LITHUANIAN ENERGY INSTITUTE

ANNUAL REPORT 2012

LITHUANIAN ENERGY INSTITUTE in 2012

MISSION OF THE INSTITUTE

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

THE OBJECTIVES OF THE INSTITUTE:

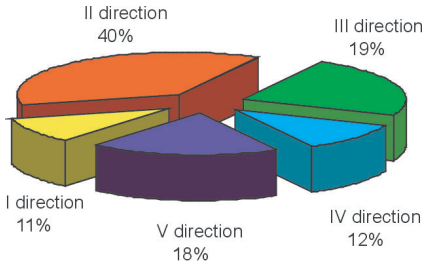
- perform permanent fundamental and applied scientific research at international level, experimental development activities, which is a must for sustainable development of Lithuania energy and other Lithuanian economy branches and for the integration to the European energy systems and European research area.
- while cooperating with business, governmental and public 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, boost co-operation with alike world science research centres.

SHORT-TERM STRATEGIC OBJECTIVES

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

SCIENTIFIC RESEARCH ACTIVITY OF THE INSTITUTE

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

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 technological platforms: Sustainable Nuclear Energy Technology Platform **(SNETP)** and Implementing Geological Disposal of Radioactive Waste Technology Platform **(IGDTP)** and national technological platforms of Hydrogen and fuel cells (H2/FC), Future production, National heat energy, National biomass and biofuel production and employment.

Year 2012 was filled with significant events and visits.

In the begining of the year the European Commission selected the European Nuclear Safety Training and Tutoring Institute ENSTTI, one founder of which is the Institute, to train experts of regulating nuclear energy organizations and technical support organizations and improve their qualification. This decision by the EC is the acknowledgment of ENSTTI in developing regulation and technical possibilities.

In January, the cooperation agreement between AB *Kauno energija* and LEI was

LEI Director Eugenijus Uŝpuras shaking hands with Giovanni De Santi, Director at EC Joint Research Centre Institute for Energy and Transport (on the right), on renewing the inter-institutional collaboration agreement

signed regarding preparation of joint project ***Monitoring of heat network thermal-hydraulic parameters, accident analysis and prevention system***.

In February, the representatives from Smart Technologies Association, Swansea University (UK), and SHIMIZU Corporation (Japan) paid visit to the Institute.

In March, the Institute was visited by the Minister of Education and Science of the Republic of Lithuania, the Ambassador of United Kingdom and USA Embassy Second Secretary - Consul. Besides, the inauguration of new association NUGENIA (Nuclear Generation II & III Association) took place in Brussels on the 20th of March. One of NUGENIA founders is Lithuanian Energy Institute.

On the 19th of April, Giovanni De Santi, Director of JRC's Institute for Energy and Transport, paid visit to the Institute. During his visit the cooperation agreement between the institutes was renewed. On the 19th of April, the agreement was signed regarding cooperation among Swansea University, Kaunas University of Technology, Lithuanian University of Health Sciences and LEI.

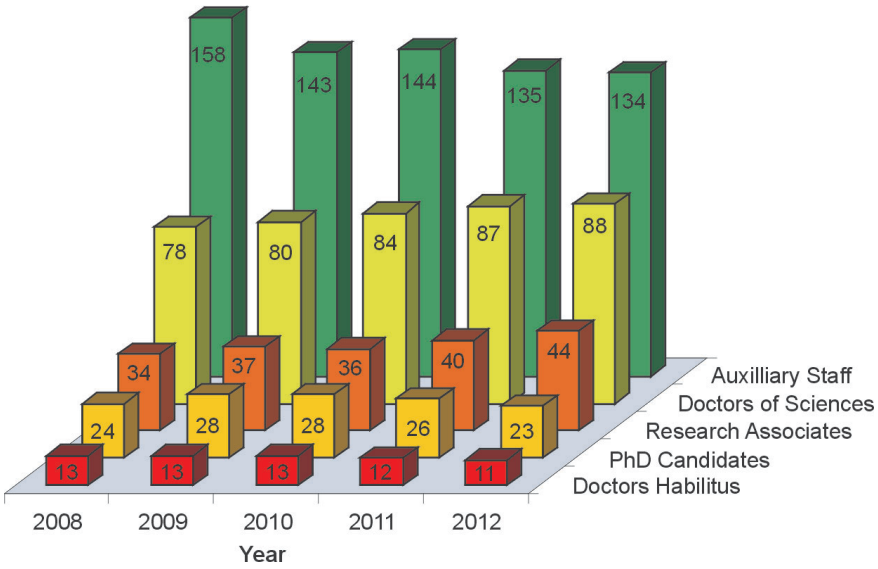
The representatives from EC, Ministry of Education and Science, Ministry of Finances and Lithuanian Research Council visited laboratories of the Institute

In May, the competition *The Laboratory of Glory* took place at the Institute, also the representatives from HITACHI paid visit to LEI. At the end of spring, annual event *9th International Conference of Young Scientists on Energy Issues* ***CYSENI 2012*** took place.

In September, Lithuanian Academy of Applied Sciences held seminar *Open access centers: application possibilities and perspectives*.

In October the Open Doors Day took place at the Institute; the delegation from SC *Lietuvos energija* visited the Institute.

In November *Conference on Energy Security: Outlook & Perspectives in the* Baltic Sea region took place in Lithuania. One of its organizers was LEI. The representatives from EC, Ministry of Education and Science, Ministry of Finances and Lithuanian Research Council visited laboratories of the Institute, which had received

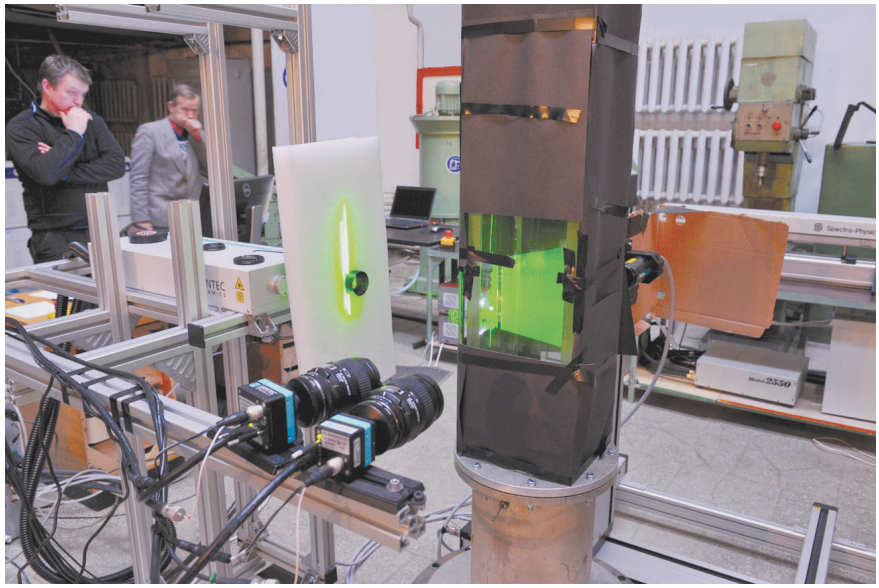


Variation of staff number

the Structural Funds support for infrastructure development in implementing SANTAKA Integrated Science, Studies and Business Centre (Valley) project ***The establishment of National open access Research Centre of Future Energy Technologies***.

In December, the Institute was granted the golden medal by the Lithuanian Confederation of Industrialists in the competition *Lithuanian product of the year 2012* for the developed facility *Facility of critical jets to verify/calibrate gas and flow meters and make experiments at varied temperatures*.

Long-term employee of the Institute Dr. Gediminas Zygmantas was awarded a special nomination *Knight of Profession* by the Lithuanian Confederation of Industrialists.



*Valley **Santaka** financed the purchase of equipment for the Laboratory of Nuclear Engineering*

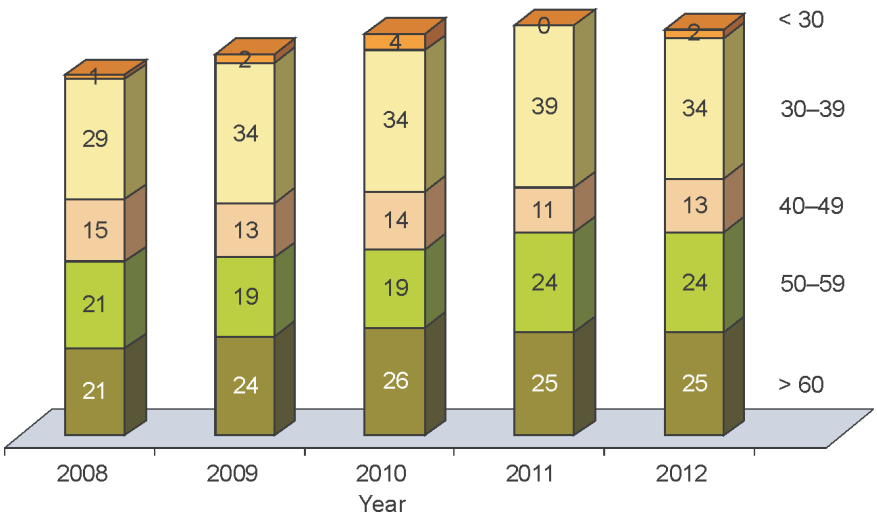
The Institute may be proud of high achievements in the Seventh Framework Programme. LEI participated in submitting 64 proposals (EURATOM-LEI is a special project of thermonuclear fusion associations), out of which 38 passed the evaluation threshold (~59.4%), 23 projects are to be financed (~35.9%).

In 2012, the Institute together with partners submitted 19 proposals, out of which 16 passed the evaluation threshold and 8 proposals are 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, IAEA, COST, and EUREKA.

VALLEY *SANTAKA*

Kaunas University of Technology, Lithuanian University of Health Sciences and Lithuanian Energy Institute implements the projects of Integrated science, studies and business center (valley) *Santaka*.

The mission of the valley – employing a well-developed infrastructure and best human resources, to generate new knowledge, technologies and products in the fields of chemistry, mechatronics, energy and ICT, and transfer all this to business units by ensuring sustainable development of Lithuanian enterprises and establishment of closely operating innovative small and medium enterprises.



Dynamics of age of scientists

On the 31st of October the agreement was signed with Kaunas University of Technology and Lithuanian University of Health Sciences regarding cooperation in implementing valley *Santaka* expansion programme and the foreseen task – to provide favourable conditions for cooperation of business enterprises and science institutions, to promote transmission of new technologies and implementation of innovations. With this cooperation it is aimed to enable (activate) the open access centers established during the projects.

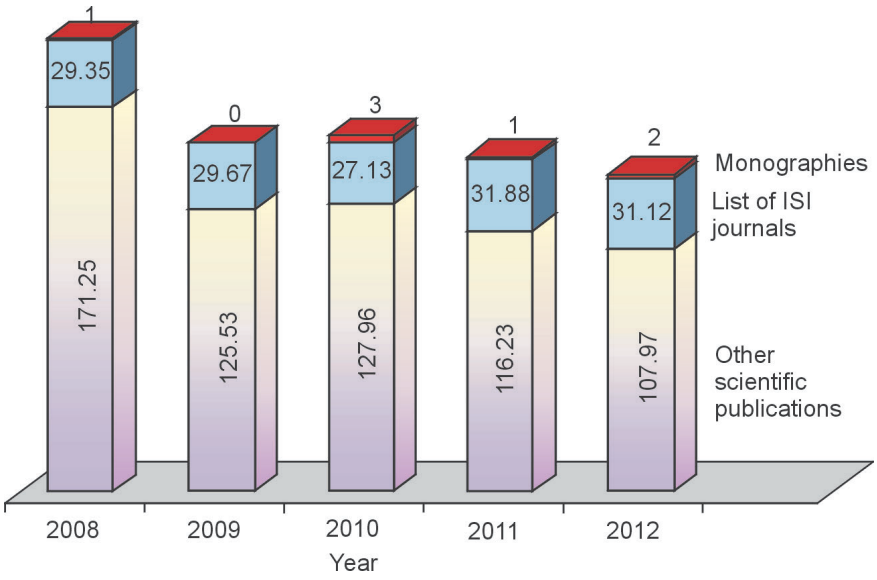
Main objective of the project implemented by the Institute – to establish a

National open access center for future energy technologies, purchasing the most essential experimental equipment and numerical analysis software. The established center would become the European level scientific research and experimental development center, cooperating with business, education and science institutions, conducting fundamental and applied scientific research.

Three year investments (2010–2012) in implementing valey *Santaka* project ***The establishment of National open access Research Centre of Future Energy Technologies*** provided opportunities to establish an equivalent research and experimental development base for EU research centers.

During project implementation in the period 2010–2012 20 million Litas from EU and Lithuanian Republic budget assets were applied, i.e. 57 pcs of experimental facility and 47 pcs of software codes were purchased. After purchasing all equipment foreseen in the project, it will be possible to state that while implementing this project 10 research subdivisions of the institute, out of which are target research centers: Center for Hydrogen Energy Technologies and Alternative and Renewable Energy Centre, are provided with up-to-date worldwide level experimental and numerical facility.

Over hundred representatives from Lithuanian and foreign science, studies and business institutions and society have already visited National Open Access Alternative and Renewable Energy Centre. Visitors are admired with infrastructure and conducted scientific 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 scientific research. In 2012 a young researcher from Norway Institute for Energy Technology made her traineeship at Center for Hydrogen Energy Technologies. In this center 4 technologies defended by patent proposals (tenders) have been developed to promote hydrogen energy, also MITA support was received to establish "the purple enterprise" – JSC *Inovatas*.



Variation of publication number (authors' contribution evaluated)

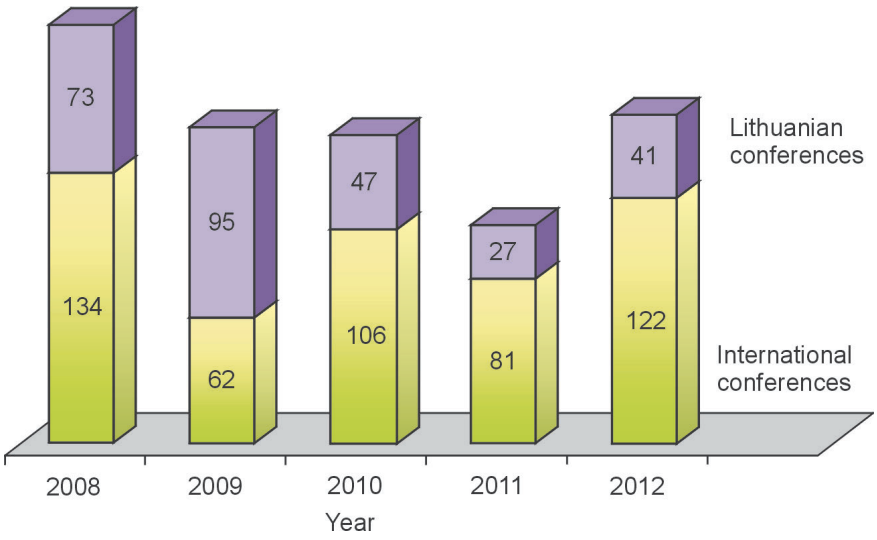
STATE FUNDED PROJECTS COMPLETED

In 2012, 15 state funded projects were implemented and 7 of them had been completed and defended, namely:

1. ***Synthesis and Property Analysis of Nano-crystalline Metal Hydrides, Designed for Energy Storage and Optical Devices*** (study executive Dr. D. Milčius).
2. ***Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing*** (study executive Prof. Dr. Habil. P. Poškas).
3. ***Research of Changes of Hydrological Regime in the Curonian Lagoon due to Environmental and Anthropogenic Factors*** (study executive Prof. Dr. Habil. B. Gailiušis).
4. ***Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology*** (study executive Dr. Habil. A. Kaliatka).
5. ***Study of influence of non-stationarity and physical properties changes in liquids and gases on flow quantities measurements*** (study executive Dr. Habil. A. Pedišius).
6. ***Study of efficiency and pollution of small and medium-scale heating systems using solid biofuel and its mixtures*** (study executive Dr. N. Pedišius).
7. ***Development of Multiobjective Decision Making Model and its Application in the Lithuanian Energetics*** (study executive Dr. D. Štreimikienė).

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.



Number of papers in scientific conferences

P. 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. V. Katinas
3. ***Scientific research of safety important processes in nuclear and thermal-nuclear equipment*** (project duration 2012–2016), project leader Prof. Dr. Habil. E. 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 duration 2012–2016), project leaders – Dr. N. Striūgas, Dr. V. Valinčius.
5. ***Economy and sustainability analysis of energy sector*** (project duration 2012–2016), project leader Prof. Dr. Habil. V. Miškinis.
6. ***Investigation of single-phase and two-phase flow dynamics, heat and mass transfer processes*** (project duration 2012–2016), project leader Dr. R. Poškas.

