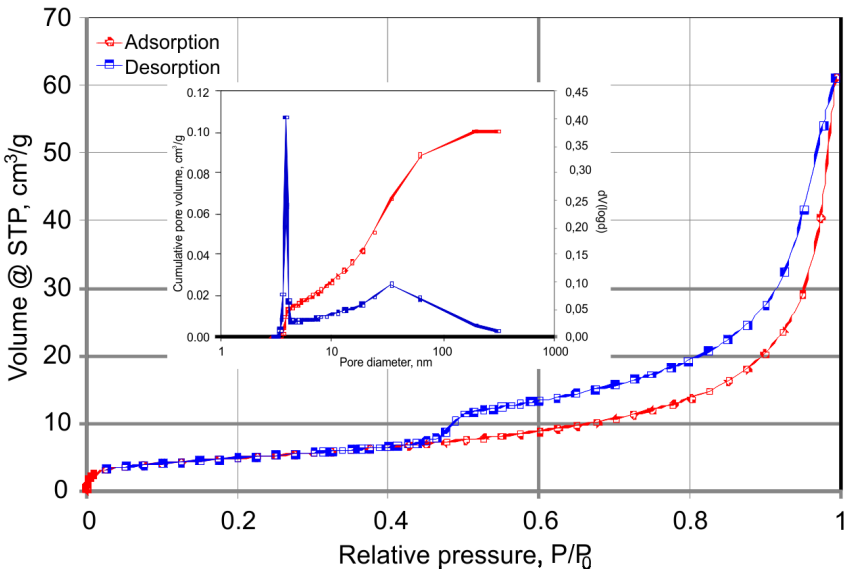
The researchers of the Laboratory are continuing the research on degrading effect of hydrogen and hydrides on zirconium alloys, initiated in 1998. Since 2011, the Laboratory is participating in a new International Atomic Energy Agency (IAEA) project ***Analysis of Nuclear fuel Cladding Resistance to Hydride Cracking During Long-Term Storage.*** The aim of this project is to develop experimental procedures in order to assess the conditions of hydride cracking in zirconium alloy fuel cladding and to determine the values of stress intensity and temperature limits at which the failure of fuel claddings can occur. The research is important for solving the issues of ensuring safe operation of nuclear power plants and assessing the resistance of fuel cladding to the hydride cracking during long-term storage of spent nuclear fuel.

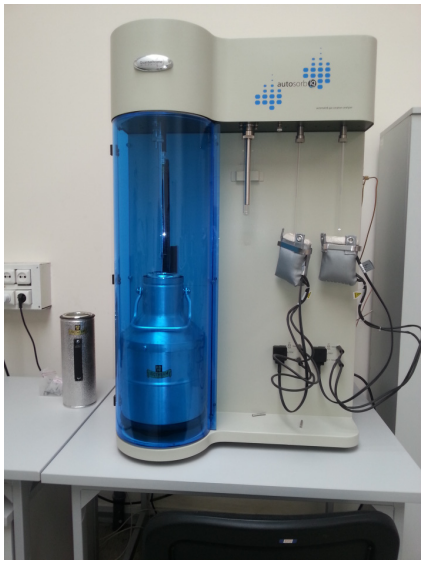
Achievements of the project the project *MATTER (MATerials TEsting and Rules)*. On 1 January 2011 started EU 7th Framework Programme project *MATTER*. Joint team including researchers from Laboratory of Nuclear Installation Safety takes part in the project. 15 work packages were established according to the project tasks, and the Laboratories participate in two working groups: “Manufacturing and welding” and “Testing activities in support of design”. In the scope of the project, a new research on materials behaviour in the operational conditions of IV generation reactors was initiated. It is aimed at the determination of the highest reliability criteria of application of new materials taking into consideration material ageing mechanisms. One of the main objectives of this experimental research is to identify the allowable fatigue resistance limits and coefficient values of steel welds in nuclear components, operating under high temperature and manufactured by applying 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 resistance tests are performed under strain controlled conditions at 550 °C using dynamic testing machine Instron (Model 8801, 100kN). During the implementation of this work, new data describing the high temperature creep and fatigue behaviour where obtained which are relevant for predicting the lifetime of welds in the reactor components and assessing the suitability of welding technologies in continuation of further research on the welding materials and assessment of influence of operational factors on the welded components in the nuclear industry.

DEVELOPMENT AND RESEARCH OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES

A subsidy-funded scientific research ***Impact of modifying additives and nano-fillers on structure and properties of constructional composite materials*** was continued in 2013. It analyses the impact of nanosized fillers and other modifying additives on the structure and properties of innovative composites, and compatibility of nano-fillers with the binders. Using together the X-ray diffraction analysis, the Rietveld structure refinement and the structure modeling techniques the crystal structure of pure gyrolite was determined as well as the crystal structure models of modified synthetic pure gyrolite and of gyrolite with intercalated Na^+ ions were created also the influence of modifiers on the interlayer structure of layered silicate montmorillonite was described. Applying X-ray structural, simultaneous thermal analysis, Fourier transform infrared spectroscopy and scanning electron microscopy research methods methodology of silicates modification was prepared and specified.

The influence of nano-sized particle fillers and modifying additives on the structure and properties of the new composite materials are studied in the task, as well as the nanofiller compatibility with the bounding material. One of research objects – structural composite material, composed of inorganic binder, inert fillers and modifying additives – micro fiber, produced after processing ceolite waste, SiO_2 micro-dust and layer silicate. Research of structure and properties of inorganic binders (three component refractory cement and ordinary Portland cement) modified with different modificators were carried





Measurement of montmorillonite specific surface area and pore size distribution; analyser of solid bodies specific surface area and pore size

out, the optimum amount of it in a binder was determined. Research of composite materials with modified inorganic binders were carried out as well: X-ray diffraction analysis, microstructural changes of the binder in a composite material were investigated considering the amount of modified additives, working temperature and cyclic thermal loads. It was found that modifying additives determine changes of microstructure and phase composition and diminish composites shrinkage and increase their resistance to long-term thermal loads at high temperatures.

SEVENTH FRAMEWORK PROGRAMME

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

In this project the researchers of the laboratory not only perform scientific research foreseen in the program but also supervise the fourth working group (WP4), the objective of which is development of methodology of phyllosilicates modification, coordination of activities and cooperation with other work groups.

In 2013 researchers of the Laboratory participated in two technical WP4 meetings – Aalborg, Denmark (Cembrit) and Zaragoza, Spain (Aragon Technology Institute). The third meeting took place in Kaunas (Lithuanian Energy Institute). Cooperating with project partner Laviosa Chimica Mineraria (Italy) a methodology of nano-bentonite modification was prepared. Closely cooperating with researchers from UK BATH University and Technical University of Denmark research are carried out in determining materials surface peculiarities, thermal and other properties.

MATERIALS TESTING, QUALITY ASSESSMENT AND ANALYSIS

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

Laboratory is accredited to carry out tests of:

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

In December the Laboratory became the winner of Lithuanian Industrialists Confederation organized competition *Lithuanian product of the year 2013*. After acquiring the methodology of pipes set thermal conductivity determination by the guarded end method in accordance with the LST EN 253 and LST EN ISO

Moments from FIBCEM seminar. The report is presented by Dr. I. Lukošiūtė

8497 standards, using its own developed equipment, the Laboratory was rewarded a silver medal of Lithuanian product of the year 2013.

The achievements of Laboratory in 2013 are as following: 3 scientific articles in the journals listed in Thomson-Reuters database. The researchers also participated and presented papers in 5 national and 3 international conferences.

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Services for customers. Testing of plastic pipes extension

LABORATORY of PLASMA PROCESSING

MAIN RESEARCH AREAS OF THE LABORATORY:

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

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

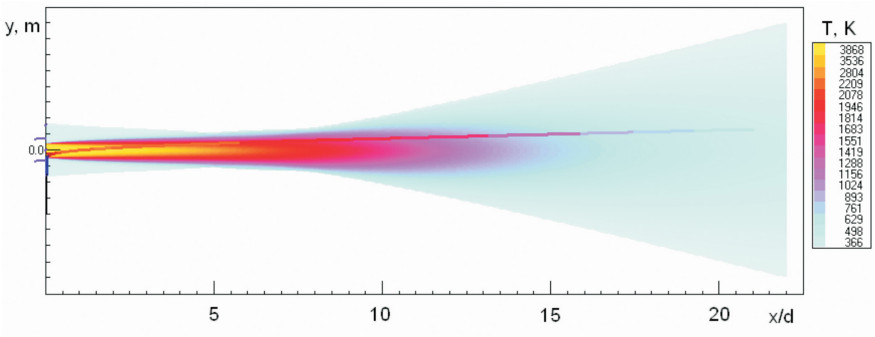
Under the basis of acquired knowledge, the Laboratory of Plasma Processing is carrying out the following researches:

DEVELOPMENT OF PLASMA SOURCES AND RESEARCH OF PLASMA JET

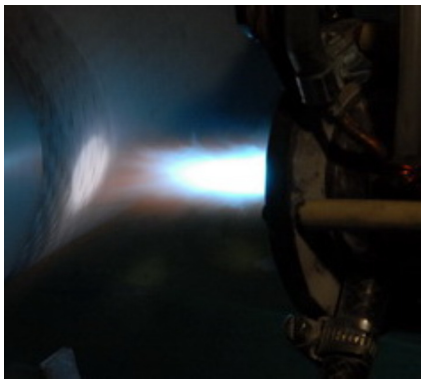
The Laboratory of Plasma Processing develops novel plasma generators up to 200 kW of capacity and improves the construction of the existing ones. Recently a novel water vapour plasma generator has been developed. Its thermal and operational characteristics were generalized on the basis of the similarity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

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

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



Arrangement of temperatures in the air plasma jet at speeding 50 μm Al_2O_3 particle



Air plasma jet discharged from constant current linear plasma generator

DIAGNOSTICS OF PLASMA AND HIGH TEMPERATURE JETS

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

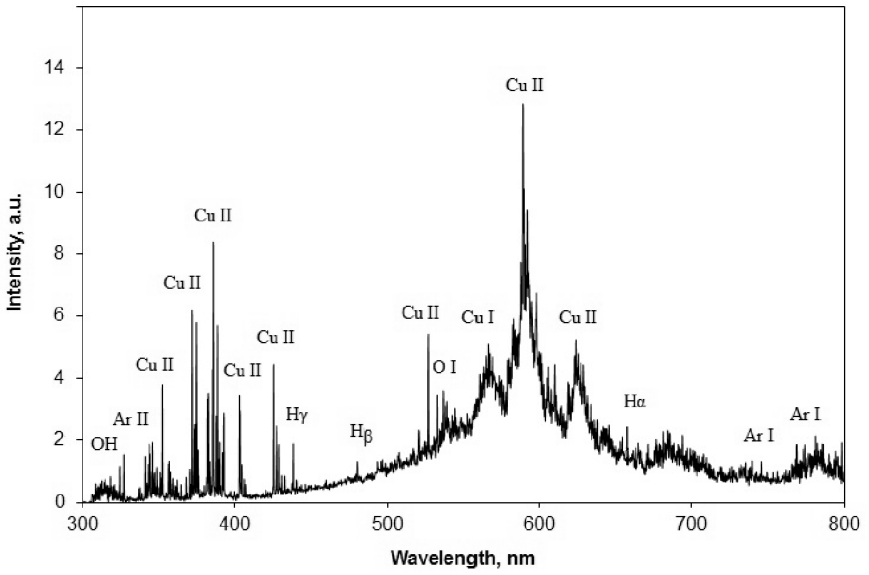
Recently, non-contact methods have been widely applied for plasma diagnostics in the Laboratory. One of them is optical spectroscopy method; its main analytical device is an optical spectrometer AOS-4. It is an optical system for rapid measurements, that may be used for the investigation of gas emission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

An high-speed optical camera Phantom Miro M310 with CCD sensor is used for multiphase plasma flow visualization and determination of some dynamic characteristics. The camera enables high-speed recording of images in 100 ns interval and also observation of very rapidly moving objects.

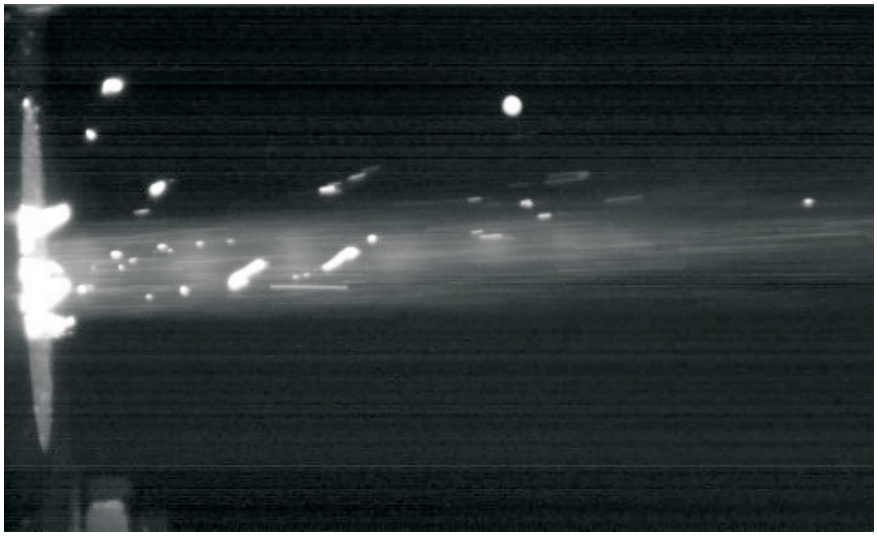
FORMATION OF CONSTRUCTIONAL MATERIAL SURFACE LAYERS BY PLASMA TECHNOLOGIES

Synthesis of coatings in plasma flows

Plasma spray technology, developed in the Laboratory, was applied for catalytic, tribological and protective coatings formation as well as for solid ceramic coatings, which are employed for improving the ope-



Composition of argon and water vapour plasma jets discharged from 35 kW plasma generator, identified using spectroscopy method. Water vapour flow G = 2 gs^{-1}



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

rational characteristics of constructional material surface layers in mechanics, chemistry, energy and medicine. These coatings accelerate the corrosion resistance up to 10^2–10^3 times, significantly diminish the friction coefficient and reduce the mechanical wear. The use of plasma technology decreases the demand for expensive constructional materials since their large amounts are replaced by cheap materials covered with different thickness coatings.

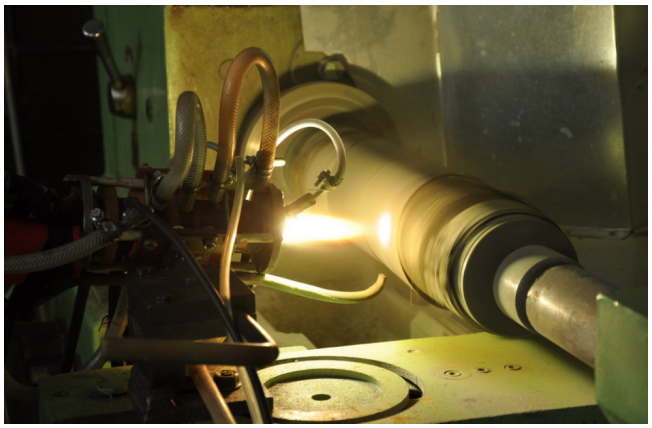
Having integrated a non- equilibrium atmospheric pressure plasma jet with non- equilibrium temperature components into the equipment presented in Fig., the activated and synthesized materials acquire different energies before reaching the treated surface. Necessary conditions for certain chemical reactions 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 developed active surface, which is especially relevant in the formation of catalytic coatings. The surface area of the coating was further enlarged by heating it in a certain temperature.

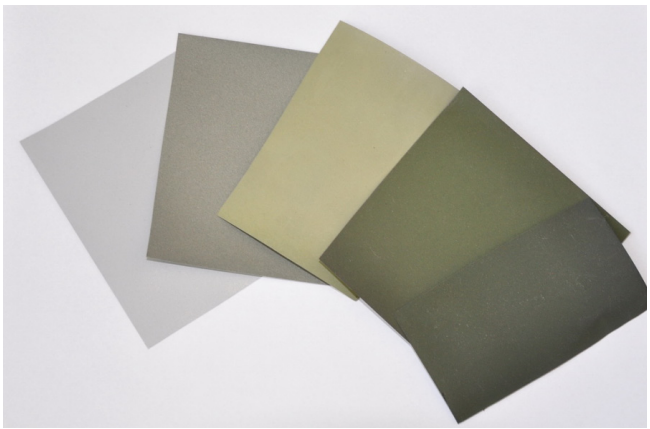
Catalytic coatings

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

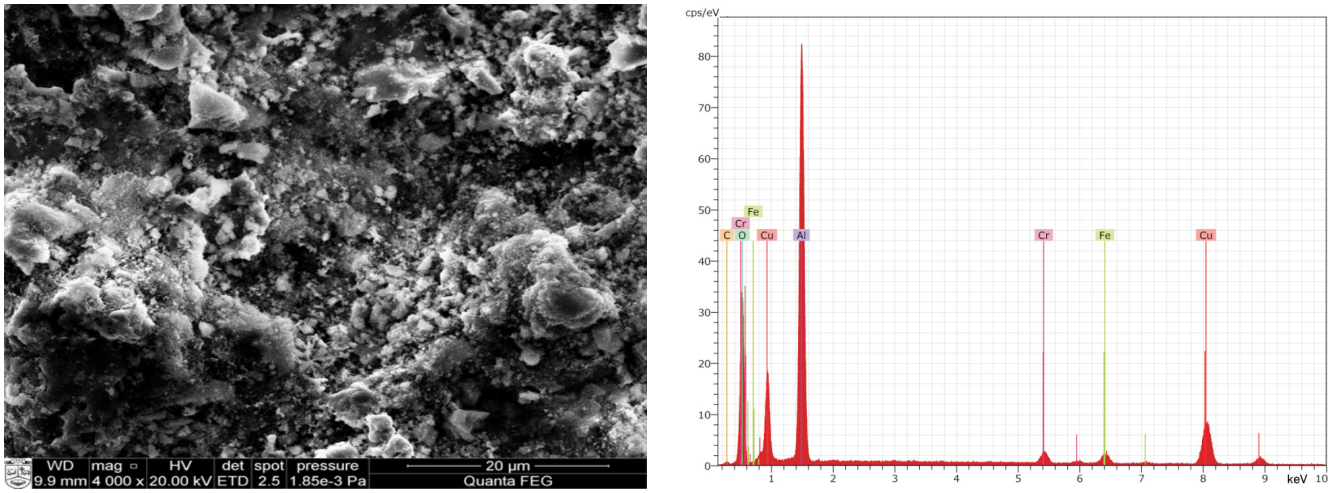
The mass and heat transfer processes taking place in the catalytic reactors made of coatings were examined using the equipment for studying catalyst coating characteristics developed in the Laboratory. Gas with CO concentrations, characteristic of internal-combustion engine, is emitted and the temperature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

For the purpose of the work, the methodology for the research of dynamic and thermal characteristics of gas in the boundary layer zone was developed; the equipment and facilities for examining the jet structure were assembled. The distribution of velocity, temperature and





Formation of surface layers of construction materials in atmosphere pressure air plasma and examples of prepared products



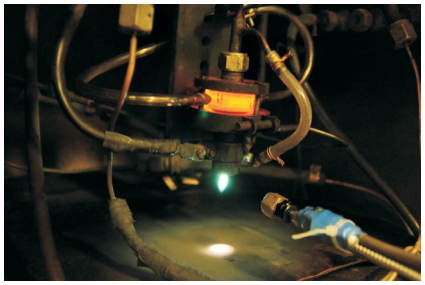
Catalytic Al_2O_3 coating (on the left) and its elemental composition (on the right)

substance concentration of the reactive gas next to the catalytic wall and the heat-mass exchange coefficients of the jet and the wall were established.

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

Carbon derivative coatings

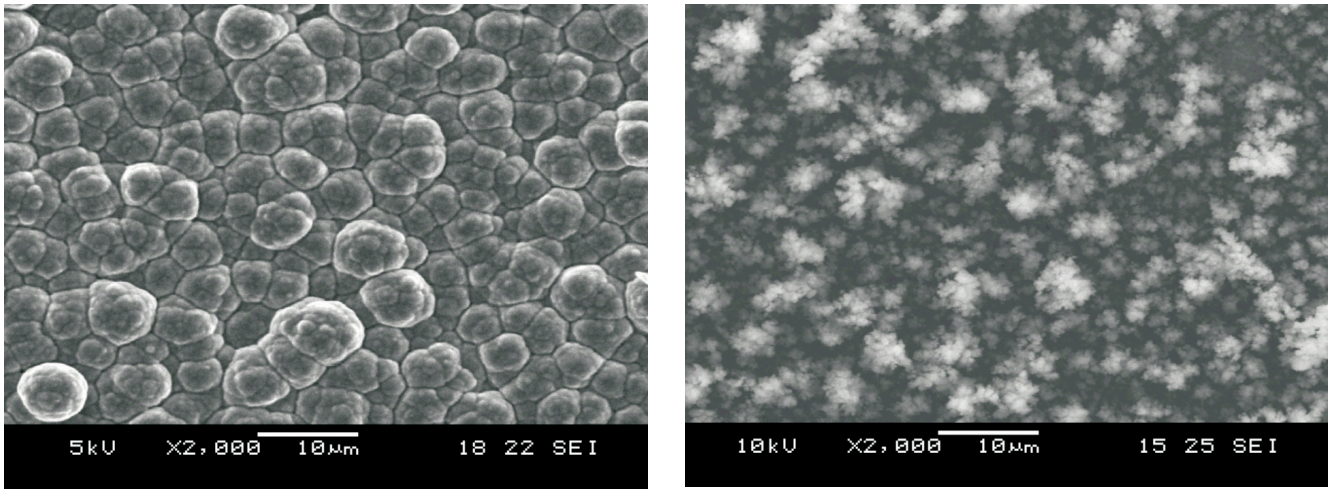
Technological modification of surface layers of constructional materials by forming multifunctional coatings is widely applied in engineering. One of the possibilities of using plasma technology is the synthesis of plasma polymers, i.e. thin membranes precipitated by plasma method that may be applied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



Operating carbon coating synthesis facility generating argon/acetylene plasma

Although the plasma coating formation process in the atmospheric pressure has been widely used for a long time, it is not fully investigated in terms of physics. It is claimed that the chemical, physical and mechanical properties of the coating as well as its composition and structure are affected by about 50 factors. The prevailing ones are the following: composition of starting materials, materials introduced in plasma jet, dislocation, construction of plasmatron, working characteristics, distance from plasmatron to substrate, temperature, pressure and the type of working gas. Presently a great deal of 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 systems operate at the atmospheric and reduced pressure of gas, such as nitrogen, argon, hydrogen,



SEM images of carbon coatings derived from argon-hydrogen-acetylene plasma

acetylene, propane-butane and their mixtures. The coatings on the surfaces of stainless steel, quartz glass and silicon, obtained during the process of synthesis, are characterized by good properties of adhesion. The SEM, XRD, IR and Raman spectroscopy methods were applied for determining the following factors: the coatings surface structure, the size, shape and composition of their particles, their dependence on the composition of gas, constituting and transporting plasma, as well as the place and means of gas introduction into the plasmatron. It was noticed that all spectra of IR photoconductance and reflection have relations common to CH_x, OH, CO, CO_2 and C=C groups.

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

Research on interaction of plasma jet and materials

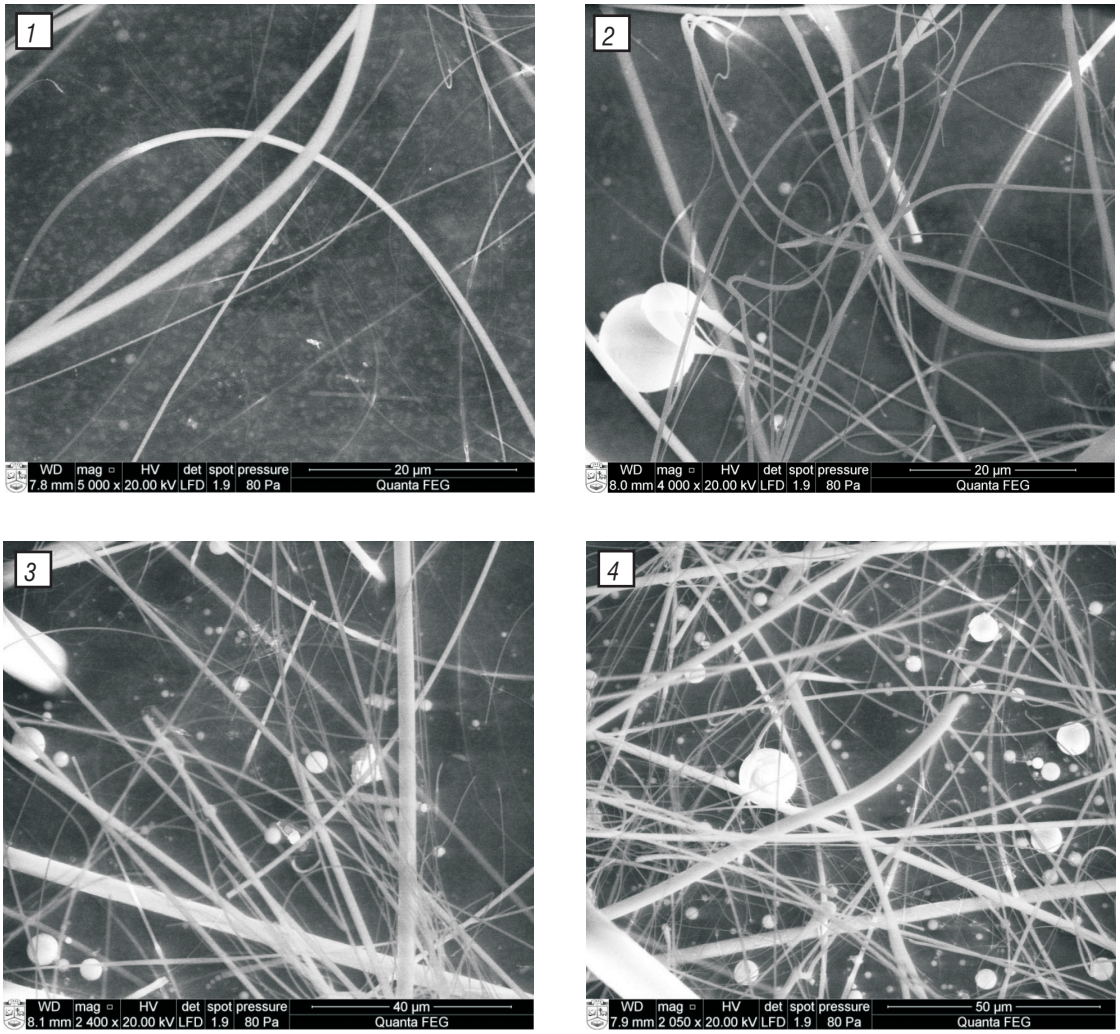
For the purpose of production of high-temperature fibre with especially small diameter, reprocessing of hazardous substances, formation of various coatings and synthesis of new materials, the interaction of electric arc and plasma jet with dispersed materials is analysed. Physical, chemical and mechanical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

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

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

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

Plasma technology is the only alternative to obtain a high quality high-temperature fibre. Melting and stringing ceramic materials and forming mineral fibre, an experimental plasma device with 70–90 kW capacity plasma generator has been developed at the Laboratory of Plasma Processing. It enables to form a splint from dispersed particles, using air as plasma forming gas and auxiliary (Ar, N_2, propane-butane) gas mixtures.

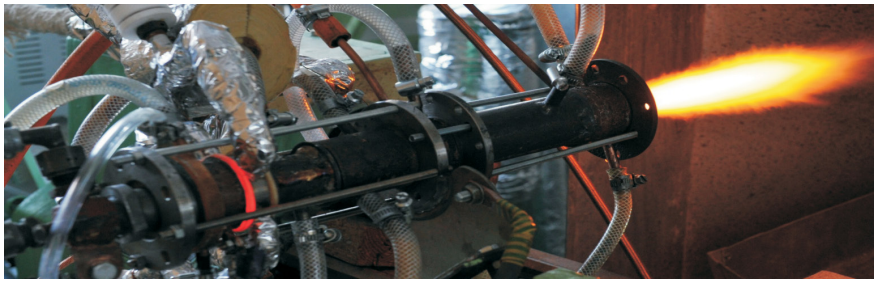


SEM images of zeolite fibre gained at different plasma flow velocities: 1 – 1600 m/s, 2 – 1500 m/s, 3 – 1200 m/s, 4 – 1000 m/s

Cheap ceramic materials (quartz sand, dolomite, clay, aluminum oxide, industrial ceramic waste, etc.) as raw materials are used for producing heat resistant ceramic fibre. After conducting experimental and numerical research it was determined that dynamic and energetic characteristics of plasma jet have major impact on the fibre process of ceramic materials. Since melting temperature of ceramic materials reaches 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 alloy and fibre ceramic dispersed particles. The average mass plasma het temperature and velocity along reactor channel length evenly reduces and changes at the end, respectively, 14 and 10%, not taking into account plasma generator operating regimes. This enables to easily regulate plasma jet parameters in the reactor discharge. After getting acquainted with the mechanism of ceramic fibre formation in plasma-chemical reactor it was determined that particles melting occurs in the reactor channel, whereas formation of fibre elements, which occurs 4–10 ms, – behind the reactor limits. After blowing raw material dispersed materials in to 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 are more intensive depending on the concentration of particles in the jet. With increase of mass cold dispersed particles concentration in plasma jet from 6 to 24%, the heat flow into the reactor wall reduces from 6 to 31% due to intensive flow heat release to particles.

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

The derived splint 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 splint can also be relevant in the manufacturing of different filtrating materials, also as constructional, concrete solidifying material, whereas certain composition ceramic splint may serve as a catalyst. Recently plasma technology has been created to form a fibre comprised of different metals.



Operating water vapour plasma facility designed for decomposition of organic materials

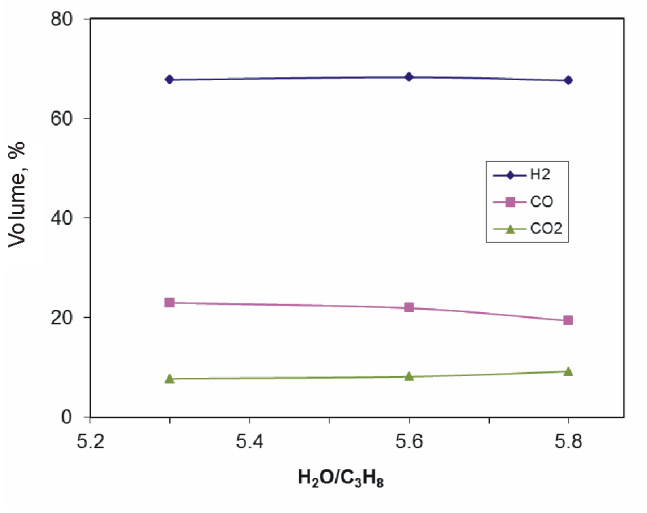
WATER VAPOUR PLASMA TECHNOLOGY

The application of water vapour plasma for various needs of energy, environmental protection and industry areas spreads worldwide. When the temperature is high (4000–5000 K), water vapour mass enthalpy is about 6 times greater than air enthalpy. This suggests that heating water vapour requires 6 times greater capacity than the same amount of air mass jets; therefore, the produced energy of the jet is much greater than of other gas plasma energies used up to now. At high temperature water vapour decomposes into oxygen, hydrogen and their compounds, which react in plasma-chemical reactions. Decomposing waste of different types with plasma method, due to its unique properties it is characterized as environmentally extremely friendly process. Plasma pyrolysis of organic waste is applied in two cases, when it is necessary to utilize extremely hazardous waste (for example, chlorine organic pesticides) or plasma-chemical processing of organic waste with the aim to derive valuable materials. Using water vapour operating plasmatron due to plasma it is possible to derive valuable gas enriched with hydrogen and CO, the so called synthetic gas.

Extremely rapid chemical processes occur in water vapour plasma, when reactive elements H and O are formed. Due to this flow property, hydrocarbons introduced into water vapour 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.

The first experiments of organic materials' decomposition were carried out. Hydrocarbon gas was chosen to perform the conversion and they were introduced into the plasma-chemical reactor.

After performing primary conversion research and analysis of reaction products using gas chromatograph and summarizing the results it was determined that at different water vapour and propane relation the formed hydrogen amount is always higher than 60%. Employing water vapour plasma technology it is possible to successfully develop different composition hydrocarbons and synthesize organic materials.



Composition of synthetic gas derived in plasma-chemical reactor at H_2O vapour flow 3.51–4.48×10^{-3} kg/s, propane flow 0.34×10^{-3} kg/s

Vater vapour plasma chemical reactor for the dissolving of liquid waste

PROJECTS IMPLEMENTED IN THE LABORATORY

In 2013 researchers of the Laboratory participated in international projects and programs:

- COST CM0903 activity ***Utilisation of Biomass for Sustainable Fuels and Chemicals*** (UBIOCHEM) till 2013. In this activity, the researches of the Laboratory are performing an individual project ***Water Vapour Plasma for Biomass Conversion and Waste Utilization***. During its implementation, an entirely new plasma technology, which has not been created before, will be developed for converting organic substances into synthetic gas containing a larger amount of hydrogen. Not only different waste, but also hazardous materials will be processed using water vapour plasma technology. Scientists from 18 European countries participate in this activity;

- 2012–2014 Research Council of Lithuania financed scientific group technological development project ***Ceramic fibre catalyst formed by plasma technologies for reducing pollution emission.*** Basic project objective – by employing plasma technology to develop a catalytic ceramic fibre of desired properties, from which to produce metal oxide fibre 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;
- International project ***Research on formation regularities and properties of multifunctional metal oxide coatings formed by combined laser-plasma methods*** carried out under the Lithuanian–Belarusian bilateral cooperation programme in the fields of science and technology. The aim of the project is to determine of structure and properties of metal oxide coatings with controlled physical-mechanical and operational characteristics formed by plasma and laser methods;
- 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 vapour plasma by reducing environmental pollution;***
- In EU support measure *Promotion of high international level scientific research* project ***Development of innovative thermal decomposition technology and its application for utilization of waste water sewage (INODUMTECH)***. A 100 kW power gasification process-technology prototype is to be developed during the project designed to utilize the sewage amounts of waste water comprised in wastewater treatment enterprises of small Lithuanian towns. The project idea is implemented together with the Laboratory of Combustion Processes, the Laboratory of Nuclear Engineering and Laboratory of Heat Equipment Research and Testing;
- 2012–2013. Lithuania–Ukraine bilateral cooperation scientific programme. Project title ***Application and investigation of water vapour plasma generators designed for fuel conversion and waste reprocessing***.

The personnel of the Laboratory of Plasma Processing consists of 8 scientists with a doctoral degree, 1 young researcher PhD student, 1 junior research assistant and well experienced ancillary personnel: 3 engineers and 2 highly qualified foreman.

Last year the scientific and technical production of the Laboratory was presented in international (10 papers) and national (2 papers) conferences, 6 scientific articles were published in the journals listed in Thomson-Reuters database and 2 articles in the worldwide reviewed publications.

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CENTER for HYDROGEN ENERGY TECHNOLOGIES

MAIN RESEARCH AREAS OF THE CENTER:

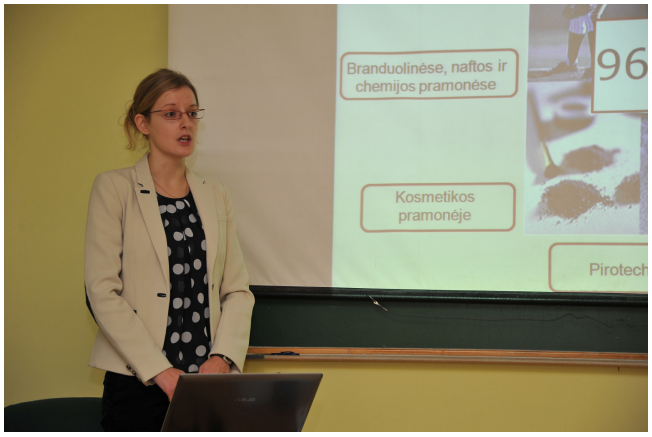
- research in the field of hydrogen energy technologies:
  - synthesis of hydrogen separation membranes and analysis of their properties;
  - synthesis and properties analysis of metals and their alloy hydrides designed for hydrogen storage;
  - hydrogen extraction using water reactions with metals and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

In 2013 state funded project ***Synthesis and characterization of Mg-Ti metal hydrides designed for energy storage*** was initiated. Main issues limiting the application of metal alloys are related with 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 dehydration occurs at 500 °C.