INTERNATIONAL PROJECTS

In 2012 **27** international programme projects were conducted, out of which **10** projects are of 7th Framework Programme:

1. ***European Fusion Development Agreement*** (EURATOM-LEI association). Lithuanian representative – Prof. Dr. Habil. E. Ušpuras.
2. ***Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology***, SARNET2. Lithuanian representative – Dr. Habil.A. Kaliatka.
3. ***MATerials TEsting and Rules (MATTER)***. Lithuanian representative – Dr. G. Dundulis.
4. ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste, CARBOWASTE***. Lithuanian representative – Prof. Dr. Habil. P. Poškas.
5. ***Fate of Repository Gases, FORGE***. Lithuanian representative – Prof. Dr. Habil. P. Poškas.
6. ***New Member States Linking for an Advanced Cohesion in Euratom Research, NEWLANCER***. Lithuanian representative – Dr. A. Šmaižys.
7. ***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***. Lithuanian representative – Dr. Habil. A. Kaliatka.
8. ***Sustainable network of Independent Technical Expertise for radioactive waste disposal, SITEX***. Lithuanian representative – Dr. A. Narkūnienė.
9. ***Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement Based Environmentally Friendly Sandwich Material for Building Applications, FIBCEM***. Lithuanian representative – Dr. J. Česnienė.
10. ***Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations (DEMI)***. Lithuanian representative – Dr. R. Škėma.

EUROPEAN SCIENTIFIC RESEARCH

In 2004–2012 LEI researchers have successfully implemented the following international programmes projects:

- the 6th Framework Programme – 12;
- the 7th Framework Programme – 15;
- Intelligent Energy Europe – 24;
- International Atomic Energy Agency – 10;
- COST – 11;
- EUREKA – 3;
- Nordic Energy Research Programme – 2;
- Baltic Sea Region Programme 2007–2013 – 3;
- South Baltic Cross-border Cooperation programme 2007–2013 – 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.

1992–2012 80 (out of 92) PhD Candidates completed doctoral studies and 53 defended doctoral theses. In 2012 3 PhD students were admitted to PhD studies, total 23 PhD students were studying.

In 2012 Kaunas University of Technology granted the Doctor of Science degree to the following researchers of the Institute:

– on 15 June Viktorija BOBINAITĖ (Laboratory of Energy Systems Research) for her work ***Wholesale and Retail Electricity Prices' Forecasting Factors, Methods and Model,*** Social Sciences, Economics (04S). Scientific supervisor Dr. Aldona Juozapavičienė (Kaunas University of Technology);

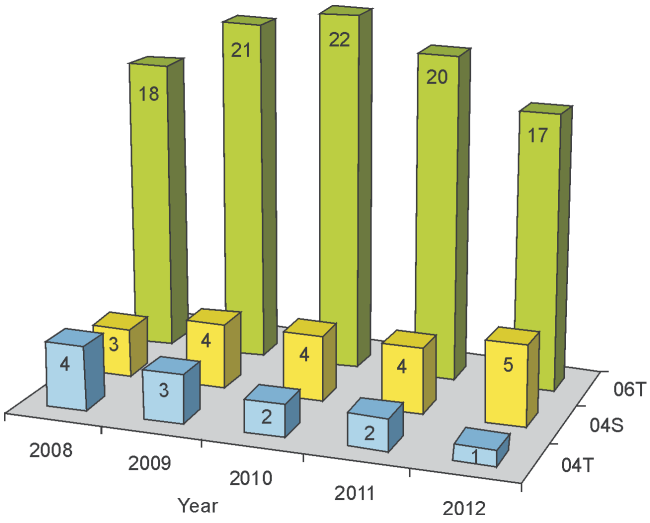
– on 21 November Mindaugas MILIEŠKA (Laboratory of Plasma Technologies) for his work ***The Investigation of Thermohydro-dynamic Processes During Plasma Fibrillation of High-Temperature Melting Ceramic Materials***, Technological Sciences, Energetics and Power Engineering (06T). Scientific supervisor Dr. Vitas Valinčius.

On 20 December Martynas LELIS (Center for Hydrogen Energy Technologies) was granted Doctor of Science degree at Vytautas MagnusUniversitety for his work ***Investigation of substrate surface effects on kinetics of thin Mg-Ni, Mg and Mg-Ti***

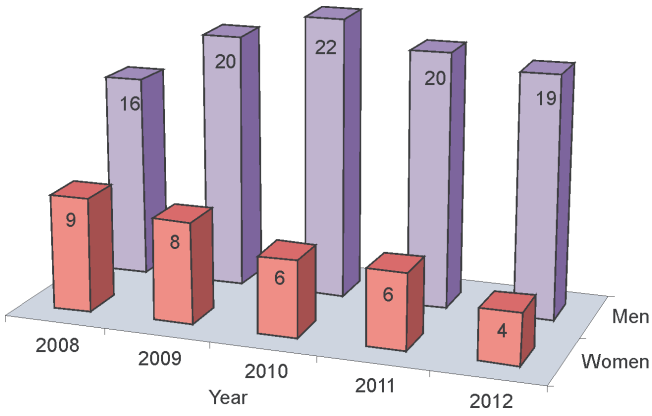
Dr. V. Bobinaitė

Dr. M. Milieška

Dr. M. Lelis



Arrangement of PhD Candidates' according to science directions



Structure of PhD Candidates' number

PhD Candidate Darius Justinavičius is giving a presentation in CYSENI 2012 conference

Deputy Director Dr. Rimantas Levinskas, Dr. Diana Meilutytė-Barauskienė and YSA Chairman Darius Laurinavičius are congratulating the PhD Candidate Linas Martišauskas (on the left), the author of one of the best papers in CYSENI 2012 conference

films hydrogenation, Physical science, Physics (02P). Scientific supervisor Prof. Dr. Habil. Liudvikas Pranevičius.

Admission to doctoral studies takes place at the beginning of July, and in September, if any vacancies remain.

Doctoral studies provide an opportunity of employment, participation in international projects, training courses in foreign science centres and international conferences. Future doctoral students are advised to meet possible supervisors in advance.

More information on doctoral studies in the Institute on **http://www.lei.lt** (in Information: Doctoral Studies).

Contact person:
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Studies Administrator
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E-mail: ***jolanta@mail.lei.lt***

LABORATORY of HEAT-EQUIPMENT RESEARCH AND TESTING

MAIN DIRECTIONS OF SCIENTIFIC RESEARCH OF THE LABORATORY:

- research of liquid and air (gas) flow structure at variable flow regimes and under the effect of flow pulsations and turbulence, caused by hydrodynamic disturbances and changes of velocity distribution and pressure gradients;
- research of accuracy and reliability of means and methods for reproduction and transfer of reference values of liquid and air (gas) flow velocity, volume and flow rate;
- research 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.

MAIN DIRECTIONS OF APPLIED WORK OF THE LABORATORY:

- provision of metrological support to the Lithuanian economy and science sectors in the field of fluid flow measurements and ensuring measurement traceability to National Measuring Institutes in Europe and Lithuanian laboratories based on the authorisation of the Government of the Republic of Lithuania to preserve the basis of standards in the field of these measurements;
- research, testing and conformity assessment of measuring devices of liquid fuel, water, heat and gas, as well as gas appliances and hot water boilers burning gaseous, liquid and solid fuel (including biofuel);
- other services related to the solutions for accurate energy and other resources accounting, supply-consumption disbalance and effective use of resources.

In 2012 basic scientific research and applied activities were continued. Researchers of the Laboratory implemented activities significant for Lithuanian industry, business and science. The Laboratory actively cooperated with Lithuanian contractors, taking into account general trends of scientific research and experimental development in European countries, developed national liquid and gas flow standards as well as measurement services for Lithuanian contractors and expanded scientific research, created experimental basis for perspective biofuel research and its practical application development.

SCIENTIFIC RESEARCH RESULTS AND PERSPECTIVES

Budget works

In 2012 two state subsidy funded scientific research projects were completed:

- In the first project *Research of impact of liquid and gas flow unstationary and their physical properties variation on the measurement of flowing quantity and preparation of practical methods for its estimation* the impact of pulsating flow on the measurement accuracy of tachometric air (gas) and water flowrate and air velocity meters, accuracy dependencies of air velocity values reproduction from flow regime and flow separation shape as well as the influence of liquids and gas viscosity on the measurement accuracy of turbine and positive displacement meters at the change of physical properties, composition, pressure and temperature of flows was investigated in 2012. Coordinating experimental and numerical methods the determined regularities, related with other significant scientific applications, were summarized.

  With this work the scientific research cycle in this direction is completed. The last emphasis should be thesis works by PhD students A. Tonkonogovas and E. Maslauskas.

- In the second project *Research of efficiency and pollution of solid fuel and its mixture application in small and medium capacity heating appliances and its practical application* new perspective scientific research direction related with application expansion of biofuel as significant renewable energy source was initiated. Contemporary equipment bought in accordance with valey SANTAKA program designed for analysis of various types of biofuel caloricity, composition, amount of heavy metals, ash content, composition of volatile materials was applied in the project. Basic factors, influencing the efficiency of combustion of various kinds of biofuel taking into account the construction of combustion chamber, secondary air supply conditions and fuel type and its preparation method, were identified.

Projects

The perspective of biofuel application and its significance is evidenced by the following implemented projects where the laboratory participates independently or in cooperation with other laboratories:

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 technologie***s (BIOKONVERS), the duration 2012–2014, executers – 3 institute laboratories;
- European Social Fund Agency projects: ***Development of innovative thermal decomposition technology and its application for utilization of sewage sullage*** (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 heating appliances*** (AGROBIOATENA), project code No VP1-3.1-ŠMM-10-V-02-011.

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

Long-term programmes 2012–2016

In 2012 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 solved; Investigation of renewable resources usage for efficient energy production and impact to environment, 2 tasks were solved.

DEVELOPMENT OF MEASUREMENT CAPABILITIES OF NATIONAL STANDARDS

New measurement and calibration capabilities of standards

In 2012 the activities were successfully implemented in accordance with agreement with the Ministry of Economy of the Republic of Lithuania (previously in accordance with annual agreements with the State Metrology Service) aiming at efficiently using and developing four national standards. For the first time the capabilities of Lithuania national standards were approved on 11 October 2005 and were announced on International Bureau of

Weights and Measures (BIPM) website. Following further research results of liquid and gas flows measurements, constantly conducted renewal and improvements of technical facility and equipment as well as increasing demands for measurement services in the field of industry, business and science on December 2011 new capabilities for standards were submitted to EURAMET TK greatly approaching the level of European countries national laboratories.

In 2012 these capabilities were estimated by regional international metrological organizations EURAMET, APMP and AFRIMET technical experts and after the laboratory had made certain correction actions, they were approved on 19 December 2012 and announced on BIPM webpage **http://kcdb.bipm.org/KCDB_news.asp?**.

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 2012. The researchers participated in the constitutive meeting of the Cooperation of Notified Bodies for European Measuring Instruments (NoBoMet) in Germany and prepared and submitted information on quality management system functioning indicators EURAMET TK Quality.

International interlaboratory comparisons

In EURAMET and COOMET technical committee meetings the following comparison results were discussed and confirmed in accordance with these projects:

- COOMET No 406/UA/07 (reg. No JCRB-COOMET.M.FF-S2) implemented in 20°C water flow rate limits from 3 m^3/h to 100 m^3/h, with participation of Germany (PTB – leading laboratory), Uzbekistan, Ukrainian, Russian, Belarus, Lithuanian and Slovakian national laboratories.
- COOMET (reg. No JCRB-COOMET. M.FF.S4 B) implemented in 20°C water flow rate limits from 3 m^3/h to 20 m^3/h, with participation of Slovakia (SMU – leading laboratory), Lithuanian, Cuban, Moldovan, Mexico and Ukrainian national laboratories;
- COOMET No 412/UA/07 implemented in air flow rate limits from 4 m^3/h to 160 m^3/h, with participation of Ukraine (Ivano-Frankovskstandartmetrology – leading laboratory), Russia, Slovakia and Lithuania national laboratories.

In all comparisons the deviation of laboratory measurement results from the average value of measurement results of participants is in allowable limits.

On October of 2012 measurements were performed in accordance with project No 1233 in 20°C water flow rate limits from 3 m^3/h to 30 m^3/h. The leading laboratory of the comparisons – Turkish national laboratory TUBITAK UME. Poland (GUM), Italy (INRIM) and Bulgaria (NCM) also participate in the comparison. It was also prepared to implement comparisons in accordance EURAMET project No 1225 in air velocity from 0.05 m/s to 1 m/s limits.

MOST IMPORTANT APPLIED WORKS AND SERVICES

In 2012 the laboratory performed the following large scope applied activities:

- Assessment and validation of the data remote and control systems – 2 new systems, which are developed by several level devices: water and heat meters installed at consumers – the 1st level; intermediary meter data storage units – the 2nd level; signal converters – the 3d level; data storage unit or modem, transmitting data to the central server – the 4th level; central server to collect, process and store data;
- The possibilities of calibration/verification of high flow rate meters of sewage under operation conditions were investigated, methodology was prepared and validated;
- 4 heat meter type examination certificates were issued as well as 281 conformity to type certificates;
- Under the contract with SC *Klaipėdos nafta* a study was prepared, where the most relevant supplier of liquefied natural gas was chosen for designed SkGD terminal;
- Research and testing services of biofuel properties were significantly expanded for Lithuanian contractors;
- 3 m^3 reference volume standard was designed in order to control and calibrate measurement systems of ethyl alcohol produced by JSC *Biofuture*. SC *Astra* manufactured volume standard, which have to be tested and calibrated.
- The laboratory continued activity by providing services to con-

tractors as complementary unit of open access Center for Renewable and Alternative Energy.

The incomes for performed applied activities in 2012 comprised 1.5 million litas.

In 2012 the possibilities of new applied services were validated:

- notified activity for biofuel burning appliances conformity assessments in accordance with Directive 89/106/EC of the European Parliament and of the Council. Information on this is submitted to the European Commission, EU member states and EFTA states which signed EEE agreement;
- notified activity for liquids measurement system conformity assessments in accordance with Directive 2004/22/EC in compliance with module F of the European Parliament and of the Council.
- the laboratory expanded accreditation field for air (gas) flowrate meter calibration from 0.0003 m^3/h; it also has acquired and accredited the test methods of solid biofuel and solid recovered fuel moisture, calorific value, ash-content and main and secondary element composition.

BASIC CHANGES IN SCIENTIFIC FIELD AND EXPERIMENTAL BASIS

In 2012 development of experimental basis, related with basic changes in scientific field was continued. It is planned to initiate scientific research according new topic *Research of gas flow mixing up and its interaction with structurized surfaces aiming at efficiently applying biofuel in heating appliances by least polluting the environment*. In this work the objective is to investigate mixing up of air supplied to combustion zones in small capacity heating appliances aiming to determine optimal conditions, which would ensure efficient combustion of solid fuel, including biofuel, as well as minimum emissions into the environment. Other important task is separation of solid particles and incombustible components from combustion gas and gas derived by gasifying biofuel. There is an objective to expand the application of developed equipment and acquired methods to investigate permeability of various materials and visualize flow structure for dealing with scientific and applied tasks of other fields. In 2012 the experimental equipment of the laboratory was supplemented with new equipment in accordance with the funds of valley SANTAKA: equipment to prepared biofuel samples, ion chromatography system, mobile smoke gas analyser, air moisture analyser, aerodynamic facility to visualize mixture processes in combustion chamber models.

Mobile smoke gas analyser

Ion chromatography system

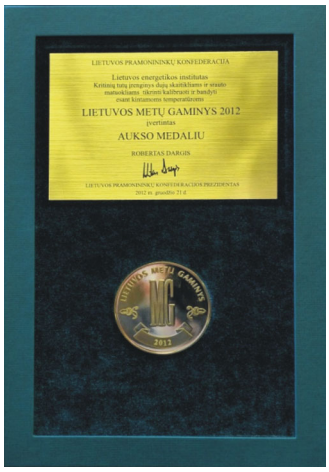
PUBLICATION OF SCIENTIFIC RESULTS AND OTHER ACTIVITIES

3 papers were presented in international conferences, 3 articles were published, one submitted to ISI journal.

ACKNOWLEDGMENT OF LABORATORY ACTIVITIES

In 2012 the results of the Laboratory activities received a lot of honourable evaluations:

- in accordance with contract No. 106596/12-1270.11.11 with SC



Lietuvos dujos the equipment of critical nozzles was updated, it was installed in Kaunas laboratory of SC *Lietuvos dujos* Central calibration and testing laboratory, awarded the golden medal *The Lithuanian product of the year 2012*. Main executers of this work senior research associate Dr. J. Tonkonogij, research associate Dr. A. Stankevicius and junior research associate PhD student A. Tonkonogovas;

- by the presidium of the Lithuanian Confederation of Industrialists research associate Dr. G. Zygmantas was nominated the Knight of Profession for professionalism in investigating flow measurements and providing applied services for Lithuania industry and business sector;
- senior research associate Dr. Habil. A. Pedišius by Lithuanian Engineering Industry Association LINPRA was awarded the Sign of Honour for personal accomplishments and input in developing Lithuanian engineering industry and strengthening its international competitiveness.

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LABORATORY of COMBUSTION PROCESSES

THE MAIN AREAS OF ACTIVITIES OF THE LABORATORY:

- combustion processes efficiency improvement;
- research on gasification of renewable fuel
- mitigation of atmosphere pollution;
- development and improvement of burners and fuel atomizers;
- research of thermal destruction and gasification of solid organic waste;
- numerical simulation of granular matter and multiparticle systems;
- environmental impact assessment.

Research of combustion process is focused on fuel-saving, mitigation of environmental air pollution and thermal abatement of hazardous waste.

RESEARCH SCOPE AND OBJECTIVES

The Laboratory activities deal with the problems of combustion process efficiency improvement, development of burners for liquid and gaseous fuel, waste thermal utilisation technologies, gasification and pyrolysis, renewable energy sources, hydrogen energy, fuel synthesis and economy programmes, mitigation of environmental pollution. In the last five years research activities were mainly focused on gasification technologies. Experience in waste gasification research gives an idea that that such technology is rather perspective and is applicable for synthesis of higher calorific value products. From this perspective, further research is being continued on developement and optimization of pyrolysis and gasification processes for steam conversion of biofuel and high-calorific waste applications at different temperatures. Recently a great deal of attention has been paid to waste utilization, RES technologies, hydrogen energy, fuel synthesis and economy programs, environmental pollution reduction tasks.

In 2012 experiments of biofuel and high-calorific organic material combustion and gasification were performed at the laboratory as well as development of models and numerical simulation in the following fields:

1. research on catalytic thermal decomposition of tars;
2. residual carbon gasification efficiency improvement by CO_2;
3. NO_x reduction for natural gas combustion by flue gas recirculation;
4. segregation of localized particle groups in granular media.

These activities has one common pattern – fuel gasification process. Without deep knowledge of the gasification process, safe, environmentally friendly and efficient waste utilization by means of combustion is not possible. The laboratory activities may be divided into two groups – utilization of solid and gaseous fuels by combustion or thermal decomposition.

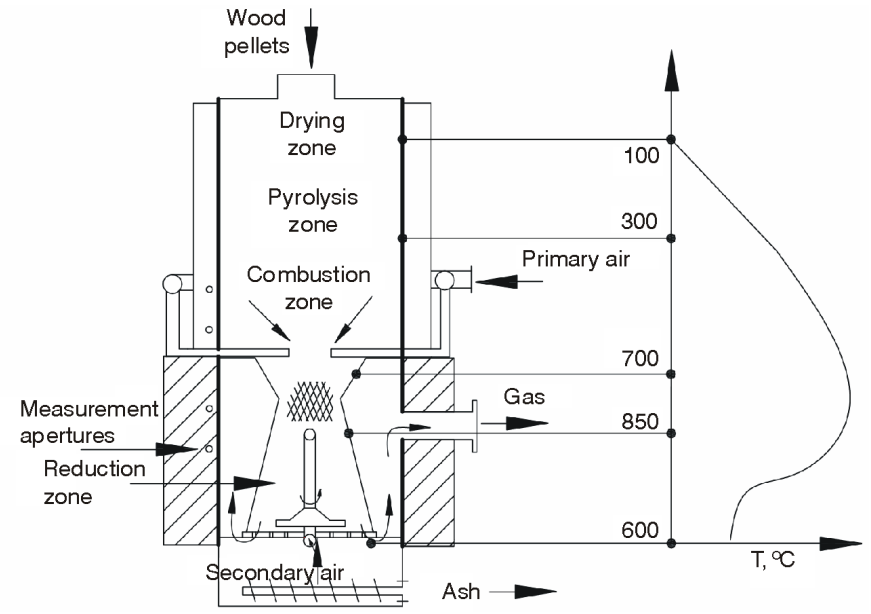
CATALYTIC TAR DECOMPOSITION RESEARCH

Gasification and formation of tars are concurrent processes. Contemporary gasification systems are comprised of gasifiers, cleaning systems and energy conversion facilities. Such systems due to operational costs are attractive and efficient

for large capacity facilities. In small countries, such as Lithuania, smaller capacity gasifiers could be applied more widely, for example, poultries, greenhouses, etc; with low demand of electric and heat energy. However, this requires huge investments and complex process control. This is not profitable for big industry. One of the cheapest and more efficient means is the use of carbon catalyst, residual carbon from gasification process or carbon derived from organic material pyrolysis process. Basic factors influencing the tar destruction process is temperature, time and decomposition atmosphere. Tars may be decomposed on catalyst surface down to CO and H_2, by so called dry reforming method. Additional oxidizer is required to achieve faster conversion rates of tar compounds during gasification. Further, tar decomposition using activated carbon residue from pyrolysis of used tires as a catalyst and influence of CO_2 as oxidizer for tar destruction was investigated. The hydrocarbon reforming efficiency, was compared to other processes: thermal destruction, steam reforming and partial oxidation. Carbon catalyst was prepared by activating residual carbon from used tires gasification. The surface area determination of non-activated, activated and used catalyst was performed using Quantachrome Autosorb iQ instrument. Research of catalytic tar removal was performed in experimental facility: biomass pyrolysis reactor, catalyst constant layer reactor and tar condensers. Stock wood pellets 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 samples were identified using *Agilent 7890A* gas chromatograph with *Agilent 5975C* mass spectrometer and NIST mass spectral database software. During investigations 18 tar compounds were analysed qualitatively. The concentration of tar compound was determined using *Varian GC-3800* gas chromatograph with a flame ionization detector. The analysis of gaseous compounds was performed using *Agilent 7890A* gas chromatograph with two channel thermal conductivity detectors. It was determined that CO_2 conversion into CO is most intensive at 900°C. At this temperature CO_2 concentration decreases from 21 to 10.8%. After introduction of extra amount of carbon dioxide, tar concentration in syngas increases. CO gas output increases in gaseous products, however, C_nH_m-H_2O and C-H_2O reactions are diminished. After performing research of catalyst efficiency from time perspective, catalyst volume reduction was determined, due to which free gas leakage occurs and volume velocity in catalyst layer increases. With increase of volumetric velocity, conversion efficiency of tars and CO_2 decreases.

INTENSIFICATION OF CARBON RESIDUAL GASIFICATION

One of the cheapest and environmentally non-hazardous raw fuel materials is wood. 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. Calorific value of syngas from wood gasification experiments is about 6 MJ/m^3 and it may replace natural gas as a fuel for small industrial furnaces. However, in order to promote application of such reactors, complete conversion of gasification material into gas should be achieved. Wood contains ~80% of volatile materials, the remaining part consists of carbon and moisture. In wood gasification reactor, after evaporation of volatiles ~10% of carbon remains from the initial raw material amount. In further process the carbon decomposes, due to this reason gas penetration through layer is more complicated. Under such condition reactor operation becomes unstable. In order to reduce hydraulic resistance of the layer, grate rotation rate is increased and more carbon is removed. However, such non-decomposed carbon removal is not efficient. In order to chieve more efficient gasification of biofuel it is necessary to reduce amount of residual carbon by intensifying thermal decomposition process. The carbon layer is required for gaseous tar hydrocarbons decomposition down to lighter gas. Higher tempera-



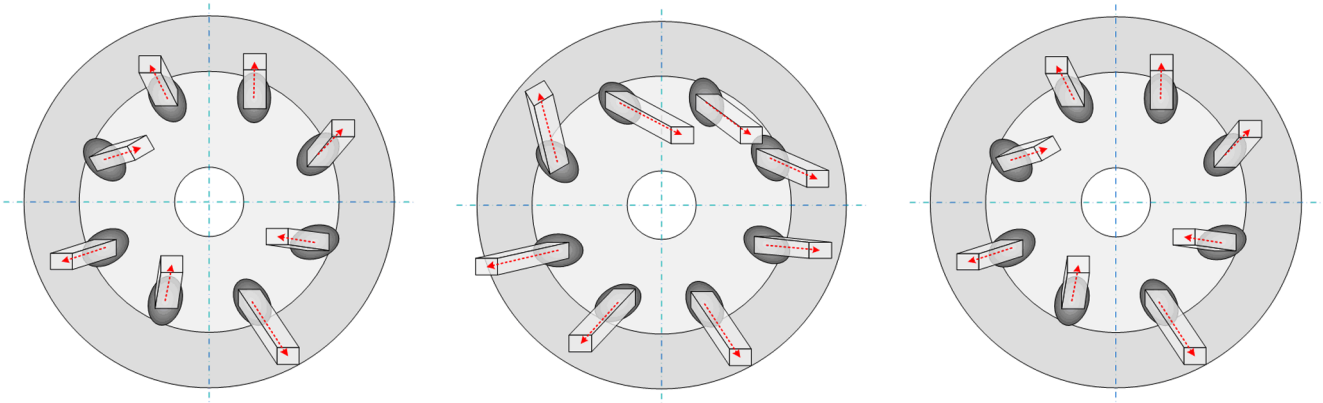
Laboratory scale downdraft biomass gasification reactor schematics

ture and reaction time is required in order to decompose the residual carbon. Carbon decomposition is possible using three oxidizers, namely, oxygen, water and CO_2. CO_2 concentration in producer gas is approximately 10%, and according to Boudouard reaction, CO gas is produced when reacting with carbon, which increase caloric value of the producer gas. Research objective was to determine optimal temperature of carbon reside decomposition. Optimal temperature for CO generation in time scale was determined experimentally using thermal analysis instrument (thermogravimeter) *NETZSCH TG STA 449 F3* . By carbon concentration change in time the constants of reaction velocities were calculated. During experiments 0.2–0.3 mm fraction wood pyrolysis carbon was used. The sample mass was within 10–12 mg. Al_2O_3 crucibles were used. Primary carbon gasification experiments were performed in CO_2/N_2 (3:1) atmosphere at different temperatures. Influence of CO_2 concentration and temperature on Boudouard reaction rate was determined. It was found that at 1100°C and gas flow ratio CO_2:N_2 60:20 ml/min carbon is gasification to CO takes 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 extends up to 32 min. Reaction velocity constants of wood carbon gasification with carbon dioxide were determined. Depending on CO_2 gas concentration and temperature, reaction rate constants changes respectively: decreases with the decrease of temperature and partial CO_2 pressure in gas mixture.

NOx REDUCTION BY FLUE GAS RECIRCULATION IN NATURAL GAS COMBUSTION

Directive 2010/75/EU on industrial emissions (*Integrated pollution prevention and control*) foresees even strict regulations for pollution prevention and control, which will come into force on 1st of January 2016. For natural gas combustion NOx emission limit value will decrease vy the factor of 3.5 (from 350 to 100 mg/nm^3), while for heavy fuel oil combustion – by factor of 2.7 (from 400 to 150 mg/nm^3); for (SO_2) the restrictions will by factor of 8.5 (from 1700 to 200 mg/nm^3), and particular matter concentration in flue gases should be reduced by 2.5 (from 50 to 20 mg/nm^3). This is a complex task for existing combustion facilities. The options are either installation of new low NOx burners or implementation of secondary NOx reduction measures. In order to reduce NOx concentration in flue gases it is necessary to avoid high temperatures of flame (1500–1600°C) in combustion zones. Currently combustion process improvement is achieved by new generation burners with a specific peripheral air function and tertiary air introduction over flame. One of the techniques used is flue gas recirculation. Recirculation does not have the major impact on combustion process, however, using it, it is possible to reduce the concentration of NOx in exhaust gas by 20–25%. More radical improvements are required for more drastical reduction of NOx and fulfillment of the required 100 mg/nm^3. Though some reliable catalytic and non-catalytic NOx amount reduction measures were developed a few decades ago, however they are still implemented in industry due to high investment cost and complex process management.

Another new method of NOx formation reduction during combustion process is an additional fuel supply to the flame zone of most highest temperature. Three NOx reduction measures are used in the laboratory research: flue gas recirculation, local additional fuel supply to the bottom burner and additional air staging to the top burner. Using burners developed in our laboratory it was easily achieved 200 mg/nm^3 of NO_x. However, in the future NOx concentration should be reduced to 100 mg/nm^3, and laboratory research focused on improving burning process in district heating and industrial boilers. The



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

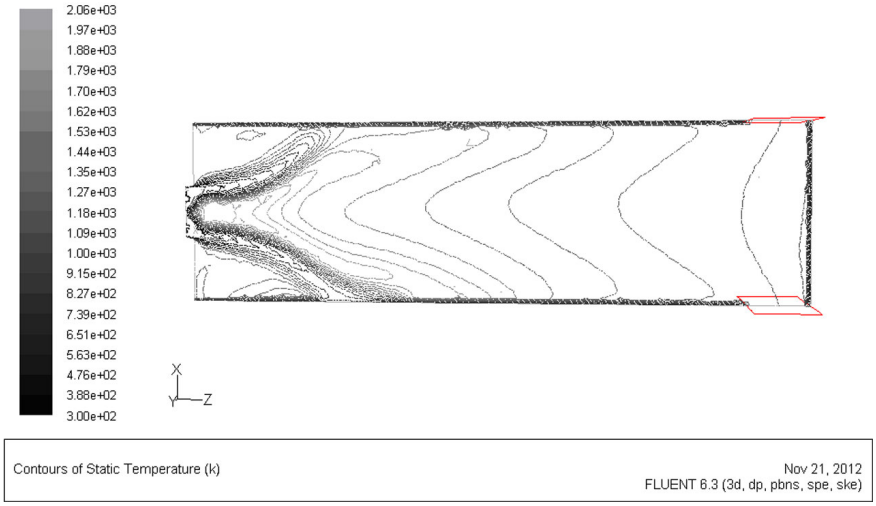
Gas stream arrangement with 3 burners in combustion chamber of KVGM-100 boiler

Flue gas recirculation channels for NOx reduction

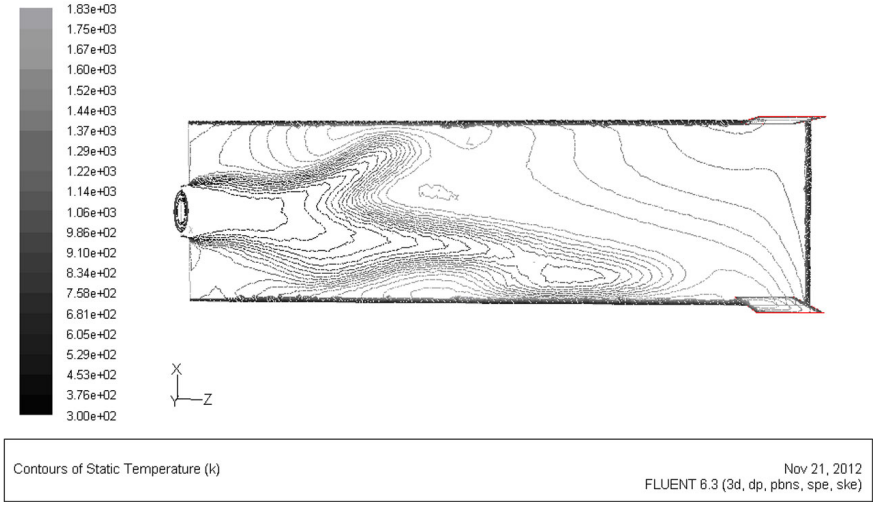
experiments were initiated with rectangular oblong furnace boiler with capacity of 50 – 70 MW. Experiments were conducted with specifically designed burners D30 for water heating boiler KVGM 100. It was determined that the combution chamber of the boiler is particularly acceptable for gas combustion. Burners were designed for water heating boiler KVGM-100. These burners have two basic features: central and peripheral air flow separation and natural gas distributed supply system by 8 atomizers around central air with 7 holes in each atomizer. The construction enabled rotation of each atomizer individually to obtain best combustion process with least air excess ratio and minimum emissions. The construction of the D30 burners perfectly corresponds to the geometry of the furnace, i.e. flame torch did not scorch the end shield, the flame followed the chamber geometry and burnout time was sufficient, the concentration of CO and NOx in flue gas was minimal. In comparison to burners at other boilers, NOx emission was a quarter less.

New experiments regarding NOx reduction were conducted at one of the biggest Lithuanian energy producers JSC *Vilniaus energija, which* operates the above mentioned water heating boiler KVGM-100 with D-30 burners. Since NOx concentration in this boiler did not exceed 150 mg/nm^3, after additional measures by introducing flue gas recirculation into combustion air it will be possible to achieve the requirements of the new EU directive. Positive results of additional experiments would allow the company to avoid extra investments for NOx reduction by carbamide.