Main objective of this work is to discover metastable phases of magnesium hydride, destabilized using titanium additives, where a material efficiently adsorbs/desorbs hydrogen. Basic originality of the work is to synthesize Mg_7TiH_{16} thin layer structures using magnetron sputtering technologies and complex hydrogenation of materials in plasma and high pressure and temperature. A great deal of attention in the work will be devoted to the impact of surface chemical composition, morphology and topography on the synthesis process of Mg-Ti-H thin films. The surface will be analysed employing available (at LEI) unique surface analysis technologies: AES, XPS, GDOES, AFM, etc. Nature of work remains variable: synthesis is performed, and then an exhaustive analysis of materials follows, synthesis/analysis work plans are revised taking into account the obtained results. Analogous methodology together with partners from Sweden, France and Japan had been applied for the first time in science history successfully synthesizing crystalline Mg_2NiH_2 thin films*.

In co-operation with lectors and students at Department of Physics of Vytautas Magnus University and Department of Physics of Kaunas University of Technology, the Center for Hydrogen Energy Technologies concentrates equipment necessary for investigations, allows teachers at Department of Physics of Vytautas Magnus University and Depart-

* *Lelis M., Milcius D., Wirt E., Halenius U., Eriksson L., Jansson K., Kadir K., Ruan J., Sato T., Yokosawa T., Noreus D. A mechanically switchable metal–insulator transition in Mg2NiH4 discovers a strain sensitive, nanoscale modulated resistivity connected to a stacking fault// Journal of Alloys and Compounds. 2010. 496 (2010). P. 81–86.*

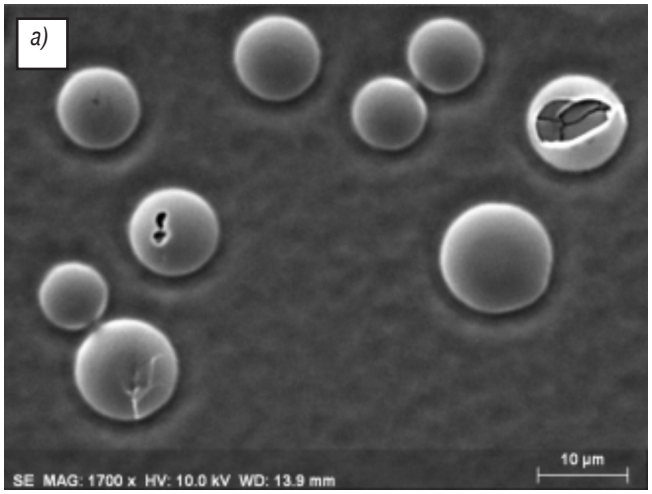


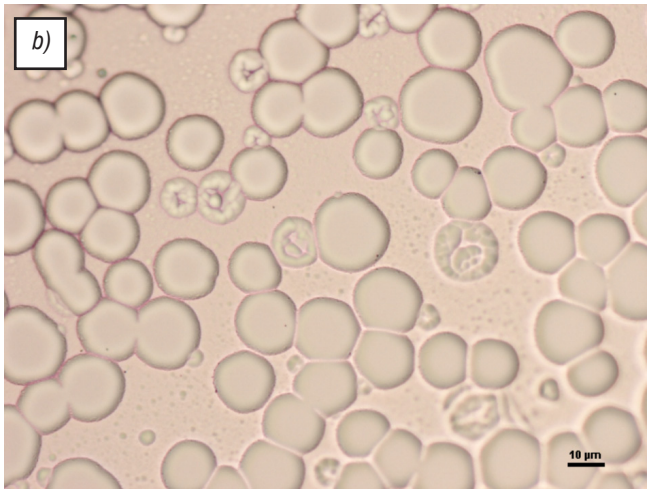
Junior research associate Simona Tučkutė's thesis defence on 19 December, 2013

ment of Physics of Kaunas University of Technology to use modern educational aids and prepare high-qualified specialists (including all study cycles) and develop competitive research. It is equally important that LEI has become a powerful centre of attraction for young researches.

Junior research associate S. Tučkutė working at Center for Hydrogen Energy Technologies on 19 December 2013 at Vytautas Magnus University defended her Doctor thesis ***Investigation of simultaneous oxidation and hydriding of titanium films in water vapour plasma*** (physical sciences, physics – 02P). In the dissertation a very actual issue of worldwide importance is being analysed – hydrogen production. Summarized scientific research are presented in the thesis, which according VDU and LEI cooperation agreement have been successfully implemented using original and up-to-date equipment available at Center for Hydrogen Energy Technologies.

During research nano crystalline 300–600 nm thick Ti films were formed on oriented (crystalline Si) and alloyed silica (SiO_2) substrates in argon gas plasma, using PVD-75 magnetron deposition system. After reconstructing the same system, simultaneous oxidation and hydration in low pressure (10–300 Pa) water vapour plasma at different generator power (20–300 W) was conducted changing exposition time in plasma from 5 to 60 min. The dependencies of $Ti_xO_yH_z$ film properties from working gas, pressure, ions energy, film's thickness and exposure time in water vapour plasma were obtained. It was determined that in ionized water vapour environment Ti films are chemically active, forming physical-chemical conditions, which enable to decompose water molecules into O and H atoms. Conducted analysis of further behavior of splitted H and O atoms in Ti material enabled to observe the following patterns: (i) that splitted oxygen atoms in the surface metal film layer form Ti-O compounds and considering irradiation time (dose) and intensity, transform metal coating into oxide one with different stechiometric ratios, (ii) part of splitted hydrogen atoms are gathered in defect traps in thin surface layer (30–50 nm), whereas the other part diffuse at room temperature





Formation of bubbles on Ti coat after exposition in H_2O plasma: a) SEM and b) optical microscope

in inter-crystalline nanostructure material regions into volume and arrange along film thickness. At concentrations which exceed solubility limit, the hydrogen bubbles are observed.

Research results obtained at Center for Hydrogen Energy Technologies form basis to retrieve multiphase titanium oxide films using a flexible and manageable technology with a perspective to employ them in photo catalysis, medicine and biotechnologies.

In 2013 the project ***Commercialism of Technologies Developed at the Center for Hydrogen Energy Technologies of Lithuanian Energy Institute*** (2012-08-13 No.31V-137) **financed by Agency** for **Science, Innovation and Technology** (MITA) was successfully completed. With this objective the researchers of the center established JSC "Inovatas", which is related with LEI *spin-off* agreement.

Main objective of the project – to commercialize most valuable technologies developed at CHET. During the project the three technologies were analysed.

The first technology – ***Hydrogenation method of metals and their alloys*** (LR patent No.5789; issued EPO proposal No.10478001.0 submitted on 29 06 2011). The project task related with this technology – to certify the developed technology. The international level feasibility study were prepared and presented for potential investors, where basic advantages and challenges of the commercialized technology would be reflected.

The second technology – ***Method of Hydrogen Production from Water, Using Water Interaction with the Metals Activated in Plasma or Their Alloy Surfaces*** (LR patent proposal No.2012026, submitted on 03 04 2012). The main market of this technology – car industry manufacturers from USA and worldwide exploiters of unstable renewable energy systems (wind, sun). The basic result of the project on this technology is synthesized nanomaterials, produced using physical material deposition technologies and designed for hydrogen production. This technology successfully presented for major manufacturers of USA car industry and risk capital enterprises.

The third technology – presently under development at CHET new generation Ni-Zr-Nb, Ni-Ti-Al, Ti-Al amorphous membranes, devoted for separation of hydrogen from hydrocarbons (natural gas, biogas, oil products, etc.) and alcohol. These membranes are much cheaper than presently used Pt, Pd based membranes. The basic project result is related with the third technology – the membrane examples were prepared and presented for potential USA consumers.

In 2013, the researchers of the Center actively participated in International Energy Agency Hydrogen Implementation Agreement (IEA HIA) Task 22, ***Fundamental and Applied Hydrogen Storage Materials Development***. In this activity, chemical destabilisation of metals and their alloy hydrides was carried out by introducing new elements into materials, which form intermediate derivatives during hydride decomposition and, thus not allowing the system to get fully relaxed to the lowest energy state, or form a destabilized hydride during hydrogenation.

Last year, the researchers of the Center published 5 scientific articles in the journals listed in Thomson-Reuters database and presented 3 papers in international conferences.

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LABORATORY of NUCLEAR ENGINEERING

MAIN RESEARCH AREAS OF THE LABORATORY:

- investigation of thermal processes in energy equipment components:
  - reduction of emission resulting along with flue gases from biofuel combustion using electrostatic precipitators; research on heat and mass transport in the equipment of biofuel-fired installations;
  - forced and mixed convection, turbulent and transition flow regimes, influence of channel geometry, variable physical properties, roughness, effect of transient conditions and centrifugal forces on heat transfer and turbulent transport;
  - numerical modelling of heat transfer and turbulent transport 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 characterisation of buildings, systems and facilities, safety and environmental impact assessment, normative and legislative base;
- fire hazard analysis of nuclear power plants and other facilities;
- research related to construction of new nuclear power plant in Lithuania.

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

Experts of Nuclear Engineering Laboratory together with other laboratories of the Institute coordinate and implement two long-term scientific research and experimental development programs, which of the beginning of 2012 were approved by the 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 program – 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 vapour condensation processes.
- ***Investigation of nuclear power plants' decommissioning and nuclear waste and spent fuel management processes and radiation impact analysis (2012–2016).*** The objective of the program – applying numerical and experimental research methods and taking into account the peculiarities of Ignalina NPP decom-

missioning 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

While burning fuel, different sizes of solid particles are being emitted. The reduction of pollution is an especially important issue in solid fuel combustion. The use of electrostatic precipitator is an effective mean for cleaning the emitted solid particles (especially small ones which are not captured by other filters (e.g.: cyclonic filters)). Electrostatic precipitators intended for deposition of solid particles and used in industrial and energy equipment are prevailing worldwide for reducing the environmental pollution down to minimum. Depending on the burnt material, the operation (efficiency) of filters changes due to the influence of different sizes and composition of particles emitted with flue gases. An exhaustive analysis of these factors enables solving relevant issues related to upgrading technologies of the Lithuanian energy sector.

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

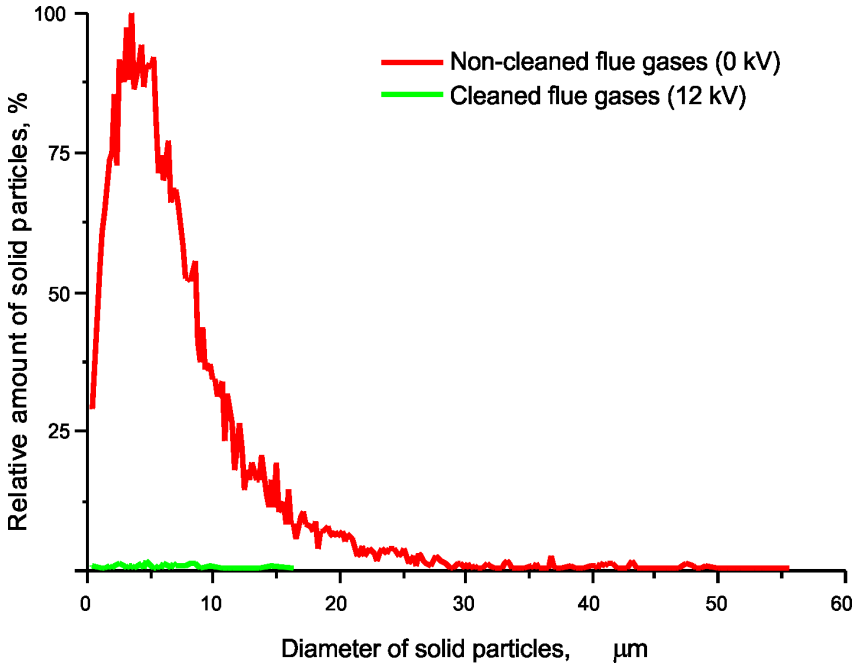
Researchers of the Laboratory in the frame of the project ***Research of local fuel thermal decomposition processes by developing efficient and ecological technologies*** (2012–2014), financed by national research program ***Energy for the Future*** of Research Council of Lithuania together with other laboratories of the institute conducted the following investigations. The Laboratory researchers together with other laboratories of the institute were implementing the measure

Research Council of Lithuania

of the third priority ***Strengthening capacities of researchers Promotion of High International Level Scientific Research*** project ***Development of Innovative Thermal Decomposition Technology and Its Application for Utilization of Sewage Sludge*** (2013–2015). Sewage sludge is retrieved as waste in Lithuanian wastewater treatment enterprises. While the infrastructure of waste gathering and treatment expands, the amount of sludge comprised during waste treatment is increasing. Huge amounts of sludge stored in sludge sites begin to evoke hazard for the environment and contradicts to sustainable development principles. Therefore the most effective methods are searched to treat wastewater sludge. One of the most innovative methods for treating 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 sludge 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.

In 2013 the methodology of foreseen experimental and numerical investigations related with treatment of biofuel combustion products was developed. Since electrostatic precipitator is to be used for treatment of combustion products, the facility necessary for investigating the deposition of solid particles is foreseen. It would enable to conduct the measurements of concentration of solid particles and their distribution (fractions), to estimate parameters of electrostatic precipitator. Preliminary assessments of combustion products treatment process were carried out by choosing real conditions for combustion products' flow, the electrostatic precipitator was designed, manufactured and tested.

The results of preliminary tests demonstrated that when burning biofuel (wood pellets) the most part of solid particles are



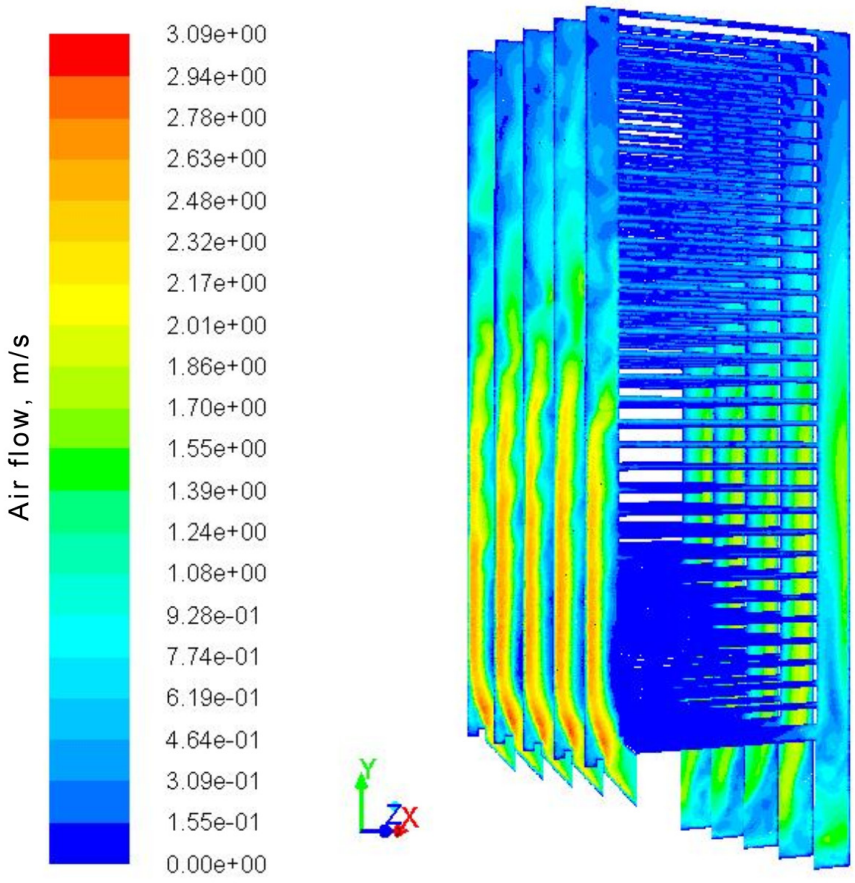
Variation of relative amount of solid particles distribution with their diameter

with diameters from ~0.4 μm to ~15 μm in flue gases. The biggest amount of particles is comprised of the particles with the diameter ~4 μm. Solid particles from flue gases are cleaned using electrostatic precipitator. When the voltage supplied to the precipitator was 12 kV, the obtained results showed that decrease of solid particles concentration was about 99 %.

Laboratory carries out investigations of heat transfer and hydrodynamics in energy equipment for different purposes (in the elements of nuclear reactor, various heat exchangers, etc.). Since in both laminar and turbulent flow cases, the effect of buoyancy forces (mixed convection) on heat transfer is manifested in many energy installations, which under certain conditions can be the reason for an accident in different installations, therefore, in order to analyse such problems the laboratory performs experimental mixed convection investigations in various channels. In parallel, investigation is also performed using the ANSYS CFD code (ANSYS, USA) which is widely used for modelling the fluids flow and heat transfer in complex two and three-dimensional systems. Depending on flow conditions various models of the laminar, transition and turbulent transfer are used. Additionally, such research was initiated in geological structures while analysing the possibilities of Ignalina NPP spent nuclear fuel disposal.

In 2013 the numerical investigations (using ANSYS CFD code) on heat transfer and hydrodynamics in flat channel for opposing mixed convection flows in the transition region were continued.

Applied experimental and numerical research was carried out within the framework of EU Structural Funds support instrument administrated by Agency for Science, Innovation and Technology



Distribution of air flows in drying facility

Inočekiai LT. In accordance with this instrument the efficiency of JSC *Wilara* bee bread dryer was improved. Experimental and numerical investigation of flow distribution were performed, and based on this drying time reduced as well as energy expenses. This implemented decision provides JSC *Wilara* product with a competitiveness advantage not only on Lithuanian market but on EU markets as well.

Safety of spent nuclear fuel management

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

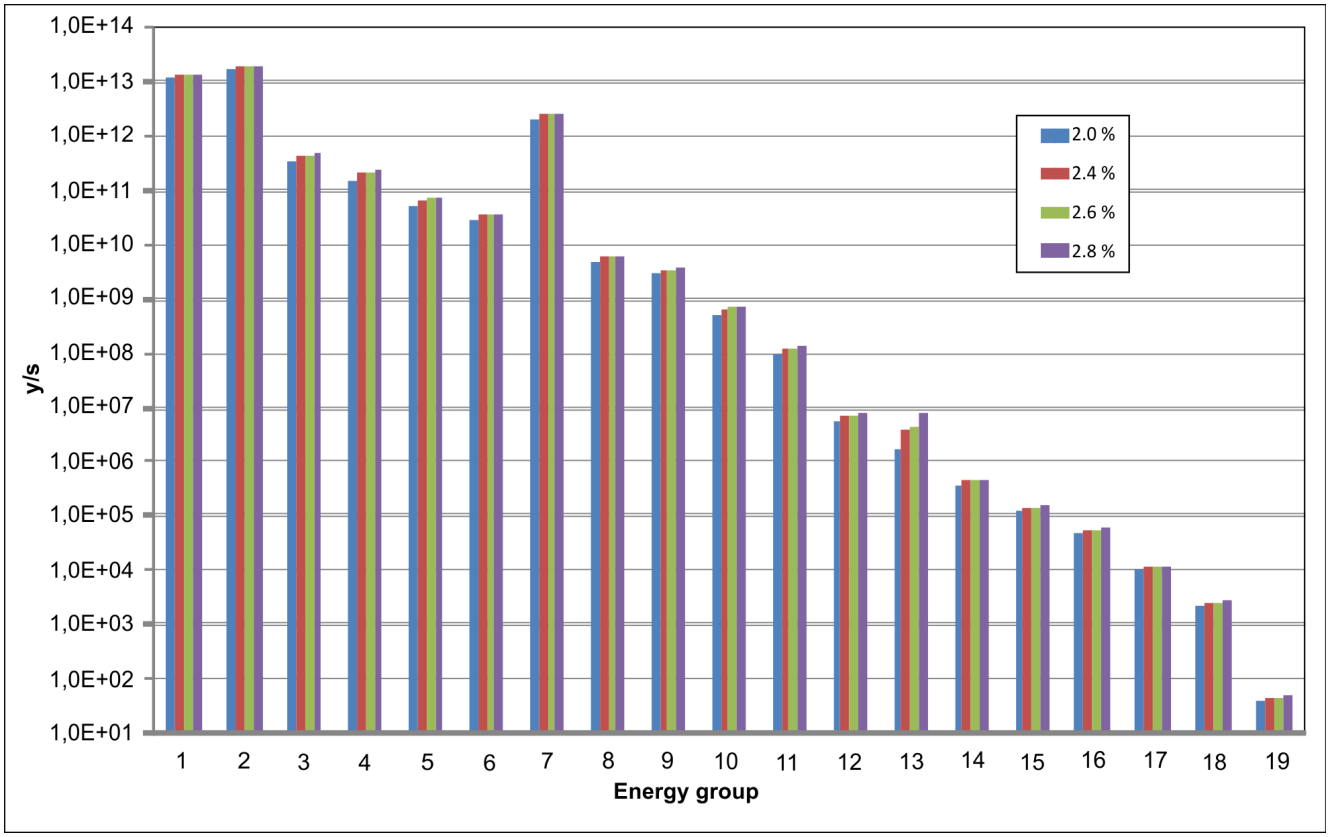
Implementing the research on SNF disposal in Lithuania, the Laboratory experts with the assistance of Swedish experts proposed the concepts of deep geological repository in clay and in crystalline rocks for SNF and long-lived intermediate level waste in Lithuania. The concepts on disposal are constantly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

was carried out and generic repository safety assessment was initiated.

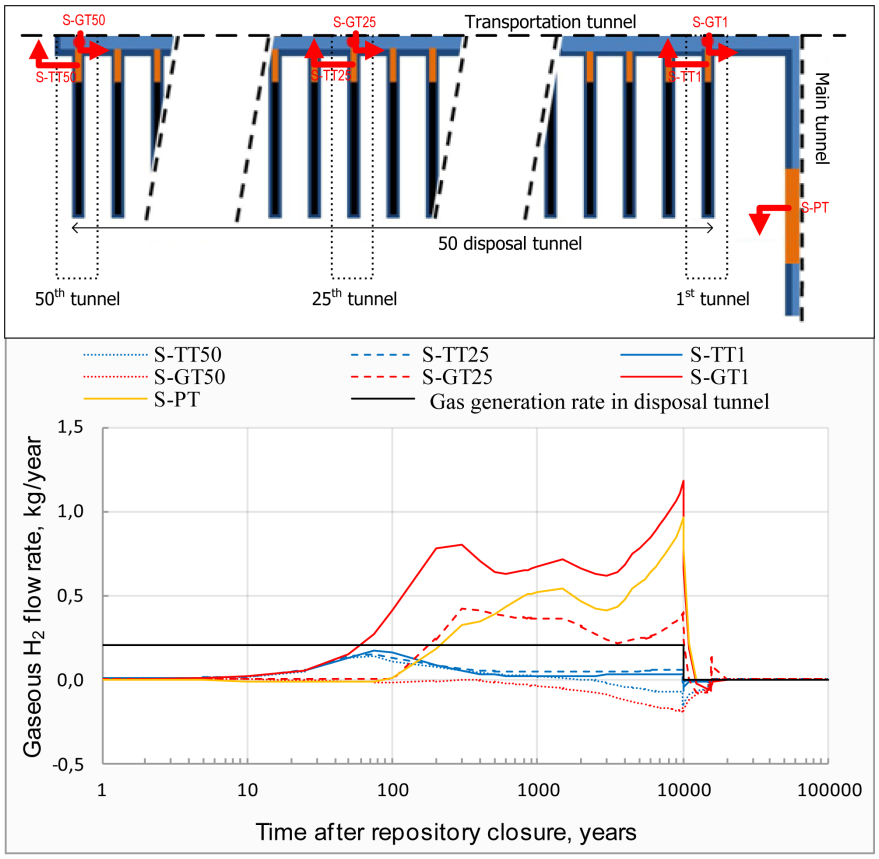
The Laboratory together with consortium GNS – NUKEM Technologies GmbH (Germany), continued an extensive project ***Design and Installation of the Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2*** (2005–2014). This project comprises the analysis of all activities related with the design, construction, installation, commissioning, operation and decommissioning of the new SNF storage facility and the performance of all necessary works related to the SNF removal, packaging, sealing and transfer as well as operation of the appropriate equipment for implementation of chosen design concept. It is planned to store approximately 200 new type CONSTOR casks with intact and damaged SNF in the new storage facility. The Laboratory prepares Environmental Impact Assessment and Safety Analysis Reports of this SNF storage facility (operational time no less than 50 years) and offers support in licensing the storage facility. In 2007, *Environmental Impact Assessment Report* was approved by the Ministry of Environment; in 2009, *Preliminary Safety Analysis Report* (PSAR) was prepared and agreed upon and the licence for construction of the new SNF storage facility was issued by VATESI. In 2010–2011, PSAR Addendum, which presents the evaluation of safety aspects of damaged RBMK-1500 nuclear fuel assemblies' management and storage, was being prepared. In 2013 SNF storage facility construction works were implemented. In 2014 the *Final Safety Analysis Report* is going to be prepared.

Implementing state funded scientific work, the Laboratory researchers estimated how the nuclide composition and radiation characteristics of RBMK nuclear fuel change as well as release of the remaining heat during long-term storage. The evaluation of these parameters is important in forecasting the impact of ionized radiation on the environment and ensuring safe operation of SNF storage facility. Fuel with different U-235 enrichments was used during Ignalina NPP operation, however as the assessments reveal the initial fuel enrichment insignificantly influences the radiation characteristics.

In 2013 complex investigations of radionuclides, gas and heat migration in natural and engineering barriers of repositories were continued. Numerical research was carried out using computer codes AMBER (Quintessa, United Kingdom), GOLDSIM (USA), COMSOL (USA), PETRASIM (USA), and COMPASS (GRC, UK). The model of the repository's module (50 interconnected disposal tunnels of high level waste) was created for the assessment of gas migration. Gas will be generated in the repository due to corrosion of steel canisters and engineering



RBMK-1500 SNF gamma spectrum after 300 years of storage



The comparison of hydrogen gas flow through different surfaces of geological repository module

components. Values of most important parameters for repository safety – maximum gas pressure and gas flow through different surface of module – were determined. Summarized results revealed that maximum pressure in the module is insufficient to disturb mechanical stability and functionality of engineering barriers' system. Most of generated gas (93%) dissolve in groundwater and diffuse toward natural geological environment surrounding the repository. The remaining part (7%) is removed from repository module in gaseous phase by advective flow.

In 2013 the Laboratory researchers participated in IAEA organized training courses, where they were acquainted with the properties of engineering and natural barriers of geological repositories. During the courses the samples of geological environment were taken in underground research laboratory, geotechnical parameters were identified and the engineering barrier was produced according indicated standards. The key topics during the courses were theory of coupled thermo-hydro-mechanical processes in geological repository. Theory was applied in practice by modelling with software COMPASS.

Researchers also participated at IAEA training courses, where they upgraded their knowledge on the possibilities of geological repositories installation as well as disposal of radioactive waste in such type repositories. Representatives from Japan Nuclear Agency shared their experience in executing the outcomes of Fukushima NPP accident liquidation; information was obtained on the up-to-date IAEA documents. During the courses the Mizunami underground laboratory was visited, the researchers were introduced with geological and hydrogeological research performed in it.

SAFETY OF RADIOACTIVE WASTE MANAGEMENT

Since 1994 the Laboratory has been actively involved in the analysis of the radioactive waste management problems at Ignalina NPP. Laboratory experts together with the experts from *SKB International* (Sweden) carried out a number of projects, which included safety assessment

Ph.D student D. Justinavičius at IAEA training courses (1–14 September, 2013, Prague, Czech Republic – Cardiff, UK)

Dr. D. Grigaliūnienė at IAEA training courses (9–16 November, 2013, Mizunami, Japan)

of existing 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 Ignalina NPP cement solidification facility and a temporary 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 the 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 devoted for the siting of a new near-surface repository of radioactive waste in Lithuania, and for scientific research related to the radionuclide migration from radioactive waste repositories and its impact on safety. With the assistance of Swedish experts, the Laboratory specialists prepared the set of criteria for choosing a near-surface repository site, improved the reference design of a near-surface repository and prepared the implementation programme. The impact of *heterogeneous* waste activity distribution on radionuclide migration from model near-surface repository was investigated.

Numerical investigation were carried out using software DUST (BNL, USA), GENII (PNNL, USA), GWSCREEN (INEEL, USA), and AMBER (Quintessa, UK).

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

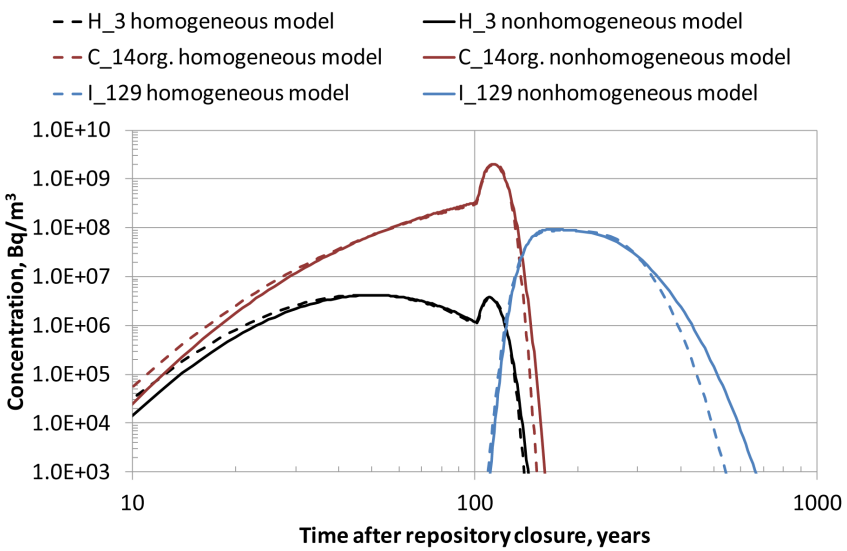
In 2013, the Laboratory together with NUKEM Technologies GmbH (Germany) continued the project ***New Ignalina NPP Solid Waste Management and Storage Facility*** (2006–2014). This facility is intended for solid radioactive waste retrieval, sorting, transportation, treatment (using envisaged technologies), packaging, characterisation and storage. The facility comprises the solid waste retrieval facility located at the existing Ignalina NPP solid waste storage buildings, the new solid waste treatment facility, the new short-lived radioactive waste storage facility and the new long-lived radioactive waste long-term storage facility.

The Laboratory prepares environmental impact assessment and safety analysis reports for this complex. *Environmental Impact Assessment Report* was agreed upon and approved by the Ministry of Environment in 2008 and two PSARs, *New Solid Waste Treatment and Storage Facilities at Ignalina NPP* and *New Solid Waste Retrieval Facility at Ignalina NPP* were prepared. The former was approved in 2009 and VATESI issued the licence for the construction of the facility. Additionally, in 2009 two more PSARs, *New Solid Waste Retrieval Facility. Retrieval Unit 1 and Retrieval Unit 2–3 at Ignalina NPP* was newly prepared, while in 2010 both PSARs were submitted to authorities for review. The former was updated following the recommendations of the authorities and approved by VATESI in the end of 2010, while in the middle of 2011, the licence to build the complex was issued. The second PSAR was modified considering the recommendations of the authorities in 2011–2012. In 2013 construction works were carried out. In 2014 *Final Safety Analysis Report* will be prepared.

In 2008–2013, the Laboratory, as a partner of Lithuanian consortium (JSC

Specialus montažas-NTP, LEI, *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. *Landfill* facility will be comprised of three repository modules and buffer storage where waste will be stored till their disposal. In 2009–2013 the Laboratory prepared *Environmental Impact Assessment Report* for the planned economic activity, two preliminary safety analysis reports, two general data sets, final safety analysis report and waste package description of the radioactive waste packages intended for disposal.

In 2013 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)*** (2009–2013). 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. Also the preparatory work of technical project was initiated. In 2013 the Laboratory researchers prepared safety analysis report related with the long-term safety of the designed repository and the repository environment monitoring program.



The comparison of the leached radionuclides' concentrations below the repository

In 2013 the Laboratory researchers investigated the impact of the waste zone inhomogeneity in estimating radionuclides migration from the near surface radioactive waste repository.

In the inhomogeneous waste zone model radionuclides from the repository are leached later than in homogenous one since backfilling of waste packages was additionally estimated in the inhomogeneous waste zone model.

In 2013 the Laboratory researchers participated in IAEA organized training courses, devoted to implementation of radioactive waste repositories, the identification, analysis and representation of spatial variability of sites selected for geological repository. The key aspects of repository safety assessment and repository components were analyzed, managing and presenting spatial variability from site investigations using geostatistics and other data analysis techniques were discussed.

Dr. A. Narkūnienė at IAEA training courses (1–5 July, 2013, Vienna, Austria)

EVALUATION OF DIFFERENT FACTORS RELATED TO DECOMMISSIONING OF NUCLEAR POWER PLANTS

In 1998 the Laboratory researchers initiated research related with Ignalina NPP decommissioning. Our experts participated in PHARE project preparing ***Preliminary Ignalina NPP Decommissioning Plan*** as well as ***Final Ignalina NPP Decommissioning Plan***.

In 2004 the Laboratory researchers in accordance with the order of Ministry of Economy of the Republic of Lithuania prepared projects for Ignalina NPP decommissioning program and its implementation measures' plan for 2005–2009. In 2005–2008 together with the Institute of Physics implemented project ***Development of Radiological Characterization Programme for Equipment and Installations at Ignalina NPP***.

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

In 2013, Laboratory of Nuclear Engineering, as a partner of international consortium (JSC *Specialus montažas*-NTP – FTMC – LEI – ATP (Bulgaria) – INRNE (Bulgaria) – VNIIAES (Russia) continued 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 NPP Units 1–4 (WWER). In 2013 the experts of the Laboratory updated the created data bases used to store the project results and provided technical assistance to consortium partners.

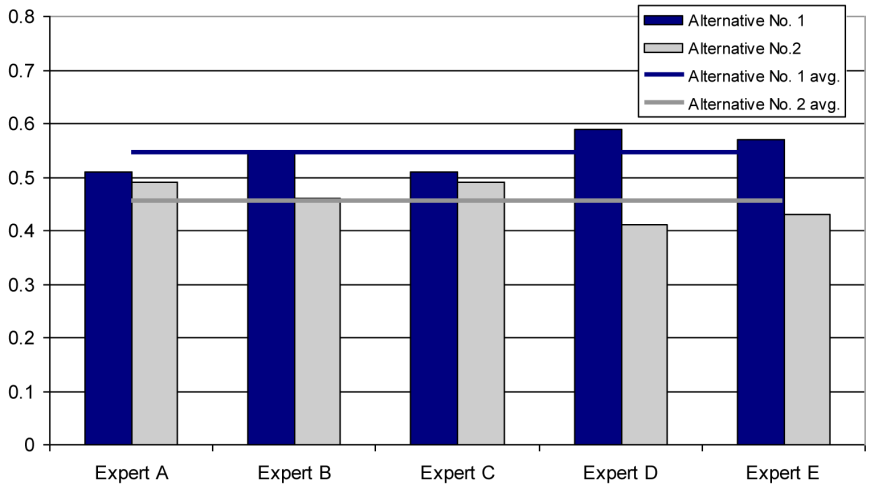
In 2013 the specialists of the Laboratory improved the ***DECRAD*** software (developed in 2009) devoted to the analysis of decontamination and dismantling of nuclear power plants, planning the demand for expenses, costs and personnel, calculation of the personnel radiation doses, planning of radioactive waste disposal and the assessment of other parameters related to the decommissioning. The software may be applied for planning and analysing decommissioning of different power plants, their separate buildings or units. Also using DECRAD software a *Multi-criteria Decision Analysis* may be performed, the AHP (*Analytic Hierarchy Process)* method used in parallel with the DECRAD software is one of the most relevant methods to select the alternatives for nuclear facilities dismantling.

In 2013 while expanding the functionality of DECRAD, the DECRAD-ACT software, designed to store and process the data on radioactive components of nuclear reactors, was developed. This newly created DECRAD-ACT software is used in the above mentioned Kozloduy NPP project.

In 2013 the Laboratory researchers were invited to participate in IAEA coordinated project ***Data Analysis and Collection for Costing of Research Reactor Decommissioning (DACCORD)*** *(2012–2015)*. It will focus on representative input data and benchmarking data needed for the costing of research reactor decommissioning at preliminary planning stages.

The Laboratory researchers also participated at international training course on nuclear facility decommissioning and environmental remediation, organized by IAEA at Argon National Laboratory (USA). During trainings the issues on nuclear facilities decommissioning planning, dismantling and decontamination technologies, radiological characterisation of waste, buildings and areas, input of interested persons when implementing dismantling and environmental remediation projects were analysed.