Burning process in the furnace is simulated using Fluent CFD software at the Laboratory of Combustion Processes with the objective to estimate possible NOx reduction effect by flue gas recirculation method. Comparing these results with the ones presented in literature, as well as with the



Furnace temperature profile with 2% CO_2 within combustion air supplied by the burner. Maximum temperature 1700 °C

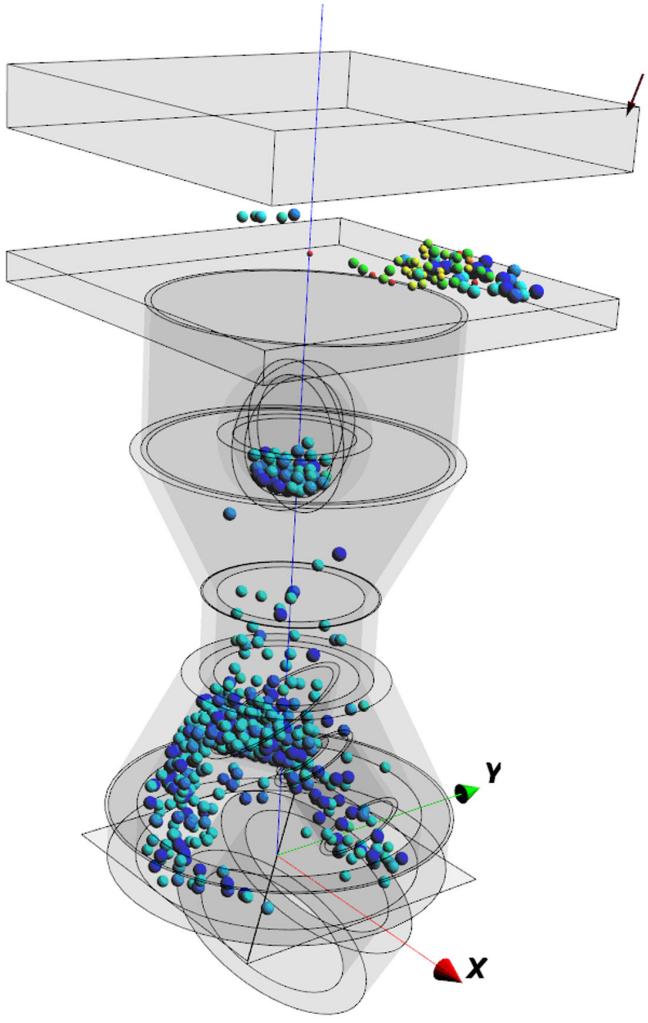


Temperature arrangement in furnace when there is 16% CO_2 and maximum temperature is equal to 1500 °C and it is spread in furnace area

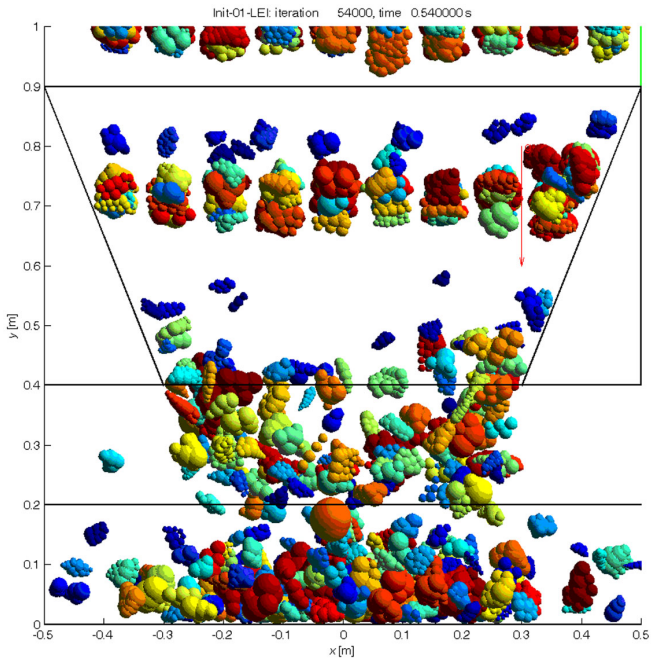
ones obtained at SC *Lietuvos elektrinė* experimentally, it was determined that NOx concentration in case of natural gas combustion may be reduced approximately by 30% . It should be highlighted that recirculation flue gas should be supplied evenly along the channel crossection into air flow and then mixed even before entering burners. During experiments flue gas was blown before air blowing fans. Flue gas was mixed with air in the fans and supplied to burners. The first measures revealed better results than expected. It was determined that at 75% and 95% boiler load and using D-30 burners, JSC *Vilniaus energija* will be able to fulfill the European Parliament Directive (24 of November 2016). Thus the obtained results suggests it is economically beneficial to redesign all available KVGM-100 power plant boilers for low NOx emissions.

IMPROVEMENT OF NUMERICAL MODEL OF PARTICLE DYNAMICS BY INCORPORATING MORE COMPLEX BOUNDARY GEOMETRIES AND MORE DIVERSE PARTICLE SHAPES

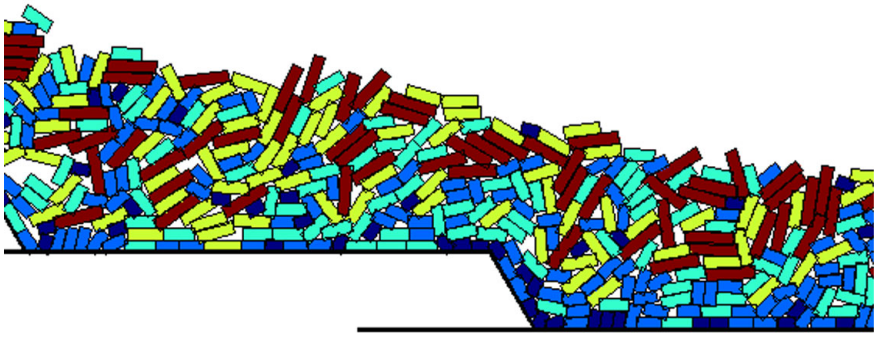
Numerical simulations of granular matter and multiparticle systems based on Discrete Element Method (DEM) usually assume spherical particles, because the mutual interaction forces are most easily calculated in this case. However, round particles are not always suitable. In many cases, particle shapes of granular matter can be approximated by ellipses or superquadrics, but even these shapes are not always adequate for numerical simulation of granular biofuels, moreover, the computational expenses are higher than in case of round particles. Other analytical shapes, such as cylinders, can be used, however, the numerical expenses increase noticeably. Currently, a method is widely used where various shapes of particles are modelled as assemblies of multiple spherical particles – the so-called multisphere approximation. This method is based on substitution of any shape of particles with sets of rigidly connected spheres in such a way that the resulting enclosing surface is close to the real surface of the particles being simulated with the desired accuracy. The mutual interactions of particles are modelled as interactions between the constituent spheres. This method is not very complicated, because the interaction forces between the actual particles are calculated analogously to the case of spherical particles. In reality, every particle is composed of spherical atoms, therefore, the smaller are the con-



Example of numerical simulation of round particles movement inside different shaped walls



Numerical simulation of crushed stone particles with multi-spherical approach of real particles



Simulation of cylindrical shaped straw particles on the moving grate by multi-spherical method, displayed as enclosing surfaces

stituent spheres, the more precisely their enclosing surface will correspond to the particle being modelled. However, the larger is the number of constituent spheres, the higher are computational costs, because the interactions between a larger number of spheres must be computed. In contrast to two particles of elliptical analytic shapes that can interact at a single point, the ellipses approximated by spheres can interact at multiple points. The multisphere method was applied in out application bed_motion and successfully utilized in various problems. For better visual representation, the particle shapes can be represented as enclosing surfaces. For this purpose, a method was developed for enclosing 2D and 3D multisphere shapes. Until now, our program bed_motion could use only rectangular flat walls, therefore, the range of solvable tasks was rather limited. The models of bounding walls were extended to include triangulated surfaces enabling to model walls of any shapes. However, in some cases, the number of triangles might be very large and this would extend the simulation time considerably. Therefore, the models of analytical shapes of cylinders (both finite and infinite), circles, hollow spheres and cones were created.

IDENTIFICATION OF LOCALIZED GROUPS OF PARTICLES IN GRANULAR MATTER

The most precise results of simulations of solid fuel combustion and other processes in granular media are obtained by using the discrete element (discrete particle) models (DEM/DPM). These models are based on tracking the motion of each constituent particle, its interactions with other particles and other structural elements of the system, as well as processes inside the particle. Simulations of this type yield the parameters of every individual particle; the set of such parameters can be perceived as a „microstate" of a multiparticle system. In practice, the generalized parameters of the system are more important than the parameters of individual particles, e.g., distribution of temperature of concentrations of certain chemical species in a packed bed (the „macrostate"). One of such examples important for analyzing the solid fuel combustion is emergence of hot and cold zones in the packed bed. Besides, these generalized parameters are more easily determined experimentally than the parameters of individual particles. Therefore, in order to better compare the simulation and experimental results and to identify the patterns in multiparticle systems, a method is needed that would enable to examine the emergence of larger-scale structures in systems of these types, provided the parameters of individual particles are known from DEM/DPM simulations. In order to develop the methods to identify particle groups sharing the same characteristics, some of the previously published algorithms for identifying groups of graph vertices ("community detection") were analyzed. Community detection is a common problem encountered in many areas, currently attracting a great deal of effort in statistical mechanics. The „macroscopic" parameters of the system are essentially determined by interactions between the constituent particles. These interactions are represented as a graph where the vertices correspond to the respective particles, and the interactions and relations between particles are represented as the edges connecting the appropriate vertices. The edge weights are proportional to intensities of interactions or relations between the particles. As a sample application of this approach, identification of hot and cold areas in a packed bed of particles on a moving grate was considered. In this case, the parameter under consideration is the particle temperature, but the described method is readily applicable also in cases when the particle groups should be identified based on other parameters, e.g., moisture content (identifying more or less dried out zones), concentrations of certain chemical species, etc. In the presented case of particle temperature classification, a „particle group" is perceived as a localized group of particles where the temperatures among the particles belonging to the group differ less than that among the particles outside this group. The considered problem is to group the particles in such a way that the particles that are in a mechanical contact and have similar temperatures end up in the same group. Since the temperature similarity graph is constructed in such a way that the contacting particles having similar temperatures are connected by edges of larger weights, the vertices of the representative graph are connected by edges of larger weight. In this way, the problem of particle grouping by their temperatures (and, consequently, identification of the localized temperature zones) becomes equivalent to identification of communities of graph vertices for which the known community detection algorithms

can be applied. For this purpose, the *igraph* software library was used. Also, two different algorithms were tested, unrelated to graph community detection, but specifically constructed for identification of localized particle groups:

1) particle classification into temperature ranges,
2) merging by particle parameter similarity.

Although the groups identified by different algorithms differ noticeably, statistical patterns can be noticed by analyzing ensembles of different particle configurations (and their representative graphs). Other two mentioned algorithms – classification by parameter ranges and merging by parameter similarity – can provide "better" partitions, i.e., those containing larger and more homogeneous groups, however, they contain adjustment parameters that must be selected appropriately. On the other hand, the results obtained by using algorithms specifically developed for identification of particle groups can be used as a template for comparison of the results provided by the "standard"community detection algorithms.

During 2012, the staff of the Laboratory published 1 chapter of a monography, 7 articles, of which 6 articles in journals from the ISI list, 1 article in a journal referenced in international databases of scientific information, 2 articles in other periodicals, and made 3 contributions in international conferences.

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LABORATORY of MATERIALS RESEARCH AND TESTING

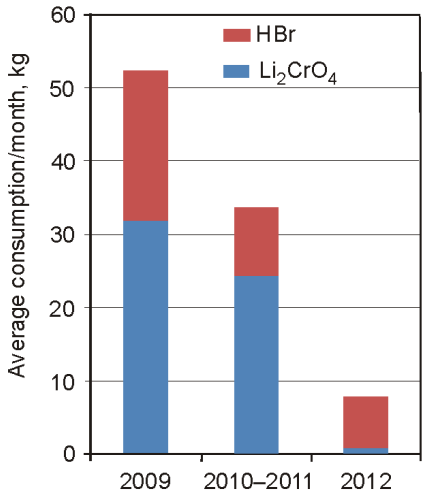
MAIN RESEARCH AREAS OF THE LABORATORY:

- 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 were studied. Experimental and numerical methods are used to predict operational reliability taking into account material ageing processes and other operational factors. The implementation of this work is focussed on the investigation of the fundamental physical and chemical phenomena affecting structure and properties of metals. 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 and nuclear waste and spent nuclear fuel management and radiation impact analysis* (Task 5).

Under the agreement with JSC *GEOTERMA* on ***Research of Processes that Influence Absorption Heat Pump Operation: Increase of Operational Reliability and Efficiency*** the work, initiated in 2010, was continued. The main tasks of the project are to analyse and identify the factors which influence corrosion process and material costs in the geothermal power plant; to give recommendations for the minimisation of corrosion process and material consumption costs as well for ensuring of stable parameters of lithium-



Variation of consumption of the materials used for supplement in JSC ***Geoterma*** *absorption heat pump*

bromide solution used in absorption heat pumps (AHP). The work includes the analysis of AHP monitoring data, control and maintaining of LiBr solution parameters.

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. An alternative and more efficient correction method for retaining alkalinity and chromate concentration was proposed.

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

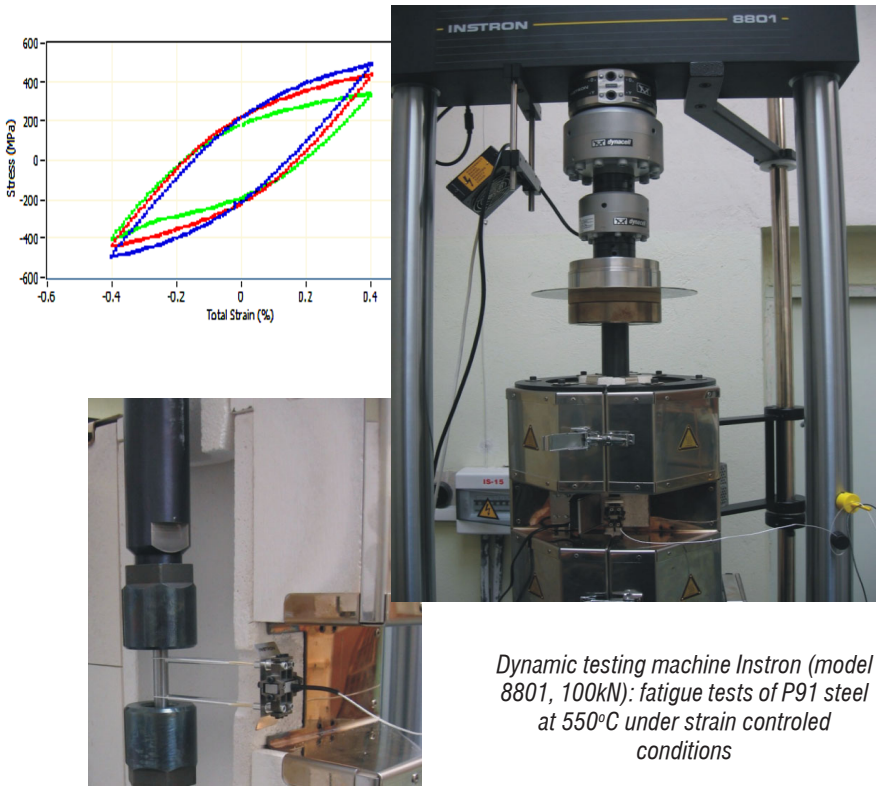
IAEA International Atomic Energy Agency

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.

SEVENTH FRAMEWORK PROGRAMME

Contract Number: FP7-211333

Achievements of the project ***MATTER (MATerials TEsting and Rules).*** On 13 December 2010 a new European Union 7th Framework Programme project *MATTER* was signed and its implementation was initiated on 1 January 2011. Joint team including researchers from Laboratory of Nuclear Installation Safety takes part in the project. 15 work packages were established according to the project tasks, and the Laboratories participate in two working groups: *Manufacturing and welding* and *Testing activities in support of design*. In the scope of the project, a new research on materials behaviour in the operational conditions of IV generation reactors was initiated. It is aimed at the determination of the highest reliability criteria of application of new materials taking into consideration material ageing mechanisms. One of the main objectives of this experimental research is to identify the allowable fatigue resistance limits and coefficient values of steel welds in nuclear components, operating under high temperature and manufactured by applying 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



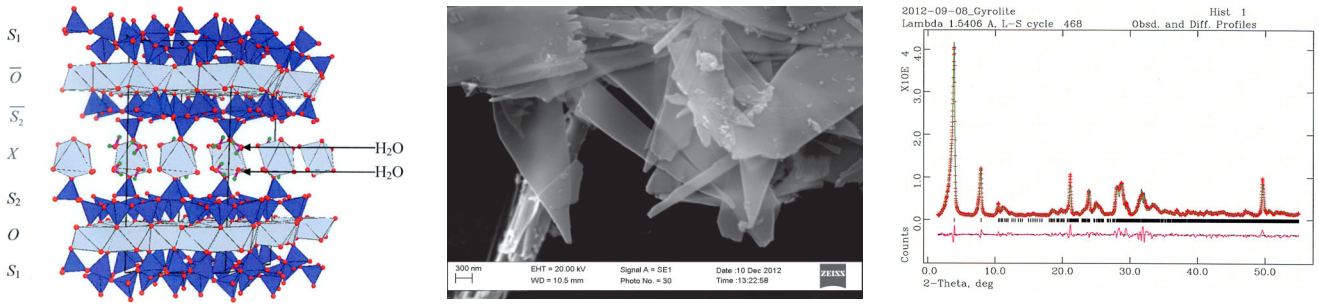
Dynamic testing machine Instron (model 8801, 100kN): fatigue tests of P91 steel at 550°C under strain controled conditions

creep and fatigue behaviour where obtained which are relevant for predicting the lifetime of welds in the reactor components and assessing the suitability of welding technologies in continuation of further research on the welding materials and assessment of influence of operational factors on the welded components in the nuclear industry.