Since 2002, the Laboratory has performed fire hazard assessments in the nuclear power plants and other important facilities. In consultation with



The comparison of alternatives for Ignalina NPP VI unit dismantling applying Multi-criteria decision analysis was performed using DECRAD software

Dr. A. Šimonis participated at international training course on nuclear facilities decommissioning and environmental remediation at Argon National Laboratory (8–9 April, 2013, Illinois, USA)

Swedish exerts, the Laboratory specialists assessed the fire hazard of Units 1 and 2 of Ignalina NPP. Fire hazard assessment of some renewed Ignalina NPP rooms for displaces purposes and newly designed Ignalina NPP SNF and radioactive waste storage facilities were carried out as well. An external fire impact on the new INPP complex for solid waste treatment and storage was assessed and the fire hazard analysis of the most dangerous areas in the case of an internal fire was performed. In 2009, the impact of fire during the implementation of Ignalina 117/1 building dismantling and decontamination was evaluated as well as the fire safety of newly designed buffer storages and disposal units of *Landfill* repository was analysed. In 2010, the impact of fire during the implementation of Ignalina V1 unit dismantling and decontamination was assessed. In 2012 based on detailed project documentation the fire hazard impact in very low activity radioactive waste repository was estimated.

In 2013 the Laboratory researchers initiated state budget funded scientific work ***Integrated research of radioactive pollution formation, its impact and dispersion during decommissioning of RBMK-1500 reactors and storage and disposal radioactive waste (2013–2015).*** The objective of this scientific work – applying up-to-date numerical research methods to estimate and specify the characteristics of radioactive waste generated during RBMK reactor decommissioning and dismantling. This is precondition for the selection of waste management methods, engineering constructions of management or storage facilities and repositories, to perform the integrated analysis of the radiation impact of ionizing radiation caused by radioactive waste and spent nuclear fuel to personnel and population. In 2013 research regarding Ignalina NPP radioactive waste and spent nuclear fuel characteristics were reviewed, investigations regarding ionized radiation and radionuclide dispersion in Ignalina NPP and its region were summarized, the pathways of radionuclides transfer from current and new radioactive waste management, storage facilities and repositories to the environment were analysed, new software were used, calculation models were developed and preliminary results were obtained.

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

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

In 20013 researchers of the Laboratory performed seven EU 7th Framework Programme funded projects. Three of them are research projects:

- ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE)*** (2008–2013);
- ***Fate of Repository Gases (FORGE)*** (2009–2013);
- ***CAST (CArbon-14 Source Term)*** (2013–2018).
- ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE)*** (2008–2013). In 2013 the Laboratory researchers

together with 30 partners from 10 EU countries and South Africa Republic completed research activities as foreseen in the project. Numerical investigations related to the RBMK-1500 reactor irradiated graphite radiological characterization were carried out in this project. MCNP (LANL, USA) and ORIGEN-S (from SCALE software system) (ORNL, USA) software were applied for these numerical investigations. Investigations of the possibilities of the final disposal of RBMK-1500 irradiated graphite in the geological repository were performed within the framework of this project also. The developed repository environment models were implemented using software AMBER (Quintessa, UK) and the radionuclide transport analysis was carried out taking into account the results of conducted research within this project. Further transport in the geosphere was estimated using developed numerical models with the software TOUGH2 (LBNL, USA).

- ***Fate of Repository Gases (FORGE)*** (2009–2013). In 2013 the Laboratory researchers together with 23 partners from 10 EU countries completed research in the Project and prepared final report which summarizes the obtained results. During the project researchers developed models for the assessment of gas migration disposal tunnel and module of geological repository. Numerical modelling of gas migration was performed using software PETRASIM (USA). The obtained results were submitted to coordinator of numerical research section, who performed the comparative analysis of the results obtained by project partners.

- ***CAST (CArbon-14 Source Term)*** (2013–2018). This project aims 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 the releases from irradiated metals (steels, Zircaloys), ion-exchange resins and from graphite. The project is implemented by 33 partners from 12 EU countries and 3 non EU countries. The kick-off meeting of the CAST project partners took place at the end of 2013 in London (UK), where work packages, their implementation plans and work schedules were discussed.

EU's 7th Framework Programme funded coordination and support action projects:

- ***New MS Linking for an Advanced Cohesion in Euratom Research (NEWLANCER)*** (2011–

Dr. E. Narkūnas with NEWLANCER project participants in the interim radioactive waste storage in Brinje (15–17 April, 2013, Slovenia)

2013). The project is performed by the experts of the laboratory in cooperation with 15 partners from 9 European countries. The main objective of the project is to analyse the research potential of EU new member States and promote scientific cooperation with the EU old member States.

In 2013 national and regional meetings of experts took place in Slovenia and Romania, during which the course of activities, results and future perspectives were discussed. The representative from LEI in these meetings presented Lithuanian national strategies and programmes as well as scientific research related with radioactive waste and spent nuclear fuel management and disposal.

- ***Sustainable network of Independent Technical Expertise for radioactive waste disposal (SITEX)*** (2012–2014). This project is performed together with 15 other organizations from the EU countries, Canada, the Netherlands and Sweden. Its main objective is to identify efficient means to implement for the establishment of a European sustainable network of independent technical expertise in the field of radioactive waste disposal. It is intended for strengthening general and mutual understanding of different aspects regarding repository safety among the regulatory institutions and organizations providing technical safety expertise and waste management. In 2013 the priorities for research were identified where technical experts should gain competence, the overview was carried out regarding the available equipment and possibilities of organizations participating in the project to perform this research, international requirements and recommendations regulating independent expertise of safety assessment, the practice of different countries were overviewed, the proposals for the development of common methodology, for competence development of technical experts, for effective public involvement in geological disposal process were formulated.

- ***Assessment of Regional Capabilities for New Reactors Development through an Integrated Approach (ARCADIA)*** (201322016). The objective of the project is to support and develop nuclear scientific research in new EU countries related with the development of IV generation reactors, main attention devoting to ALFRED (lead cooled reactor) demonstrator. The project is implemented by 26 partners from 14 EU countries. At the end of 2013 the kick-off meeting of ARCADIA took place in Bucharest (Romania), where work packages of the project, the peculiarities of their implementation as well as work schedule were presented and discussed.

- ***Building a platform for enhanced societal research related to nuclear energy in Central and Eastern Europe (PLATENSO)*** (2013–2016). The objective of PLATENSO is to enhance the capabilities of research institutes in Central and Eastern European countries to take part in EU research with respect to governance, social and societal aspects linked to nuclear energy. The project is performed by 19 partners from 12 EU countries. At the end of 2013 the kick-off meeting of PLATENSO took place in Bratislava (Slovakia) where work packages of the project, the peculiarities of their implementation as well as work schedule were presented and discussed.

The researchers of the Laboratory participate in two research projects coordinated by IAEA, namely,

- ***Treatment Requirements for Irradiated RBMK-1500 Graphite to Meet Disposal Requirements in Lithuania*** (2010–2014). This project is performed within the framework of IAEA coordinated research project ***Treatment of Irradiated Graphite to Meet. Acceptance Criteria for Waste Disposal***. In December 2013 the third meeting took place in

Dr. A. Šmaižys at IAEA coordinated scientific research project meeting (15–19 April, 2013, Villa General Belgrano, Argentina)

Vienna (Austria) where research related to the radiological properties of RBMK-1500 irradiated graphite were presented as well as gathered information about the ongoing investigations in other countries.

- ***Investigation of RBMK-1500 Spent Nuclear Fuel and Storage Casks Performance During Very Long Term Storage*** (2012–2016). This project is performed within the framework of IAEA coordinated project ***Demonstrating Performance of Spent Fuel and Related Storage System Components during Very Long Term Storage***. On April 2013 the first meeting took place in Villa General Belgrano (Argentina) where research conducted in other countries as well as research of RBMK-1500 spent nuclear fuel and storage container's features conducted in Lithuania were presented. The participants visited the spent nuclear fuel storage site of Embalse Nuclear Power Plant. In July 2013 in Vienna (Austria) the Laboratory researchers participated at IAEA organized international technical meeting devoted to the issues of spent nuclear fuel storage.

MAIN RESULTS

In 2013 the following EU's 7th Framework Programme funded projects were completed:

- ***New MS Linking for an Advanced Cohesion in Euratom Research (NEWLANCER)*** (2011–2013),
- ***Fate of Repository Gases (FORGE)*** (2009–2013),
- ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE)*** (2008–2013),
- ***Sustainable network of Independent Technical Expertise for radioactive waste disposal (SITEX)*** (2012–2013).

Researchers of the Laboratory carried out 17 applied research projects and earned almost 2 million LTL. Researchers of the Laboratory were improving their qualification by actively participating in different training programmes and coordinating meetings. They made 7 presentations at international conferences (USA, Greece, Belgium and Lithuania) and published 13 scientific articles in the Lithuanian and international journals.

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LABORATORY of NUCLEAR INSTALLATION SAFETY

MAIN RESEARCH AREAS OF THE LABORATORY:

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

In 2013, the researchers of the Laboratory, together with other national and foreign subjects, were implementing the following 23 projects: 3 state subsidy funded scientific research projects; 2 projects funded by the national research programme ***Energy for the Future****;* 1 permanent institutional scientific research and experimental development program; 17 international projects (10 projects of the EU 6th and 7th Framework Programmes (FP).

1. NATIONAL RESEARCH PROGRAMME *ENERGY FOR THE FUTURE*

In 2013, two projects, financed by the Research Council of Lithuania, were continued as a part of the national research programme ***Energy for the Future***.

The aim of the project ***Reliability and risk study of Lithuanian energy systems*** is to perform reliability and risk study for the Lithuanian energy systems. The project, started in 2012, is to be implemented by the end of 2014.

During the second year of project implementation expansion and revision of activities for energy system models and modelling measures were continued, probable emergency events in electric

power, heat supply and gas systems were simulated, the reliability analysis of these systems was carried out. The updating process was carried out for individual energy systems' (electricity, heat and gas networks) reliability parameter electronic data bases. The Bayesian assessment methods designed for statistics analysis and assessment and updating of parameters were applied for this purpose. Technical maintenance and reliability assessment as well as reliability parameters uncertainty analysis of energy systems were continued.

Applying complex reliability assessment methodology, reliability assessment of Kaunas city DHS system was carried out. When conducting thermal-hydraulic analysis extreme accident network regimes were analysed aiming to determine the maximum DHS loads. Strength assessment of pipeline as well as structural integrity probabilistic analysis were performed for most dangerous DHS sections, taking into account failure statistical data and thermal-hydraulic analysis results. Assessing Lithuanian gas supply system reliability, data for the Lithuanian gas supply system disturbances and their causes were updated using new statistical information. Experiments for assessing gas pipelines metal mechanical characteristics and fatigue parameters, were performed.

Experimental results will be used in the next stage of the project, when gas pipelines structural integrity and fatigue probabilistic analysis will be performed. The results obtained in 2013 will enable to further implement foreseen task aiming at conducting detailed energy system reliability and risk assessment study. The obtained results will also be employed for other project of ***Energy for the Future*** program devoted to research of security of energy supply in Lithuania.

In 2013 together with partners from Vytautas Magnus University national research program ***Energy for the Future*** project ***Investigation of Lithuanian energy security and assessment of energy security level*** was continued. The objective of the project is to estimate Lithuanian energy security and perform its research in accordance with the methodology developed in Research Council of Lithuania funded project ATE-08/2010. 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***. 5 tasks are set to achieve the project objectives, out of which, in 2012, the following were completely implemented: assessment of technical parameters of economical model of Lithuanian energy system and preparation of initial data of the model; assessment of probabilistic parameters of resistance of Lithuanian energy system to disturbances; identification of energy system hazards evoking biggest social stress and social instability.

In 2013, a set of final threats, occurring for Lithuanian energy system, was developed. Disturbance development model in energy systems emerging from threats was completed. The model follows linear programing method and is designed to simulate optimized activity of energy systems. Measurement metric of energy security was also introduced, according probable Lithuanian energy system expansion scenarios several scenarios (mentioned in the National energy independence strategy) were simulated. After analyzing events tree, probabilistic model of energy system was developed and outcomes of threats realization were estimated, i.e. probabilities of gas supply disruption, increase of gas prices, electricity import disruption, etc.

2. SAFETY RESEARCH OF NUCLEAR ENERGY OBJECTS

Researchers of the Laboratory participate in most advance international nuclear energy research projects devoted to development of new nuclear reactors and their future application not only in electricity and heat production but also dealing with issues related with nuclear energy safety. Cooperation was continued related with trainings and knowledge transfer to other countries' nuclear energy infrastructure organisations. All these activities enable to strengthen Lithuanian competence in nuclear energy field, which is necessary for each country having nuclear energy objects (nuclear power plants, nuclear fuel and radioactive waste storages and repositories, etc.) and executing state's nuclear program.

Long-term institutional R&D program ***Scientific research of safety important processes in nuclear fission and fusion facilities*** was continued. The objective of this five year duration program, initiated in 2012, is to perform research of safety important processes in innovative and new generation nuclear fission reactors and fusion facilities. At present time 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 integrated, where integrated deterministic and probabilistic analysis methodology is applied for safety assessment encompassing the fields of neutron kinetics, thermal-hydraulics, strength analysis, material science, mathematical modeling, etc.

In 2013 verification and validation of software codes used in nuclear power plants' safety analyses were continued. It is conducted for new generation nuclear fission reactors and fusion facilities during operation, design accidents. Also severe accidents, probable scenarios of application of hydrogen evoked hazard mitigation means in nuclear power plants were developed. Ageing analysis of mechanisms for new generation nuclear reactors in the main circulation circuit was carried out, regulating documents used for estimation

of structural integrity were reviewed. Also other program stages, devoted for research of safety important processes occurring in new generation nuclear reactors and fusion facilities and for preparation of high level integrated (deterministic and probabilistic) safety analysis methodology, were implemented as well.

Research performed during program implementation will greatly contribute to improving the competence of Lithuanian researchers in the field of nuclear energy, which is necessary while estimating safety of nuclear power plants constructed or to be constructed both in Lithuania and neighboring countries in all NPP lifetime stages – selection of NPP, design, construction, operation, its shutdown and management of spent nuclear fuel. Participation in design and analysis activities of nuclear fusion facilities will enable to keep up with up-to-date technologies and retain high level scientific potential.

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

2013 was final year for project ***SARNET-2*** (the Grant Agreement was signed in 2009). This project aims at the integration of NPP severe accident and operational research in Europe. 41 scientific and business institutions from EU countries, including LEI, participate in this project. The researchers of the Laboratory take part in the activity of the three following working groups of the project:

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

While participating in WP4 ASTEC working group activity LEI representative attended ASTEC group meeting, which took place on 28 of January – 2 of February 2013 in Marseille, France. Research results of ASTEC users when simulating with this code were presented. The program creators introduced with new improvements of the package, new possibilities and informed on further activities. LEI representative presented his achievements applying ASTEC code in simulating nuclear fusion facility. Also in the scope of this group activity the Laboratory specialists simulated non-design emergency events in Ignalina NPP spent nuclear fuel pools in the case when cooling water is lost.

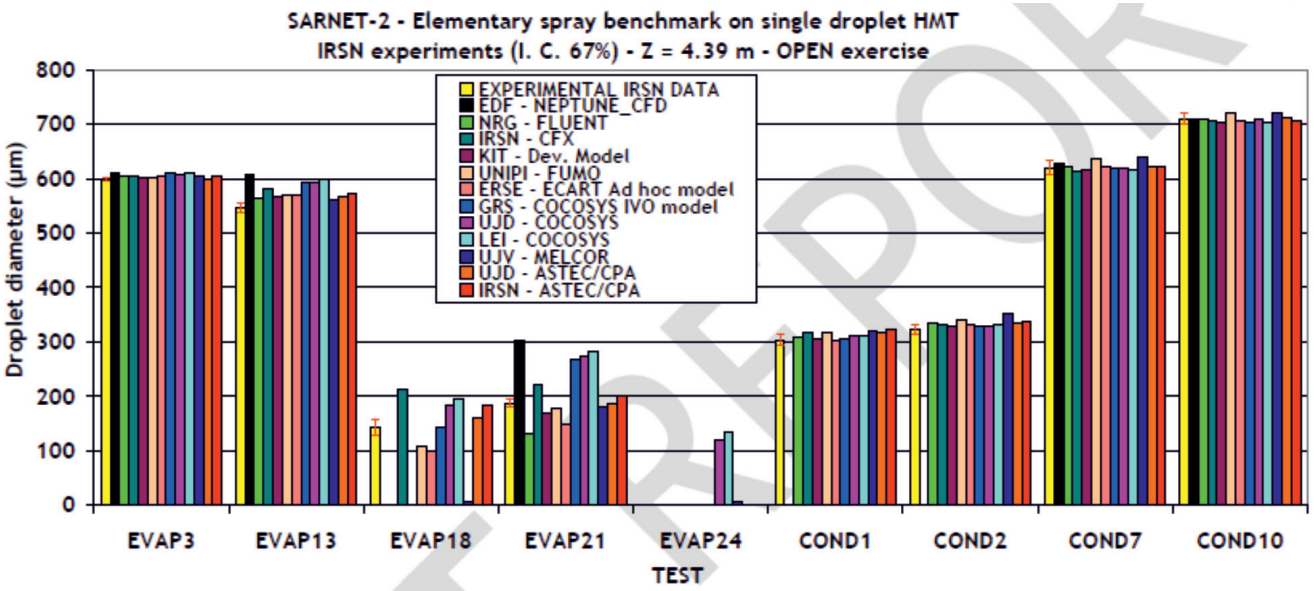
In 2013 conducted work peculiarity – numerical research performed using three codes ATHLET-CD, RELAP/SCDAPSIM and ASTEC designed for severe accident analysis. Simulation of the same phenomena using different codes and comparison of the obtained results enabled to comprehensively estimate the possibilities of computer simulation means. It was determined that applied different simulation presumptions and different numerical solutions used in software packages evoke differences of numerical results.

Participating in WP5 COOL group activity LEI representatives conducted numerical research of reflooding of the reactor core – the experiments performed in Forschungszentrum, Karlsruhe QUENCH facility were simulated. QUENCH-03 experiment, when drastically heated fuel assembly imitating reactive core is flooded with water, was simulated using RELAP/SCDAPSIM and ASTEC codes. The impact of simulation parameter sensitivity on the results of numerical simulation was investigated as well. Most of attention was devoted to simulation of rapid exothermic zirconium-vapour-reaction, during which hydrogen and a big amount of thermal energy is released. Conducted analysis enabled to determine most relevant numerical solutions.

On 19–21 of January, 2013 the finite meeting of WP-7CONT working group took place at Lithuanian Energy Institute. 20 representatives from different organisations participated in the meeting.

In 2013 LEI participated in two WP7 CONT tasks: *WP7.2 – Hydrogen mixing*

Participants of SARNET-2 WP7-CONT Meeting at LEI



Comparison of measured and calculated diameter of water droplet (participants' results)

and combustion in containment, and *WP7.3 – Bringing research results into reactor application*.

WP7.2 – Hydrogen mixing and combustion in containment

Modelling of injectors used in the protective shields

The interaction of water droplets and containment atmosphere is a significant research object since in case of hypothetical severe accident the water spray systems installed in NPP containment would be used to avoid dangerous pressure due to steam release and to ensure even gas concentration distribution in volume thus preventing from the formation of dangerous local hydrogen concentrations.

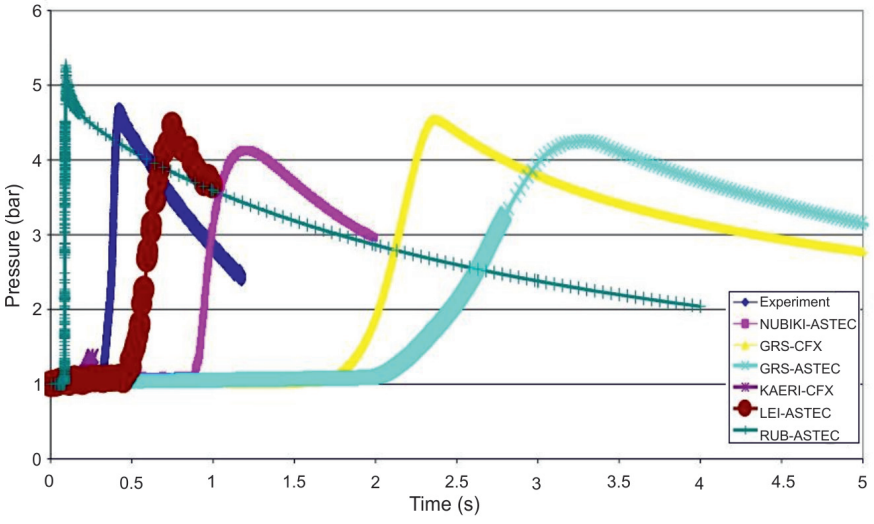
The experiments were performed by IRSN organisation, whereas other organisations conducted analytical work and using available computer codes were aiming to simulate the sequence of experiments.

The comparison of measured (by participated organisations) water drop diameter is depicted in the Figure. The performed work enabled to estimate merits and drawbacks of each code and identify basic incongruity reasons.

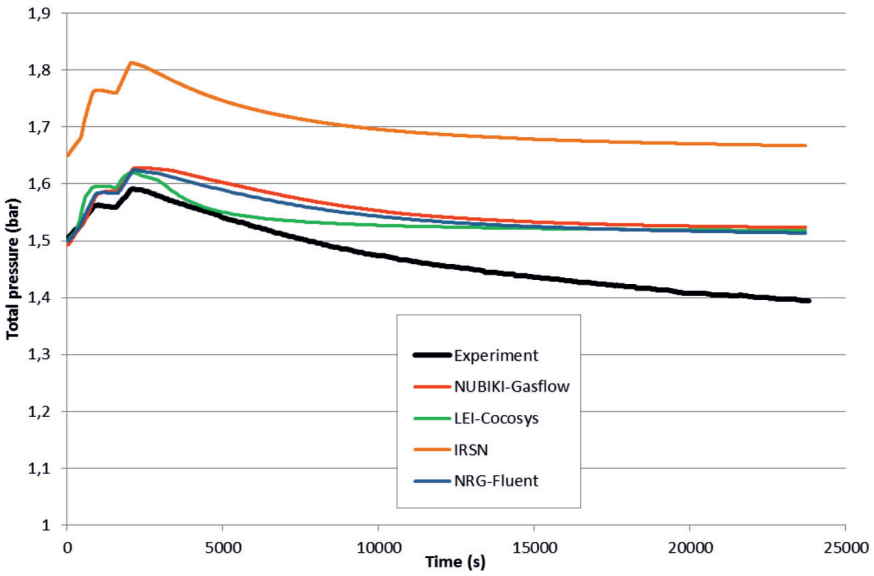
Hydrogen combustion

Hydrogen combustion is important since after ignition of gas in the containment shield its construction may be failed and radioactive materials could release far beyond nuclear power plant borders. Aiming to understand the occurring processes and estimate the capabilities of computer codes, the comparison of measurements and simulation results was carried out in SARNET-2 project in order to simulate these processes. Hydrogen combustion experiments were carried out at IRSN (France) organisation, whereas other organisations, using various computer codes conducted experiment simulation (see Fig). Basic conclusions of the work are as follows:

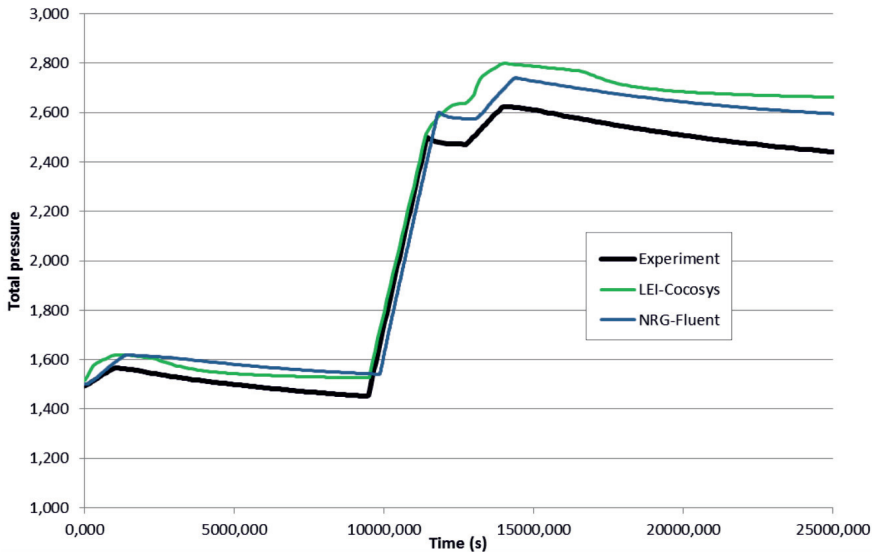
- Computer codes are able to calculate maximum pressure value and hydrogen burn-out degree;
- In order to better estimate the impact of diluents in quasi-laminar combustion regime, combustion acceleration and deceleration



Comparison of measured and calculated pressure behaviour (participants' results)



Comparison of measured and calculated pressure behaviour, PAR2 experiment (participants' results)



Comparison of measured and calculated pressure behaviour, PAR4 experiment (participants' results)

phases, the hydrogen combustion models should be corrected.

Bringing research results into reactor application (WP7.3)

Analysing passive autocatalytic recombiners modelling

Passive autocatalytic recombiners (PAR) are often used in nuclear power plants in order to reduce hazards caused by hydrogen combustion. In this task PAR models, used in various computer codes, were estimated. The experiments were conducted by GRS mbH (Germany) at THAI test facility. The main conclusion reached – codes can simulate basic processes occurring in PAR, however, since significant drawbacks were observed of the present models, they should be further improved.

Network of Excellence of Nuclear Plant Life Prediction

In 2012 planned activities of EU 6FP NULIFE (***Nuclear Plant Life Prediction***) were completed, as a consequence of which a methodology of nuclear equipment durability management was prepared.

Other objectives of this project was the establishment of virtual institute which would be able to conduct life assessment scientific research in European nuclear equipment production industry. However, in 2011 it was decided to establish an association instead of a virtual institute, which would unite not only institutions conducting life assessment research, but also organizations performing joint scientific research and development projects in the field of nuclear energy.

Therefore on 14 of November, 2011 the association NUGENIA, covering the activities of three networks of excellence: SNETP, Gen II/III, NULIFE and SARNET, was established. Continuing with the activity implemented during NULIFE project, in 2013 the researchers of the institute participated in the group activities, preparing guideline documents related with NUGENIA structural integrity; materials ageing and life; safety and risk assessment as well as proposals for new projects INCEFA (*Increasing Safety in NPPs by Covering gaps in Environmental Fatigue Assessment),* LOTERINT (*Long Term Integrity of RPV internals) and PROSafe (Harmonized understanding of uncertainties and their propagation in PRObabilistic evaluations on SAFEty margin assessments of nuclear reactor pressure vessels and piping).*

NUGENIA
NUclear GENeration II & III Association

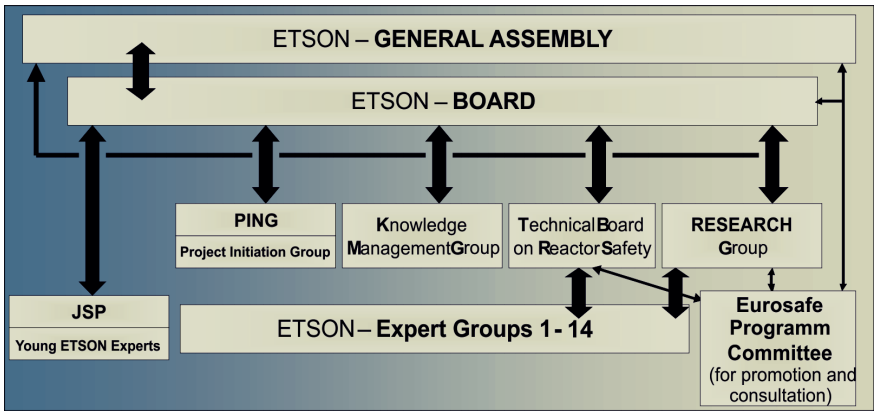
NUclear GENeration II & III Association

Established in 2011 NUGENIA covers the activities of 3 networks (SNETP TWG Gen II&III, NULIFE and SARNET). NUGENIA is an association dedicated to the research and development of nuclear fission tech-

nologies, with a focus on Generation II and III nuclear plants. It gathers stakeholders from industry, research, safety organisations and academia, committed to develop joint R&D projects in the field. NUGENIA scope of activities covers 8 main technical areas. Lithuanian Energy Institute is a member of NUGENIA association and together with other ETSON organisations actively participate in all eight NUGENIA R&D areas.

In 2013 ***NUGENIA Roadmap 2013*** was prepared. It identifies challenges and activity priorities in conducting scientific research relevant for nuclear reactors of generation II and III. Representatives of the laboratory continued their activity in this association providing proposals for ***NUGENIA Roadmap 2013*** as well as proposing ideas on new projects.

ETSON General Organisation



ETSON network activity

European Technical Safety Organisations Network

The scientists of the Laboratory of Nuclear Installation Safety have been actively participating in the activities of the ***European Technical Safety Organisations Network (ETSON)*** since 2009. 10 organisations of European countries (Belgium, Bulgaria, Czech Republic, Finland, Germany, France, Lithuania, Slovakia, Slovenia, Switzerland) are the members of ETSON, whereas 3 countries' (Japan, Ukraine, Russia) organisations – the associated ETSON members.

Main objectives of ETSON are as follows:

– to promote implementation of nuclear safety scientific research programmes;

ETSON Junior summer seminar, LEI

– to establish a suitable forum for voluntary exchanges on analyses and R&D in the field of nuclear safety;
– contribute to fostering the convergence of professional services in all fields of nuclear safety, radiation security and waste management;
– facilitate the application of the European directive on the nuclear safety.

In 2013 during the ETSON General Assembly Meeting the ETSON Board was elected, the members of which became representatives from IRSN (France), LEI, GRS (Germany), BelV (Belgium), SSTC (Ukraine). Prof. E. Ušpuras was elected LEI representative for the Board. Election of LEI representative to the main ETSON management structure indicates recognition of LEI competence and input in conducting ETSON activities.

14 experts groups are established in ETSON network. The researchers of the Laboratory actively participate in the activities of the following experts groups:

– Operating Experience Feedback, including Incident and Precursor Analysis;
– Mechanical Systems;
– Severe Accidents;
– Environmental qualification;
– Safety Fluid Systems, including auxiliary systems;
– Human and Organisational Factors;
– Probabilistic safety analysis (PSA);
– Lifetime-Management (equipment ageing);
– Thermal Hydraulic Analyses (Transients, Accidents);
– Safety concepts, Defence-in-Depth;
– Core behaviour (operational and accident conditions);
– Emergency preparedness;
– Radwaste and NPP decommissioning.

In ETSON expert groups and coordinating meetings participation of ETSON organization in implemented EU projects is constantly discussed. Participation in such expert meetings of EU countries enables directly to get acquainted with the newest ideas of deterministic safety, risk assessment and probabilistic analysis performance and application and get involved into new scientific and applied activities in the field of safety analysis.

On 26–30 of August, 2013 LEI held ETSON *Junior summer seminar* at the LEI premises on the issues of accidents management. A great number of participants attended the seminar (42 participants from 11 organisations).

Safety Assessment of Innovative Reactors

The 7FP project ***SARGEN_IV*** was continued 2013. The objective is to develop a coordinated European methodology, devoted to safety assessment of innovative reactors with fast neutron spectrum planned to be built in Europe. It is coordinated by the Radioprotection and Nuclear Safety Institute (IRSN, France) and LEI is one of 22 European institutions which participate in the project. In the scope of the project, the researchers of LEI take part in the activities of the following two working groups:

(1) experimental application of the European safety methodologies;
(2) development the European Action Plan for the scientific research and technologies of fast neutron reactor safety.

In the first working group under the leadership of specialists from German company GRS mbH a report was prepared where the application of safety assessment methodologies was discussed for selected initiating events. This work enables to estimate relevance of this methodology and prepare recommendations for future research projects devoted to develop the prototypes of different generation IV nuclear reactors. Laboratory researchers prepared a section on the early application of deterministic, phenomenological and probabilistic safety analyses. Deterministic, phenomenological and probabilistic safety analyses are an integral part of analytic means, comprising integrated safety assessment methodologies (a safety assessment process tool developed by generation IV nuclear reactor international forum). This analysis enables to emphasize probable outcomes of reactor accidents and at the same time to create conditions for improvement of their constructions.

Participating in the activity of the second working group, LEI specialists with partners identified unsolved issues as concerns generation IV nuclear reactors safety. The four prototypes of generation IV reactors were distinguished in SARGEN-IV project:

(1) gas cooled fast neutron reactor,
(2) liquid sodium cooled fast neutron reactor,
(3) liquid metal cooled fast neutron reactor,
(4) lead-bismuth cooled facility operating as accelerator.

During the each concept investigation, the safety important phenomena and experience gained after the Fukushima NPP accident analysis were estimated.

According the obtained results and work conclusions a preliminary future work program was proposed, i.e. the action plan of scientific research and technology

development in Europe designed for fast neutron reactor safety was prepared.

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

In 2013 the agreement was signed for EU 7FP project ***ARCADIA***, which started on 1 of November. This project covers two nuclear energy implementation fields, foreseen in the technological platform SNETP strategic research and innovation plan:

1) ESNII (European Sustainable Nuclear Industrial Initiative) via support for construction of liquid lead cooled generation IV reactor in Rumania and
2) NUGENIA via support in dealing with the remaining safety issues of generation III nuclear reactors.

Total 26 organisations of European countries take part in the project, which is coordinated by Romanian company INR. The project has 7 work packages and LEI participates in 5 of them, where in 2 of them LEI is the coordinator (WP5 – Co-operation and dissemination and WP6 – Research Reactors networking for LFR technology and improved LWR safety). The first project meeting took place on 14–15 of November 2013 in Bucharest (Romania).

NC2I-R

Nuclear Cogeneration Industrial Initiative – Research

Nuclear Cogeneration Industrial Initiative - Research and Development Coordination

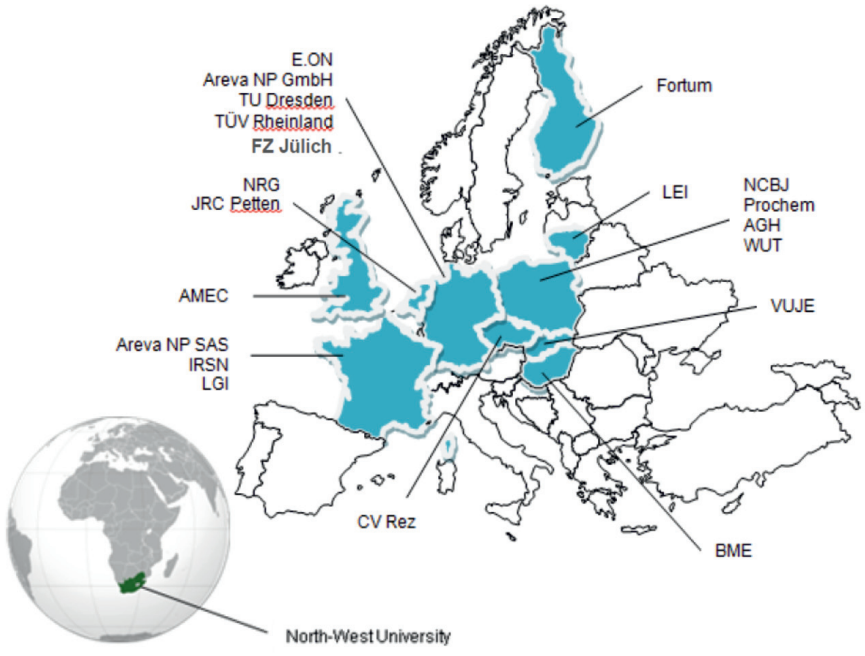
In 2013 7FP Euratom initiated international project NC2I-R was started. Strategic objective of the project – to structure the European public and private R&D capabilities for delivering a nuclear cogeneration demonstrator which fully meeting the market needs. During the project, coordinated by Polish Nuclear Research Centre NCBJ, where participate various countries research institutions as well as industry enterprises (total 21 participants), a feasibility study will be carried out – to use nuclear reactors not for electricity only but also to produce the heat. Steam produced in classical nuclear power plants is too cold (though it reaches 280 °C) to be useful as source of technological process heat, for example, to produce hydrogen or synthetic gas, in chemistry industry, etc. Such hot steam may be produced by High Temperature Reactors (HTR) which is foreseen to be analysed in the project, it is capable of providing steam of required parameters (~600–700 °C). Such nuclear cogeneration complex system should be tested, its efficiency, benefit, safety should be proven in demonstrator facility till its implementation in industry, thus scientific research are required, first of which are initiated and will be performed under this Project. The activity of NC2I-R project also aims at identifying the present and future activity infrastructure in worldwide context as well as necessary competence; to define safety requirements to prepare for the future licensing process for a nuclear cogeneration system; to prepare joint roadmap to achieve the strategic objective of the project and deployment scenarios of this initiative; also educative activity is planned for different society groups and relations with stakeholders. Most of their efforts the researchers of the Laboratory will give to the activities of task 3 *Safety and licensing:* performing the analysis of licensing process currently applied for nuclear objects for adjusting it for nuclear cogeneration system, as well defining necessary research scope for estimating safety of such systems.

cesam

Code for European Severe Accident Management

Code for European Severe Accident Management

EU 7FP project **CESAM** ***Code for European Severe Accident Management***



Country participants in NC2I-R project

was started on 1 of April, 2013. The aim of the project is to consolidate the ASTEC code in Europe as the main mean to manage severe accidents in all European II and III generation power plants ((PWR, BWR, CANDU). The project, with a total duration of 4 years, consists of four activities:

- 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 code using experimental data and performance of benchmarking calculations;
- application of ASTEC code to analysis of power plants and to analysis of efficiency or possible improvement of severe accident management measures, and development "reference" input decks for typical European PWRs and BWRs.