DEVELOPMENT AND RESEARCH OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES

A state subsidy-funded scientific research ***Impact of modifying additives and nano-fillers on structure and properties of constructional composite materials*** was continued in 2012. 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. In the first stage of project implementation, the parameters of pure gyrolite and sodium substituted gyrolite crystal lattices, exact atomic positions and the fractional occupancy of their atomic sites were determined by applying Rietveld crystal structure refinement method. X-ray diffraction analysis, Rietveld structure refinement and crystal structure modelling methods were combined to prepare a methodology for the determination of the exact atomic positions and the amount of inserted Na^+ ions in the crystal lattice of low crystallographic symmetry minerals – synthetic gyrolite and sodium substituted gyrolite. Applying X-ray diffraction, simultaneous thermal analysis, Fourier transform infrared spectroscopy and scanning electron microscopy research methods methodology of silicates modification was prepared and specified.

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



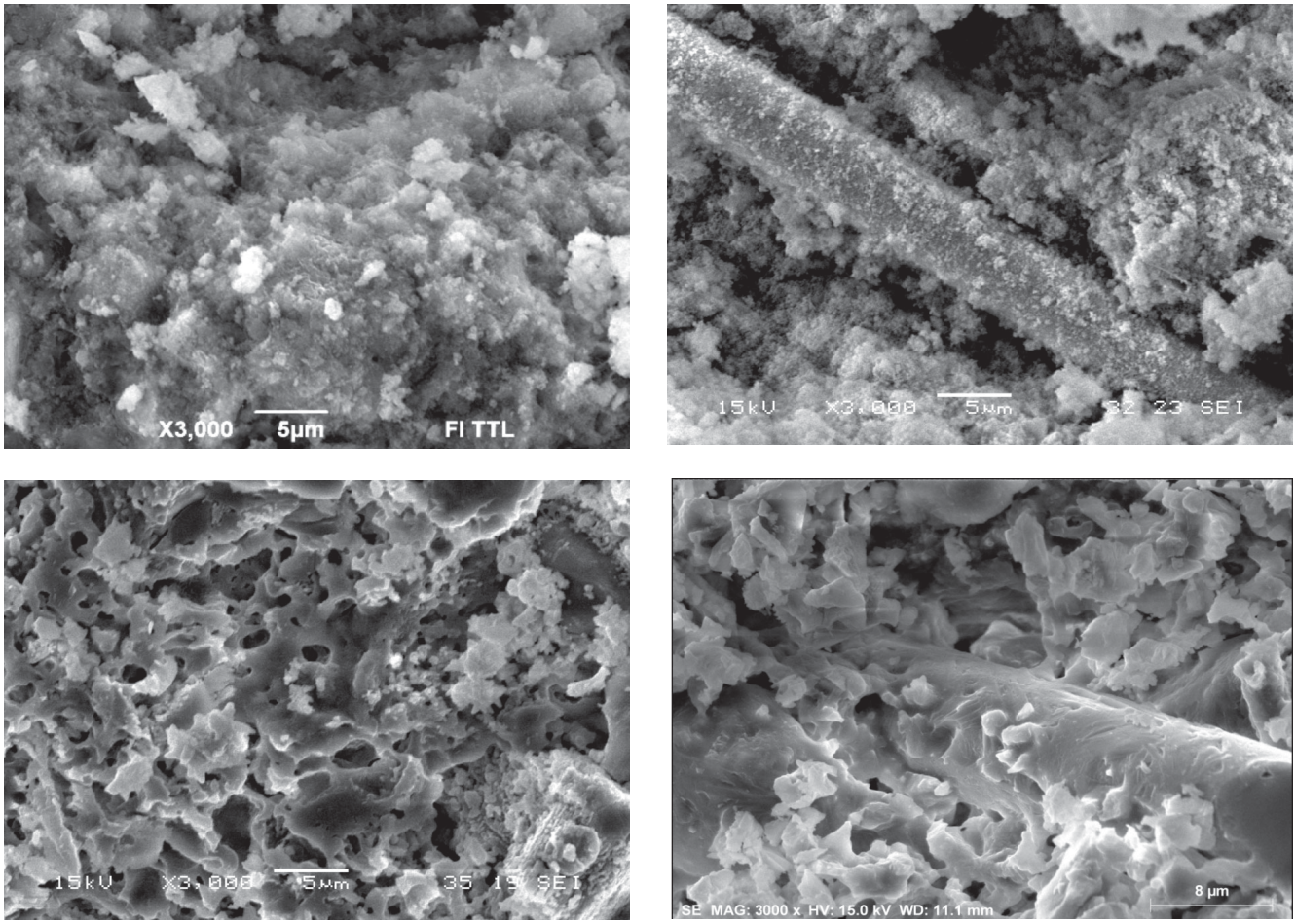
Scheme of synthetic gyrolite crystalline structure, image of scanning electron microscopy and specification of the structure by ***Rietveld*** *refinement method*

In order to prolong the lifetime of the composites, several modifying additives were selected, namely silicon dioxide micro-dust, microfiber and layered silicate, each of which has a specific function, i.e. to prevent the formation of macrocracks in the material, to increase material volume or reduce the content of the binder. Whereas the material is to be used under high temperature, the impact of temperature on the physical-mechanical properties of the modified adhesive was evaluated experimentally. Furthermore, X-ray diffraction analysis was carried out, microstructural changes of the binder were investigated according to the selected modifying additive, and the optimal amount of additives in the material was determined.

SEVENTH FRAMEWORK PROGRAMME

Contract Number: FP7-211333

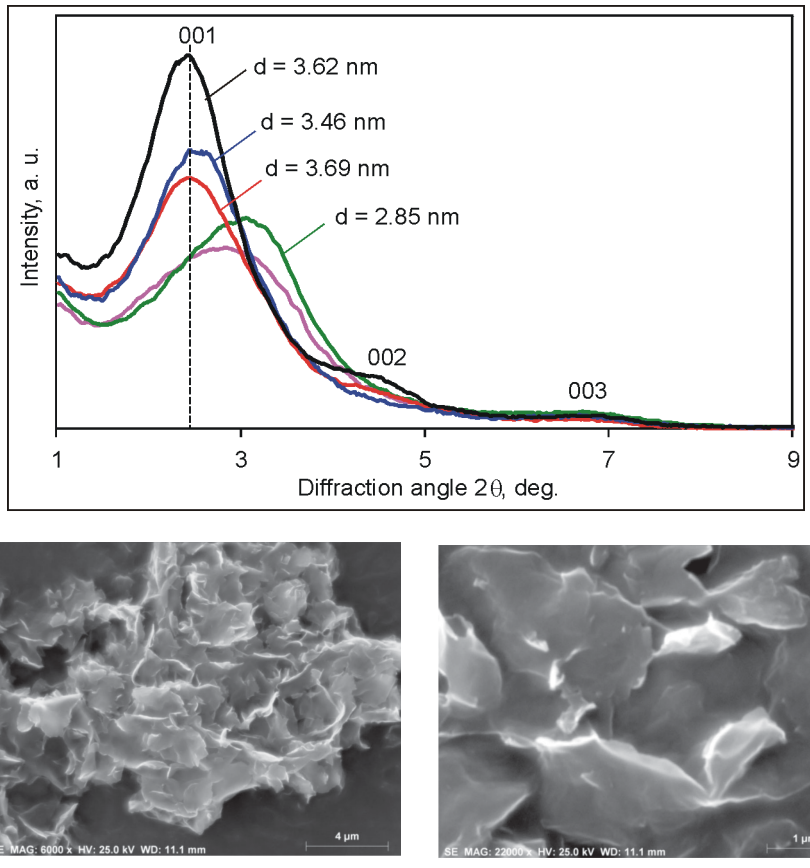
European Union 7th Framework Programme project ***Nanotechnology Enhanced Extruded Fibre Reinforced Foam Cement Based Environmentally Friendly Sandwich Material for Building Applications*** **(FIBCEM).** The three-year FIBCEM project was initiated in December 2011 with participation of 10 partners from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



Images of microstructures of non-modified composite (on the left) and the composite modified with micro-fiber (3%) and SiO_2 microdust (5%) after heating treatment at 100°C (on the top) and at 1000°C (on the bottom)

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

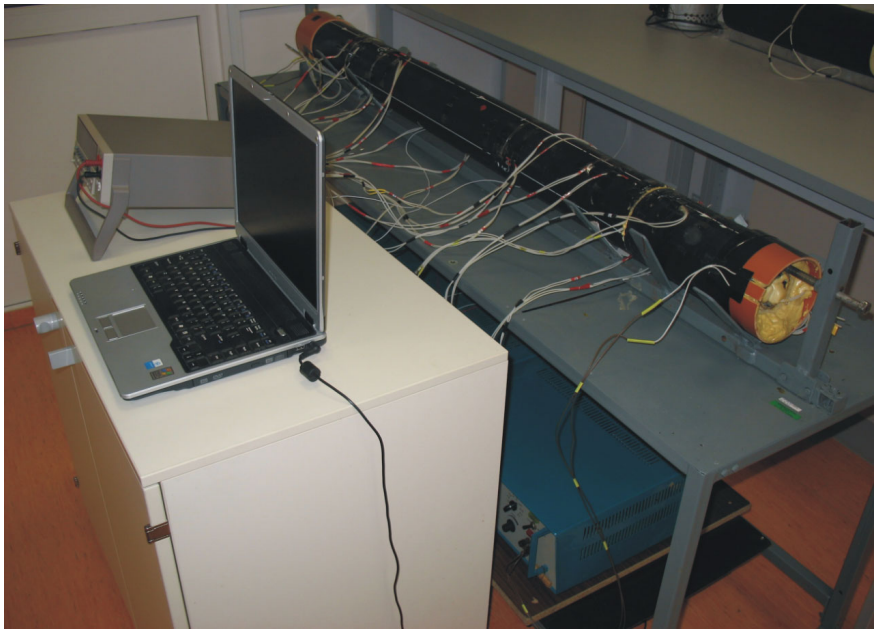
In 2012 researchers of the Laboratory participated in four technical WP4 meetings – Beroun, Czech Republic (Cembrit); Livorno, Italy (Laviosa Chimica Mineraria), London, UK (Brunel University); Copenhagen – Lingby, Denmark (Technical University of Denmark). Nano-bentonite modification method was prepared in cooperation with the project partner Laviosa Chimica Mineraria (Italy).



XRD curves of modified bentonite and SEM images

MATERIALS TESTING, QUALITY ASSESSMENT AND ANALYSIS

Researchers of the Laboratory provide accredited services; perform material testing and assessment of their quality in accordance with the LST EN ISO/IEC 17025 standard. As a result of successful collaboration with commercial enterprises, the Laboratory carries out research and gives advises on guarantee for quality of products. After acquiring the methodology thermal conductivity identification for pipes set by the guarded end method in accordance with the LST EN 253 and LST EN ISO 8497 standards, the accreditation field of the laboratory was expanded.



Identification of pipe set thermal conductivity by protective end method

The achievements of Laboratory in 2012 are as following:

5 scientific articles: 4 of them in the publications on the ISI list and 1 in reviewed conference materials were published. The researchers also participated and presented papers in 4 national and 1 international conferences.

Dr. Albertas GRYBĖNAS
Head of the Laboratory of Materials Research and Testing
Tel.: +370 37 401 908
*E-mail: **grybenas@mail.lei.lt***

LIETUVOS NACIONALINIS AKREDITACIJOS BIURAS

Nacionalinis akreditacijos biuras yra Europos akreditacijos organizacijos (EA) Daugiašalių pripažinimo susitarimų ir gerosios laboratorijų praktikos kalibravimo ir bandymų laboratorijų, darbuotojų, įvertinio ir vadybos sistemų sertifikavimo bei kontrolės įstaigų, srityse

AKREDITAVIMO PAŽYMĖJIMAS

Nr. **LA.01.006** Galioja iki 2015-09-21

Nacionalinis akreditacijos biuras liudija, kad

Lietuvos energetikos instituto
Medžiagų tyrimų ir bandymų laboratorija
Breslaujos g. 3, LT-44403 Kaunas

atitinka LST EN ISO/IEC 17025:2005

reikalavimus ir akredituota atlikti:

statybinių skiedinių, plytelių klijų, glaistų, plastikinių vamzdžių, izoliuotų vamzdžių ir ugniai atsparių gaminių bandymus

Akreditavimo sritis pateikta pažymėjimo priede

Pirmasis akreditavimo pažymėjimas išduotas 1996-12-17

Direktorė Irena Mikelionienė

2010-09-21, Vilnius

Laboratory is accredited to carry out tests of:

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

LABORATORY of PLASMA PROCESSING

MAIN RESEARCH AREAS OF THE LABORATORY:

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

Researchers of Laboratory of Plasma Processing have over 40 years 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, Laboratory of Plasma Processing is carrying out the following researches:

DEVELOPMENT OF PLASMA SOURCES AND RESEARCH OF PLASMA JET

Laboratory of Plasma Processing develops novel plasma generators up to 200 kW of capacity and improves the construction of 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.

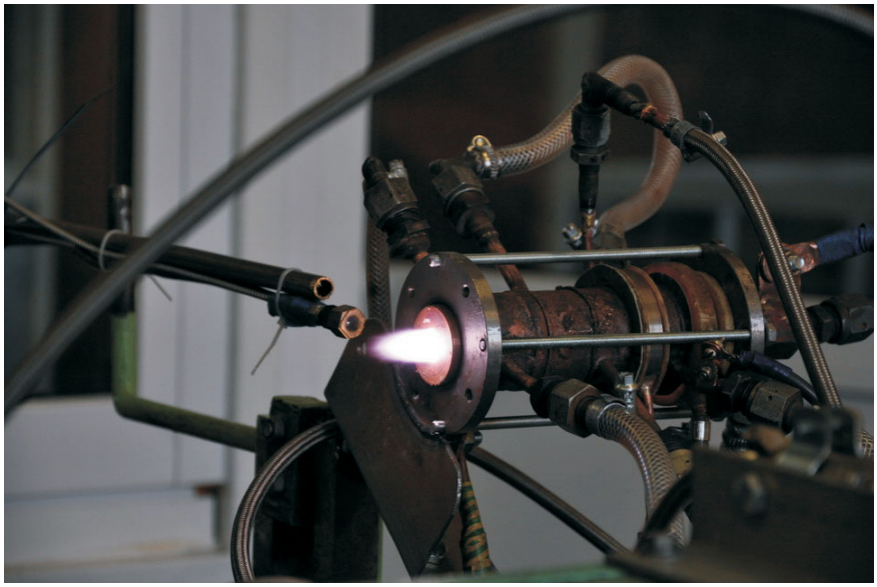
Laboratory continues carrying out the investigations of heat transfer in plasmatron reactive arc zone, electric arc strength

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.

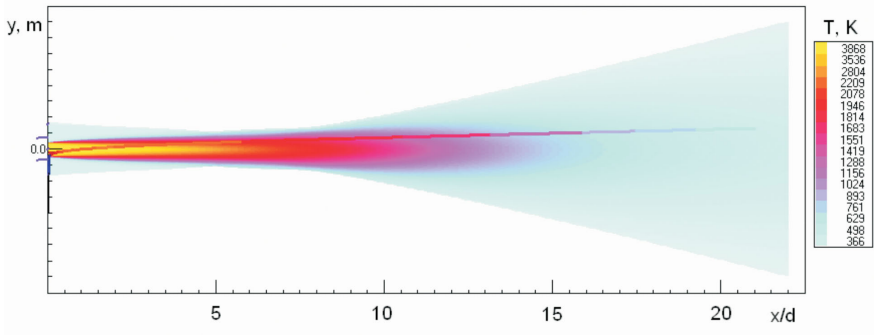
DIAGNOSTICS OF PLASMA AND HIGH-TEMPERATURE JETS

Formation of high-temperature and plasma jet, its dynamics and heat exchange characteristics in the channels of different configuration and heat exchanger cells and elements are investigated in the Laboratory. Plasma diagnostics is available by numerical and experimental methods. A numerical research of heated gas jet in the channel was performed applying hydrodynamics software *FLUENT*. It was used to solve full Navier-Stokes and energy equations based on the dynamic *k–å* 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.

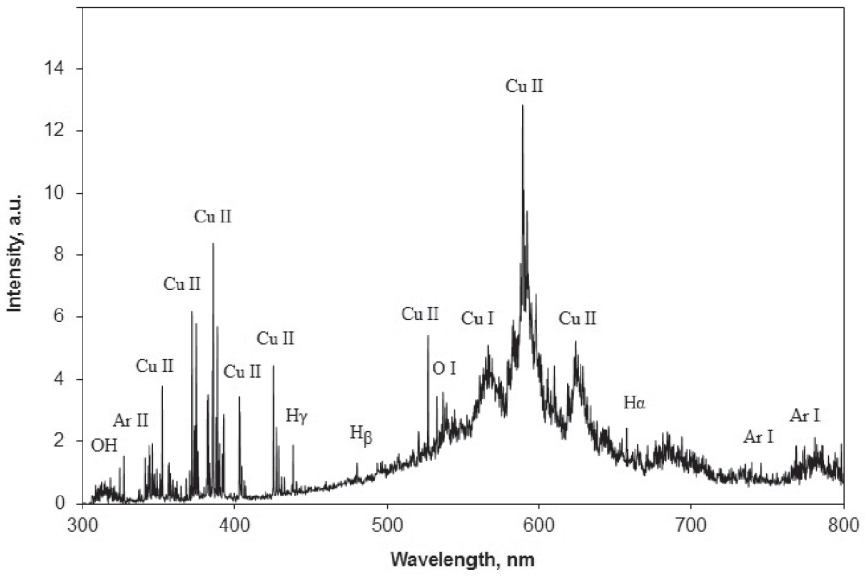
Recently, non-contact methods have been widely applied for plasma diagnostics in the Laboratory. One of them is optical spectroscopy method; its main analytical device is an optical spectrometer AOS-4. It is an optical system for rapid measurements, that may be used for the investigation of gas emission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



Argon plasma jet discharged from constant current linear plasma generator



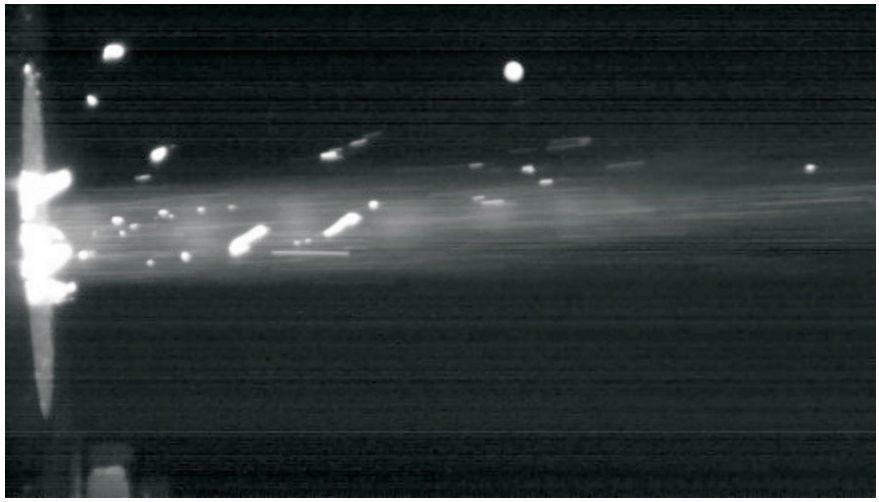
Arrangement of temperatures in the air plasma jet at speeding 50 μm Al_2O_3 particle



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

800 nm. The system is used also for the examination of plasma element composition and emission spectra.

An X-series high-speed optical camera RedLake Motion Pro X4 with CMOS (Complementary Metal Oxide Semiconductor) sensor is used for multiphase plasma flow visualization and determination of some dynamic characteristics. The camera enables high-speed recording of images in 100 ns interval and also observation of very rapidly moving objects. A high-speed optical camera MotionPro X4 is used in the Laboratory.

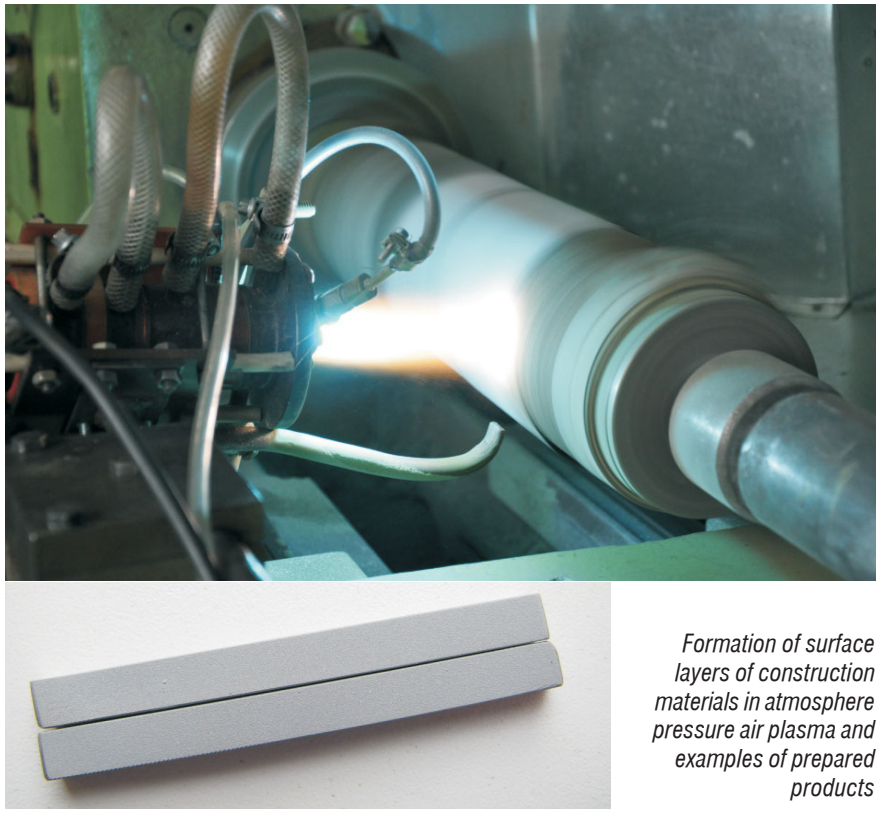


Movement of alloy and granules and mineral splint formation process in supersonic plasma jet, observed by high-speed video camera

FORMATION OF CONSTRUCTIONAL MATERIAL SURFACE LAYERS BY PLASMA TECHNOLOGIES

Synthesis of coatings in plasma flows

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



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

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 g 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

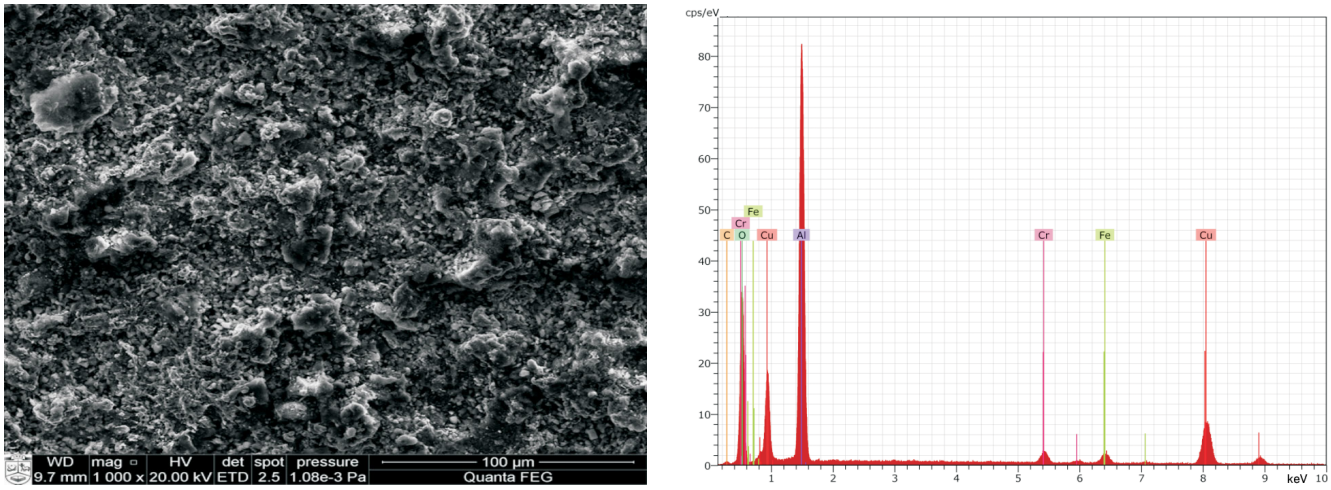
In the fields of science and production, a worldwide attention has recently been given to the renewable energy technologies, hydrogen energy, programmes of fuel synthesis and saving, issues related to the reduction of environmental pollution and their solution. All these areas require special purpose 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 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.

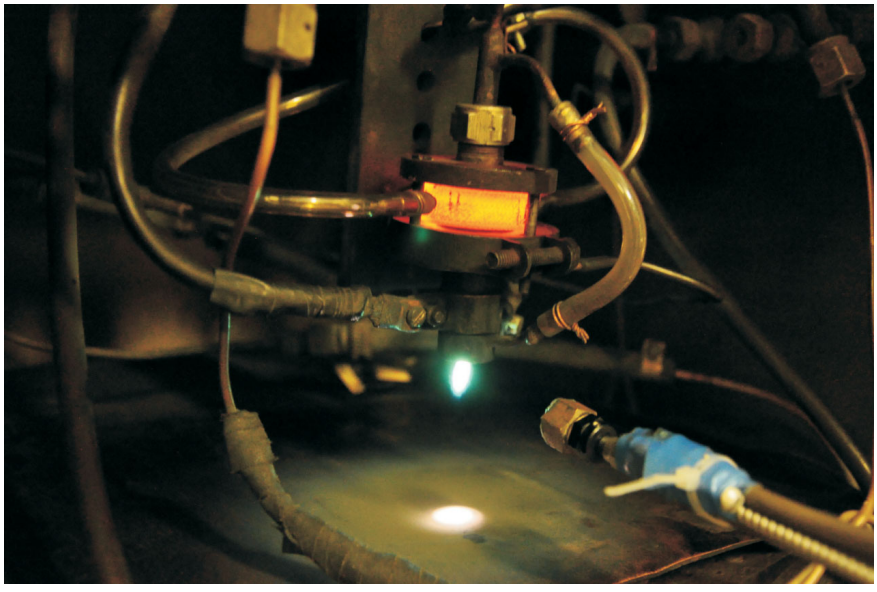
On the basis of oxide catalytic coatings, formed employing plasma method, catalytic reactors efficiently reducing the emission of CO, SO_2, NO_x, HC and other pollutants have been developed. By the catalytic combustion behaviour these reactors are very similar to the ones composed of noble metals. The 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.



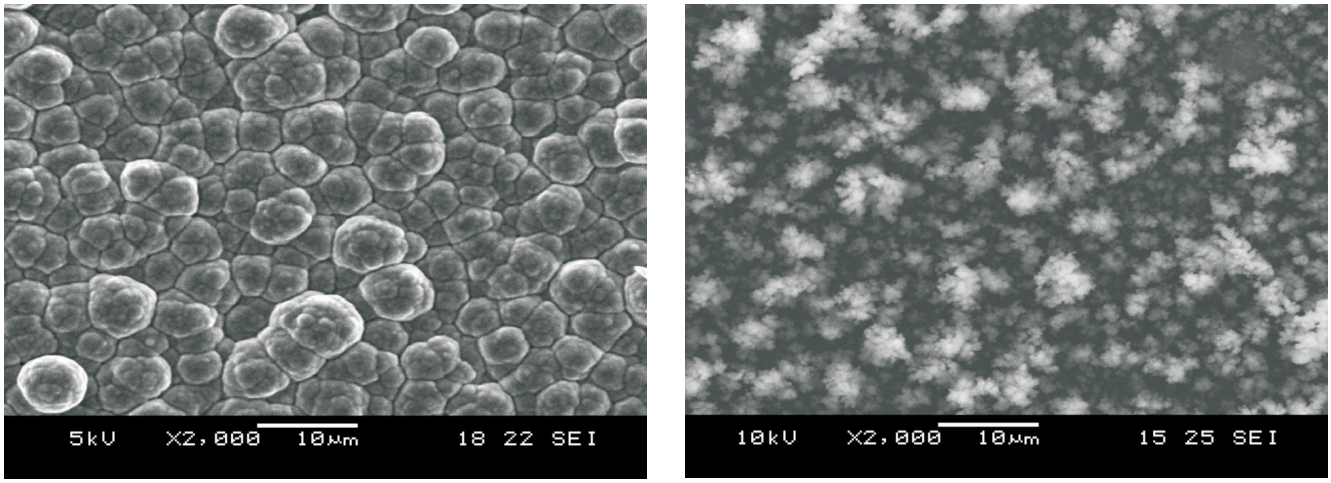
Catalytic coating (on the left) and its element composition (on the right)

Carbon derivative coatings

Technological modification of surface layers of constructional materials by forming multifunctional coatings is widely applied in engineering. One of the possibilities of using plasma technology is the synthesis of plasma polymers, i.e. thin membranes precipitated by plasma method that may be applied in a wide range of fields: microelectronics, medicine, biotechnologies, semiconductors manufacturing, etc. Plasma polymers are usually synthesized in a vacuum, but their structures are not thoroughly studied yet. Due to the low price and good mechanical properties (resistance to corrosion, toughness, small au-



Operating carbon coating synthesis facility generating argon/acetylene plasma



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

tonomous 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.

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, 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.

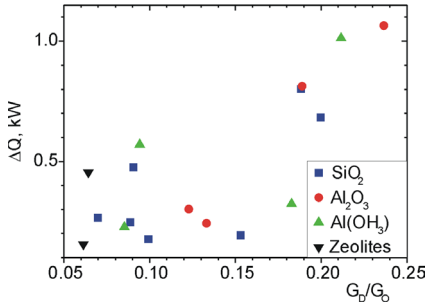
The plasma processing efficiency depends on the nature of chemical reactions, the value of plasma ambient temperature and velocity, the pressure of material in high temperature zone, etc. The surfaces formed employing plasma method are obtained by laminating many dispersed particles, which before the 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

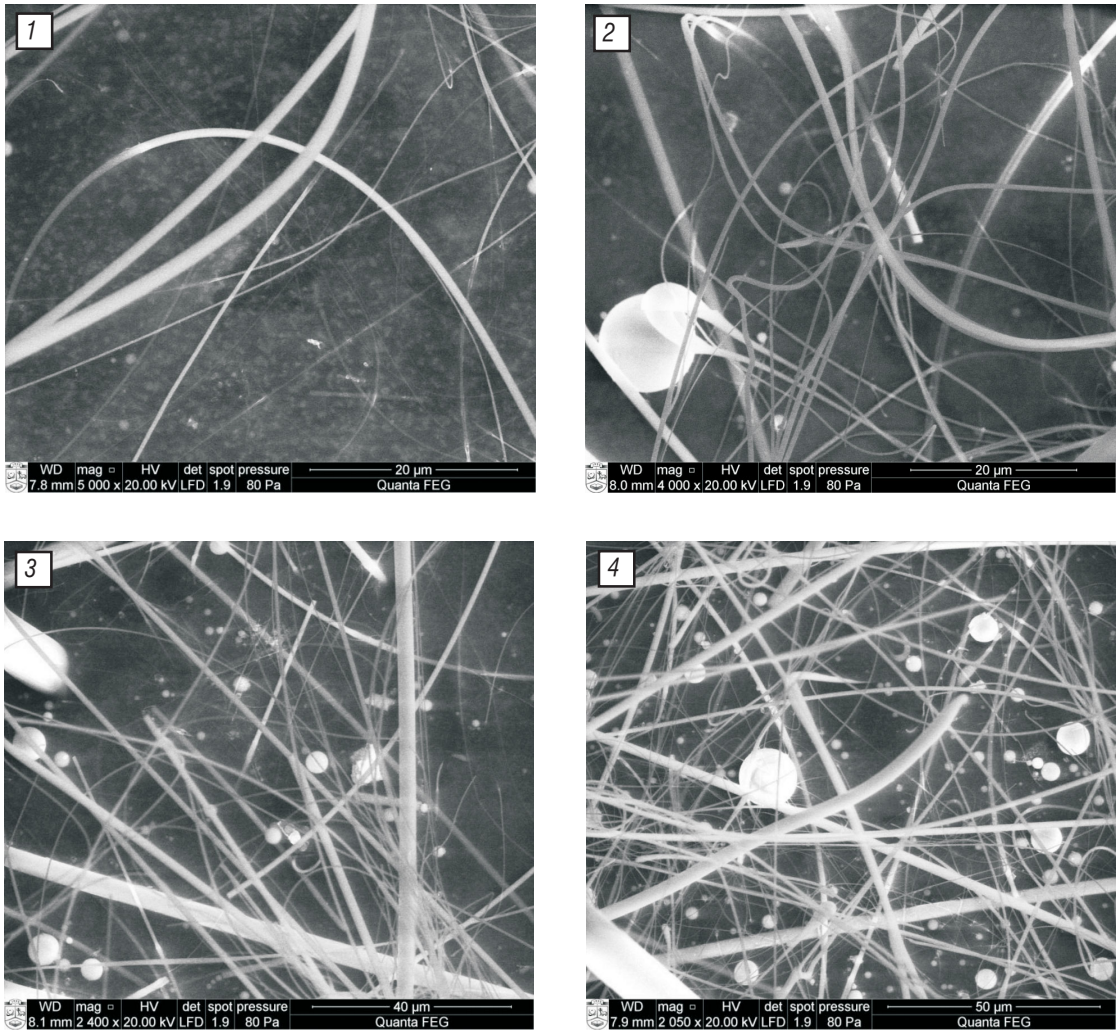
Traditional technology and equipment presently used to produce mineral fibre require continuous operation process, complex and expensive alloying furnaces and insulation materials. The quality and composition of fibre produced traditionally are also limited by the melting-point of raw materials; therefore, 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,



The impact of dispersed particle on the dropdown of heat flow into the reactor walls D. G_D and G_0 – flows of particles and air

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 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.