18 EU institutions, including Lithuanian Energy Institute, participate in this project. LEI researchers participate in working package WP40 ***Plant applications and Severe Accident Management (SAM***), which is coordinated by EC Joint Research Centre (JRC). LEI specialists, together with partners will develop "reference" ASTEC input deck for the NPP with BWR type reactor, and using ASTEC and RELAP/SCDAPSIM codes will perform benchmarking calculations of spent fuel pools of a selected BWR nuclear power plant.

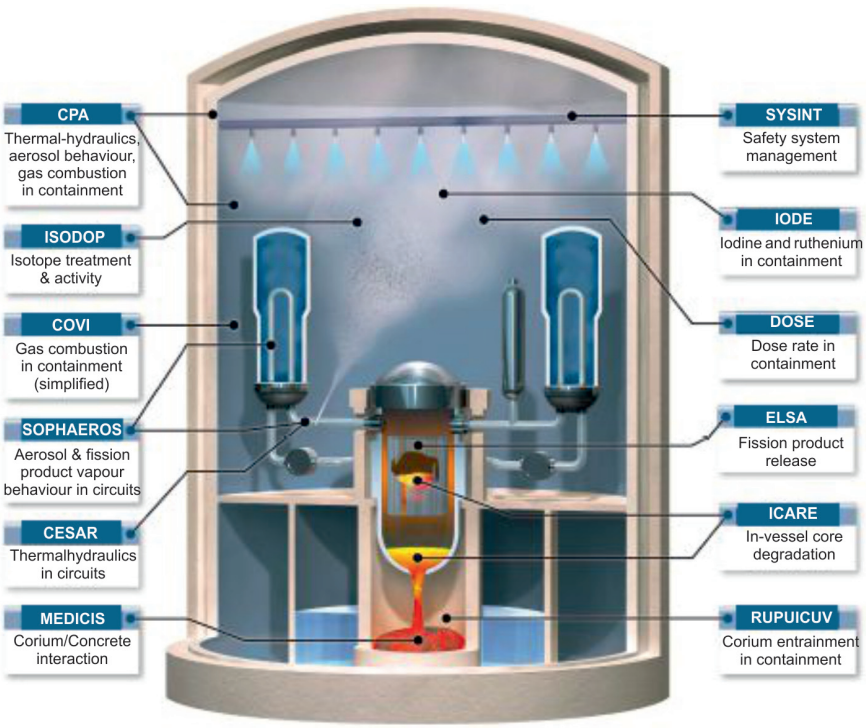
In 2013 LEI researchers collected information on the processes in BWR type nuclear plants during normal operation and in accidental conditions, and collected information on severe accident management methods and measures in BWR power plants. Together with project partners a format of engineering handbook (description of the reference computational model) was prepared and discussed. At present moment two NPP with BWR type reactors are submitted to be discussed, for which typical ASTEC models are to be developed:

1) GE BWR4-Mark I (St Maria de Garona power plant in Spain or Muhleberg power plant in Switzerland),
2) Siemens KWU BWR 72 (Grundremmingen power plant in Germany).

LEI specialists analysed and described Laguna Verde power plant's GE BWR-5 reactor model and prepared RELAP/SCDAPSIM code input deck. Using this input deck the analysis of severe accident (station blackout), similar to the one which occurred in Fukushima NPP, was carried out.

LEI researchers also obtained ABWR numerical simulator, where nuclear reactor is simulated, as well as its safety systems, and which is able to simulate different accidents. Using this simulator accidents occurring in ABRW reactor were analysed as well as reaction of safety systems.

Based on the experience acquired with ASTEC and RELAP/SCDAPSIM codes former LEI applications to the SFPs of the Ignalina NPP the initial input decks for SFP of BWR type reactor were created using ASTEC and RELAP/SCDAPSIM codes.



Structure of ASTEC integral code

ASAMPSA-E (Advanced Safety Assessment Methodologies: Extended PSA)

In the consortium, headed by Institut de Radioprotection et de Sūreté Nucléaire (IRSN), LEI participates in implementing new EU 7FP project ***Advanced Safety Assessment Methodology: Extended***

PSA. The beginning of project activity – 1 of July 2013; project duration – 36 months. Project partners – 28 organisations from 18 European countries; in addition, several associates members also participate in the project US-NRC, JANSI and TEPCO.

In 2013 the activities were initiated in all five main work packages:

- WP10: *Relationship with End-Users*;
- WP21: *Initiating events (internal and external hazards) modeling*;
- WP22: *How to introduce hazards in L1 PSA and all possibilities of events combination?*;
- WP30: *General issues regarding extended PSA scope and applications*;
- WP40: *Specific issues related to L2 PSA*.

LEI plans to participate in the activities of all work packages. In 2013 most of attention was paid to the activities, related with the identification of initial events (internal and external hazards), review of literature references covering project activities and preparation of questionnaire for end-users.

MATTER

MATerials TEsting and Rules

The EU 7FP project ***MATerials TEsting and Rules*** started on 1 January 2011 and was continued in 2013. The Laboratory of Nuclear Installation Safety and the Laboratory of Materials Research and Testing are participating from LEI. Its main objective is to carry out detailed research of material behaviour during the operation of Generation IV reactors.

In 2013 research on obtained base P91 steel were performed and fatigue testing methodology was specified. Samples were manufactured and part of fatigue experiments, necessary for fatigue curve formation, were performed. In future stage the fatigue experiments of the welded samples will be performed and the values of welding coefficients will be identified. These activities were performed by researchers from the Laboratory of Materials Research and Testing.

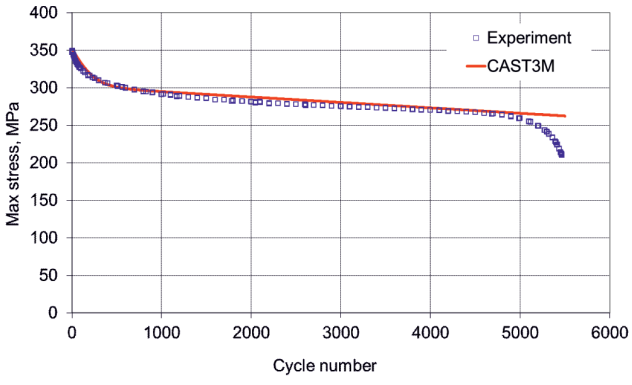
Modelling of materials' fatigue using finite element methodology was carried out. The results of finite element analysis enabled to better understand material behaviour during fatigue. Finite element software Cast3m was used for fatigue numerical research. This is the finite element software developed at CAE, France. The activities were carried out by the researchers of the Laboratory of Nuclear Installation Safety.

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

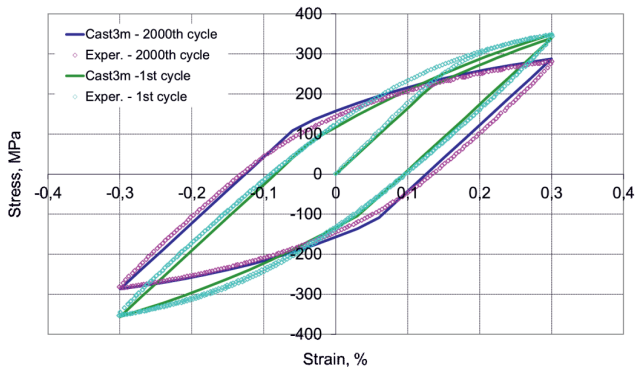
ensti
TRAINING & TUTORING NUCLEAR SAFETY

European Nuclear Safety Training and Tutoring Institute

The ***European Nuclear Safety Training and Tutoring Institute (ENSTTI)*** was established in 2010 by ETSON organisations, urged by the Institute for Radiological and Nuclear Safety (IRNS). Recently there are four members in ENSTTI: Bel V (Belgium), IRSN (France), GRS (Germany) and LEI (Lithuania). ENSTTI provides training and tutoring in methods and practices required to perform assessment of nuclear safety, nuclear security and radiation protection. The institute encourages technical support organisations to share experience in order to improve nuclear safety by spreading knowledge and practical experi-



Max stress vs. cycle number



Hysteresis loop on the 1st and 2000th cycles

ence in the field of nuclear safety culture.

ENSTTI organised a 4-week summer training (3 June – 28 June) in Germany (GRS). The researchers of the Laboratory gave lectures on the NPP dismantling strategies and particular issues of Ignalina NPP dismantling. 22 participants from Armenia, Brazil, Egypt, Philippines, Indonesia, Jordania, Malaysia, United Emirates, Mexico, Poland, and Vietnam participated in the summer training.

ENSTTI became even more active since it had submitted applications to IAEA and the European Commission regarding the organisation of similar training, namely ***Training and preparation of nuclear regulatory institutions and their technical support organisations***.

In the frame of this project ENSTTI consortium (besides LEI there participate IRSN (France), GRS (Germany), SSTC (Ukraine), ENEA (Italy) and VUJE (Czech Republic) perform activity according task LOT2 *Nuclear Safety Assessment and Inspection*, training is devoted to 15 countries developing nuclear energy: Tunis, Indonesia, Malaysia, Jordan, Belarus, Georgia, Vietnam, Morocco, Philippines, Russia, Ukraine, Armenia, Egypt, Mexico and Brazil.

Since these courses are devoted to analyse very specific safety issues of nuclear facilities, the lecturers of the courses should be the experts of respective field. In 2013, LEI researchers gave lectures in five training courses, namely:

1. *Radiation safety*, France, Paris 21–25 January.
2. *Safety assessment II*, Köln, Germany, 04–08 March.
3. *Nuclear fuel cycle*, Marcoule, France, 09–20 September.
4. *Safety of nuclear reactors I*, Bologna, Italy, 21–25 October
5. *Safety of nuclear reactors II* France, 16–20 December.

Discussion of the results of Belarusian's tutoring

ENSTTI institute organizes not only lectures but also tutoring during which people from nuclear energy developing (or planning to develop) countries come to ENSTTI organisations and are tutred there. On 16 of September – 11 of October, 2013 LEI within framework of ENSTTI activities held tutoring for experts of SOSNY institute from Belarus. The tutoring occurred in two directions:

- Senior engineer Dr. Siarhei Sinitsyn and engineer Dzianis Mitrokhin were tutored in the field of analysis of containments of nuclear power plants;
- Leading researcher dr. Natallia Harbachova was tutored in the field of emergency preparedness in case of accidents.

LEI experts trained the specialists from Belarus how to develop numerical models of containments, to study processes occurring during severe accidents, to analyse worldwide and in Lithuania gained experience emergency preparedness at NPPs. At the end of the tutoring LEI experts evaluated the accomplishments of Belarusian specialists. There were visiting experts who also participated in the evaluation process: Mr. Holger Wolff (GRS) and Mrs. Marie-Line de Heaulme (ENSTTI). The tutoring of Belarusian specialists were evaluated positively. Belarusians will use their experience in estimating and improving their national nuclear power plant safety. The qualification of Belarusian specialists will contribute to increase of Belarus NPP safety. Since Belarus NPP is being built near Lithuanian border, participation in training Belarusian specialists is very important for Lithuanian safety as well.

It should be emphasized that these were the very first implemented ENSTTI tutoring. Therefore other organisations, participating in ENSTTI activity and being future tutoring organizers, have employed our experience. On 4–8 of November, 2013 the expert Dr. Egidijus Urbonavičius attended the tutoring organized for Armenian technical support organisation at GRS mbH in Germany. During the tutoring not only the lectures were given but also practical tasks on working with COCOSYS code were performed.

Participation of LEI specialists in the activity of this project enables to gain experience in organizing similar training courses and increasing qualification. Such experience may be useful during future

Visaginas NPP construction, when it will be necessary to prepare new employees.

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

In 2013 LEI cooperating with *RISKAUDIT IRSN/GRS INTERNATIONAL (GEIE)* continued to provide support for Belarus nuclear safety institutions. In 2013 EC and RISKAUDIT project BY3.01/08 (BE/RA/06) ***Transfer of European Regulatory Methodology and Practices to the Nuclear Safety Authorities of Belarus – Institutional and Technical Cooperation with Gosatomnadzor to Develop its Capabilities on the Basis of Transferred European Safety Principles and Practices*** *was finished*, meanwhile a new project BY3.01/09 (BE/RA/07) ***Development of Technical Cooperation in Nuclear Safety in the Field of Assistance to Regulatory Authorities*** was initiated. The new project objectives continue the activity of previously implemented projects:

- To provide support in the activity of Belarus Gosatomnadzor nuclear safety regulation, related with submitted planned NPP license proposal;
- To prepare and train Belarus experts so that they would be able to properly perform the review of documents related with nuclear activity, including the use of codes applied for analyzing accidents.

Project BY3.01/09 (BE/RA/07) is comprised of two parts:

A) Support in the field of licensing – improvement of technical, scientific and applied capabilities of Belarus nuclear safety regulation and technical support institutions in all Belarus NPP construction, launching and operation stages as well as in case of probable emergency situations.
B) Provision of training in the use of accident analysis codes and code transfer.

LEI participates in the activities of both project parts. In 2013 the Laboratory researchers provided support to Belarus nuclear safety Regulatory Body and its Technical Support Orgnisations, performing the review of Preliminary Safety Analysis Report of constructed NPP. Verification of this report completeness was also performed, for instance, whether all necessary information is provided in the report, whether all report sections comply with the requirements of international regulating documents. Laboratory specialists reviewed the following sections:

- Description of NPP site and location area;
- General provisions and approaches to the design of buildings, structures;
- Auxiliary systems;
- Quality assurance;
- Decommissioning of NPP.

After reviewing the preliminary safety analysis report, the EU experts' (participating in the project) comments and remarks were transferred to Belarus nuclear safety Regulatory Body, during meetings in Europe and Belarus specialists of Belarusian Gosatomnadzor and TSO were trained how to prepare documents for licensing.

In 2014 activity was continued in the first part of the project and the second part will be initiated, where Laboratory researchers will participate in training Belarusian specialists to use COCOSYS, ATHLET and ASTEC codes. Such support for neighbouring country is necessary in order to ensure timely and effective supervision of a newly built Belarusian nuclear power plant by the Belarusian nuclear regulatory institutions. This is relevant not only for Belarus, but also for Lithuania (at which borders the nuclear power plant is built) and the whole Europe.

FUSENET

the European Fusion Education Network

FUSENET association is the European Fusion Education Network which provides a platform for the coordination of European universities, scientific research centres and industry organisations, participating in fusion research. ITER international organisation also belongs to this network. LEI is member of this association. Laboratory researchers participate in this activity since mid 2013 and this provides a possibility for PhD students and junior researchers to participate in different trainings and exchange programs.

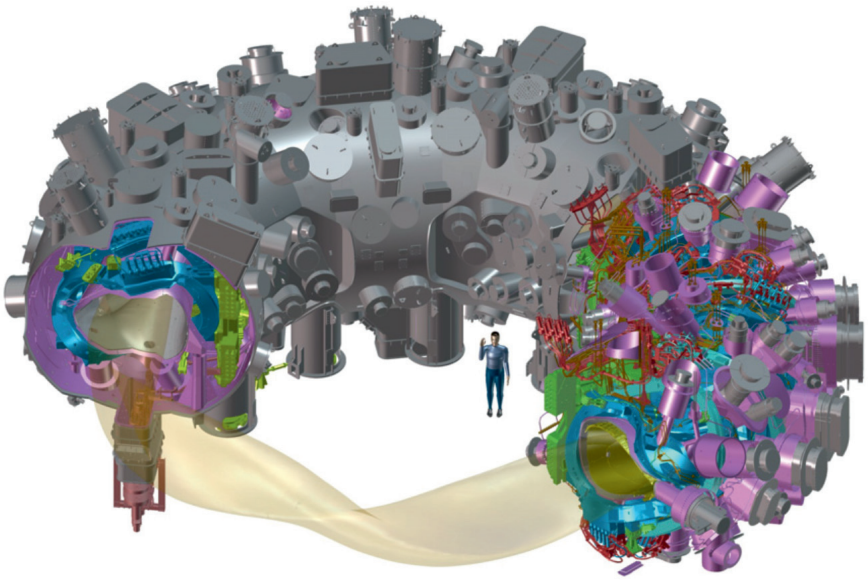
4. SAFETY ANALYSIS OF FUSION REACTORS

Scientific research of fusion energy development is one of the priorities of the EU FP7. While implementing the research of this field, LEI continued the work described in ***7BP EURATOM – LEI Association Agreement.*** Cooperation between LEI and Max-Plank-Institut für Plasmaphysik (IPP) (Greifswald, Germany) where the test facility Wendelstein7-X (W7-X) is being built started in 2007 and continues up to now. LEI also participated in the activity of *Power Plant Physics and Technology Agreement* conducted within the scope of EFDA agreement. In 2013 LEI for the first time signed the agreement to conduct

scientific research in the presently operated *Tokamak* type facility JET.

Analysis of test facility W7-X

Analysis of loss of coolant accident was carried out assuming facility operation in different regimes, limit loads were identified for plasma vessel port AEU20 welds. On 16–17 of December, 2013 LEI experts visited Max-Planck-Institut für Placmaphysik (IPP), where the obtained results were discussed as well as further cooperation in EUROFUSION project in the frames of Horizon-2020 programme.



W7-X stellarator construction scheme [Nuclear fusion. 2013. Vol. 53, No. 12, [p. 1–16]

Analysis of loss of coolant accident

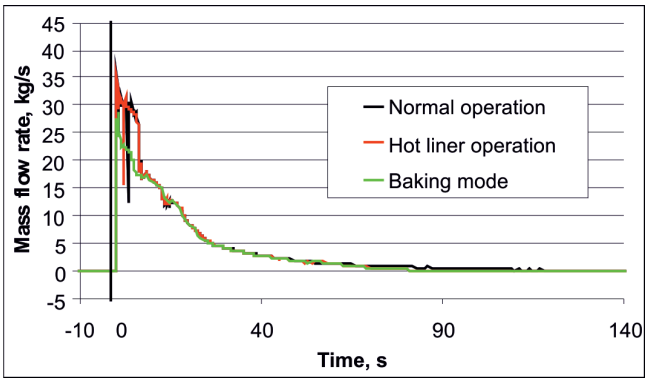
Analysis using RELAP5 code

In W7-X project it was determined that rupture a 40 mm diameter pipe, supplying water for divertor cooling, is the most severe accident according pressure increase rate in plasma vessel. In order to avoid damage of components, the absolute pressure inside torus should not exceed 1.2 bar. For this reason a safety valve is installed, which is opened when pressure inside torus reaches 1.1 bar and releases steam to environment.

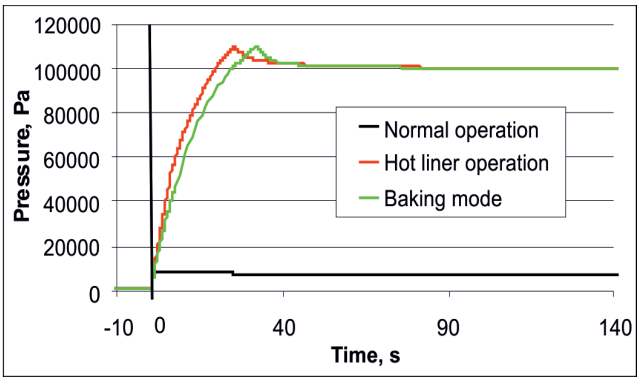
After getting the updated information from designers in 2013 W7-X plasma vessel cooling system model RELAP5 code was updated, calculations of probable accidents were performed for W7-X facility operating at different modes.

"Baking" mode is designed to heat up torus structures and clean plasma volume before igniting plasma. The other two W7-X operation modes: 1) "Normal" and 2) "Hot liner", during which a facility is cooled by the main cooling circuit, differently from the "baking" mode, when main cooling circuit is not operating. During "normal" mode 3 cooling circuit pumps are operating and water temperature in divertors are maintained ~35 °C. "Hot liner" mode is a separate case when the components of plasma vessel may be heated up to 150 °C, whereas other parameters are the same as in case of "Normal" mode.

In case of 40 mm diameter pipe rupture the coolant is released to plasma vessel and despite of operation mode the same thermal-hydraulic processes occur, however there are different coolant injections, plasma vessel pressurization rates, pressure change in cooling circuit, membrane's rupture time and plasma vessel venting system operation (amount of released and condensed steam). After performing calculations and comparing the results of all analysed operation modes (see Fig.) it was determined that according to the plasma vessel pressurization rate the most dangerous is a "Hot liner" mode. However, the safety valve diameter and



Water flow through the broken pipe in to the plasma vessel at different operating modes

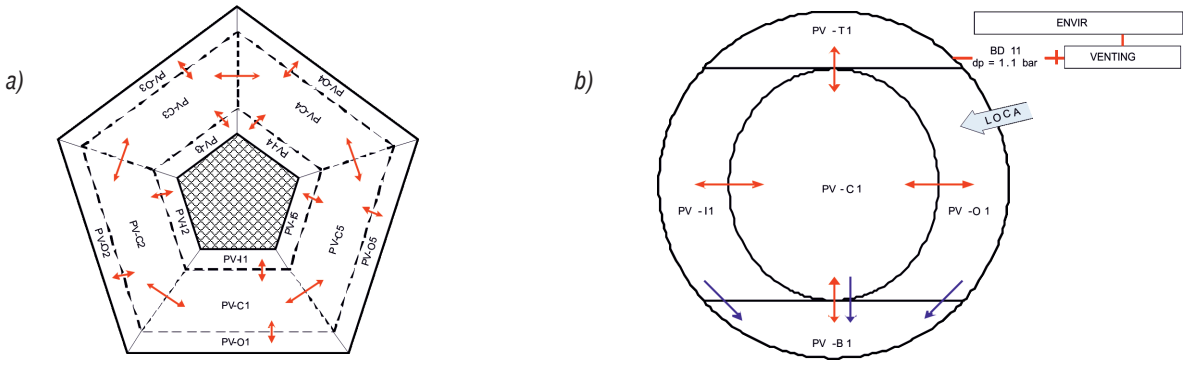


Pressure in the plasma vessel at different operating modes

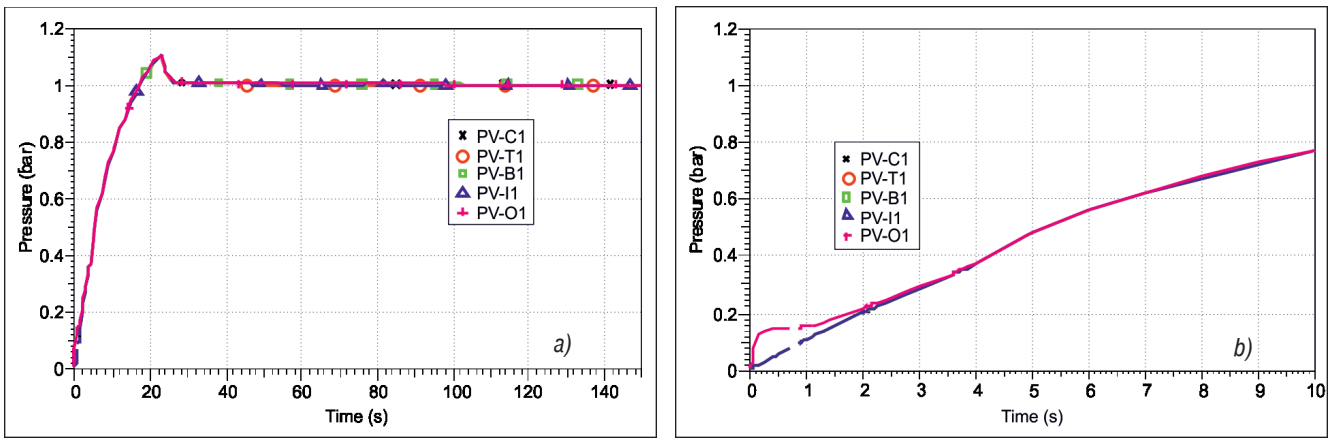
venting system is enough to protect the plasma vessel in case of 40 mm diameter pipe rupture.

Analysis using COCOSYS code

COCOSYS code is developed to analyse processes occurring in the containments of nuclear power plants and may be applied for research of processes occurring in fusion facilities. In 2013 a numerical model was developed for W7-X plasma vessel using COCOSYS code, which enables to estimate in-vessel components (see Fig). After rupture of 40 mm diameter pipe the water is released to the space between plasma vessel wall and in-vessel components, whereas later through the existing gaps it enters an inner space of plasma vessel. The obtained analysis results reveal that pressure maximum in plasma vessel is achieved within 22 s after safety valve opening, thus, in the initial accident stage a difference of pressures is comprised which affects internal plasma vessel constructions. Later the atmospheric pressure prevails in the plasma vessel.



W7-X pressure vessel model, COCOSYS code a) horizontal cross-section; b) vertical cross-section



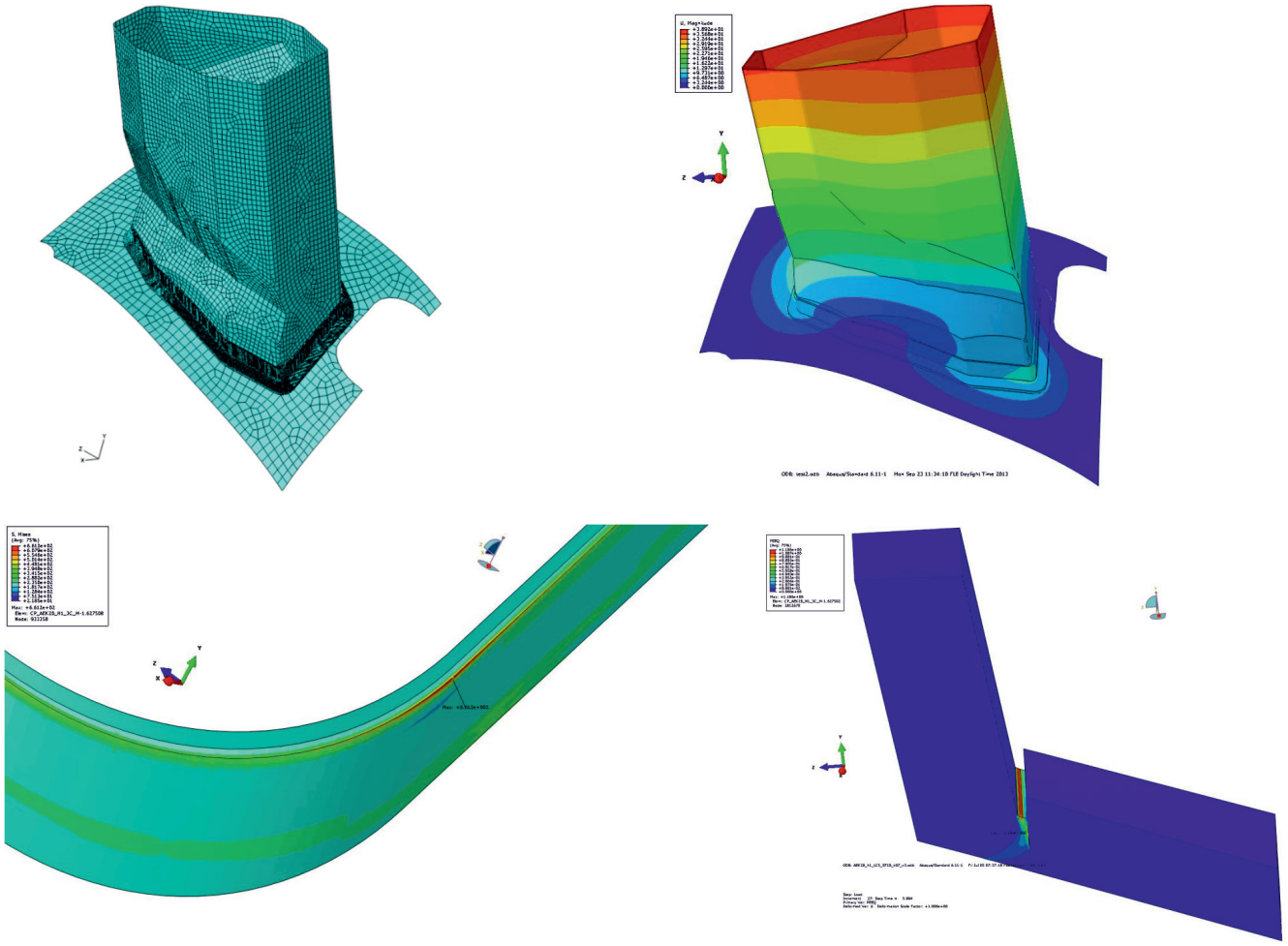
Pressure variation in plasma vessel: a) over the analyzed period; b) in the first 10 s

Simulation and limit loads analysis of W7-X plasma vessel port welds

Objective of the work was to prepare numerical models for finite elements of plasma vessel port welds and perform a strength analysis, i.e. to identify loads at which a welded connection fail. ABAQUS/Standard software was used to estimate strength. During the study, the limit strains of plasma vessel AEU20 port welds at 1 mm thick welds and under different welding quality (0.7 and 0.85) were estimated. The prepared geometric models were transferred to the finite element software ABAQUS/Standard which was applied for preparing finite element models of port welds of the plasma vessel.

Obtained displacements, maximum stresses and equivalent plastic strain distributions in plasma vessel port are given in Figures (on next page). The analysis was performed up to load limit, at which displacement in the force action point start to increase rapidly, calculation convergence is being lost (see Fig.) at this limit load, it is considered that the analysed construction fails.

While analyzing plasma vessel port AEK20 1 mm thick weld strength loads it was determined that with decrease of welding quality limit load (load's scale factor) diminishes. Form the results it can be observed that at welding quality 0.85 load scale coefficient is 6.2 (V_3_k085 curve), whereas at welding quality 0.7 load's scale coefficient is 6.0 (V_3_k07curve).



Finite element model and analysis results of 1 mm welding seam of plasma vessel port AEK20

Power Plant Physics and Technology program

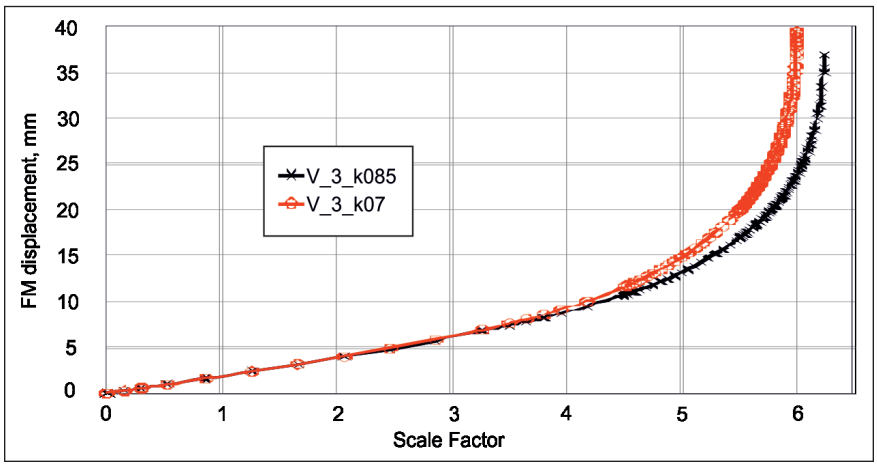
After completing ITER reactor construction, during next stage the prototype reactor DEMO project will be implemented. Basic objective of DEMO – to show that in this type devices produced energy may be used in energy power industry. In 2012 EFDA project participants signed the agreement with EC and started to implement the program ***Power Plant Physics and Technology Implementing Agreement***, the objective of which is to develop physical and technological basis for future nuclear fusion plants and prepare their conceptual project DEMO. This agreement is executed within framework of EFDA project. In 2013 LEI participated in implementing the following program tasks:

- WP13-DTM-02: RAMI analysis;
- WP13-SYS-02: System level analysis;
- WP13-SYS-04: Safety.

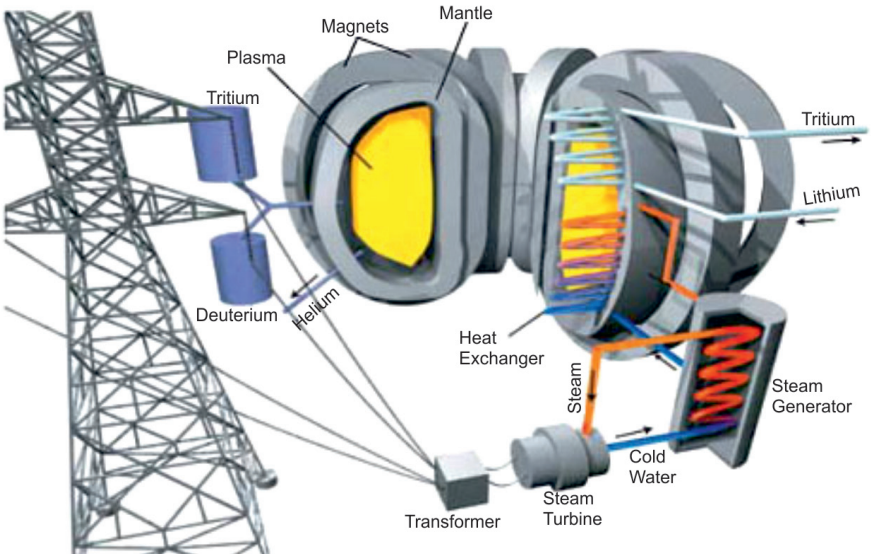
RAMI analysis (WP13-DTM-02)

When executing this task the Laboratory researchers participated in the researches of two groups:

- Method to evaluate and integrate



Displacement vs load scale factor of plasma vessel port AEK20 at load acting point (FM)



Artists impression of a fusion power plant [http://fusionforenergy.europa.eu/understandingfusion/demo.aspx]

diverse RAMI input data;
- Analysis of the DEMO availability requirement.

EFDA intends to apply RAMI concept during all DEMO project stages. With this in minds it was necessary to identify what is historically justified initial availability and increase of availability of DEMO power plant.

Method to evaluate and integrate diverse RAMI input data

The first meeting of this task executers' took place on 12 April, 2013 at EDFA premises, in Garching (Germany). The final discussion of works took place on 12 December. LEI representative T. Ješmantas participated in these meetings.

Since the most of DEMO facilities' systems will be conceptually new, never operated before, thus there is no information on reliability of such systems or such data is very rare. Thus it is foreseen that data from different sources, which is of different quality and significance, will have to be analysed. Also information of experts will be used, particularly in the initial development phase of DEMO. Executing these activities a methodology, which enables to connect different information, such as data base reliability parameter estimates or experimental knowledge, was created. The methodology employs Bayesian statistics simulation tools, which enable to connect subjective and objective information. The available resources were reviewed and lacking information was identified, it was also suggested how to structurize information for its efficient application.

Vitality of created methodology for RAMI information integration was revealed by analyzing reliability of water cooling cycle pipelines of helium cooled pebble-bed. Research results revealed the significant impact of additional expert information on the estimates of failure intensity.

Analysis of the DEMO availability requirement

The first meeting of this task executers' took place on 12 of April, 2013 at EFDA premises, in Garching, Germany. The final discussion of works took place on 12 December. LEI representative R. Alzbutas participated in these meetings.

In 2013 part of this research was devoted to investigate availability requirements for DEMO power plant and their probable interpretation. Earlier it was planned that availability of DEMO power plant should reach not less than 30%, however aiming for competitiveness of power plant, it should be in the range of 40–70%. Reviewing various performance indicators applied in the energy industry, part of their relevance was revealed as well as application specifics at pulse regime for operating DEMO power plant. After conducting the above mentioned research, a report was prepared and results were presented. LEI activities related with availability requirements covered the following:

1. Identification of relevant measures and suitable parameters of Availability Requirement to reflect the actual efficiency (including economic output) of the DEMO facility.
2. Demonstration / modeling and clarification of various definitions and alternatives considering different measures and parameters of Availability Requirement for DEMO.
3. Analysis of selected DEMO Availability Requirement taking into account energy sector industry practice (and further development/investigation of analytical models possibly applicable for DEMO specific pulse-operation).

Systems' level analysis (WP13-SYS-02)

The first meeting of this task took place on 9 of April, 2013 at EFDA premises, in Garching, Germany. LEI representative G. Stankūnas participated in this meeting.

Regarding this topic LEI participated in the activities of Calculation of activation and radiation dose map. The activation analysis was conducted for certain "blanket" conception (HCLL), concentrating towards assessment of structural materials. LEI conducted the comparative analysis of stainless steel (SS316 NL, HT F-M ir Eurofer) activation and decay heat

release. In accordance with presented foreseen DEMO scenario, in certain fields of *tokamak* central "blanket" module and divertor, using MCNP code, neutron fluxes were calculated. Later this information was transferred to FISPACT code and activation of steels were calculated, the dominant nuclides were identified and decay heat was estimated up to 1000 years after shutting down of DEMO power plants.

Safety (WP13-SYS-04)

The first discussion of this task was held on 24 of September, 2013 at EFDA premises, in Garching, Germany. Final discussion of activities took place on 3 of December. LEI representative E. Urbonavičius participated in these meetings, in the discussion of ***Review of modelling codes and identification of development needs***. This investigation will be performed in cooperation with ENEA (Italy), additional information on the codes was obtained from other organisations. The codes present today in the world were reviewed, in the future they may be applied for performance of safety analysis of DEMO reactors. After performing the task, the following codes were proposed:

- FUS-TPC and ECOSIMPRO for tritium penetration analysis;
- for SIMMER and RELAP5-3D/4.0 tasks, related with liquid metal phenomena;
- MAGS events in the magnet system;
- for GASFLOW hydrogen and gas burning/explosion analysis;
- AINA transitional plasma phenomena;
- 3D code ANSYS-FLUENT for local phenomena research;
- MELCOR and ASTEC for all emergency transitional process analysis;
- RELAP5/MOD3.3 exclusively for thermal-hydraulic cooling circuit analysis;
- CONSEN rapidly calculating code for common accident significance assessment.

RAMI analysis for W7-X plasma vessel

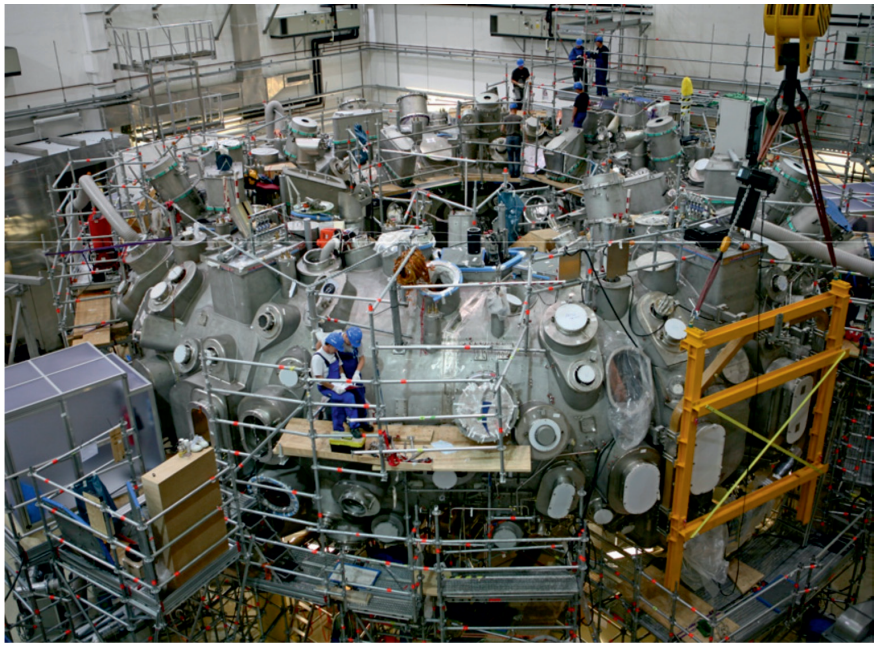
For efficient operation of nuclear fusion experimental device W7-X it is strived to ensure low unreliability and to reduce the unavailability, i.e. to minimize the outage number and its duration due to failures and maintenance. Due to this reason at least installed stellarator systems should have high level of reliability and availability.

Continuing international cooperation LEI and Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald in 2013 signed the contract ***Reliability Analyses of the Divertor Target Cooling Circuit ACK10 & Plasma Vessel / Ports Cooling Circuit ABK10***, the objective of which – to conduct reliability and availability analysis of two W7-X cooling circuits and provide recommendation how to ensure efficient operation of this device. Main tasks of this order are as follows:

1. to perform plasma target cooling circuit ACK10 analysis;
2. to perform plasma vessel cooling circuit ABK10 analysis for W7-X device at plasma operation and plasma vessel "baking" operation;
3. to analyse failures and failure types of circuit separate components (electricity loss, management loss, pressure loss, circulation loss, pipe ruptures).

Due to efforts of LEI researchers new system reliability models were developed and expanded, when failure trees and/or reliability diagrams development methods and specific software RiskSpectrum PSA (Scandpower) are applied.

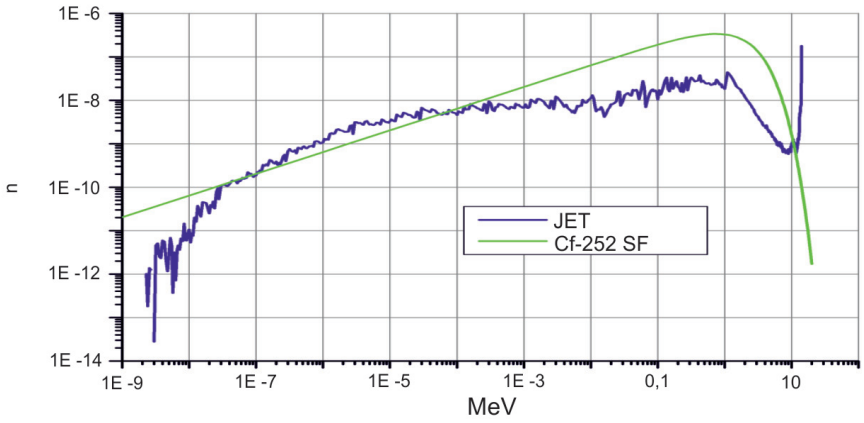
Basic results of this work – estimated reliability and availability levels of plasma target cooling circuit ACK10 and plasma vessel cooling circuit ACK10 for different W7-X vessel operation cases. Also main factors (possible failures of equipment and errors of personnel) influencing system unavailability were identified. Besides, on the basis of performed scientific research the technical recommendations for improvement of reliability and availability and common safety of fusion W7-X device were presented.



Construction of W7-X, May 2013, [Nuclear fusion. 2013. Vol. 53, No. 12, p. 1–16.]

JET research

JET *tokamak* is the biggest operated fusion facility in the world. In 2013 in accordance with EFDA JET work programs with EC JET Notification agreement No JW13-NFT-LEI-03 ***Activation cross sections for DD, DT and TT neutrons from JET plasmas*** was signed. Objectives of this agreement are as follows:



Neutron spectrum in JET plasma vessel

- to estimate and update values of nuclear reactions cross-sections, which are relevant for 2.5 and 14MeV neutron energies under DT plasma conditions;
- in order to achieve this target a great deal of attention is devoted to estimation of JET neutron spectrum uncertainties;
- to determine relevant cross-sections for performance of TT neutron spectrum measurements and estimate the uncertainties.

During the project activation and fusion reactions, which are occurring in JET facility at the moment and which could be significant for upcoming DTE2 cycle, were reviewed. IRDFF library was used for obtaining activation reactions data, when neutrons spectrum is described in 640 energy groups and ENDF-6 format. IRDFF is a standardized evaluated cross-section library used to define dosimetry reactions with covariance matrixes. The activation coefficients (- reaction rate) were estimated using neutron flux spectrum (obtained in JET plasma vessel) in DD, DT plasma cases and above mentioned contemporary 640 energy group format and using the up-to-date dosimetry IRDFF-v1.02 library cross-sections. Uncertainties of JET neutron spectrum were estimated using covariance matrixes present at IRDF library and MCNP code (see Fig.).

On 11–14 of June, 2013 the discussion of executed works was performed at Culham Centre for Fusion Energy (GB), where LEI researcher Dr. G. Stankūnas also participated.

5. ASSESSMENT OF ENERGY SUPPLY SECURITY

In 2013, a three-year state subsidy funded research project ***Development and application of assessment methods of critical energy infrastructure*** was continued. Its main objective is to develop probabilistic methods for criticality of critical energy infrastructures and apply them for Lithuanian energy system. In 2013 a method devoted to estimate functionality and criticality of infrastructure (when interrelations between gas supply system and electricity and heat systems are considered) was developed. The proposed assessment method enables to take into account technical characteristics of system's elements, intersystem connections of elements and reliability characteristics of elements.

Baltic Energy Security Research Platform

In 2013 after the *Memorandum of Understanding* was signed between EC JRC's Institute for Energy and Transport (The Netherlands), Lithuanian Energy Institute, Vytautas Magnus University, Kaunas University of Technology (Lithuania), Institute of Physical Energetics (Latvia), Tartu University (Estonia) and Royal Institute of Technology (Sweden), the *Baltic Energy Security Research Platform* was established, the objective of which is to expand cooperation of the Baltic sea region states' scientists, conducting research in the field of energy security and critical infrastructure and perform comparative research of energy security in the Baltic sea region. The platform began to operate on 18 December, 2013, in Brussels, at the round table discussion *Energy Transition from a European Perspective* organized by JRC's Directorate-General for Energy and Germany Federal Ministry of Economics and Technology.

6. PARTICIPATION IN PROJECTS OF DECONTAMINATION AND DISMANTLING OF NPP EQUIPMENT IN LITHUANIA AND SLOVAKIA

The activities for project ***Development of the Ignalina NPP V1 Building Equipment Decontamination and Dismantling Project (B9-2)*** were completed in 2013. This project was under the implementation of Babcock (United Kingdom), LEI, Nukem Technologies GmbH (Germany) and Ansaldo (Italy) Consortium. The main objective was to prepare an optimal dismantling and decontamination strategy of the equipment, which is located in Ignalina NPP V1 building, as

well as to develop all design and safety justification documentation necessary for implementing the project, and to provide support for the Client during the licensing and implementation stages of the project. The researchers of the Laboratory participated in the preparation of the Strategy, Basic Design, Safety Assessment Report, Detailed Design; all the documentation was approved by the Client. The possibility was foreseen in the project to provide support for Ignalina NPP by conducting project implementation activities. However, Ignalina NPP decided not to use this opportunity and do not ask for support during project implementation stage. As was admitted by Ignalina NPP, this demonstrates confidence of the contractor in work performed in earlier stages, when preparing project documentation and coordinating it with VATESI. Using developed documents Ignalina NPP staff successfully completed preparation activities for building V1.

According to the agreement with GNS (Gesselshaft für Nuklear-Service mbH, Germany), a project ***Modification or Replacement of the Cask Handling Systems in the Spent Fuel Halls (SPH) at Ignalina NPP*** was continued in 2013. The work is carried out in cooperation with SC *TECOS* and AB machinery plant *ASTRA*. During its implementation, 6 shock-absorbers (3 in each INPP unit) and other equipment for cask handling are going to be produced and installed in the spent fuel halls of the NPP. The purpose of the main equipment, i.e. the shock-absorbers, is to absorb energy in case of earthquake or drop of containers filled with spent nuclear fuel, ensuring that the loads on the building and container constructions will not exceed the allowed limits. In 2013 the construction of shock-absorbers was improved by selecting optimal parameters for energy absorbing components (pipes). Pilot production of pipes was initiated at machinery plant *ASTRA* aiming to test the possibilities of required wall thickness and diameter pipe production, and the accuracy of produced pipe characteristics.

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Feasibility Study for the Management of V1 NPP Primary Circuit Components

In accordance with decommissioning program for Slovakia VI NPP two units, in 2013 LEI together with JSV *Specialus Montažas-NTP* and VNIIAES (Russia) successfully completed the feasibility study, the objectives of which are as follows:

- to analyze, improve and justify variants for decontamination and dismantling of primary circuit components (reactor pressure vessel and internals, main circulation circuit pipelines and pumps, steam generators, annual water tanks, reactor biological protection and etc.);
- in accordance with proposed alternatives to prepare proposals for present VI NPP and Mochovc surface storage safety justification reports;

Researchers of the Laboratory participates in this project by selecting decontamination and dismantling variants for primary circuit components, conduct Slovakia and IAEA regulatory documents analysis and prepare proposals for updates of present safety justification reports.

In 2013 the assessment report of the VI NPP primary circuit components and waste management system valid in Slovakia was prepared and coordinated with Client. Also, according available data, the variants for decontamination and dismantling of primary circuit components were developed, and their initial and comprehensive assessment were performed. After performing the assessment, an optimal way to decontaminate and dismantle the VI NPP two units equipment was proposed. On 30 December 2013 the Contractor officially approved the project completion.

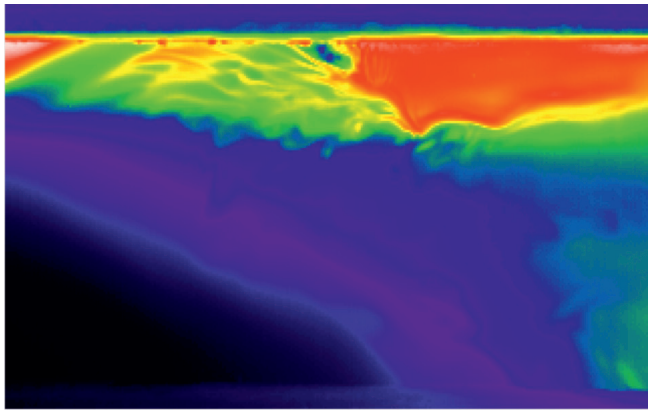
7. OTHER PROJECTS

In 2013 state funded project ***Research of condensed two phase flow velocity field in horizontal rectangular channel*** was continued.

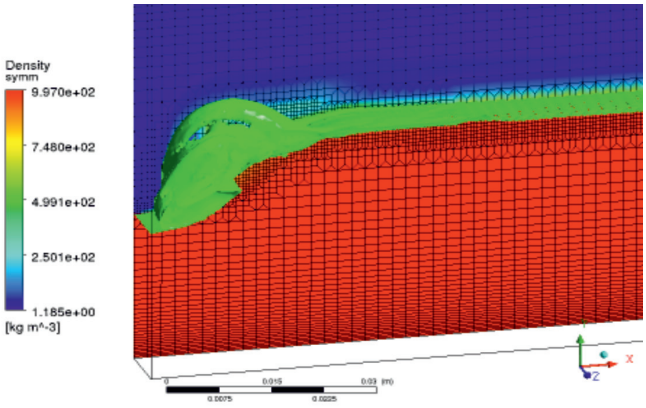
During the second year the registration and research methodic (using IR radiometry method) of water temperature field dynamics in the condensing two phase flow was further developed. Applying this methodic on condensing two-phase flow, a phenomenon of turbulence initiation in laminar water flow was found. A preliminary numerical model of condensing two-phase flow was developed using finite elements code ANSYS CFX.

In 2013 a three year duration state funded project ***Application of best estimate method in performing analysis of thermal-hydraulic processes in nuclear and fusion facilities*** was initiated. Best estimate method – when performing a deterministic simulation of processes the probable uncertainty of parameters is estimated and the sensitivity analysis of parameter influence on calculation results is carried out. This method has been applied in the Laboratory for over 10 years. During earlier research the universality of this method was proven, applying it to the analysis of processes which occur in technical, natural and social systems. However, conducting previous works the following gaps were identified:

- The best estimate method was not applied sufficiently for the analysis of severe accidents in nuclear installations;
- The best estimate method has not yet been applied for analysis of thermal-hydraulic processes



Initiation of turbulence in horizontal rectangular channel



Preliminary results of two-phase flow modelling

in fusion facilities.

Therefore main objective of this new work is related with these issues, during work it is foreseen to prepare specific recommendations for application of best estimate method.

In 2013, using RELAP5/SCDAPSIM versions Mod 3.4 and Mod 3.5 as well as ASTEC ICARE module, processes taking place in fuel assemblies in QUENCH-06 experiment were simulated. Calculation results were compared with the values measured during experiment. Such simulation of processes occurring during severe accidents in the core of nuclear reactors enables to estimate relevance of used computational tools and the impact of used correlation dependences on the calculation results. For example, the calculations of QUENCH-06 experiments, performed using ASTEC code ICARE module, revealed that calculation results greatly depend on the chosen correlation intended for description of zirconium oxidation by steam process. The results of calculation showed, that the best fitting with the experimental results is obtained when the URBANIC correlation is used for the description of steam - zirconium oxidation process.

In order to better understand the processes, occurring in spent nuclear fuel storage pools and identify the uncertainties of simulation parameters, the accident of Fukushima Daiichi NPP unit 4 spent nuclear fuel storage pool was analysed. The analysis of available published papers showed, that despite that a long period of time has passed after the accident and many reports and articles were published on this, it is not easy to collect detailed information on this accident. There was an attempt to estimate probable accident outcomes, which would happen if it was impossible to supply a cooling water using non-regular measures to the Fukushima Daiichi NPP unit 4 spent nuclear fuel pool. The analysis was conducted taking into account probable different decay heat power in spent nuclear fuel poll, probable different thickness of pools' external walls and different outside environment temperatures. The results of simulation performed using ATHLET-CD code revealed that fuel failure in case of not taking any accident mitigating measures, would occur after 9–12 days. In real conditions in case of not taking any accident mitigating measures, fuel failure would occur after more than 15 days. If nuclear fuel overheats the damage of fuel elements occurs, therefore hydrogen is generated, the maximum amount of which under Fukushima unit 4 conditions would reach the amount of 5000 kg.

In the future, implementing this budget funded work, a sensitivity and uncertainty analysis will be performed. This will enable to determine parameters which make the biggest influence on the results of severe accident simulation and, according to this, numerical models will be improved.

ESReDA

European Safety, Reliability & Data Association)

ESReDA, the member of which is LEI, 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. ESReDA constantly organizes seminars and initiates projects devoted to preparation of publications (books) in the relevant fields of scientific research of energy and industrial objects' reliability and safety. LEI prepares such joint ESReDA publications, and at the present moment participates in the project *Reliability-based Optimisation of Life Cycle Cost of Structures*.

In 2013 Dr. G. Dundulis participated in the 45th ESReDA seminar *Dynamic learning from incidents and accidents. Bridging the gap between safety recommendations and learning*. During the seminar a post presentation *Structural Probabilistic Analysis of District Heating System* was presented. The assessment methodology for district heating network piping degradation probability and its ap-

plication results to Kaunas DH network, as an example, were presented. During the seminar the objectives, tasks and duration of the future ESReDA project *Critical Infrastructure Preparedness and Resilience* were discussed. LEI plans to attribute to this project since this topic is related to the project *Assessment methodology and research of energy systems reliability and its impact on energy security* executed at the Laboratory.

Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations

In 2013 experts of the Laboratory continued and completed research in EU 7FP project ***Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations (DEMI)***, the aim of which is to enhance existing product/process design systems with features that will enable engineers to collaboratively design energy efficient and ecologically optimal discrete manufacturing processes, and generate appropriate extended monitoring and decision making services to support manufacturing installations to ensure optimal ecological impact over the process life cycle.

The project was implemented together with 8 partners from 7 EU countries. Project coordinator – Spain technological research center *Tecnalia*. LEI project was coordinated by *Efficient energy consumption research and information center*.

In accordance with the project program implemented in the recent years in 2013 the final prototype of DEMI project information and communication technologies (ICT) component *Energy Simulator* (dealing with all foreseen tasks) was updates and expanded. Testing and its functioning assessment of final prototype was carried out, also together with demo means *Energy Simulator* methodology (devoted to ICT and industry specialists) was prepared.

Applying available experience of hybrid systems modelling and acquiring new ICT possibilities an universal software and with it related modelling methods were developed. These means of modelling and energy consumption assessment operate taking into account system configuration defined remotely by *Energy Analyser*, design requirements and limit conditions. Different control of system and its process variables (e.g. pressure and flow) as well as system models reflecting different working conditions are formed using MATLAB (Simulink and SimScape) software and applying means of automatic modelling and assessment of energy consumption.

8. RESEARCHERS' QUALIFICATION AND PUBLICATION OF SCIENTIFIC RESULTS

In 2013, there were 6 PhD students in Laboratory of Nuclear Installation Safety. Two PhD Thesis in the field of energetics and power engineering were defended – ***The Numerical Study of Aerosol and Radionuclide Transport in the Containments of Nuclear Power Plants*** (A. Kontautas) and ***Study of the Steam and Gas Mixing Processes in the Containments of Nuclear Power Plants*** (M. Povilaitis). Young researchers together with experienced scientists presented the investigation results in science research reports. 32 scientific articles were published (including 8 scientific articles in the journals listed in Thomson-Reuters database) and 26 papers were presented in scientific conferences. The researchers of the Laboratory participated in the events related to nuclear energy and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena occurring in them were analysed. The researchers actively participated in different international and national training courses, IAEA seminars, committee and coordinating meetings, activity of FUSION development committees and other organisations and scientific institutions.

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LABORATORY of ENERGY SYSTEMS RESEARCH

MAIN RESEARCH AREAS OF THE LABORATORY:

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

In 2013 project ***Economic and sustainability analysis for the energy sector development*** was contiued in co-operation with the experts of Laboratory of Regional Energy Development and Laboratory of Systems Control and Automation.

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

1) to develop a theory of harmonious progress in the energy sector on the basis of sustainable development and interrelations with knowledge based economy conception;
2) to analyse possibilities of perspective development for the Lithuanian energy sector and prepare recommendations related with rational perspective technical directions in the energy sector development, 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 Lithuanian power system with ENTSO-E, taking into account the perspective development of generating capacities.

While implementing the second task, in 2013 most of attention was given to the development of complex modeling base of the energy sector development. Experience of previously conducted analysis of the energy sector development was efficiently applied in performing research of the Lithuanian power system perspective development and economic efficiency of Visaginas NPP. This stage of research was aimed to performe long-term perspective development analysis of Lithuanian power system by adequately simulating:

- the current state of the country's power system and its relations with district heating system;
- development of the Lithuanian economy and feasible scenarios

of GDP growth;

- forecast of electricity and district heat demand related with economic growth, their change in time;
- interconnections with power systems of neighboring countries, in particular expected in the electricity market and possibilities to supply reserve capacities;
- potential of indigenous energy sources and trends of their use;
- forecast of worldwide and regional prices of primary energy sources, particularly electricity and natural gas, development of energy and heat production technologies, their availability, technical-economical indicators;
- objectives in energy security, environmental requirements and other factors.

This investigation was aimed at estimating the impact of new nuclear power plant on perspective development of the Lithuanian power system, on the country's balances of fuel, electricity and district heat of, on the balance of installed capacities (as well as reserve ones), country's trade balance, also to identify demand of investments, operation and maintenance expenses, fuel expenses and amount of imported electricity. To perform such analysis an explicit model of the power system including essential links with power systems of neighboring countries was prepared.

The prepared optimization model, applying the MESSAGE software, provided a possibility from the set of all available and probable future technologies to determine the optimal structure of generating capacities, types and amounts of primary energy sources, electricity and heat production at the power plants, import export requirements of electricity and reserve capacities and to meet the foreseen country's energy demand at the least cost in the long-term perspective and at the same time at least prices for end-users.

Since operation time of new nuclear power plant reaches 60 years, the system development was analysed over the period up to year 2080, taking into consideration operation conditions and efficiency of different type power plants at different operation regimes, during a year period including 128 operation regimes and adequately balancing different types of energy flows produced in power plants and imported or exported.

Out of 70 analysed power system development scenarios the main two scenarios were submitted to the Government of the Republic of Lithuania and Seimas – a nuclear scenario and flexible non-nuclear scenario. Energy security of a state, which was defined as an objective to produce no less than 70% at Lithuanian power plants beyond the year 2023 and no less than 80% from the total electricity demands beyond the year 2030, may be ensured by:

- investing into new generating capacities, most of which may be not competitive in the electricity market and which requires subsidies in order to ensure their viability;
- building Visaginas NPP, which according technical and economical indicators identified in the business plan, is one of the most attractive options, but this power plant also should be subsidized;
- foreseeing additional burden for consumers, which would be conditioned by local generation support and the share of which would amount to 17% of total power system development and operation expenses;
- identifying energy security component in the price of electricity supplied to the network, the value of which would amount to 4 ct/kWh.

Detailed modelling results and benefits and probable risk of priority scenarios implementation were presented at Visaginas NPP supervision committee meeting, attended by representatives from Estonian, Latvian and Lithuanian energy ministries and energy enterprises. Results of performed analysis showed that in order to justify Visaginas NPP project continuity, it is expedient to improve technical and economic indicators of this project, to ensure a favourable funding conditions from international institutions and to share expenses of its implementation, responsibility and risk between strategic and regional partners. The conducted analysis will serve as valuable basis for regional project partners when making decisions regarding Visaginas NP viability.

Based on analysis of energy and economic indicators (available at Lithuanian Statistics department data basis) as well as on the comparative analysis of information available at statistical publications and data bases of other Baltic countries and international organizations (Eurostat, International Energy Agency, etc.), the variation trends of indicators, which define sustainable development of the country's energy sector, were identified. In Lithuania primary intensity and final energy intensity decreases more rapidly than in most EU countries, whereas the indicators defining role of renewable energy sources (the share of energy from renewable sources in gross primary energy balance, the share of electricity from renewable sources in gross electricity consumption, the share of energy from renewable sources in gross final consumption of energy) also changed significantly.

The project funded by the Research Council of Lithuania ***Assessment of potential for greenhouse gas emission reduction in households in Lithuania***

Research Council of Lithuania

(project leader Dr. D. Štreimikienė), was successfully implemented; energy consumption and greenhouse gas emissions in households are analysed in the project, basic social-economic and technological as well cultural factors influencing greenhouse gas emission in households were identified.

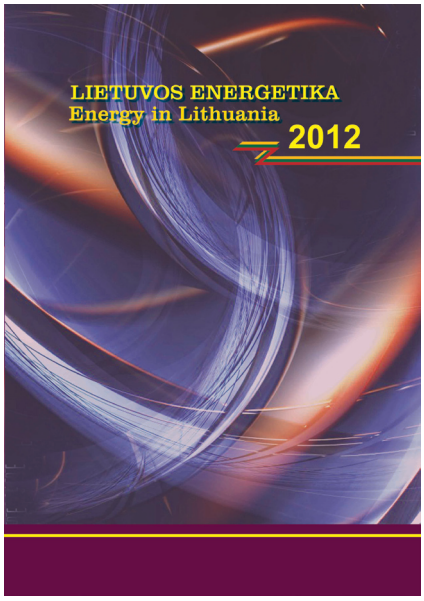
SCIENTIFIC RESEARCH WORK FOR STATE'S ECONOMY

Under the agreement with ***JSC Dolaurus*** scientific research work ***Feasibility Study of High Efficiency Cogeneration Power Plant Installation in Mažeikai City*** was completed. Interim results of economical efficiency assessment for various types of cogeneration power plants were submitted in the report. In order to ensure the comparability of economic indicators of various types power plants, all calculations were performed making an assumption that the installed capacity of each analysed cogeneration power plant is 1 MW. Besides, economical efficiency of power plants was determined applying the same conditions formulated in the technical task:

a) technologies most prevailing in the market at present time are analysed – gas turbine, gas internal combustion engines, biomass and combined cycle turbine cogeneration power plants;
b) technical-economic indicators of power plants are identified by analysing data provided in catalogues of technologies and projects implemented in a country;
c) do not biding oneself to specific local conditions and making an assumption that cogeneration power plants operate with combined heat and power generation;
d) defining the use of installed capacity by maximum load time T_{max} and analysing its duration in the range of 8000–2000 hours;
e) maintaining natural gas prices, including expenses for its transportation, all lifetime of power plant at 1450 Lt/1000 m^3 level, whereas the price of biomass comparing to average wood chip prices in 2012, i.e. 550 Lt/tne;
f) making an assumption that electricity and heat purchase price from power plant is respectively 350 Lt/MWh and 210 Lt/MWh.

Based on analysis of the results given in the report, it was concluded that least investment risk would be while installing cogeneration power plants, which can compete on electricity and heat markets. Under this criterion a priority should be given to cogeneration power plants using biomass. Under present conditions in electricity and heat markets they are competitive if maximum load time is no less than 4000 h/year. In order to objectively justify expedience of power plant construction, its installed capacity and amount of electricity production, it is necessary to estimate thoroughly heat demand variation during a forecasted period, its variation during the year, to estimate competitiveness of other heat sources and perform optimization calculations of heat production ammounts using different technologies.

Under the agreement with the Ministry of Energy and the main national energy associations ***(Lithuanian District Heating Association, Lithuanian Association of Biomass Producers and Suppliers, Lithuanian Electricity Producers Association*** and ***Lithuanian Energy Consultants Association)***, the annual issue of statistical indicators ***Energy in Lithuania 2012*** was published. It presents the recent information describing tendencies in the development of the Lithuanian energy sector and its branches in 2009–2012 as well as detailed fuel and energy balances and the key indicators of the national energy sector, which are also compared with Estonian and Latvian indicators. It also presents data about greenhouse gas emissions in 1990 and 2011, including their structure by the sectors, in the Annex 1 countries to the United Nations Framework Convention on Climate Change and the Kyoto Protocol.



The comparative indicators of EU-28 countries, the largest world countries and countries of the Organization for Economic Cooperation and Development as well as economic and energy indicators (GDP, energy consumption per capita, energy intensity, etc.) for the years 2010 and 2011 are presented in the publication. These comparative indicators were prepared following methodology of the International Energy Agency. According to this methodology, indicators of the total final consumption include non-energy use and electricity consumption does not include electricity losses in the network.

The publication summarises the changes in the national economy and the

energy sector. Over the period 2000–2008 the Lithuanian economy was growing rapidly (approx. 7.4% per year), but declined by 14.8% in 2009. Within the next three years the cointry's GDP was increasing approximately by 3.8% annually and in 2012 amounted to LTL 83.9 billion (in chain-linked volume) or LTL 28.1 thousand per capita. In 2012, the primary energy consumption increased by 1.1% and comprised 7.39 billion toe, whereas the final energy consumption for energy needs rose by 2.6% and equaled to 4.84 million toe. Furthermore, the final electricity consumption increased by 4.0% and amounted to 8.92 TWh, while the primary energy consumption per unit of GDP in 2012 dropped by 2.5 %, whereas the final energy intensity decreased by 1.0%.

The publication ***Energy in Lithuania 2012*** was prepared in close cooperation with the specialists from *the Statistics Lithuania, Lithuanian District Heating Association,* specialists of energy companies and associations. The information invoked in the preparation of the publication was taken from the publications of the *Statistics Lithuania* (Energy Balance, 2009, 2010, 2011 and 2012), and annual reports of energy companies as well as from publications and data bases prepared by international organizations (International Energy Agency, Eurostat).

Under the agreement with the Ministry of Environment a new scientific project ***National Greenhouse Gas Emissions Inventory for Energy Sector Preparation 2014*** was launched. While implementing the above project, a National greenhouse gas emission inventory for energy sector for the period 1990–2011 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 National greenhouse gas emission inventory preparation commission, National climate change committee and NER 3000 financial instrument projects

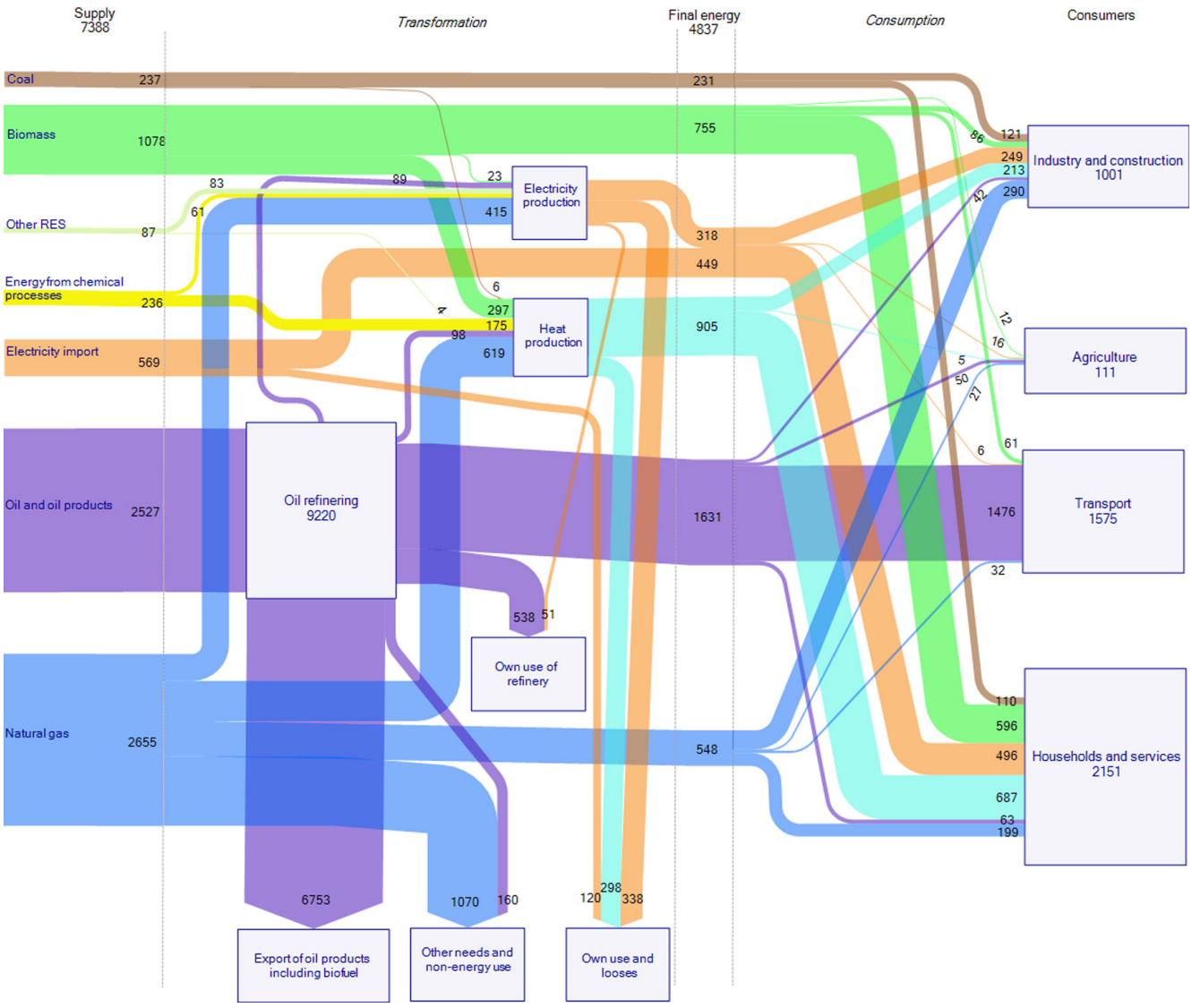


Diagram of the main fuels and energy flows in Lithuania in 2012, ktoe

selection commission, actively contributed for implementation of this project.

PARTICIPATION IN INTERNATIONAL PROGRAMMES

The three year duration project ***Sustainable development analysis of Lithuanian renewable and other energy sources, earth and water use*** coordinated by the IAEA was continued in 2013. Main objective of the project is to foresee milestones for sustainable development of the Lithuanian energy sector, earth and water use. Usage of RES influence on sustainable development since it enables to reduce negative environmental impact, promotes national and regional economic development, impact energy prices, creates extra working places, etc.

Country's energy security (ensuring energy demand for socially acceptable price) is also an inherent part of sustainable economic and social policy. Aiming at implementing the objectives, it is foreseen to encompass and analyse total chain of energy flows. It starts from energy resources and finishes with the use of separate energy types obtained from these resources seeking to meet society demands, including the use of nonrenewable energy resources and assessment of their environmental impact, taking into account country's commitments to the EU 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 using MESSAGE software is being created.