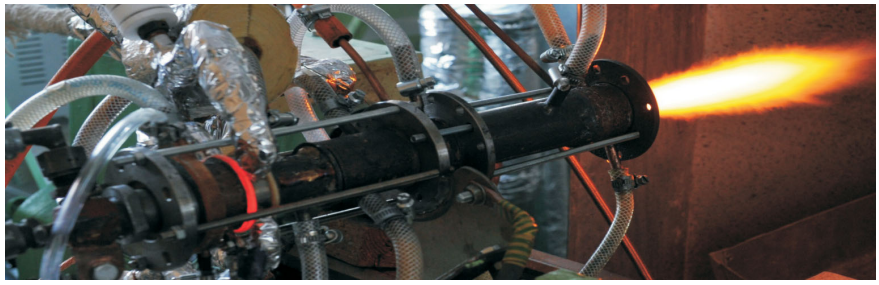
Plasma jet velocity is one the basic factors conditioning the quality of ceramic fibre since with the increase of plasma jet (60%) velocity discharged from the reactor the developed fibre yield increases by 5%, whereas the fibre diameter comprising the splint and granular amount in it reduces.

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 s 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.

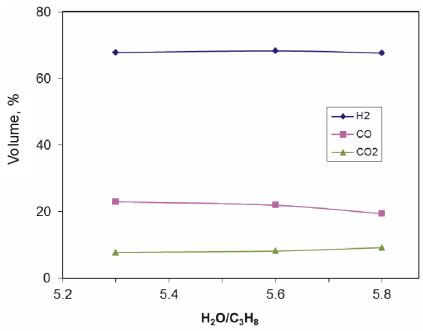
WATER VAPOUR PLASMA TECHNOLOGY

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.



Operating water vapour plasma facility designed for decomposition of organic materials



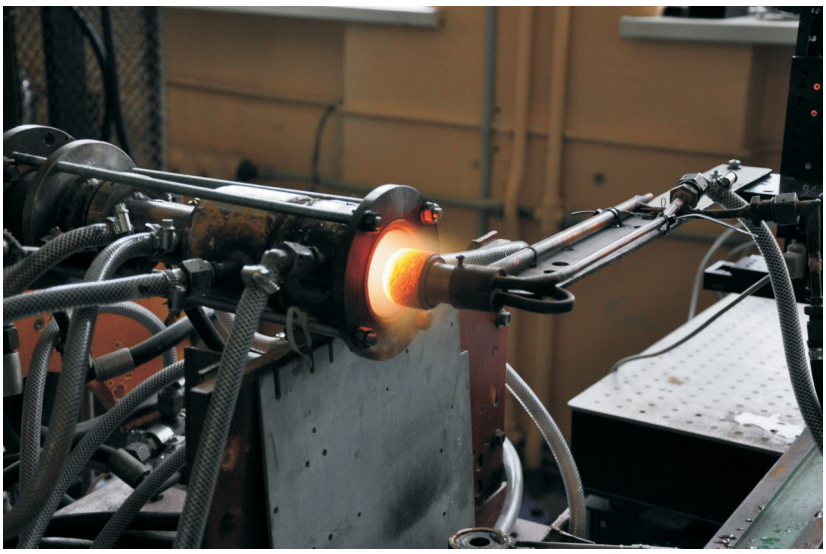
Composition of synthetic gas derived in plasma-chemical reactor at H_2O vapour flow 3.51–4.,48×10^{-3} kg/s, propane flow 0.34×10^{-3} kg/s

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. Propane gas (C_3H_8) was chosen for decomposition as an initial sample since it encompasses

active carbon and hydrogen, when decomposing it in the water vapour environment the exhaust of hazardous materials in to the environment is avoided. The propane conversion in the water vapour plasma environment is endothermal reaction (498 kJ mol^{-1}) :

$$C_3H_8 + 3H_2O \rightarrow 7H_2 + 3CO.$$

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%.



Investigation of behaviour of hardly alloying materials in high temperature zone. On the right – example after the plasma jet impact

LABORATORY ACTIVITY IN THE NATIONAL SPACE PROGRAMME

In 1981–1989 the researchers of Laboratory of Plasma Processing worked hard by experimenting with various materials, used for producing space shuttle hulls of the former Soviet Union, in plasma jets and flows. The effect of high temperature and velocity to the changes of structure and properties of the given material was investigated, and the tested material was used for the manufacture of the hull for the space shuttle *Buran*.

Presently for the similar purposes the Laboratory employs analogous plasma equipment with 150 kW capacity. The temperature of plasma jet, flowing from the plasma generator, is 1600–7500 K, while its velocity reaches 150–750 m/s. This creates a possibility to examine the behaviour of various materials in plasma jet, form the surface layers of multi-purposeful constructional materials, develop protective coatings for a vide range of application, having different properties and suitable for rocket engineering and space exploration.

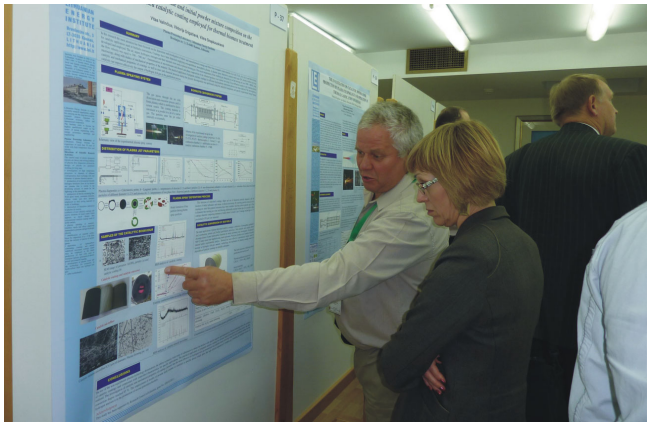
In 2010 the research of material testing and experiments were reinitiated. The research on ***Novel materials for use in the surface thermal protection system of re-enter space vehicles using low-temperature plasma jet*** was initiated in cooperation with the Laboratory of Materials Research and Testing under the innovation cheque contract. During the implementation of this study, samples of refractory materials were placed in plasma flow and the impact of high temperature and velocity on the structure and erosion of the materials was investigated. The work in this direction is still continued.

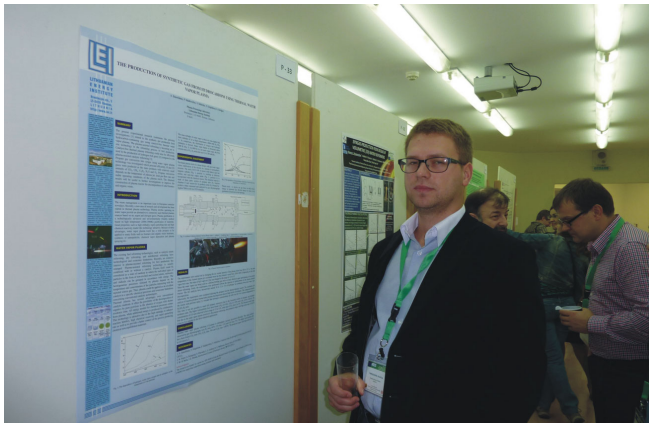
THE EVENTS OF 2012

ISFV-15 conference, in Minsk, Belorussia. Dr. Viktorija Grigaitienė was granted the Soloukhin nominal award for presented results in the field of flow visualization (photo left).

Mindaugas Milieška defended his doctoral thesis ***Research of thermal-hydrodynamic processes in plasma by fibreing hardly alloyng ceramic materials*** (06T).

Excursion to the Laboratory of Plasma Processing during the open doors day in LEI





*Presentation of the results of implemented **Future Energy** projects at international conference UBIOCHEM-2012*

PROJECTS IMPLEMENTED IN THE LABORATORY

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

In 2012 together with researchers from Laboratory of Combustion processes new long-term R&D programme *Experimental and numerical research of combustion and plasma processes for improvement of energy generation technologies from renewable biofuel and reduction of environment pollution* was initiated. The objective of the laboratory is to create water vapour plasma technology designed for conversion of biomass and solid fuel, using numerical and experimental methods to investigate processes occurring during the conversion and identify their regularity patterns. To investigate possibilities and create conditions to employ water vapour plasma generator in the field of development of new environmental technologies.

In 2012 a new scientific work, funded from budget assets, ***Synthesis of carbon coatings in argon-acetylene and argon-hydrogen-acetylene plasma and investigation of their properties*** was initiated. Conducting work tasks, applying long-term experience of LEI researchers and available facilities it is aimed at investigating possibilities and conditions for development of new generation carbon coatings. During the project plasma process of formation of amorphous and crystalline solid carbon coatings will be implemented. Supplying various modification additives, there is an objective to investigate their impact on the structure and properties of obtained coatings.

cost CM0903

In 2012 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- Belorussian 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 science program *Future Energy* project ***ATE02/ 2012 Research of local fuel thermal decomposition processes by developing efficient and ecological technologies.***
- National science program *Future Energy* 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 wastewater comprised in wastewater treatment enterprises of small Lithuanian towns. The project idea is implemented together with Laboratory of combustion processes, Laboratory of Nuclear Engineering and Laboratory of Heat Equipment Research and Testing.

- Project ***Dissemination and Fostering of Plasma Based Technological Innovation for Environment in BSR*** *(PlasTEP) o*f Baltic Sea Region Programme 2007–2013. The main objectives of this project are to develop and use plasma technologies for solving environmental problems. It is also important to develop equivalents that prove the possibility to practically improve air and water quality and to introduce plasma technologies in the field of environmental protection.
  Main tasks of the project:
  - control and reduction of hazardous material emission;
  - application of plasma technologies for the neutralisation of toxic industrial waste;
  - reduction of air and water pollution;
  - development of environmental technologies clusters in Baltic Sea region;
  - promotion of support and investment into novel environmental technologies;
  - incorporation of politicians and government representatives into the project activity
  - group formation of industrial and scientific partners in the field of environmental protection;
  - specialised group formation aiming at reducing NOx and SOx emission, neutralising VOCs compounds) and smells as well as cleaning the water;
  - spread of knowledge and environmental technologies in the states of Baltic Sea region.

The personnel of the Laboratory of Plasma Processing consists of 8 scientists with a doctoral degree, 1 young re-

***PlasTEP** project partners*

searcher PhD student, 1 junior research assistant and well experienced ancillary personnel: 3 engineers and 2 highly qualified foreman.

Since 2007, the Laboratory has been taking active participation in the activity of Plasma Technology Network of the Baltic countries. Last year the scientific and technical production of the Laboratory was presented in international (13 papers) and national (3 papers) conferences, 6 articles were published in the ISI indexed journals 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;
  - synthesis of hydrogen fuel cell elements: anodes, electrolytes and cathodes applying physical vapour deposition methods.

In 2012 a state subsidy funded project ***Synthesis and Property Analysis of Nanocrystalline Metal Hydrides, Designed for Energy Storage and Optical Devices*** was successfully completed. Basic issues restricting application of metal alloys is related with hydrogenation/dehydrogenation process. Presently widely used metal alloys, devoted for storage of hydrogen, are formed using chemical technologies. Hydrogen pressure of the extracted alloys during hydration process amounts for 10 MPa and dehydration occurs at 500°C.

The originality of this work is to identify the unstable conditions of uninvestigated magnesium alloys, where the materials effectively adsorb/desorb hydrogen. Non - equilibrium physical technologies are applied during which energy activation will be realized, developed by structure corpuscular particle flows (photons, electrons and ions), derived from plasma. The derived materials due to structural peculiarities (nanocrystalline or atmospheric structure, amount of defects, texture) are distinguished for unique adsorption/desorption properties and are real candidates to develop new generation hydrogen storage devices, to employ in batteries and switching optical mirrors.

A wide spectrum of experiments related with Mg-Ti, Mg-Ti-H, Ni-Mg-Ti-H and Mg-Al-H synthesis and analysis of properties was carried out. Magnetron vapour deposition method was used for the synthesis, whereas hydrogenation of the derived structures was performed using two technologies: equilibrium hydrogenation at high pressure and temperature and non-equilibrium hydrogenation process in low temperature plasma.

During synthesis, the Mg_7TiH_{16} composition was successfully derived; it is widely used for hydrogen storage, optical devices and batteries. It is also shown that during Mg_7TiH_{16} synthesis Pt and Pd may be successfully changed into Ni catalysts. The efficiency of LEI patented technology was approved, the hydrogenation of plasma activated Mg conducting at high hydrogen pressure and temperature. It is shown that the properties of substrates on which thin film structures are obtained have great influence on the extracted hydride properties (Fig.1).

During the implementation of the EU Structural Funds project ***Foundation of Na-***

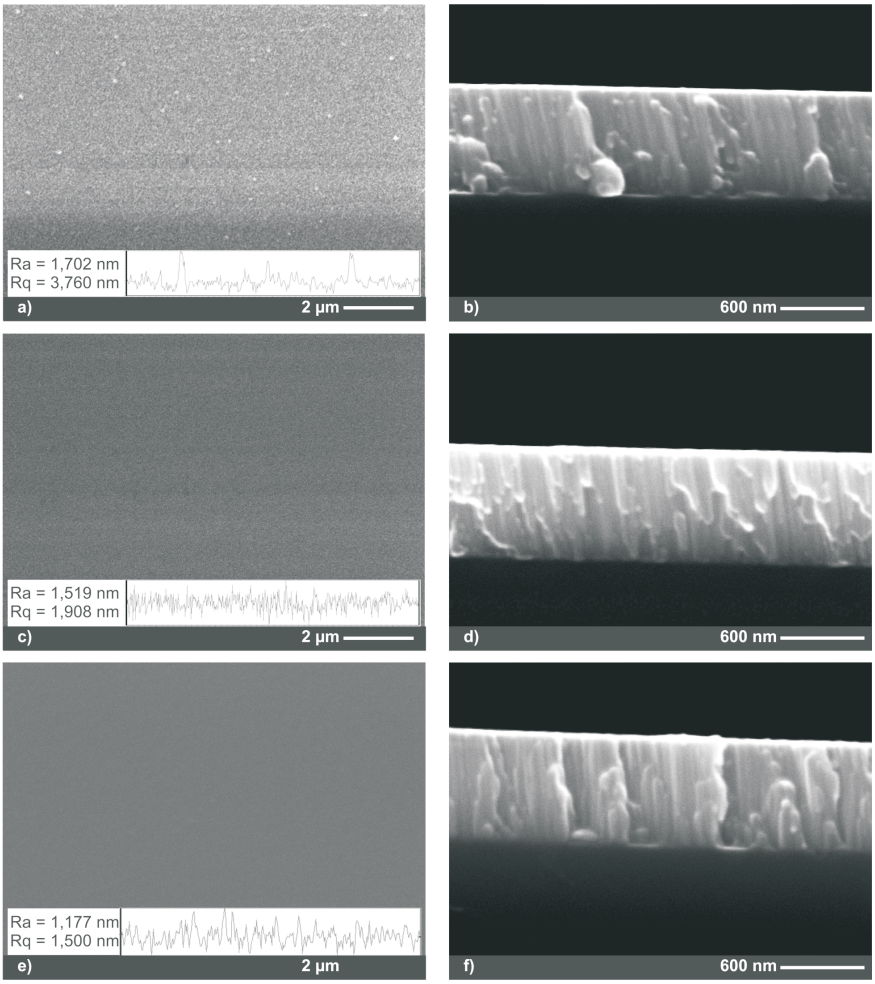

Fig.1. SEM images of Mg-Ni coatings on Si substrates deposited on the primary (a and b) and processed with constant current sources (c and d) and impulse constant current source (e and f) generated plasma. Additionally, AJM profiles of samples are inserted in a, b, and c SEM images, their roughness parameters are identified (the analysis performed using different methods, thus the place of sample analysis does not coincide)

other devices of Center for Hydrogen Energy Technologies is foreseen to be employed in developing and investigating nanocrystalline materials designed for portable, space and transport hydrogen energy devices and systems.