Relevant issues of the Lithuanian energy sector development as well as wider application of RES and increase of energy consumption efficiency aspects are analysed in international projects of ***Intelligent Energy Europe*** Programme. In 2013 two new projects were initiated, namely ***Policy Dialogue on the assessment and convergence of RES policy in EU Member States (DIA-CORE)*** and ***Monitoring energy efficiency in the EU (ODYSEE MURE 2012).***

With project *Policy Dialogue on the assessment and convergence of RES policy in EU Member States* (*DIA-CORE)*

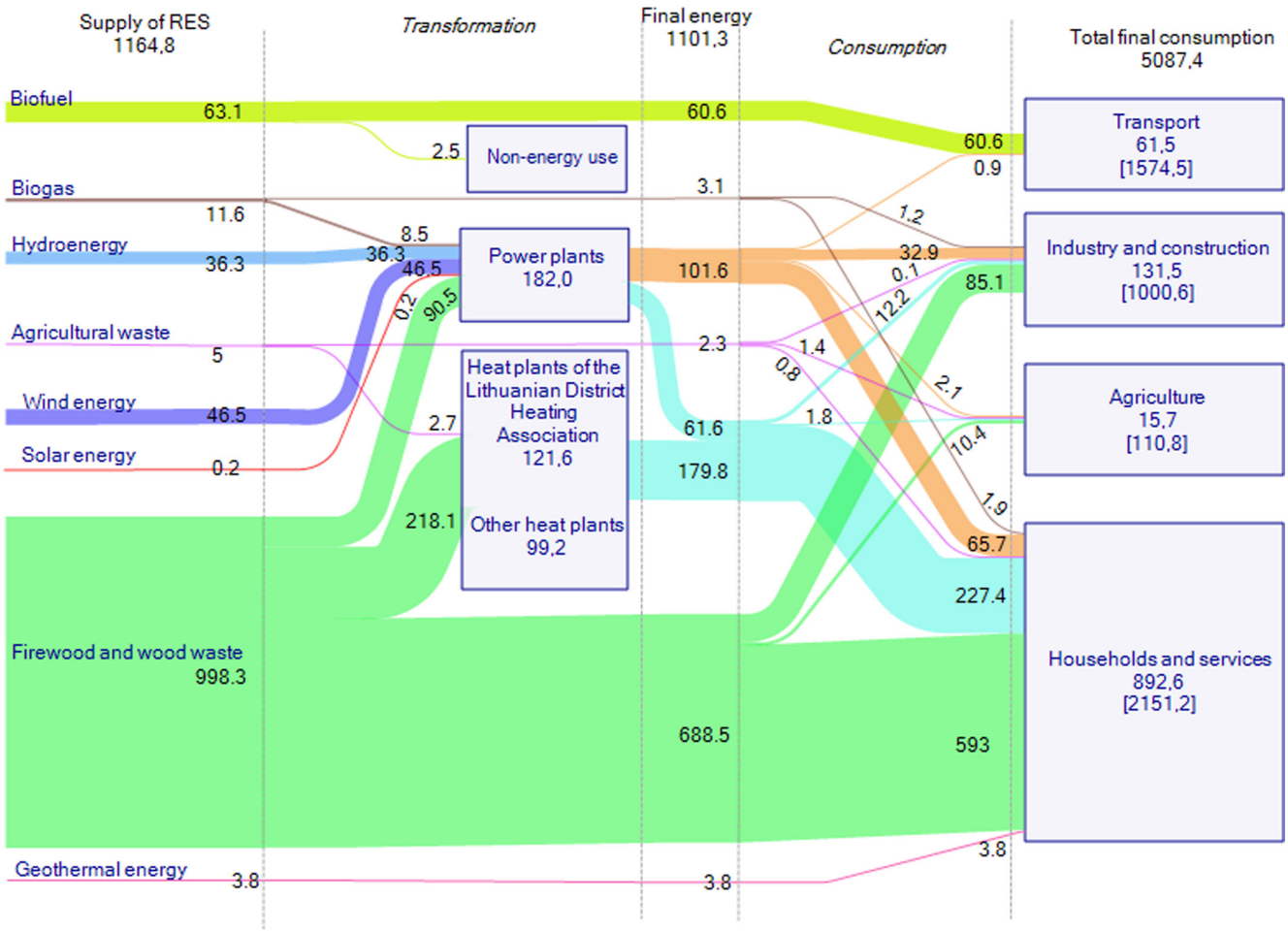


Diagram of renewable energy sources flows in 2012, ktoe

it is aimed at ensuring continuity of RES support schemes assessment and to develop a productive 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).

Within the project ***Monitoring energy efficiency in the EU (ODYSEE MURE 2012)*** it is aimed to implement a thorough monitoring of energy consumption efficiency and energy efficiency policy measures 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 is used at the international level:

- By preparing specialists to model scenarios of the energy sector development in the trainings organized in Egypt, Indonesia and Sweden. Dr. A. Galinis as an expert delegated by the IAEA and responsible for application of the MESSAGE model when solving tasks of long-term energy planning shared his experience and performed practical training for experts of modelling involved into long-term energy sector development program.
- By conducting practical training for modeling specialists in Benin and Tanzania – experience was shared by IAEA delegated expert Dr. D. Tarvydas.
- By performing centralized greenhouse gas emissions inventory review process organized by UN Framework Convention on Climate Change for Germany, Netherlands, Ukraine and Kazachstan in Bona (Dr. I. Konstantinavičiūtė).
- Analyzing Programme ***Horizon 2020*** energy research proposals for 2014–2015. Dr. D. Štreimikienė was elected a member of Energy advisers group of EC ***Program Horizon 2020***.

Year 2013 were significant in improving the qualification of Laboratory researchers:

- Junior research associate V. Lekavičius on the 6th of December, 2013 at public meeting of Economy sciences direction council defended his dissertation in social sciences ***Modelling the impact of changes in energy supply on the national economy***, where he performed an analysis of mechanisms of energy and economy interrelations and formation of energy supply changes and their impact on the whole economy, which enables to identify basic role of energy infrastructure in the spreading of energy shocks to other areas of the economy.
- In March research associates E. Norvaiša and D. Tarvydas participated in IAEA trainings ***Fundamentals of nuclear reactor technologies and nuclear fuel cycle***, which took place in Turkey. These trainings provided a possibility to get acquainted with nuclear power expansion, different types of reactors and their components, preventive measures for incidents occurring at nuclear power plants, issues of safety and nuclear waste management, as well as progress in developing new generation and technologies of small nuclear reactors.
- In August junior research associate V. Lekavičius participated in trainings which took place in Sweden; most of attention was devoted to the assessment of MESSAGE software, developed by the IAEA, application capabilities. It was aimed at training energy experts capable in the future to provide training courses on energy development modeling, regarding the application of MESSAGE model. In September, in Austria, V. Lekavičius presented a report on Lithuanian experience in investigating energy and economy relations; the studies related with the assessment of nuclear energy social and economical impacts were discussed at the technical meeting.

In 2013, the researchers of the Laboratory participated in the conferences in France, Sweden, Turkey, Germany and other countries, where 9 papers were presented. The researchers of the Laboratory published 10 scientific articles in Lithuanian and international journals and proceedings of international conferences (4 scientific articles in the journals listed in Thomson-Reuters database).

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LABORATORY of REGIONAL ENERGY DEVELOPMENT

MAIN RESEARCH AREAS OF THE LABORATORY:

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

OBJECTS AND TASKS OF SCIENTIFIC RESEARCH

EU and Lithuanian energy sectors have set targets to reduce dependence on imported energy resources via wider use of indigenous and renewable energy sources and reduction of energy demand by improving energy efficiency. This will reduce negative impact of greenhouse gases emissions on the environment and will add to mitigation of climate change. EU research and innovation programme „Horizon 2020" is aimed in this direction, with main focus on efficient energy consumption, competitiveness of low-carbon energy technologies, formation of sustainable energy cities and communities. Buildings consuming most of energy resources, energy generation and supply systems, including supply networks and their control, energy storages, stakeholders' involvement in energy demand management via smart grids are the basic energy areas which are analysed as research objects. Significant role is attributed to financial issues of energy sector reformation and development of infrastructure for implementing measures of energy efficiency improvement as well as investigation of new innovative projects' financing mechanisms.

EU member states plan and elaborate tools for implementation sustainable energy supply and consumption, define tasks and interim targets, necessary financial resources. A great number of issues arise related to the efficiency assessment of sustainable energy implementation measures, their impact on energy prices and relations with other economy sectors. Experience of EU countries revealed that a flexible economic promotion policy is necessary to tackle technological progress and change of economic environment. For example, excess feed-in tariffs may occur due to increased technologies offer and reduction of their prices; a boom of investments may emerge thus increasing total energy production costs, which are covered by all energy consumers.

The scientific problem is related to the objective assessment of the public benefit due to the RES development, capable of revealing the advantages which could not be disclosed by assessing only financial benefits; solving the environmental and social problems at the same time should be regarded as well. It is usually impossible to identify single-valued solutions since the problem itself is diverse. This requires versatile knowledge which could be systemized and purposefully disseminated. Exceptional regulatory measures may be treated in the society as implementation of interests of EU bureaucrats and certain lobby groups.

State funded research project ***Assessment of implementation measures for sustainable energy development on regional level from technological, economic and social aspects*** was completed in 2013 and revealed that promotion of basic measures for sustainable energy

development – wider use of RES and improvement of energy efficiency - is based on the necessity to compensate market's imperfections due to society's benefit depreciation in market's relations. It should be emphasized while summarizing scientific references that there is no unitary approach defining efficient use of RES technologies. It was determined that such promotion measure as feed-in tariff may be a strong tool for promotion of RES consumption, however, producers and investors are not sure regarding feed-in tariffs in the future since they may be changed by politicians, at the same time increasing investment risk. Lower risk is when support (subsidy) is provided to investment.

Cost of renewable energy is the most important direction in identifying demand promoting measures, however, the financial-economic support measures should be justified by their efficiency. It is a must to apply RES promotion tools with regard to expand the use of RES taking into account their economic efficiency and pursued objective. Rapid development of RES with the least costs may be achieved by supporting the types of renewables and RES technologies which ensure the best economic results under Lithuanian climate conditions. However, often this fact is not taken into account as practice reveals and surplus financial support is given to technologies the effect of which is very small on national level. Adequate rated pollution fees and CO_2 emissions trade quotas improve competitive environment for wider RES usage.

Development of RES, mostly biomass (including straw and municipal waste) is the biggest target object of Lithuanian DH sector: electricity generation in biomass burning CHP plants, gradual renovation of DH networks and expanded competitiveness against individual heat supply using fossil fuel as well as planned development ensuring security of investments and connection of new consumers where DH is feasible.

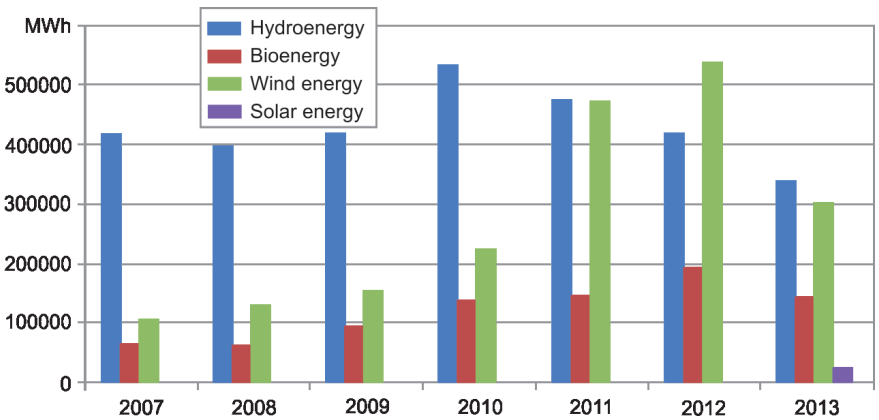
Slow growth of renovated buildings share is the main issue which is not directly related to responsibility of DH sector. Current subsidizing system for space heating does not encourage efficient heat consumption since it is not related to heat consumption and energy saving, and depends only on income. Thus market signals are distorted for consumers when decisions in social policy are confused with energy policy. Support for heat consumption reduces the incentives to save energy and search for more efficient heating solutions when heat is getting more expensive. It is expected that buildings renovation process will speed up motivating socially supported families – by relating social support for heating with participation in the building's renovation.

Five most relevant and recommended promotion measures in DH sector (without priorities) are: planning of waste management and prohibition to dump combustible waste in the landfills; buildings' regulations identifying responsibilities on the use of primary resources; subsidies for investments into the use of RES and waste in CHP plants; carbon fee to non ETS system installations and support for investments into heat production facilities and connection to DHS.

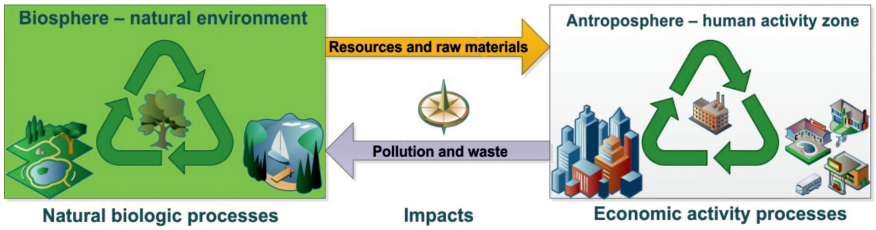
The results of the analysis on promotion measures reveal that efficiency of Lithuanian RES promotion policy is lower than the best indicators of other EU member states. The indicators of potential exploitation speak about significant opportunities for technological development, however, profitability of investments into innovative technologies are lower in most cases comparing to those in the leading EU countries.

Attention should be drawn to supported RES types. At present the biggest support is provided to biomass using technologies. Meanwhile, big potential of solar heat application is observed in buildings sector. This potential may be implemented via renovation of dwelling houses and at the same time modernizing heat supply systems inside buildings. The use of solar collectors for hot water preparing in dwelling houses is one of the most perspective trends at present. This potential is estimated up to 40% of heat amount needed for hot water preparing.

The state may implement national objectives employing the current DH infrastructure: increase the use of indigenous and renewable energy, utilize household waste, diversify fuel balance aiming at security of energy supply, implement district cooling in buildings, as well as efficient electricity generation using combined heat and power production; reduce greenhouse gases emissions.



Volumes of electricity generated from different RES types (hydro, biomass, wind and sun)



Interrelation between economic activity and natural processes

Correct assessment of RES benefit for society and environment is related with territorial aspect. The *green* villages is a relevant form enabling to employ the available infrastructure for implementation of RES development, financial sources and is expedient to use RES at wider scale than previously. A number of factors influence a successful development of *green* villages. Initiative of residents and relevance of territories are the most important factors influencing the application of *green* village's model. Initiative of residents and support of the Government would enable developing of *green* villages in any location of Lithuania, despite the fact whether this is long ago settled area, village or a new land site, and this would enable to deal with social separateness issues. The most important issues should be dealt with support of municipal administrations, whereas states' role should be directed to support small and medium business when dealing with the issues of *green* villages' development as tasks of sustainable development implementation in Lithuania.

LONG-TERM RESEARCH PROGRAMMES

The long-term research programme ***Economic and sustainability analysis for Energy sector development*** in 2013 was oriented towards two directions:

a) economic assessment definition of exhaustion (completeness) and renewal (incompleteness) difference of energy resources, participating in economic process, reflection of this feature in economic theory and evaluation in economic analysis;
b) economic decision making of an issue of the conflict between sustainable development oriented towards future perspective and wealth maximization in this period.

The Laboratory participates in 2 topics of long-term 2012–2014 Economy sciences research programme *Lithuanian challenges of long-term economic competitiveness:*

1. Assessment of RES and energy saving technologies acquisition in wide scope on GDP, foreign trade balance in order to make economic presumptions for justification of state's support. Analysis of economic presumptions for development and spreading of RES technologies was performed. Methodology was prepared in this work for assessment from the macroeconomics of RES technologies' acquisition at wide scope point of view. RES classification according renewability nature and impact on environmental, social and economical indicators was carried out, the relations between RES acquisition and GDP, foreign market balance and social indicators were analysed. Theoretical algorithm of RES acquisition impact on economy development was developed, planning and organization methods and presumptions for territorial (cities') economy and energy interactions, which enable to integrate RES and energy saving options, were justified. Technical-financial assessment for solar collectors' plant for hot tap water preparation in Varėna town was performed using EnergyPro 4.1 software tool in order to verify theoretical presumptions. Scenarios are developed regarding increase of RES application demand on the producer's and consumer's sides on the basis of options for modernization of DH systems. Basics of modern DH systems organization, technological progress and pricing were summarized, recommendations are being prepared for improvement of DH systems in Lithuanian cities and technical feasibility scenarios are developed for the consumers connected to DH systems using RES to produce certain share of electricity and heat. The properties of DH pricing as well as possibilities were provided by new financing schemes to expand the use of RES technologies are analysed.
2. Identification of assessment principles for the use of state budget and structural funds and various financial measures for advanced energy technologies. Economic research was carried out in identifying the relationship between support for advanced technologies using renewable energy with the pursued result of state programs in energy on the basis of formulated research methodology. Methods for assessment of interrelations between RES acquisition and selected macroeconomic indicators were selected and calculation algorithm was formed. Software tool was created for mathematic estimate. Inventory of RES financial, economic support forms was carried out including justification of financial sources, results indicators and dynamics of their achievement. The overview on advanced energy technologies

financing from international funds (for example, JESSICA, JEREMIE, etc.) in Lithuania was performed. The occurrence of reasonable financial funding channels and use of innovative financial instruments for end-users and industry was assessed. Energy, economic, social and environmental analysis of the chosen region (Riešė and Avižieniai local authorities) was conducted by estimating energy potential and scenarios for energy economy expansion were formulated, their assessment was carried out. The feasibility analysis on benefits, drawbacks, investments and operation costs was carried out for wind energy technologies.

INTERNATIONAL COOPERATION

The Laboratory completed the project ***Regions Paving Way for a Sustainable Energy in Europe (ENNEREG)*** in 2013, which was partly funded by the EU IEE programme. The project was coordinated by Danish partner Energy Consulting Network Agency. The project objectives were related with the Covenant of Mayors and EU goals: to reduce carbon dioxide emissions by 20%, increase the share of renewable energy sources up to 20% of final energy consumption, and improve the efficiency of energy consumption by 20%.

ENNEREG project was represented by 12 European regions, in Lithuania this was Kaunas region alongside with twin-regions, including Šilutė municipality.

10 sustainable energy development projects were selected all over Lithuania during the project, which were presented as good practice examples in other EU regions. These projects along with the good practice examples in all EU (http://regions202020.eu/cms/inspiration/good-practice/) should promote sustainable energy development in EU.

Project participants estimated the input of projects implemented in each region as well as sustainable energy development and CO_2 emissions reduction in accordance with 8 project groups in EU countries. The data on implemented projects was collected during direct communication with their executers and performing development monitoring in project regions.

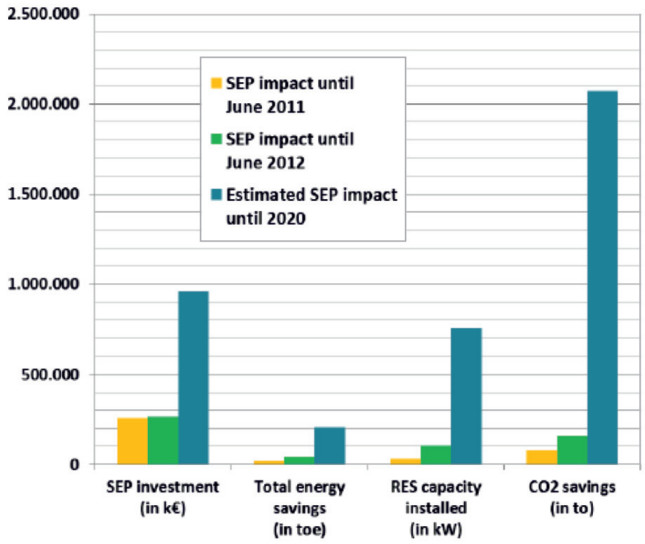
A seminar was arranged at LEI ***Aspects of Sustainable Development while Elaborating Municipal Renewable Energy Development Action Plans*** on 31 of January 2013 together with other EU funded project. The objective of the seminar was to assist municipalities and encourage them to prepare the action plans as foreseen in the RES Law.

The presentations of several projects achievements took place during final project meeting in Brussels; they were initiated by EC Intelligent Energy Europe technical support initiative „ManagEnergy“, where ENNEREG Project was presented as extremely fruitful, having great impact to implementation of the Covenant of Mayors initiative and sustainable energy planning as well as the EU objectives in the regions.

The material may be accessed at: www.regions202020.eu.

Project partners also prepared ***Inspiration Guide*** for all who want to join the Covenant of Mayors, to plan sustainable energy activity in their cities and find inspiring examples from the regions who participated in the project

Examples of Lithuanian good practices



Results of projects' implementation. Source: ZREU

Discussion during a seminar

http://www.regions202020.eu/cms/inspiration/inspiration-guide.

New business opportunities for solar district heating and cooling

A 36 month duration project *New Business Opportunities for Solar District Heating and Cooling (SDHplus)* was continued in 2013. The project is coordinated by the partners from Germany – Research Institute for Solar and Sustainable Thermal Energy Systems SFZ Solites. The project encompasses 18 partners from 12 EU member states. The successive project *SDHplus* is directed towards wider integration of solar plants in district heating networks and for meeting heating needs in buildings.

SDH solar district heating

The objectives of *SDHplus* project is to foster wider use of solar energy in district heating by: describing and promoting good practice examples of successful solar energy integration into solar 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 increasing energy efficiency; developing and implementing new market strategies for solar energy in district heating sector (e. g., the green tariff, purchasing models).

Expected project results are: new SDH business models and SDH marketing strategies opening new opportunities for DH suppliers and other market stakeholders and thus creating a relevant contribution to the market growth. Show cases are created for integrating *SDH* into various specific district heating situations. These show cases respond to the market barriers of DH stakeholders (e.g. combination of solar collectors with CHP, high generation costs, etc.). According to EU experts, estimated potential of SDH markets in the newcomer countries can reach a capacity of 500 MW_{th} until 2020.

Dissemination of information is particularly important via international SDH seminars and DH market participants' visits to present SDH power plants. Two

Moments from final events

meetings were organized for project participants in 2013. A conference took place in Sweden, Malmö city, in April, devoted for discussions on technical solutions of SDH systems, cities' planning and business models.

The second meeting took place in Graz city in Austria, where 1 MW capacity solar collectors are installed for direct supply of heat into DH systems. SDH supply to city's DH system is usually performed by energy services companies (ESCO) in Austria.

The possibilities to use solar heat are analysed in Lithuanian DH networks while implementing the project. The analysis covered 17 DH systems, most of which are in smaller towns. The results of primary analysis enable to expect that solar energy systems may be competitive with other ones, for example, biomass technologies in case of relevant financial support. Such systems along with short-term storages would enable covering heat demand during summer season and saving significant volumes of biomass and other fuel. Basic 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 facility, heat battery, pipes, circulation pumps in each house, overheating issues of collectors are dealt more easily.

Solar heat collectors in Graz city, Austria

More detailed information on project activities and results is provided on project's website: www.solar-district-heating.eu.

Another project ***Ecoheat4Cities,*** related to district heating sector, was completed in 2013. Its long-term objective was modernization and development of DHC systems with regard to meeting the principles and criteria of sustainable energy. With this objective ecological labelling scheme was established and tested on the example of Lithuanian DH systems.

The established labelling scheme motivates DHC companies to advertise their services to consumers from the primary energy sources perspective. The European consumers, including private and public sectors, will be able to define the environmental benefit for DHC system. The criteria for the labels are to be determined to enable a simple comparison of DHC with other types of heating and cooling, similar to the currently applied and future schemes of energy efficiency and "green" labelling.

DH systems of 5 cities were estimated and labelled, namely, Birštonas, Ignalina, Mažeikiai, Tauragė and Šilutė during pilot labelling.

More detailed information on project activities and results is provided on project's website: **http://ecoheat4cities.eu.**

Solar collectors in Sweden, Malmö city

Certificate for Utena city DHS system

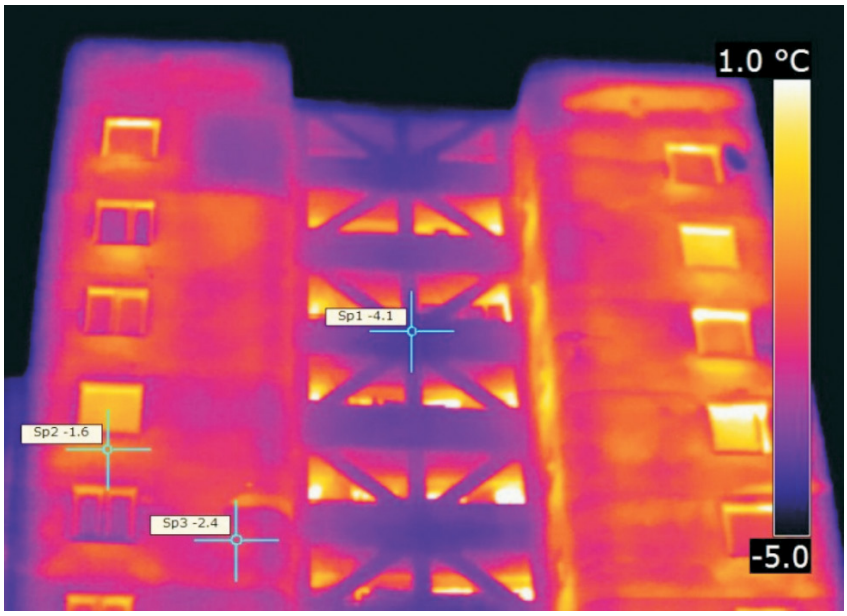
SERVICES PROVIDED BY THE LABORATORY

Consultation activities

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

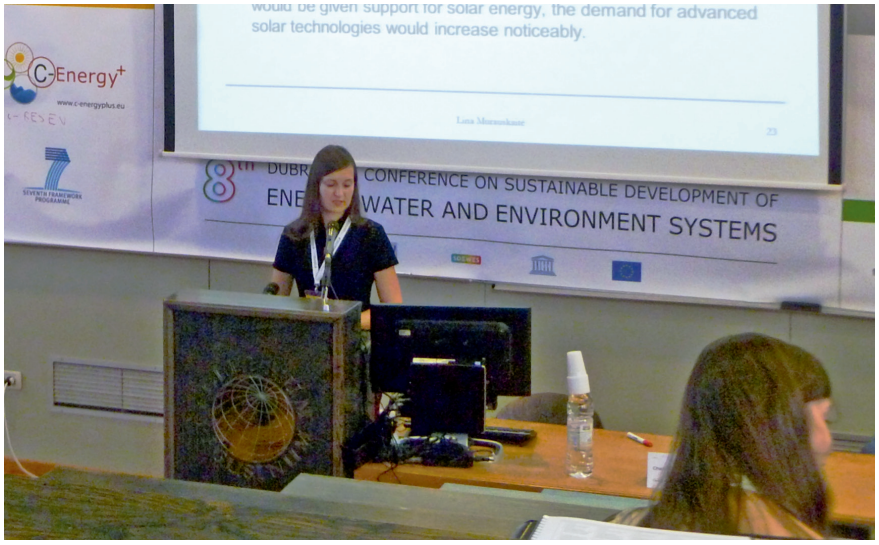
Thermo-visual diagnostics of buildings, electricity sector and technologic processes

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



Thermal vision research

Example energy efficiency certificate of the building



PhD student Lina Murauskaitė makes her presentation at Dubrovnik international conference

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

Certification of energy efficiency for buildings

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

PHD STUDIES

E. F. Dzenajavičienė has successfully defended her doctoral thesis ***Research of Efficient Biofuel Use for Sustainable Development of Municipal Energy Sector*** on 8 January 2013. 3 other PhD Candidates are studying and preparing their doctoral theses in the Laboratory.

PhD student K. Biekša completed his studies in 2013. His theses were approved. PhD student L. Murauskaitė was extremely active also in academic activities, she received PhD students' scholarship for academic achievements; she was elected as the most active PhD student of the *second* and *third* year in LEI competition of most active PhD students.

DISSEMINATION OF SCIENTIFIC RESEARCH RESULTS

The Laboratory researchers submitted 3 scientific articles in the journals listed in Thomson-Reuters database, 3 articles referred in the international scientific databases. The Laboratory researchers presented 10 papers at national and international conferences, submitted 2 scientific articles in professional journals.

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LABORATORY of RENEWABLE ENERGY

MAIN RESEARCH DIRECTIONS OF THE LABORATORY:

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

RESEARCH OF RES USING TECHNOLOGIES DEVELOPMENT

The Laboratory carries out research related to wind, solar, biomass energy and biogas use as well as research related to technologies development devoted to ensure sustainable RES usage development in the country, to promote development and implementation of new technologies, to reduce dependence from imported energy sources.

Research of application and intensification and development possibilities in Lithuania of small-scale wind power plants and solar energy systems was continued in 2013. Performing this work analysis of technical characteristics and expansion possibilities of small-scale wind power plants in the country was conducted, efficiency of small-scale WPP and dependence on wind conditions was estimated. The offer of small-scale WPP has increased in the recent years, however, technical parameters of WPPs with similar nominal power are often different. Therefore when choosing a small WPP it is necessary to find out the individual energy demands as well as under what wind conditions WPP is capable to produce the declared amount of electricity. Besides, it is recommended for at least half a year to measure wind velocity on the site where a small WPP is to be installed. If average wind velocity is less than 4 m/s, the WPP will most probably not satisfy ones expectations. If comparing experience of different small WPP usage in Europe, the conclusion was drawn that WPP, with the relative rotor diameter of 12 m^2 for one kW of installed capacity, at low wind conditions may produce approximately 2 times more energy than the standard ones, 4–6 m^2/kW rotor diameter WPP. It was also determined that the average efficiency coefficient of small WPP amounts for 0.16. If compared to big WPP, this coefficient is equal to 0.4.

Since 2013, while performing small-scale WPP research, a PhD thesis was initiated under the title ***Investigation of renewable energy technologies and application in urban environment.***

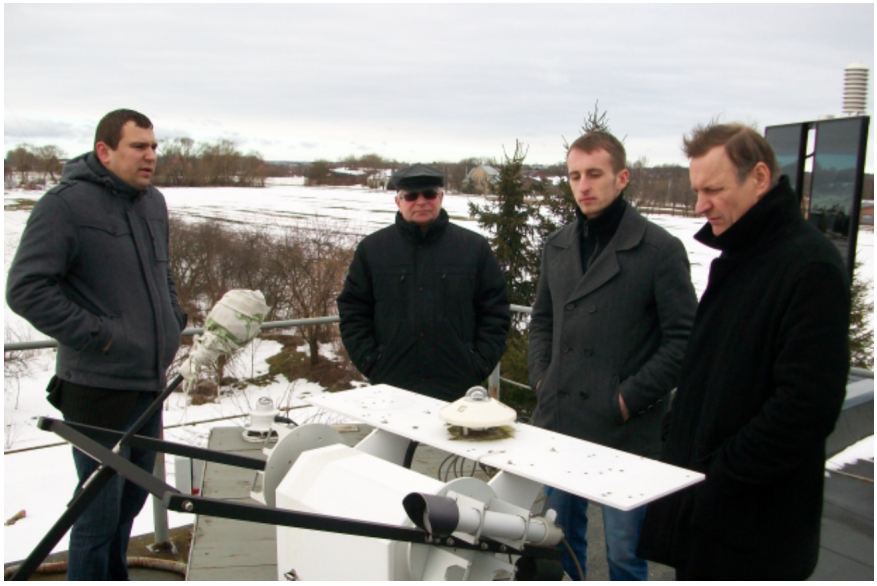
Conducting this research wind velocity and direction measurements are performed in Kaišiadorys ir Lazdijai districts, the impact of meteorological conditions, surface roughness and terrain on the op-

eration of WPP is analysed. Efficiency of electricity production in photovoltaic power plants was analysed in different state's regions, the impact of environmental air temperature was estimated, feasibility study of electricity production in photovoltaic power plants non-integrated into electricity network was carried out.

Short-term forecasting methodology of WPP capacity is created, based on the application of artificial neural networks, comprising physical and statistical forecasting methods and which enables to increase the accuracy of forecasts.

In 2013, during spring, three different photovoltaic modules (total installed capacity 740 W) were equipped on LEI roof, nearby 1 kW power wind turbine, to analyse the capabilities of household supply with electricity. When installing photovoltaic modules, a possibility was provided to change their inclination angle. With a specific tool – pyranometer – solar radiation is measured, whereas data of energy produced by photovoltaic modules are recorded at chosen time interval and are stored in data base. It was determined that in case of solar radiation 950 W/m^2, the power of photovoltaic modules reaches 90% of installed capacity. The conducted research of photo modules surface temperature revealed that during sunny summer day their surface heats up to 55–60 °C. In 2014, data of this system will be used in analyzing the efficiency of hybrid solar-wind power plant and possibilities of household supply with electricity.

Solar-wind hybrid power plant on the roof of Lithuanian Energy Institute



Consultations on scientific research issues at Kaunas Meteorological station

In 2013 long-term institutional scientific research and experimental development (further SR&ED) program project ***Research of RES application for efficient energy production and environmental impact*** was continued.

In 2013 the analysis of increasing the possibilities of using biomass traditional (wood, straw) and non-traditional (buckwheat shelling, grain cleaning waste, sullage, etc.) sources for producing energy was carried out. It was determined that possibilities of increasing solid wood biofuel usage to produce heat and electricity are limited because the potential presently exploited is approximately 85–90%. Calculation methodology of solid biofuel potential should be emphasized since assessments of potential as presented by various sources significantly differ. Major part of potential of straw resources and energy willow plantations expansion is not exploited. In order to conduct foreseen plans to increase biofuel share in Lithuanian DHS up to 70–80%, the area of productive osier plantations should amount to no less than 15–16 thou. ha, thus annually 2–3 thou. ha of willow energy plantations should be introduced. The estimated preliminary energy potential of grassy plants amounts for 722 GWh (2.6 PJ). If plants' fertility comprises 5 t/ha, 40 000 ha land is needed to grow them.

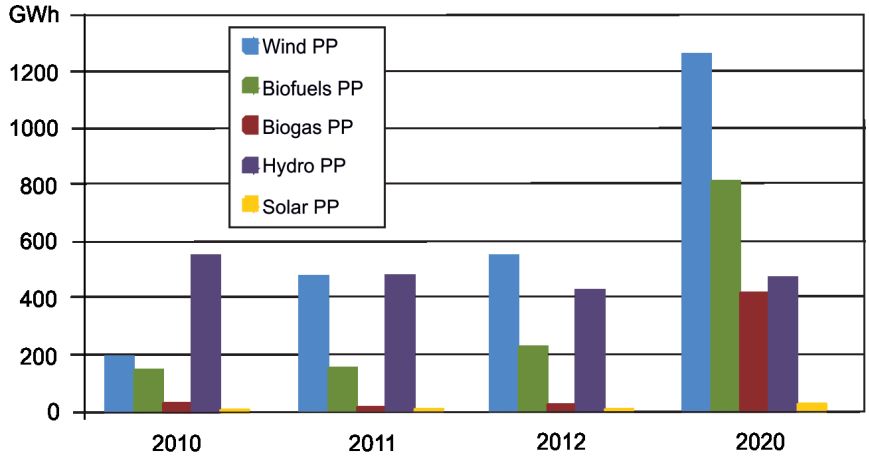
Research of biofuel and biogas application development in EU countries and Lithuania are carried out. Executing the EU requirements from 2010, biofuels comprise 5.75% of total transport fuel amount present in the market. Research reveals that during biodiesel production process approximately 10% of technical glycerol is composed, up to 3% of free fat acids and two times more rape oilcake than biodiesel is produced. However, burning glycerol as liquid fuel with oil products, additionally chemically processed fat acids returning to the biodiesel production process, whereas rape oilcake using for forage, production scale of biofuel may be increased, cost price of their production may be reduced and environmental impact of biofuel may be mitigated as well.

At present time 5 biogas power plants reprocessing different type of liquid

organic waste are operating in Lithuania; 5 power plants are installed in state's dumping grounds, where extracted biogas is used in stationary cogeneration power plants to produce heat and electric power. In Lithuania total annual biogas production amounts for 6.3 million m^3 per year, this corresponds to 3.4 ktoe.

Dealing with the issues of environmental impact of WPP, evoking complaint of local societies, research of WPP noise was carried out. Portable noise analyser 2250 Bruel&Kjaer and special software were used for this research. Noise measurements were conducted nearby 250 kW wind turbine and nearby 6 MW wind farm, at different distances. It was determined that at WPP generated noise frequency spectrum the biggest changes occur in the range of 200–3150 Hz, whereas in low (20–200 Hz) and high (15–20 kHz) frequency ranges only insignificant changes of these spectrums are observed. The measurements revealed that during wind velocity of 6 m/s the noise level does not exceed the permissible limit of 45 dBA 50 m and at larger distance from WPP.

Measurements of WPP noise



Present and forecasted electricity production from different RES types

Research and modeling of wind flow characteristics variation and variation forecast of wind power plants' capacity

In 2013 measurements of wind velocity and direction in Kaišiadorys district were continued, where a 50 m height meteorological tower with the measurement equipment of wind velocity, direction and atmosphere physical parameters, purchased on the funds of *Santaka valley,* is erected.

Wind velocity is measured at 10, 30 and 50 m heights, whereas direction – at 50 m height. Measurement results show that average annual wind velocity at 30 m height reaches 4,5 m/s. Since the tower is installed on the hill, very often wind vertical shear phenomena are observed when wind velocity at 10 and 30 m height is higher than at 50 m.

Expanding experimental research activities, a 11 m height pole with wind velocity and direction measurement equipment was installed in Lazdijai district. The measurements results reveal that wind velocity at 11 m height reliably correlate with wind velocity measured on Seirijai wind farm turbines.

Wind measurement data are used for the improvement of methodology of short-term wind velocity forecast in wind farms. Measurement data are compared with the corresponding period of the data from the numerical weather forecasting model run at Lithuanian Hydrometeorological Service. In 2014 testing of new complex methods based on the application of artificial neural networks will be carried out.

While performing research of wind power forecasting methods since 2013 a PhD thesis ***Investigation of the impact of meteorological and topographical conditions on short term wind power prediction*** is being prepared.

In 2013 the researchers of Laboratory published 4 articles in scientific publications, registered in international scientific information databases, 1 science promoting article was published, research results were presented in 3 presentations at national scientific conferences.

PARTICIPATION IN INTERNATIONAL PROGRAMMES

Baltic Sea Region
Programme 2007–2013

In 2013 in accordance with EUSBSR tool ***Seed Money Facility*** funding was received to prepare a proposal for EU partially financed Baltic Sea Region program project ***Baltic Sea Region Club of Sea Technologies***. Participants of the pro-

posal preparation from Germany, Sweden, Poland and Lithuania by the year 2014, August, should gather a team of partners, to identify potential members of the sea technologies club, to establish participation rules in a club and in accordance with partners' ideas and competence to define future activity trends (in the field of energy technologies, aquaculture and cultivated industry, navigation, transport technologies, environment protection, planning of safety of seashore and sea territories, deep-water technologies, etc.). Future project partners and club members should be science and business organisations working in the field of sea technologies or related to it.

Project objectives: competitive assessment of up-to-date scientific research and technologies market expansion, promotion of science and business organisations, initiation of international projects, establishment of partner teams and implementation of projects, publication of research, discussion and project results in the Baltic sea region.

In 2013 analysis of sea technologies sector was carried, potential project partners were identified as well as team members, topics of future projects related with Laboratory activity trends were foreseen.

PEA
Public Energy Alternatives

Public Energy Alternatives: Sustainable Energy Strategy for Regional Development (PEA) *2010–2013* of Baltic Sea Region Programme 2007–2013 was completed. The project was implemented by 21 partners from 6 countries of the Baltic Sea region. Lithuania was represented by the following five institutions: Lithuanian Energy Institute (LEI), PE Ignalina Nuclear Power Plant Regional Development Agency (INPP RDA), Ignalina District Municipality Administration, Visaginas Municipality Administration and Zarasai District Municipality Administration.

While implementing the project the laboratory researchers investigated the possibilities of alternative energy sources application in Ignalina nuclear power plant region (Zarasai, Ignalina and Visaginas municipalities), critically estimated consumed energy amounts and determined energy saving potential and revealed new energy saving methods. It was determined that the region has a possibility to employ abundant local RES and with them relate assimilation of new technologies and business development. The data were summarized and submitted in *The study of INPP region current state*, the strategy of region's energy consumption efficiency and alternatives as well as action plans of municipalities for the period up to year 2035 were prepared.

WINDENERGY IN THE BSR 2

The scientific research project ***Wind Energy in the Baltic Sea Region 2 (WEBSR2)*** of South Baltic Cross-border Co-operation Programme 2010–2013 was completed.

During the project annual electricity production amounts of wind farms were analysed as well as the most perspective construction sites for WPP. Also technical, economical, legal and social obstacles related with more rapid wind energy development were identified. On the basis of the research results recommendations were submitted to institutions which prepare RES usage promotion scheme, performing environmental impact assessment, preparing territorial planning documents. During the project research of wind power development and energy accumulation technologies were performed, the possibilities were analysed how to use hydro accumulation power plants with wind farms and different compressed air systems, including compressed air storage in underground rock cavities.

Wind energy information centre was established with the objective to promote wind energy technologies, the demonstrational wind power plant and solar photovoltaic modules were installed on LEI roof.

APPLIED SCIENTIFIC WORK

In 2013, in accordance with MITA support tool **Inočekiai** scientific research activity was initiated with business enterprises. A cooperation agreement was signed with an enterprise *Entiumas*, manufacturing small wind turbines, on the basis of which research of efficiency of small-scale wind turbines and environmental impact aspects are carried out. The dependence of small-scale WPP on meteorological conditions is investigated, the dispersed noise is measured. In accordance with cooperation agreement with JSC *Terma* research of dependence of solar power plants' power on meteorological conditions is carried out. Research results will be used for the selection of constructions sites for new small-scale WPP and photovoltaic power plants, also for the improvement of constructional elements of small-scale WPP.

SCIENCE PROMOTION ACTIVITY

While implementing scientific research and international projects, society is introduced with scientific ideas and performed research results, which encourage people to be interested in diversity of RES and opportunities of practical application.

Promoting ideas on RES development in Lithuanian regions the laboratory researchers in July and December 2013 participated in the conferences ***Action program for the period 2014–2020 to overcome unemployment and poverty in***

Practical activities for students: research of solar and wind PP operation principles

Šiauliai region; in September a presentation in international scientific conference *Overview of European energy technologies and innovations policy. Discussion of RES innovative technologies development strategy* was made

Cooperating with Vytautas Magnus University, Kaunas and Alytus colleges, the laboratory specialists gave lectures to students on RES technologies and their usage in Lithuania. Practical activities were organized for Vytautas Magnus University students during which the students analysed the peculiarity patterns of electricity production in wind power plants and got acquainted with the principles of photovoltaic modules operation.

Students are actively interested in RES development, conduct practice at the laboratory, under the supervision of laboratory researchers write course papers, bachelor and master thesis. Consultations are given on the issues of wind and solar energy, biogas production from organic materials and biofuel production and consumption. In 2013 the Laboratory researchers supervised three final Bachelor works for students from Vytautas Magnus University faculty of Natural Sciences on the topics of wind and solar energy, two students performed practice – learned how to calculate wind energy resources using WindPro software and simulated solar-wind hybrid power plant operation. In the future, with assistance of the Laboratory researchers, the students plan to perform detailed research and choose studies programs related to RES technologies application.

Wind Energy Information Center was established in 2012, the objective of which is to provide objective, science-based information about wind energy technologies, advantages and disadvantages of its technologies, to promote scientifically based society attitude towards rational application of wind energy resources. Consultations on wind energy project preparation and legal basis issues, seminars are organized for industry and energy specialists, businessmen, lecturers, and students. Other activities are implemented as well: lectures and practical trainings for students, competitions and excursions.

In 2013 consultations were given on the issues of preparation of wind energy projects and legal basis, science promotion activities were implemented as well: lectures and practical activities for pupil and students. The participants got acquainted with the opportunities of small-scale wind power plants application, analysed specific practical examples, improved calculation, construction and scientific testing performance abilities, common and professional activity competences.

Excursions – practical activities for pupils

Visit of the European Wind Energy Association representative at LEI Wind Energy Information Center

*Winners of contest **Wind challenge***

On the 23 of May, 2013 the competition of wind turbine models produced by pupils of Kaunas city, *Wind challenge*, took place. The event's partner Kaunas Gediminas sports and wellness high-school. The event finished a month duration stage of production and preparation related to the knowledge on wind energy and wind turbine models. Teams comprising of 7–9 classes pupils from 8 Kaunas city education institutions participated in the competition. During the event pupils deepened their theoretical knowledge on wind power technologies and competed in the contest of one's own created wind turbine models, for which a special wind tunnel was manufactured.

A unique event was of great interest to representatives of wind energy industry, university lecturers and other societies of Lithuania education institutions, thus the same competition is planned to be organized in 2014.

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ENERGY EFFICIENCY RESEARCH AND INFORMATION CENTER

MAIN RESEARCH AREAS OF THE CENTER:

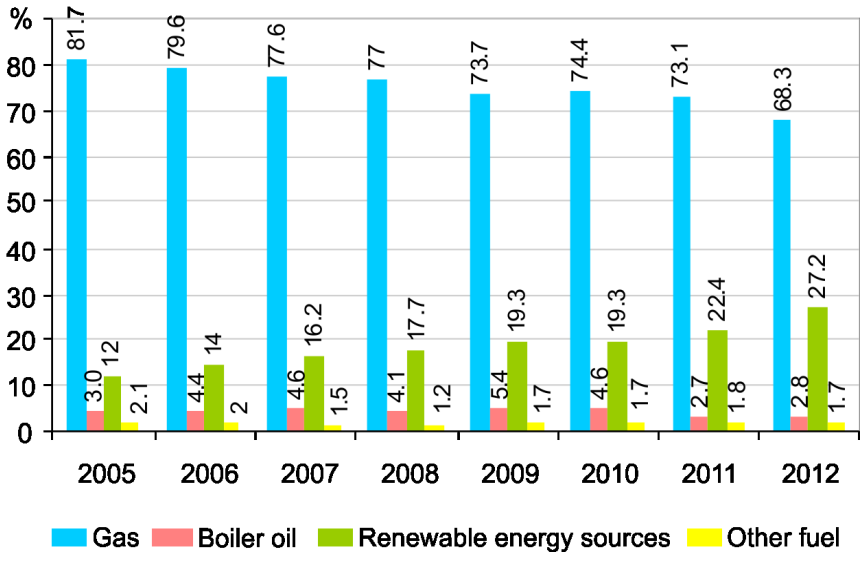
- in pursuance of scientific research, to compile, analyse and provide to experts and society the experience of efficient energy production, transmission, distribution and end-use in Lithuania and worldwide;
- projects related to the realization of National Energy Efficiency Programme;
- participation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

RESEARCH OF ENERGY PRODUCTION AND CONSUMPTION EFFICIENCY IN LITHUANIA

In 2013 a state funded research project ***Investigation of new generation heat pumps' application for heat production*** was continued.

At present time approximately 40% of total energy consumed in the EU is consumed in the EU buildings. In separate EU countries, including Lithuania, this number is even higher. In all countries, construction sector is expanding, due to this fact energy consumption in buildings will increase. Therefore reduction of energy consumption and usage of renewable energy in buildings are very important measures necessary to reduce EU countries' energy dependence and green house gas emissions. By consuming less energy and more renewable energy one can contribute to the increase of energy supply security as well as scientific research of new energy production technologies and their wider application.

Reduction of energy consumption in buildings and usage of RES is one of key priority strategic directions in the EU. To achieve these objectives, new *EU Directive 2010/31/EC on Energy Performance of Buildings* (PEND) was approved. Implementing the latter directive, the EU Commission promotes that no later than the 31st of 2020 all newly built houses were close to the passive or null energy buildings. This opens up new possibilities for new technologies, such as heat pumps, thermal energy devoted to heating buildings in the field of production.



Fuel expenditure dynamics for district heating production in the period 2005–2012

Perspective heat pumps of foreign companies promoted in Lithuania are reviewed in the work, among which German Viessmann Werke Gmbh & Co.KG Vitocal series heating pumps, Swedish NIBE Energy Systems produced NIBE FIGTER heat pumps, Swedish Octopus Energi AB unique construction "air-water" heat pumps, German *Alpha-InnoTec* and Italian *enEX* manufactured heat pumps. Lithuanian heat pumps produced by SVEP and JSC SALDA were also reviewed.

Main requirements which should be followed in designing heating, cooling and hot water preparation systems with heat pumps were discussed. Geothermal heating systems with horizontal surface and vertical collectors were discussed in detail as well as building's supply with heat by heat pump with thermal pole.

Lithuanian legal acts of 2009–2013 were reviewed, where measures are foreseen to implement heat pumps in Lithuania. A list of 39 projects, which were granted financing according measure ***Application of RES (solar, wind biofuel, geothermal energy, etc.) in individual housing, built in accordance with technical regulations active till the year 1993***, was submitted.

Total these projects were granted 270105 LTL, out of which 12 heat pumps implementation projects were granted 104930 LTL, i.e. ~40% of all subsidies sum.

The activities of heat pumps operating under real conditions in Lithuania were reviewed. Feasibility technical expert assessment of heat pumps implementation in apartment building was submitted.

A dwelling house – Sukilėlių pr. 82, Kaunas city: 5 blocks, 70 flats, built in 1981, total (useful, heated) area – 3383.55 m^2. The house is partially updated: heating unit is updated, most of windows are changed, staircase doors are renovated, part of balconies are glassed, basements are equipped with German window packets. DH is supplied by SC *Kauno energija*.

In accordance with the invoices for the period 2004–2012 submitted by *Kaunas energija* for supplied heat, the analysis of heat expenses to heat up a house, to prepare hot water and to maintain hot water temperature in house's hot water system ("coil pipe") and relevant expenses was carried out.

Participants and activity moments of seminar ***Perspectives of biofuel development in Lithuania – benefit and hazards***

It was determined that mostly heat prices increased in October of 2012, up to 0.3051 LtL/kWh (excluding VAT). Heat amount per 1 m^2 heated area during heating season reduced by:

– 2011 (relatively warm year) – 98.14 kWh/m^2/heat. season;
– 2012 (relatively cold year) – 104.73 kWh/m^2/heat. season.

After considering these conditions, a Swedish heat pump NIBE™ F1245-60, of 60 heating capacity, using heat obtained from thermal bores with vertical collectors was chosen. After installing a 60 kW heat pump, it would produce up to 65% per year of all necessary heat energy. It would be possible to save approximately 790000 LTL/year.

It should be noted that up to year 2011 the implementation of heat pumps in Lithuania was not promoted in any way though to assimilate aero thermal, hydrothermal and geothermal energy is possible only by using heat pumps.

It should also be noted that the National Control Commission for Prices and Energy has not approved reduced tariff for heat pumps for consumed energy, though it is foreseen in the above mentioned Lithuanian Renewable Energy Law.

PARTICIPATION IN INTERNATIONAL PROJECTS

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

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

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

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

Having completed the project, a general methodology and the following ICT components, compatible with the existing design systems, were developed:

- Energy Dependency Selector for pre-design analysis which enables selecting equipment (device), matching both industrial an energy efficiency requirements during the whole life-cycle of the designed process or product. For this purpose, TRIZ method (Russ. acronym, translated as “the theory of inventive problem solving”) and eco-design principles will be applied.
- Energy Monitoring Setup for designing and selecting ambient intelligence-based technologies and other measurement systems ensuring the energy efficiency of the installed industrial process.
- Energy Analyser for the energy efficiency optimization of industrial process and equipment.
- Energy Simulator for modelling design alternatives of industrial processes and equipment and assessing their energy consumption.

During the implementation of the project, currently functioning industrial processes and product design systems were updated with the mentioned ICT components. The design solutions obtained using the updated systems were verified using the data of actual industrial processes. Such solutions are expected to reduce the energy consumption at least by 15%. After employing experience of hybrid system modelling and acquired new ICT possibilities, universal software (applied in production) and with it related modelling methods were developed. These modelling and energy expenses assessment measures are operating taking into account system configuration determined by Energy Analyzer remote control, design requirements and extra conditions. System models reflecting different systems’ and their variables control and operation conditions are developed using MATLAB (Simulink ir SimScape) software and using developed automat modelling and energy expenses assessment measures. On 24–25 of March, 2013, final project results were presented for the responsible people from 7th FP in Brussels and were estimated very well.

Taking into account one of DEMI objectives – development of DEMI software, most of attention was devoted to promotion and development of new methods and software. At present time LEI researchers while participating in the activities related with project also can contribute in preparing new information technologies or other innovative projects.

Energy Alternatives in the Public Sector – Sustainable Energy Strategies as a Chance for Regional Development (PEA)

In 2013, the Energy Efficiency Research and Information Center and the Laboratory of Renewable Energy together with 21 partners from 6 Baltic Sea region countries (Germany, Estonia, Lithuania, Latvia, Poland and Finland) continued the implementation and completed the international project ***Public Energy Alternatives – Sustainable Energy Strategies as a Chance for Regional Development*** **(PEA)** of ***Baltic Sea Region Programme 2007–2013.*** The project was partially financed by the EU (European Regional Development Fund).

The objective of the project was to promote regional development by improving their energy condition and accomplishing the tasks of energy saving and efficient energy use. The goal of PEA was to accumulate, share and implement innovative energy technologies by transmitting the acquired experience to the whole Baltic Sea region (BSR). For this purpose, new educational modules for energy-related leading executives and staff, obliged to implement and further develop the regional strategy and means, were created.

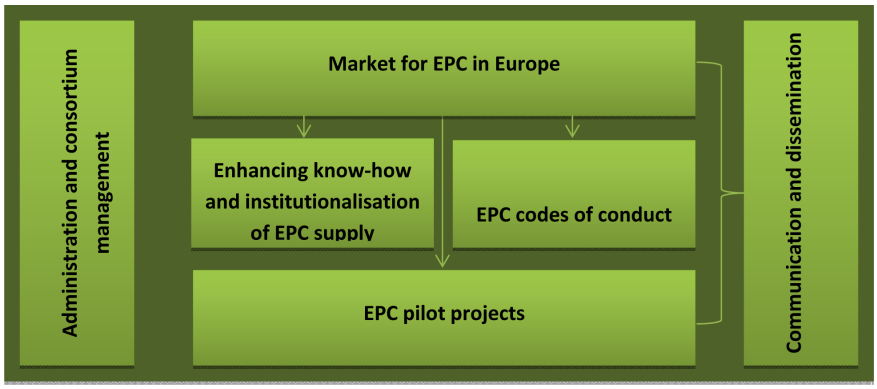
In accordance with technical projects for several public buildings renovation in the region of INPP were prepared, which enabled assessing energy saving potential and laid a firm basis for building renovation. While implementing the project, the municipalities mounted solar collectors on several public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

Theoretical and technical potential of final energy and RES were determined, analysis of strengths-weaknesses and capabilities and hazards of RES potential in Ignalina NPP region was carried out. While cooperating with Ignalina NPP Regional Development Agency, representatives from JSC *Eksponentė* as well as Ignalina, Zarasai and Visaginas municipalities, sustainable development strategy for NPP region was prepared as well as future action plans of municipalities devoted to implementation of Regional energy strategy.

Final conferences of project PEA took place in Germany (Wittenberge) during which the cooperation results were dis-

Meeting of international PEA project final conference participants in Wittenberg (Germany)

cussed, achievements were summarized and relevant conclusions were made. With increase of energy prices and with reduction of financial resources energy saving and expenses economy is the main task for municipalities. All project partners presented their strategies: how municipalities would be able to implement energy saving measures and use of RES, to save money and more attractively present region's achievements. The project partners summarized scientific and technical achievements of the executed project in the Energy declaration of the Baltic countries. The Declaration content is defined in detail in the volume of *Energy* journal 2013. T. 59, No. 2.



Structure and tools of project ***Transparence*** *for achievement of project objectives*

Bioenergy Promotion 2: from the strategy to the activities. In 2013, an international project ***Bioenergy Promotion 2*** financed from the EU Baltic sea region programme funds was continued.

One of the main objectives of the project – to assist regions, municipalities administrations in implementing bioenergy production expansion justified scientifically and in economic calculations, and particularly, following sustainable development principles. Bioenergy projects are most often executed after receiving target financial support from EU Structural and other funds. The overview of the projects which received EU financial support revealed that when providing financial support not always sustainability aspects are estimated properly, such as sustainable development of regions, sustainable biofuel production and consumptions and social aspects, particularly in village areas. On the basis of performed overview the recommendations were prepared, which could be used in estimating new projects devoted for bioenergy expansion in Lithuania.

In 2013, a new international project ***Increasing Transparency of Energy Service Markets*** was initiated, implemented in the framework of *Intelligent Energy Europe*. Project implementation duration – 30 month. Project coordinator Czech efficient energy consumption center SEVEn.

The project was executed together with partners from 20 EU countries (Czech Republic, UK, Germany, Slovenia, Sweden, Belgium, Austria, Bulgaria, Italy, the Netherlands, Poland, Slovakia, Spain, Greece, Hungary, Denmark, Norway and Latvia).

A model of Energy Performance Contracting is currently used to finance energy consumption efficiency increase projects in the EU; it enables to achieve good energy saving results. The basic feature of agreement regarding energy consumption efficiency, i.e. agreement between benefit receiver and service supplier (ESCO) is that services supplier guarantees (at his financial resources) energy saving amount foreseen in the agreement, which will be reached after implementing energy saving measures at contractor's place. The benefit receiver (contractor) (pays off completely or partially, considering the mutual

What is EPC?

Energy performance contracting (EPC) is a "contractual arrangement between the beneficiary and the provider of an **energy efficiency improvement measure**, **verified and monitored** during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a **contractually agreed level of energy efficiency improvement** or other agreed energy performance criterion, such as financial savings".

European Directive 2012/27/EU

agreement) for the services provided to him not instantly, but during certain period of time (as foreseen in the agreement) from the incomes obtained for factually saved energy or energy resources).

Basic objective of international project Transparence is to collect as much as possible information on the activities of Energy services companies in the EU, to provide conditions for different countries to exchange experience on the above mentioned companies' achievement and issues. To find out obstacles which prevent from the application of the agreements mentioned above. Project results will enable to increase expansion of projects devoted to energy saving in the EU countries. The results obtained during project execution will increase knowledge on the activities of energy services companies and their capabilities in different EU countries. The project results will be constantly presented during various trainings and seminars. Experienced EU energy experts will enable to initiate and implement pilot projects in 20 countries participating in the project.

PUBLICATION OF SCIENTIFIC RESULTS

In 2013, in accordance with the implemented projects, the research results were submitted in 10 scientific papers, 2 papers were presented at scientific conferences (1 of which in international conference), two seminars were organized.

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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 steady-state mode and with the same current frequency in parallel with neighbouring systems over the wide areas. The operational modes of PS are specified by active and reactive loads and generations, energy transfers, voltages, currents, phase angles and other parameters. All the parameters should be kept within the pre-determined limits, and this is the major responsibility of PS operator. Such a control is rather complicated procedure even in case of normal conditions. Nevertheless, the systems often experience the stressed operations caused by various contingencies and then the systems should be secured from going out of control. Uncontrollable operational modes may lead to voltage collapses, underfrequency situations, loss of dynamic stability and even to splitting or blackout of a power system. Here the preventive and control automatics with embedded relays and multiple digital controllers, provided with data communication channels, support the operators in controlling the systems and networks and protecting against contingencies and emergencies.

When preparing the control measures (plans of equipment switchover, set-points of automatic devices, dispatching control signals, etc.), the operators rely on modelling results, i.e. on calculations of operational modes. This is an activity which requires deep scientific knowledge

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

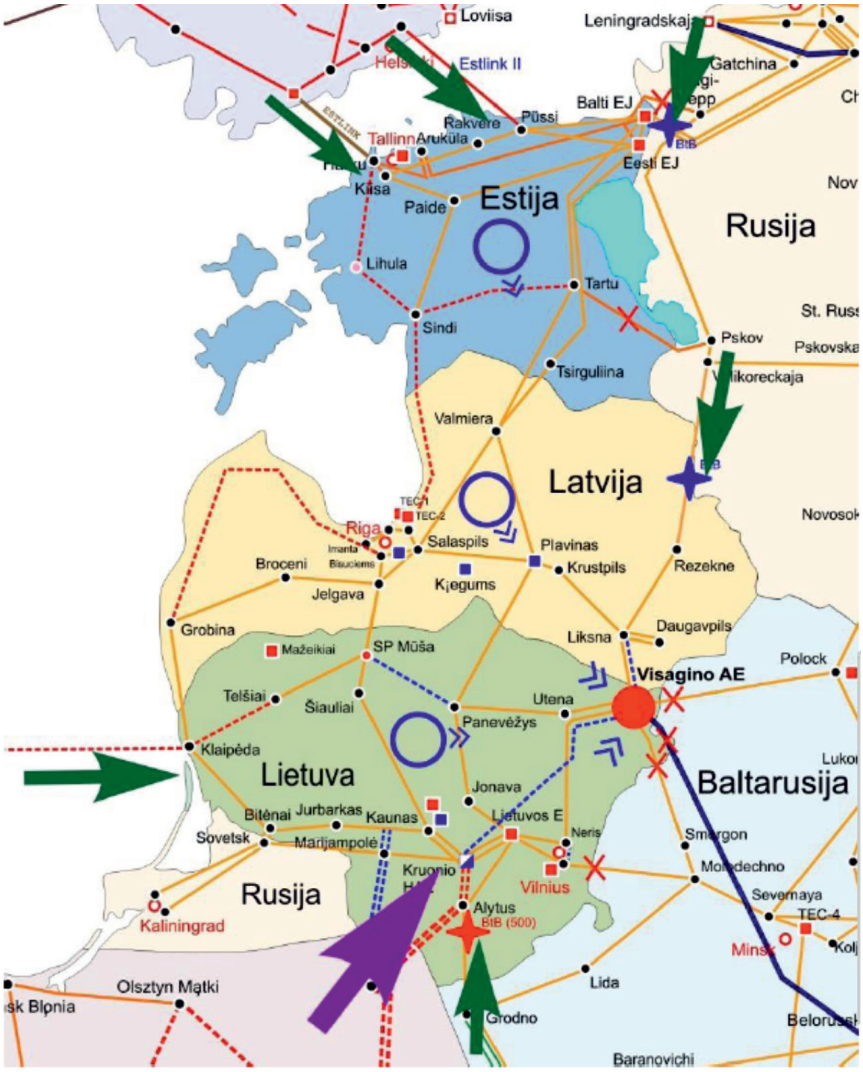
- mathematical modelling of power systems, analysis and assessment of their parameters;
- investigation of PS control issues and development of respective algorithms to deal with frequency regulation, active and reactive power control, static and dynamic stability, minimization of transfer losses, electric 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.

necessary to develop relevant calculation algorithms, evaluation methodologies and analysis procedures.

Major changes are currently tracked in the evolution of modern PS. Multi-system electricity markets are spreading geographically as well as in variety of market products (active power reserves, ancillary services, forward financial transactions). Electricity consumers and small generators are increasingly involved into electricity market and provision of ancillary services. Electricity is becoming more ecological due to growing share of renewables-based generation, and, maybe, due to eventual expansion of nuclear energy. Power systems turn to be more robust against disturbances, with better reliability of power supply and improved energy quality (close-to-regular shape of voltage sine curve, less flickers, etc.). Such improvements are induced by smart technologies which play the role of drivers towards *smart grids* defined by as new concepts as *smart generation, smart electricity network, smart relays, smart metering* and even *smart house*. Smartness is ensured by computer logic devices (controllers with microprocessors) and their communication networks, including links to power network dispatchers. Smart technologies enable operators to more efficiently and reliably control their networks in real time and, in general, simplify their work (since most part of control and monitoring functions is performed by smart controllers without human intervention). On the other hand, control infrastructure itself becomes more sophisticated since more algorithms and software programmes are embedded into controllers. Respectively, the actions of controllers should be coordinated and the controllers "reprogrammed" in order to remove the observed inadequacies.

In the scope of the national programme ***Energy for the Future***, the project ***Research and Assessment Methodology of Energy Systems Reliability and its Impact on Energy Security*** was carried out (together with the Laboratory of Nuclear Installation Safety). For the project purposes, the software **PSS™E-33** was used to investigate Lithuanian steady-state operational modes. The calculations were performed on the perspective scheme of year 2020 for winter maximum and summer maximum modes (winter minimum and summer minimum modes will be investigated later), assuming Baltic PS and Kaliningrad PS operating synchronically with Continental Europe Network (CEN). The interlinking with Russian and Belarus PS was simulated via DC links (back-to-back converters) in Estonia, Latvia and Lithuania (in line Alytus–Gardinas, while other four 330 kV Lithuanian–Belarus cross-border lines being disconnected).

The detailed network models were developed for Lithuanian, Latvian, Estonian, Kaliningrad, Belarusian, Ukrainian, Northwest and Central Russian systems, while NORDIC and Continental Europe were represented by equivalent nodes. Lithuanian PS included 1123 nodes, 812 transmission lines and transformer branches, 368 generators (out of which 310 wind turbines).



Power systems of the Baltic countries

Imitating various contingencies in Lithuanian 330 kV network, post-contingency modes were obtained and the networks were examined for overloading constraints.

According to the contract with SC *LIETUVOS ENERGIJOS GAMYBA*, the study ***Overview and comparative analysis of Lithuanian power reserve market*** (2012–2013) was carried out. Intensive cross-border trade is currently taking place in Lithuanian electricity market and here the emerging NordPool Spot power reserve market seems to be promising. In order to successfully participate in this market, it is necessary to analyse current situation and outline the future trends and related opportunities. In this work, methodologies for identification of active power reserve are discussed as they are seen in Lithuania, Continental Europe and NORDIC countries. The expected changes in secondary and tertiary reserve market relevant for Lithuanian PS were identified, with respect to the upcoming operation of NordBalt and LitPol Link connections.

According to the contract with SC *LITGRID*, the project ***Analysis of asynchronous operation (swings) in cross-border sections*** was carried out. The following tasks were tackled:

- drafting of Methodology to choose the measures for automatic elimination of asynchronous mode and the respective settings;
- scenarios of eventual swing emergence and development;
- analysis of functionalities of the already installed automatics for swing elimination on Lithuanian–Latvian cross-border lines and its modernization needs for the year 2017;
- Feasibility to equip other Lithuanian–Latvian cross-border lines with swing elimination automatics;
- analysis of functionalities of the already installed automatics for swing elimination on Lithuanian–Belarusian cross-border lines and its modernization needs for the year 2017;
- feasibility to equip other Lithuanian–Belarusian cross-border lines with swing elimination automatics;
- Feasibility to provide Lithuanian–Kaliningrad cross-border lines with swing elimination automatics, with regard to the functionalities of existing automatics on Kaliningrad side.

The simulations were performed with the power system modelling software **PSS™E-33**. The project is to be completed in 2014.

Under a national long-term research programme, the Laboratory staff analyses issues covered by the project ***Possibilities of Lithuanian power system synchronous operation with ENTSO-E taking into account perspective development of generation sources***.

Aiming at real energy independence in power sector, main objective of Lithuanian energy policy is operation of Baltic States in synchronous mode with CEN. However it is not enough to just install interconnection links – lines and converter substations. It is necessary to deal with much more complicated than currently system control tasks. Operation control system must satisfy a number of specific requirements. In course of the project, a list of Baltic power plants was drawn up, and their basic technical characteristics having the biggest impact on frequency-load regulation were determined.

In 2014, the research will be continued to outline the availabilities of frequency and power reserves in Lithuanian power system and the activities which are relevant for the development of market concept of reserves trading. Research will be performed under the project ***Economical and sustainability analysis of energy sector development***, which is under joint responsibility of the Laboratory, **Laboratory of Energy Systems Research and Laboratory of Regional Energy Development.**

Researchers of the Laboratory and Laboratory of Renewable Energy Sources currently proceed with the state-funded project ***Research of application of small wind power plants and solar energy systems and their extension possibilities in Lithuania***. In this study, the forecasting model of wind generation is developed, for which the statistical model and general model of physical forecasting employing artificial neuron networks (ANN) will be constructed and combined.

In 2013, the results of research were presented in the proceedings of 2 international conferences. Also one chapter was published in a handbook and one scientific article in the journal listed in Thomson-Reuters database.

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LABORATORY of HYDROLOGY

MAIN RESEARCH AREAS OF THE LABORATORY:

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

OBJECTS AND TASKS OF RESEARCH

The most significant research objects of the Laboratory are Lithuanian rivers and lakes, Kaunas Reservoir, the Curonian Lagoon and the Baltic Sea. The condition of these water bodies is determined by extreme natural phenomena, such as global warming, storms, floods and economic activities (energy production, 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 hydrometeorological database and the modern digital modelling systems, the Laboratory solves the following tasks:

- impact of climate change on water bodies;
- analysis of river flood variation;
- environmental impact assessment of anthropogenic activities on water bodies and justification of environmental protection measures;
- environmental assessment of new sea ports and the ports under reconstruction;
- exploitation of sea harbours and waterways, ensuring the nautical depth;
- investigation of quays interaction with water flow and selection of optimal constructions;
- assessment of environmental conditions using water bodies for different objectives;
- estimation of mixing and dispersion of sewage under critical conditions in water bodies;
- sensitivity and uncertainty analysis of hydrological and hydrodynamic processes.

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

In the recent decade, the Laboratory has been implementing research related to the assessment of the impact of climate change on water resources. In the period 2013–2015 a state funded research project ***Research of Extreme Hydrological Phenomena of Lithuanian Rivers*** (supervisor Dr. J. Kriaučiūnienė) has been under implementation. Research of extreme hydrological phenomena (floods and droughts) are relevant in making designs and operating the most important infrastructures, such as polders, bridges and culverts, as well as for general flood

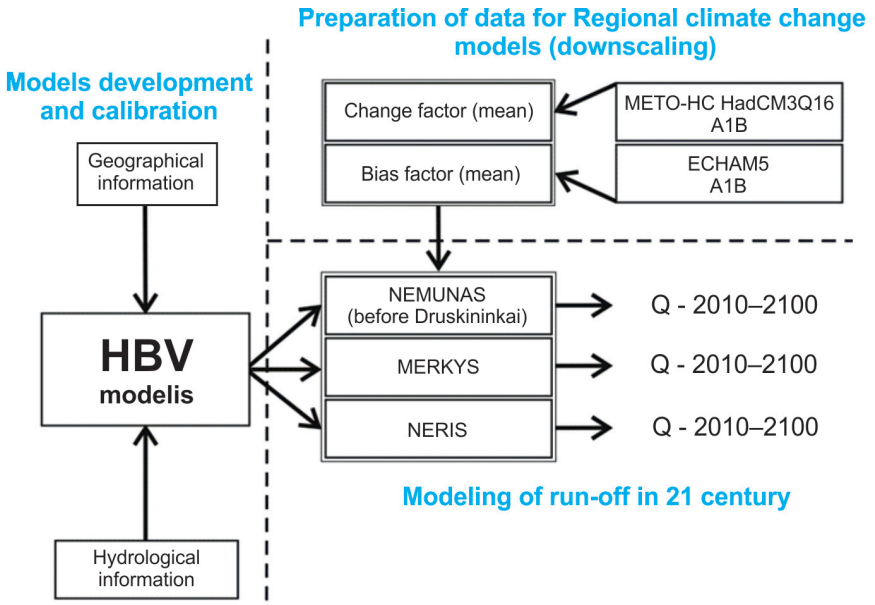

Fig. 1. Basic scheme of simulation using HBV model of the Nemunas (up to Druskininkai), Merkys and Neris rivers' run-off

risk management and planning aiming to escape human casualties and material loss. The preparation of such measures for Lithuanian rivers is based on the observations of rivers run-off, their analysis and numerical simulation. The overview of extreme hydrological phenomena and modern flood forecasting methods in different countries was carried out; original methodology of spring and flash floods assessment during annual period was developed as well as methodology of extreme hydrological phenomena forecasting (climate change models and hydrological simulation) (Fig.1). The performed calibration and validation of hydrological models of the Nemunas, Neris and Merkys rivers reveals the relevance of numerical HBV model for the forecast of run-off extreme phenomena. The Bias correction and Change factor methods selected in Lithuanian area were adopted for regional climate change models.

INTERNATIONAL COOPERATION

FLOODFREQ COST Action ES0901
European Procedures for Flood Frequency Estimation

Together with scientists from 23 European countries, the researchers of the Laboratory participate in the COST ES0901 project ***European Procedures for Flood Frequency Estimation*** (2009–2014). 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 15/06/2013 J. Kriaučiūnienė and D. Šarauskienė participated in COST committee meeting in Warsaw (Poland). The issues of working group reports, the organization issues of final conference (05–06 03 2014), activity budget planning, organization of short-term scientific training and other questions were discussed. On 17–18 03 2013 the researchers of the Laboratory participated in the meeting of working group *The Impact of Environmental Changes on the Assessment of Flood Frequency* in Oslo (Norway). The possibilities were discussed to conduct simulation of rivers run-off in the selected river basins according to the equal climate change scenarios. Scientists from different countries presented their reports on the selected river basins. Lithuanian representative J. Kriaučiūnienė presented report on the Merkys river basin. During the meeting 15 climate models and 8 model grid *downscaling* methods were chosen according to which a hydrological simulation in each country's river basin will be performed.

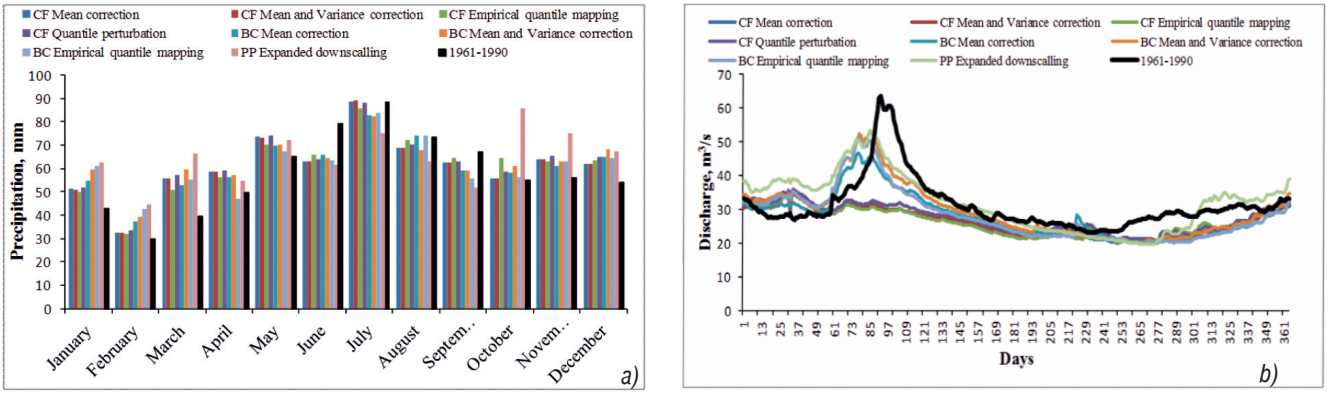

Fig. 2. The amount of precipitation (a) and water discharge (b) in the Merkys river basin following the climate scenario MPI-M-REMO SCN ECHAM5 and downscaling methods of 8 models net in the period of 2071–2100 (the black line defines the average precipitation and discharge values in the period of 1961–1990)

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 04 November 2013 a new project Latvia-Lithuania cross border cooperation network ***Towards a Harmonized Water Quality and Pollution Risk Management HOTRISK*** was initiated. The project duration 04 11 2013 – 31 12 2014. The project partners are Latvian Environment, Geology and Meteorology Centre and Laboratory of Hydrology of Lithuanian Energy Institute. During the first meeting (25–26 November 2013), the experts from both parties got to know each other and discussed the future project. The main objective of the project – to achieve a high quality of the surface water chemical composition in Lithuania-Latvian frontier rivers.

European Network of Freshwater Research Organisations (EurAqua, 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 organise conferences on relevant topics (the impact of climate change on water resources, flood analysis and forecast in Europe, etc.)

The moments of Project meeting in Riga

The XXXX meeting of *EurAqua* members took place on 15–16 May, 2013 in Wallingford Center for Ecology and Hydrology (CEH Wallingford, United Kingdom), whereas the XXXXI meeting took place on 19–20 November at Brussels University (VUB, Belgium). The participants discussed the political aspects and further use of European water resources, and established topical issues of the new scientific research and innovation programme ***Horizon 2020*** related to the most relevant aspects of freshwater use and protection.

COOPERATION WITH STATE AND SCIENTIFIC INSTITUTIONS

Baltijos slėnis

The Laboratory of Hydrology closely cooperates with the Institute of Environmental Engineering of Kaunas University of Technology and have been publishing scientific journal ***Environmental Research, Engineering and Management*** since 1995. The researchers carry out complex environmental 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 the modern scientific research equipment and ship, a National Maritime Science and Technology Centre is going to be established.

The partners of the Baltic Valley (Klaipėda University, Nature Research Centre, Lithuanian Energy Institute, 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, working and technical resources, participate in implementing 2007–2013 Human Resources development operational program **Priority Axis 3:** *Strengthening the capacities of researchers* project ***Development of Lithuanian marine sector technologies and environmental research***.

Researchers of the Laboratory together with KU researchers actively participate in the activity of project ***Simulation of Hydrodynamic and Litodynamic Processes in the Baltic Sea Nearshore***.

MAJOR APPLIED RESEARCH WORKS

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 ***LGT impact on the flow and sediment balance of the Klaipėda strait, erosion and accumulation processes and bottom changes and measures to mitigate this impact***, the results of which are applied for EIA of liquefied natural gas terminal, was prepared. On 20 December, 2013 ***JSC Sweco Lietuva*** was granted the golden medal from the Lithuanian Confederation of Industrialists *Lithuanian product of the year 2013* for prepared LNG terminal EIA report.
- 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 preparing ***The Expansion Plan of Maximum Deepening and Widening Possibilities for Klaipėda State Sea Navigation Channel.***
- Under the agreement with ***Sweco Hydroproject*** a study ***Mathematical Model of the Kiaulės Nugara Island Slope's Erosion and Sediment Processes*** is to be prepared.
- Under the agreement with **Nature Research Center** the assessment of Kaunas hydro power plant reservoir water level fluctuation was carried out.

MIKE 21 modelling system 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 straight ***The Expansion Plan of Maximum Deepening and Widening Possibilities for Klaipėda State Seaport Navigation Channel*** is to be prepared in 2013–2014.

The Laboratory researchers estimated the possible impact of Klaipėda Straight deepening and widening on the Klaipėda Strait flows and sediments 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 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.

Navigation in the deepened Klaipėda strait

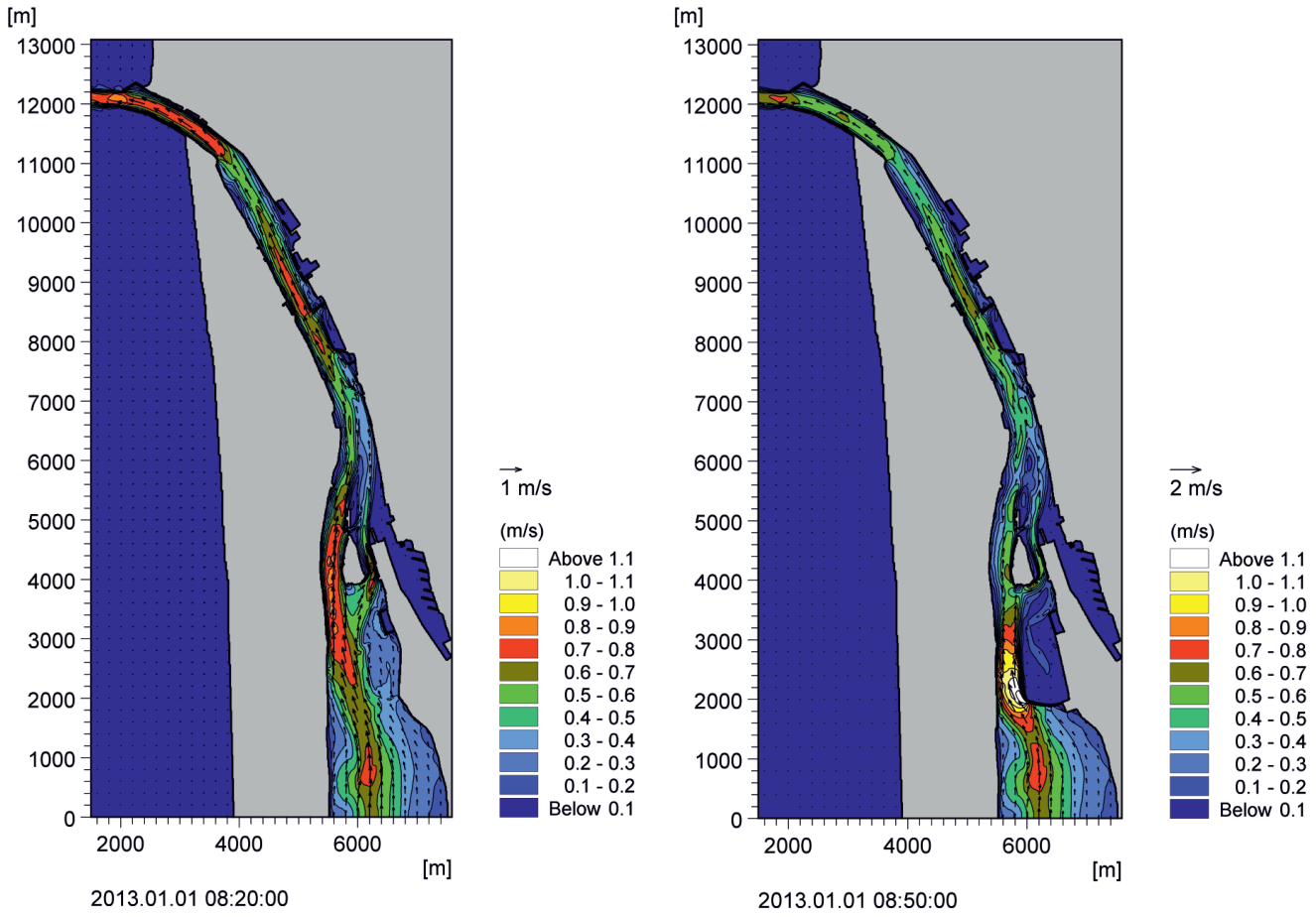

Fig. 3. Structure of the Klaipėda Strait flow according Alternative 0 (a) and Alternative A (b), when a discharge of 2730 m³/s flows from the Curonian Lagoon to the Baltic Sea

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 (in the chosen water area sectors deepening and widening up to maximum parameters 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 KSS navigation channel maximum deepening and widening expansion plan according to Alternative A (maximum expansion possibilities after implementing environmental impact mitigating measures) drastically (up to 10.4%) will increase permeability of the Klaipėda Strait. The installation of 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 in the first stage of the port expansion it is proposed to implement the solutions of Alternative B. The configuration of southern breakwater should be analysed since in this Expansion plan only breakwater version was analysed (700 m length breakwater). In the future such a southern breakwater construction should be selected 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.

The possibilities of MIKE 21 modelling system application for port development projects are considerable. Modelling results are especially useful for assessing the impact of port development, harbour construction and waterway on the ecosystem of the Curonian Lagoon and the Baltic Sea. In 2013 the water area of Klaipėda

PADĖKA

Prof. habil. dr. Brunonui Gailiušiui

už svarų indėlį ir nuoširdų darbą 2012–2013 m. organizuojant ir vykdant didžiausios Klaipėdos uosto istorijoje apimties ir vertės infrastruktūros projektą – laivybos kanalo gilinimo ir platinimo darbus.

The Director of state enterprise Klaipėda State Seaport A. Vaitkus grants the note of gratitude to Prof. B. Gailiušis

Seaport was deepened up to 14.5 m in accordance with the project ***Preparatory Works of Klaipėda State Seaport Channel Deepening and Widening: Environmental Impact Assessment, Project for Deepening Activities and Engineering Research*** (supervisor B. Gailiušis). This is the biggest infrastructure project in its scope and value in the history of Klaipėda Seaport related to navigation channel deepening and widening activities.

In 2013 the researchers of the Laboratory published 4 scientific articles in the journals listed in Thomson-Reuters database, 1 in the reviewed scientific journals and 3 in science promotion journals. The researchers presented papers in two Lithuanian scientific conferences.

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YOUNG SCIENTISTS ASSOCIATION

The Young Scientists Association (YSA) of the Lithuanian Energy Institute has been actively working on its activities since 2002. Pursuing its objectives it performs the following activities: maintains and develops interrelations with operating researchers and youth organizations in Lithuania and abroad; prepares, discusses and proposes documents related with member rights and their legal interests, projects; organizes social queries, meetings, discussions, seminars, conferences, forums and other events; represents the interests of members and LEI postdoctoral students, protects their rights in LEI self-government units, national and social organizations, associations and public movements.

ANNIVERSARY 10TH INTERNATIONAL CONFERENCE CYSENI 2013

On the 29th of May, 2013, the Institute was bustling with young people: a three-day international anniversary conference of doctoral students and young scientists, ***Conference of Young Scientists on ENergy Issues – CYSENI***, began. The conference, which has been organized for 10 years in a row by YSA, this year has attracted a great number of speakers from the Lithuanian scientific and research institutions (Vytautas Magnus University, Vilnius Gediminas Technical University, Mykolas Romer University, Kaunas University of Technology, Vilnius University, Center for Physics and Technological Sciences). **Many young scientists arrived to the conference from the scientific and research institutions of the neighbouring countries,** most active of which were our closest neighbours Latvians (19 participants), Belarusians (12), and Ukrainians (7).

Conference topics

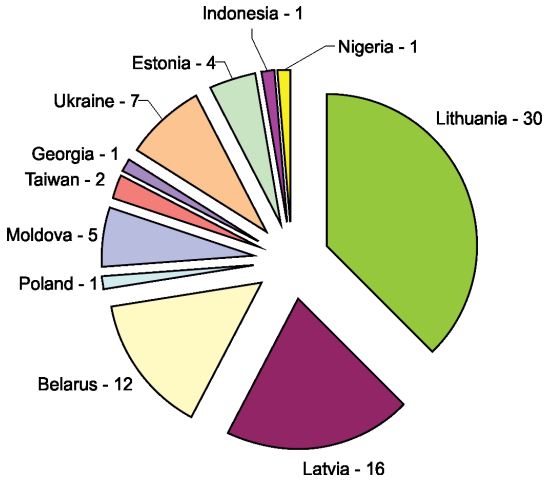
The main energy-related topics covered in the conference are the following: Hydrogen and fuel elements; Renewable energy sources and their use; Smart energy networks; Energy efficiency and saving; Knowledge for energy policy making; Research in the fields of thermal physics, fluid and gas mechanics and metrology; Nanosciences and nanotechnologies; Research on multifunctional materials; Research on combustion and plasma processes; Global change and ecosystems; Fusion energy; Nuclear energy and radiation protection; Complex energy aspects.

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

Conference during the last ten years

The conference was first organized back in 2002 in pursuance to provide a possibility for the young scientists of the Institute to present the results of their research and become acquainted with the work done by their colleagues, discuss the relevant energy-related issues and promote scientific cooperation.

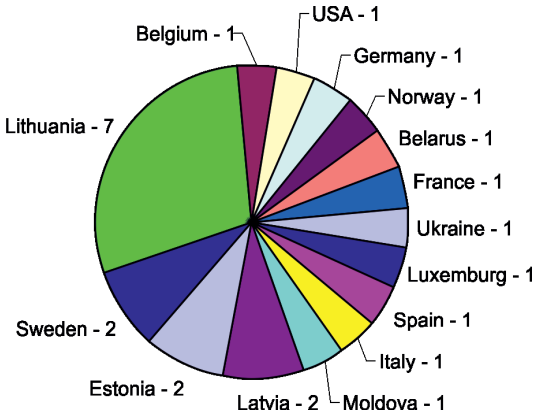
In 2003 it was decided to call to the conference younger researchers from other Lithuanian science and education institutions as well and thus encourage spread of results in the country, initiate and promote communication.



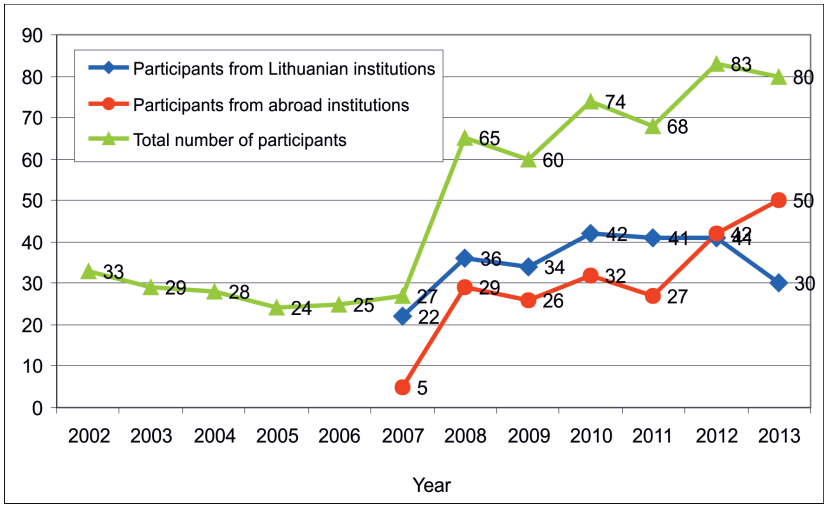
Arrangement of the conference participants according countries

Conference science committee

During 10 years of conference establishment the number of committee member increase drastically and in 2013 it was comprised of members from Lithuania and 14 foreign countries.



Arrangement of the conference science committee members according countries (data of 2013)



Variation of number of conference participants

The anniversary conference

In the first session of the conference visiting presenters, well-known scientists, were invited to present their papers: Dr. Axel Winter (ITER, France), Dalius Klyvis (AGA, Lithuania), Dr. Jurga Lazauskienė (Lithuanian Geology Office).

The conference guest Prof. Raymond Viskanta (Purdue University, USA) read his report on thermal engineering challenges on the second day of the conference, and granted Raymond Viskanta nominal award established by Vydūnas youth fund to two LEI young re-

searchers, actively working in the fields of thermal physics, heat exchange, nuclear energy: Andrius Tamošiūnas (for 2012) and Tadas Kaliatka (for 2013).

Prof. Raymond Viskanta

138 annotations were submitted for the conference 2013, out of which 98 were presented in the conference. From the submitted scientific publications experience reviewers selected 80 publications suitable to be published in the conference material.

The work of the conference took place in 2–3 parallel sections in which the reviewers of the articles, experts of the technological sciences, were also present. They were provided a possibility to overview the submitted papers of the young scientists and researchers before the conference; thus, during the event, they asked questions, commented on the work of the young scientists and lead the discussions. To improve the public communication skills of doctoral students and young scientists, the participants of the conference and the representatives of the Board of LEI Young Scientists Association acted as chairpersons.

The conference material

One of the most important conference results is summary of young scientists performed research, preparation of qualitative scientific publications and their submission for scientific society. Scientific publications and annotations of the conference participants are published in the conference material, issued in electronic format (CD, ISSN 1822-7554). The published material will reach main research centers and libraries of the country as well as some foreign libraries and research centers.

The authors of best works

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

In the group of postgraduate students and the first and second year doctoral students:

1. Artjoms Obushevs (Latvia);
2. Chun-Min Liu (Taiwan);
3. Tomas Iešmantas (Lithuania).

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

1. Yauhen Baranyshyn (Belarus);
2. Tadas Kaliatka (Lithuania);
3. Anton Brin (Belarus).

The winners Yauhen Baranyshyn and Artjoms Obushevs were greeted and granted awards for their accomplishments from LEI Scientific Secretary - Head of Information Department Dr. Rolandas Urbonas and one of the conference organizers Dr. Diana Meilutytė-Barauskienė

Organizers and sponsors

The initiative of LEI YSA to organize such event was supported by the Institute leadership, who granted financial and

technical support. Sponsorship to organize the conference was also provided by *AGA* and *REO Investment*.

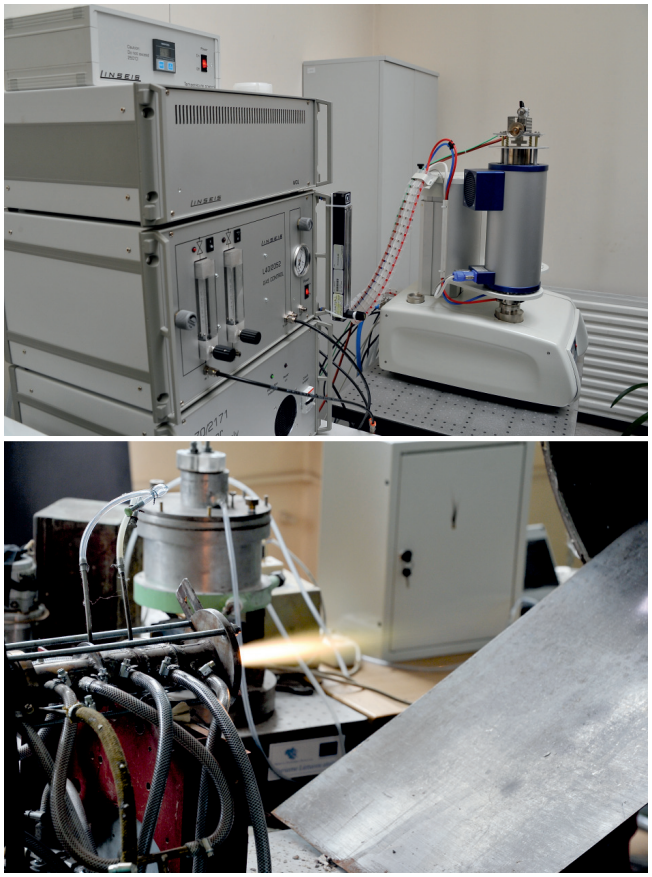
LEI OPEN DOORS DAY

This is a superb opportunity to find out more about the activities performed at LEI, scientific research and experiments, to communicate with the representatives of institute's laboratories, to see laboratories' presentations, and what is most important, to submit one's questions of interest.

LEI is known as one of the most advanced state's scientific centers, actively participating in international science programs, executing scientific research relevant for Lithuanian and foreign clients, closely cooperating with business, science and education institutions.

Each scientific institution needs renewal, thus LEI aims at attracting young, various specialties people who are eager to achieve a career of scientist. Educating a shift for experienced researchers, new PhD students are accepted annually, favorable conditions are developed for young people to work or perform practice at the institute.

With the open day event we aim to reveal that the EU Structural Funds are employed relevantly, the purchased most advanced equipment was employed successfully for scientific research, whereas the youth will be provided with the opportunities to achieve new scientific results at the National Open Access Scientific Center for Future Energy Technologies.



Differential scanning analyzer of specific heat of materials and Operating atmospheric pressure plasma generator

KTU CAREER DAYS

On 13 March 2013 an already traditional event ***KTU Career Days 2013*** took place in Kaunas University of Technology and the representative of LEI also participated in it. For nine years KTU Career Centre and Student Association have been organizing the event which attracts many students from thirteen different faculties of the University, the representatives of the largest Lithuanian enterprises and foreign visitors. Each year the event receives considerable attention from students, professors and the representatives of companies.

Main objective of the biggest event of such kind in Lithuania – direct exposition of both parties demands and exchange in contacts.

The representatives of LEI: the Studies Administrator J. Kazakevičienė, and YSA members participated in the event in order to present the Institute and provide information about the scientific career possibilities to the students. The stand of the Institute mainly attracted the students studying **electrical power engineering and technologies**, applied physics, applied mathematics, **electronics engineering, chemical technology** and engineering and **thermal engineering**.

After *Career Days 201*3, 3 KTU students were admitted to doctoral studies and 7 worked for practice.

WORKSHOPS AND TRAININGS ORGANIZED BY YOUNG SCIENTISTS

LEI YSA annually organizes seminars and trainings for institute's PhD students and young scientists on different topics. On 5 of March 2013 LEI YSA organized seminar *Shale gas in Lithuania:*

present situation and perspectives, where scientists, representatives of the ministries, members of oil extraction companies and interested associations discussed the potential of clay shale oil/gas in Lithuania, present situation of deep geological research prospect, environmental requirements and shale gas extraction perspectives. Papers were read by Dr. Jurga Lazauskienė (Lithuanian Geology Office at the Ministry of Environment), Laura Rimšaitė (Ministry of Energy of the Republic of Lithuania), Giedrius Giparas (the Ministry of Environment of the Republic of Lithuania), Ignas Vaičeliūnas (JSC *Minijos nafta*).

In 2013 trainings were organized for PhD students, younger researchers and other academic society members on the search of scientific information, database, abundant scientific information management tools, scientific journals' reference indicators. The objective of trainings – to help young researchers to more easily conduct information search, to verify relevant literature sources for publications and efficiently manage scientific information.

During the ETSON JSP workshop LEI activities were presented by the Institute's director E. Ušpuras, LEI YSA board chairwoman L. Murauskaitė spoke about LEI Young Scientists Association, workshop program was discussed by organiser T. Kaliatka

ETSON JSP SUMMER WORKSHOP

On 26-30 of August, 2013 for the first time in Lithuania, LEI, ETSON (European Technical Safety Organisation Network) JSP (Junior Staff Programme) summer workshop took place. ETSON network is comprised of 13 institutions from different countries. Since 2008 ETSON JSP summer workshop is organized in different country's institutions. The seminar topic was *Monitoring of accidents*. A great number of participants participated in the workshop total 42 participants from 9 different scientific technical support institutions (BE1 V, GRS, IRSN, NRI, VUJE, PSI, SEC-NRS, SSTC-NRS, and LEI) and 2 regulatory organizations (NRG and SUJB).

During the workshop an excursion was organized to VATESI and Kruonis hydro pumped storage power plant. The JSP summer workshop topic *Monitoring of accidents* thus participants were acquainted with the activity of VATESI Emergency Operations Center. The lower and upper water pools were shown at Kruonis hydro pumped storage power plant as well as machines hall, power plant's operation basics, center of operators.

FINANCIAL HIGHLIGHTS

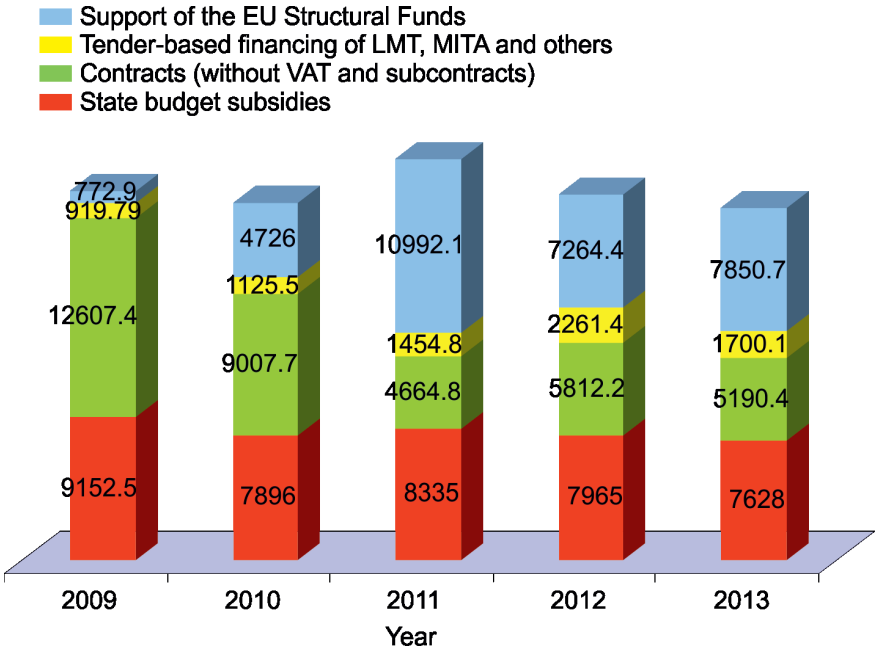
THE FINANCIAL SOURCES OF THE INSTITUTE CONSIST OF:

- 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 Incomes.

Structure of Income and Total Expenses (thous. LTL)

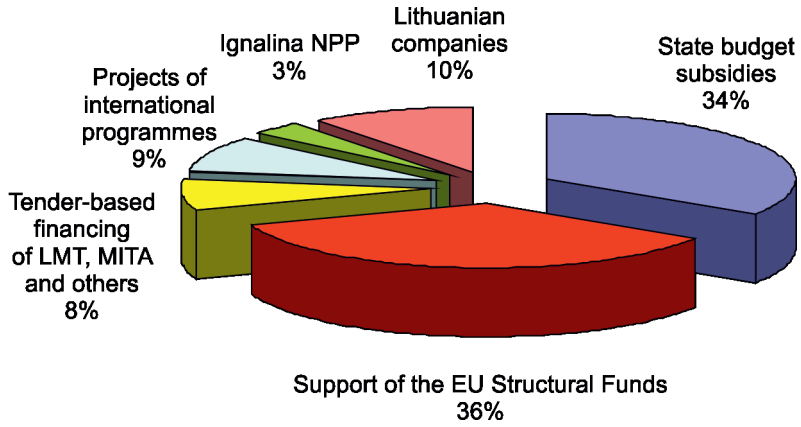
	2009	***2010***	***2011***	***2012***	***2013***
Income:					
State Budget Subsidies	*9152.5*	*7896.0*	*8335.0*	*7965.0*	*7628.0*
Contracts	*9646.4*	*9356.0*	*6071.0*	*7975.2*	*6786.1*
SF Support	*772.9*	*5403.6*	*10992.1*	*7264.4*	*7850.7*
Other Income	*1155.3*	*99.7*	*95.5*	*98.4*	*104.4*
Total:	*20727.1*	*22755.3*	*25493.6*	*23303.0*	*22369.2*
Expenses:					
Salaries (soc. ins. incl.)	*13722.0*	*13843.0*	*14273.0*	*13618.0*	*13713.0*
Operating and other Expenses	*3749.0*	*2432.3*	*3435.0*	*2547.8*	*5973.0*
Capital Funds	*392.0*	*6122.0*	*10863.0*	*7616.4*	*3010.4*
Total:	*17863.0*	*22397.3*	*28571.0*	*23782.2*	*22696.4*
Long-term Projects Assets	*4967.0*	*5325.0*	*2247.6*	*1768.4*	*1441.2**

** – A financial claim in the sum of 909.8 thous. Litas for the liquidated bank SC **Ūkio bankas***

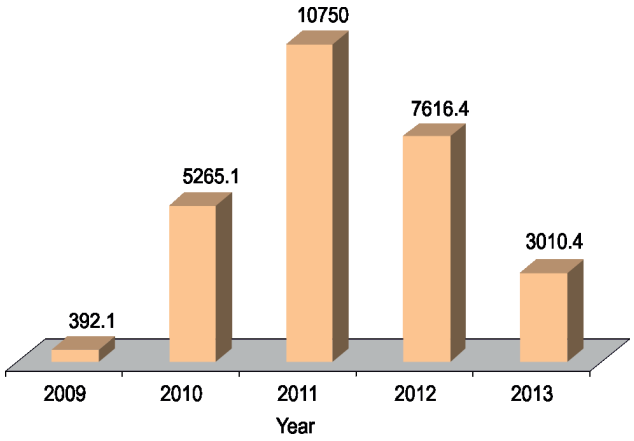


LMT – Research Council of Lithuania;
MITA – Agency for Science, Innovation and Technology.

Evolution of financial recourses, thous. LTL



The structure of finances obtained from the contractors of LEI for year 2013



Dynamics of assets devoted for equipment purchase, thous. LTL

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

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3. Čepelė A., **Kaliatka T.** BWR šiluminių elementų modeliavimas naudojant FEMAXI-6 programų paketą. *Mechanikos inžinerija-2013: 12-oji jaunųjų mokslininkų konferencija: pranešimų medžiaga*, Kauno technologijos universitetas, 2013 gegužės 17. Kaunas: Technologija, 2013. ISSN 2335-8815, p. 18-23.

4. **Gurskienė V., Striūgas N.** Medienos anglies likučio skaidymas panaudojant CO2 dujas. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 81-88.

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10. **Lisauskas A.** Saulės energijos integravimas į centralizuotas šilumos tiekimo sistemas. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 201-204.

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13. **Milieška M., Kėželis R., Mėčius V.** Plazmos srauto ir dispersinių dalelių sąveikos plazmocheminiame pluoštinimo reaktoriuje tyrimas. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 75-80.

14. **Mockevičius M., Zygmantas G.** Šilumos ir vandens apskaitos prietaisų matavimo ir duomenų perdavimo sistemų metrologinės patikros ypatumai. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 195-200.

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18. **Striūgas N.** Granuliuotos biomasės dujinimo technologijos taikymo šilumos gamybai tyrimas. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 23-28.

19. **Šutas A.** Šilumos mainų CASTOR RBMK-1500 ir CONSTOR RBMK-1500 konteineriuose modeliavimas RELAP5 programų paketu. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 57-60.

20. **Tamošiūnas A., Grigaitienė V.** Šilumos atidavimas į plazmos generatoriaus elektrodus, tekant vandens garo plazmos srautui. *Šilumos energetika ir technologijos-2013: konferencijos pranešimų medžiaga*, Kauno technologijos universitetas, 2013 sausio 31-vasario 1. Kaunas: Technologija, 2013. ISSN 2335-2477, p. 69-74.

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17. **Savickas J.** Prof. habil. dr. Vladislovui Katinui – 75. *Energetika*. ISSN 0235-7208. 2013. T. 59, Nr.4, p. iii-iv.

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20. **Tomkevičienė A.** Skirsnemunės toponimai ir antroponimai. Skirsnemunė. Straipsnių rinkinys. Vilnius: Diemedis, 2013. ISBN 978-9986-23-180-6, p. 15-22.

THE MAIN EVENTS in 2013

11 January.
Member of the EU Parliament Zigmantas Balčytis paid visit to LEI

25 January.
LR patent No. 5895 *Method of hydrogen extraction from water* was issued

31 January.
ETSON workshop

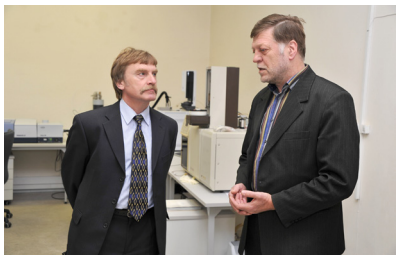
31 January.
Seminar *Sustainable development aspects in preparing plans for municipalities' RES usage development actions*

14 February.
Conference *Lithuanian Science and Industry*

20 February.
7BP project SARNET2 workshop

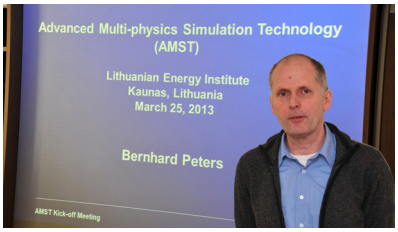
4 March.
Visit of the representatives of the Ministry of Education and Science of the Republic of Lithuania at LEI

13 March.
Visit of director Dr. Igar L. Pobal of Scientific Engineering Center of Physical-technical Institute of National Academy OF Sciences of Belarus PLASMOTEG



13 March.
LEI representatives participate in *KTU career days*

25 March.
Seminar *Advanced Multi-Physics Simulation Technology (AMST)*

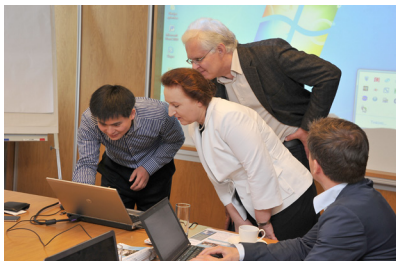


2 April.
Visit of École Polytechnique Fédérale de Lausanne (Switzerland) students

16 April.
Dr. Habil. Algirdas Kaliatka was granted Algirdas Žukauskas award

27 April.
Famelab competition semifinals

22 May.
Meeting of 7BP project FIBCEM M18 participants



24 May.
Visit of Minister Dainius Pavalkis of the Ministry of Education and Science of the Republic of Lithuania

27–28 May.
Training for EURATOM participants and NCPs

29 May.
Visit of Purdue university professor Raymond Viskanta

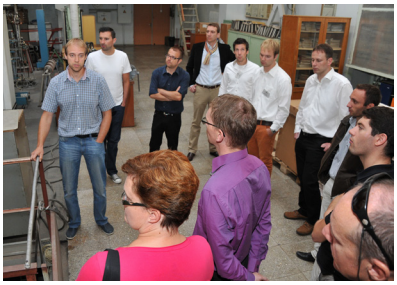
29–31 May.
The 10 anniversary conference ***CYSENI 2013***

14 June.
Gratitude of Klaipeda State Seaport authority to Prof. Dr. Habil. Brunonas Gailiušis

25 June.
Participation of pupils in Vytautas Magnus Unversity organized Robotics Academy summer camp

22 August.
Visit of Brandenburg Economic Development Board and TSB Innovationsagentur Berlin GmbH representatives from Germany

26–30 August.
ETSON JSP summer workshop 2013



11 September.
Visit of GE-Hitachi Nuclear Energy representative Mr. Ziemovit Iwanski

13 September.
Science festival *Spaceship* ***Earth***

27 September.
Researcher's Night 2013

7 October.
Vizit of Prof. Pavel Krukovskyi (Engineering Thermal Physics Institute, Ukraine)

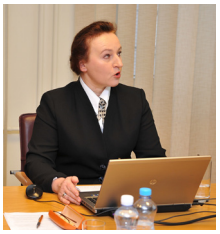
8 October.
Visit of Norwegian Scientific Council special adviser Dr. Dag Høvik

14 October.
United Euratom conference ***FISA Euradwaste'13***

15 October.
Belarus SOSNY employees traineeships

7 November.
Visit of Deputy Director Dr. Gunta Šlihta of Latvian Physical Energetics Institute

13 November.
Moments from work reports' defence funded by national funds



26 November.
Visit of Thor Energy (Norway) representatives

4 December.
Visit of Dr. Elene Prokofieva Scotland Napier University (Institute of Sustainable Construction)

9 December.
Visit of researchers from Ukraine National Academy of Sciences, Gas Institute at the Laboratory of Combustions Processes

17 December.
LEI was granted a silver medal in the competition *Lithuanian product of the year 2013* organized by Lithuanian Confederation of Industrialists for developed service *Identification of thermal isolated tube thermal conduction*

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