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

Since 2012 the **Agency** for **Science, Innovation and Technology** (MITA) has been financing project ***Commercialism of Technologies Developed at the Center for Hydrogen Energy Technologies of Lithuanian tional Open Access Scientific Center for Future Energy Technologies***, HITACHI S-3400N scanning electronic microscopy was bought and installed in LEI Center for Hydrogen Energy Technologies in 2012 (Fig.2). It is the highest-quality analytical equipment designed for the metal hydrides, used to store hydrogen and oxides, designed for analysing morphology of hydrogen fuel elements and extraction membrane surfaces and cross-sections. The device may be used for analysing thin coatings as well as powder samples. The results obtained with this device will enable to receive fundamental information on the structure, morphology, existence of surface/volumetric defects and structure of analysed samples. This device along with

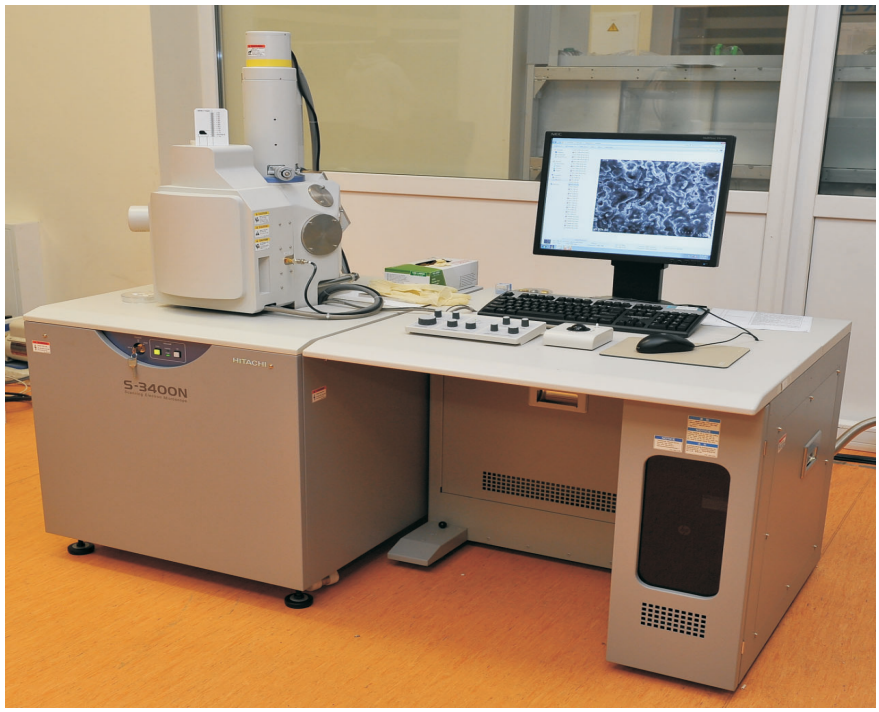

Fig. 2. Scanning electron microscope HITACHI S-3400N

Energy Institute (2012-08-13 N0 31V-137). With this objective the researchers of the center established JSC *Inovatas*, which is related to LEI with *spin-off* agreement.

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

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 possibilities study of international level devoted to potential investors, where basic advantages and challenges of the commercialized technology would be reflected, is to be prepared during the project. A demo device is to be developed where it would be possible to implement metal hydrogenation experiments using material amounts similar to the demands of real portable devices – thus demonstrating the operation principles of technology to potential investors.

The second technology – *Method of Hydrogen Extraction 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 for this technology – manufacturers of car industry and worldwide exploiters of unstable renewable energy systems (wind, sun). The basic tasks of the project is to prepare nanomaterials designed for hydrogen production, using ball milling and physical material deposition technologies and present this hydrogen production technology for major manufacturers of USA car industry and risk capital enterprises.

The third technology – presently new generation Ni-Zr-NB, Ni-Ti-Al, Ti-Al amorphous membranes, devoted to separation of hydrogen from hydrocarbons (natural gas, biogas, oil products, etc.) and alcohol, which are produced at CHET. These membranes are much cheaper than presently used Pt, Pd based membranes. The basic project tasks are to prepare and characterize the membranes, preparing them for the market and present the developed membranes for potential consumers.

HYDROGEN IMPLEMENTING AGREEMENT

In 2012, 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 3 articles in the publications on the Institute for Scientific Information (ISI) list and presented 9 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:
  - forced and mixed convection, turbulent and transition flow regimes, influence of channel geometry, variable physical properties, roughness, centrifugal forces and transients effect;
  - numerical modelling of heat transfer in various channels and geological structures;
  - reduction of emission resulting along with smoke from biofuel combustion using electrostatic filters; research of heat and mass transport in the equipment of biofuel-fired objects;
- 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 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 are coordinating and implementing two long-term scientific research and experimental development programs, which were approved by the Ministry of Education and Science of the Republic of Lithuania at the beginning of 2012:

- ***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, 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 flow non-stationary, transient, impact of physical features and thermo gravitational forces and vapour condensation processes.
- ***Investigation of nuclear power plants' decommissioning and radioactive waste and spent fuel management processes and radiation impact analysis*** (2012–2016). The objective of the program – to analyze and estimate radiation impact on humans and environment during management, storage and disposal of SNF and radioactive waste with application of numerical and experimental research methods and taking into account the

peculiarities of Ignalina NPP decommissioning,

RESEARCH OF THERMAL PROCESSES IN ENERGY EQUIPMENT COMPONENTS

Laboratory carries out investigations of heat transfer and hydrodynamics in energy equipment for different purposes (in the elements of nuclear reactor, various heat exchangers, etc.). Since in both laminar and turbulent flow cases, the effect of thermogravitational forces (mixed convection) on heat transfer is manifested in many energy facilities, which under certain conditions can be the reason for an accident in different facilities. For this reason, the Laboratory performs experimental mixed convection investigations in pipes and has initiated the research in flat channels as well. Additionally, such research was initiated in geological structures while analysing the possibilities of Ignalina NPP spent nuclear fuel disposal. In parallel, research is also performed using the ANSYS FLUENT code (ANSYS, USA) which is widely used worldwide for modelling the fluids flow and heat transfer in complex two and three-dimensional systems. The Laboratory uses various models of the laminar, transition and turbulent transfer.

In 2012 the numerical investigations (using ANSYS FLUENT code) on heat transfer and hydrodynamics in flat channel for opposing mixed convection flows in the transition region were continued. The obtained heat transfer and flow hydrodynamics results expand the understanding on the transition from the laminar to turbulent flow under the impact of thermogravitational forces.

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

In 2012 researchers of the laboratory in frame of the project ***Investigation of local fuel thermal decomposition processes in developing efficient and ecological technologies*** (2012–2014), financed by national science program ***Future Energy*** of Research Council of Lithuania, together with other laboratories of the institute conduct the following research. In 2012 scientific and practical demands fields' analysis of biofuel combustion products cleaning research was carried out with the aim to determine research fields and expansion possibilities. The facility was designed at the laboratory to perform such investigations.

In 2012 participating in ***Santaka valley*** project *Foundation of National Open Access Scientific Center for Future Energy Technologies* the laboratory was equipped with LDA and PIV equipment devoted to investigate flow structure in gas and fluids in wide velocity variation limits. This equipment is able to measure velocities and their pulsations, frequency of vortex rotation, to visualize them, etc. Also the laboratory purchased liquid crystal thermography facility, which enables to measure temperature of different objects as well as the varia-

On the open days at Lithuanian Energy Institute senior research associate Dr. R. Poškas presents the activities of the Laboratory to students (10 September 2012, LEI)

The representative of equipment manufacturer training the laboratory scientist how to use the equipment purchased under the framework of ***Santaka valley*** *project (02 February 2012, LEI)*

tion of temperature of separate investigated object image parts by remote non-invasive method.

SAFETY OF SPENT NUCLEAR FUEL MANAGEMENT

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

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

In 2012 a scientific project ***Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing*** (2010–2012) financed by the state budget grant was finalized. The research on the radionuclide migration from deep SNF repository in case of container defect scenario was performed. The scenario assumes that a disposal container with a small defect (untightness) in its wall may pass the inspection by non-destructive control methods and be disposed of in the repository. Thus, radionuclide transport from disposal container through the wall defect is modelled. Having spread from the container, the radionuclides migrate through the bentonite layer (engineering barriers) and diffuse to the groundwater, which flows in the fracture intersecting the tunnel in crystalline rocks.

During the investigations, the model of radionuclide migration from RBMK-1500 SNF deep repository was developed in order to evaluate the impact of uncertainty, related to the increase of container wall defect, migration on the separate radionuclide from the container. In 2012, the inpact of defect enlargement time and other pa-

Dr. A. Narkūnienė during IAEA training course on Identifying and managing uncertainty for post-closure safety assessments in support of repository development programs (16-23 June, 2012, Portugal)

DPhD student D. Justinavičius with the representatives from other countries in experimental research tunnel at the clayey environment (IAEA training courses, 09-16 September 2012, Tournemire, France)

rameter uncertainty on the assessment results of long-lived radionuclide ^{129}I and ^{226}Ra migration (the average and the maximal flux) was analysed. Sensitivity analysis of time dependant radionuclide flux and maximum radionuclide flux was performed, the parameters having the largest impact at predefined time were identified.

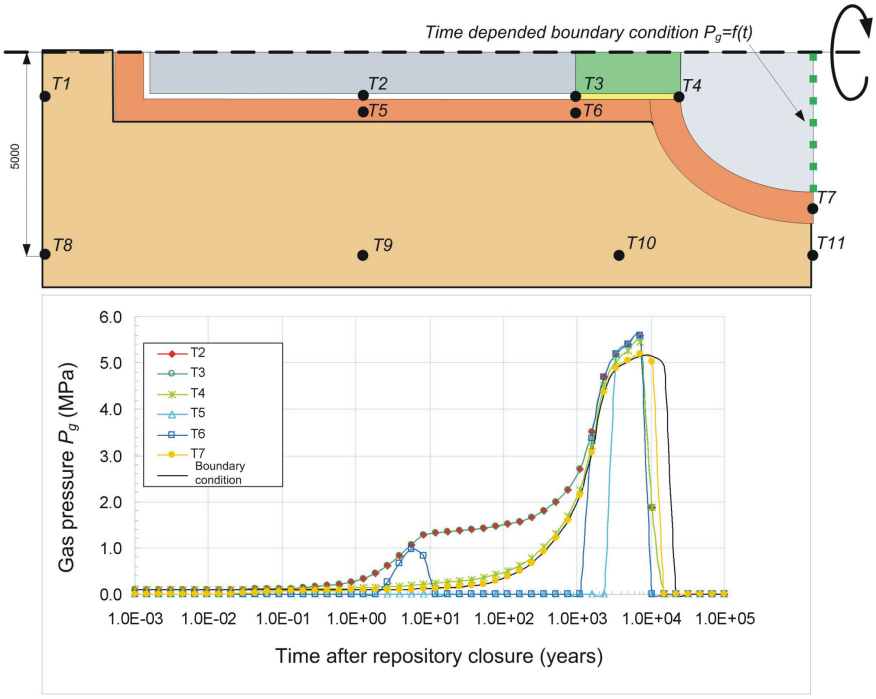
The probabilistic assessment of radionuclide migration demonstrated that in order to optimize the analysis of radionuclide ^{129}I transport through engineering barriers, it is worthwhile to concentrate the further research on the parameters defining bentonite diffusion, instant release fraction and SNF matrix dissolution rate. In the case of ^{226}Ra the revision of the SNF matrix dissolution rate, bentonite sorption coefficient and the equivalent flow rate of groundwater is recommended.

It was also determined that the defect enlargement time uncertainty has no significant impact on radionuclide ^{129}I and ^{226}Ra maximal flux outside the repository engineering barriers, however it is significant for the average flux of ^{129}I. It was also determined that the defect enlargement time uncertainty has no significant impact on radionuclide ^{129}I and ^{226}Ra maximum transport behind repository engineering barriers, however it is significant from the perspective of ^{129}I average transport.

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

FORGE
Fate Of Repository Gases
EURATOM

In 2012 the research of gas migration from deep SNF repository was continued. Gas in the repository will be generated due to corrosion of steel (engineering components and disposal containers), whereas their amount will depend on the type of radioactive waste and the selected disposal concept. This research is performed together with 23 partners from 10 EU countries under the project ***Fate of Repository Gases (FORGE)*** (2009–2013) financed by the 7th Framework Programme (FP7) of



Variation of gas pressure P_g in disposal tunnel of radioactive waste

the EU. In 2011 a gas migration model in single disposal tunnel was developed and numerical modelling was carried out using PETRASIM (USA) software package. The values of parameters important from the perspective of repository safety – maximum gas pressure and gaseous fluxes (from disposal tunnel to the transportation tunnel) – were determined. In 2012 sensitivity analysis of these results was performed – it was estimated which factors influence their increase or reduction. The obtained results correlate with the modelling results of the project partners.

In 2012, as a partner of consortium GNS – NUKEM Technologies GmbH (Germany), the Laboratory continued an extensive project ***Design and Installation of the Interim Storage Facility for RBMK Spent Nuclear Fuel Assemblies from Ignalina NPP Units 1 and 2*** (2005–2011). This project comprises the analysis of all activities related with the design, construction, installation, commissioning, operation and decommissioning of the new SNF storage facility and the performance of all necessary works related to the SNF removal, packaging, sealing and transfer as well as operation of the appropriate equipment for implementation of chosen design concept. It is planned to store approximately 200 new type CONSTOR casks with intact and damaged SNF in the new storage facility.

The Laboratory prepares Environmental Impact Assessment and Safety Analysis Reports of this SNF storage facility (operational time no less than 50 years) and offers support in licensing the storage facility. In 2007, *Environmental Impact Assessment Report* was approved by the Ministry of Environment; in 2009, *Preliminary Safety Analysis Report* (PSAR) was prepared and agreed upon and the licence for construction of the new SNF storage facility was issued by VATESI. In 2010-2011, PSAR Addendum, which presents the evaluation of safety aspects of damaged RBMK-1500 nuclear fuel assemblies' management and storage, was being prepared.

SAFETY OF RADIOACTIVE WASTE MANAGEMENT

Since 1994 the Laboratory has been actively involved in the analysis of the radioactive waste management problems at Ignalina NPP. Laboratory experts together with the experts from *SKB International* (Sweden) carried out a number of projects, which included safety assessment of existing waste storage facilities and the possibilities to transform them into repositories. Together with French companies *Thales Engineering and Consulting*, *ANDRA* and the Institute of Physics, PHARE project ***Safety Assessment and Upgrading of Maiçiagala Repository in Lithuania*** was implemented. The Laboratory specialists participated in preparing *Safety Analysis Report*, developed the database containing information on the radioactive waste, which is stored in the Maišiagala storage facility, and performed a comprehensive nuclide composition analysis. The Laboratory together with *Framatome ANP GmbH* (Germany) participated in executing the environmental impact and safety assessments for Ignalina NPP cement solidification facility and a temporary solidified radioactive waste storage facility. Additionally, the Laboratory constantly participates in the research programmes coordinated by IAEA.

In recent years, a great deal of attention was devoted for the siting of a new near-surface repository of radioactive waste in Lithuania, and for scientific research related to the radionuclide migration from radioactive waste repositories and its impact on safety. With the assistance of Swedish experts, the Laboratory specialists prepared the set of criteria for choosing a near-surface repository site, improved the reference design of a 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 research was 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 2012, the Laboratory together with NUKEM Technologies GmbH (Germany) continued the project ***New Ignalina NPP Solid Waste Management and Storage Facility*** (2006–2013). This facility is intended for solid radioactive waste retrieval, sorting, transportation, treatment (using envisaged technologies), packaging, characterisation and storage. The facility comprises the solid waste retrieval facility located at the existing INPP solid waste storage buildings, the new solid waste treatment facility, the new 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 Re-*

"Hot" tests of container conducted at the Buffer storage of the Landfill repository

trieval 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 facility was issued. The second PSAR was modified considering the recommendations of the authorities in 2011–2012.

In 2012, the Laboratory, as a partner of Lithuanian consortium (JSC *Specialus montažas-NTP,* LEI, *Pramprojektas*, JSC *Vilstata*) continued implementing the project ***Installation of Very Low Level Radioactive Waste Repository (Landfill)*** (2008–2010). *Landfill* repository is intended for disposal of very low-level radioactive waste generated during Ignalina NPP operation and decommissioning. *Landfill* facility will be comprised of three repository modules and buffer storage where waste will be stored till their disposal. The Laboratory prepared *Environmental Impact Assessment Report* for the planned economic activity (approved by the Ministry of Environment in 2009) and two PSARs, *The Buffer Storage of the Landfill Repository* (approved by VATESI in 2009) and *The Disposal Modules of the Landfill Repository* (agreed with VATESI in 2010). *General Data Set on the Buffer Storage of the Landfill Repository* was completed (approved by the European Commission in 2010), whereas in 2011 *General Data Set on the Disposal Modules of the Landfill Repository* was submitted to the European Commission for review.

In 2012 Waste Package Specifications (WPS) for three types of radioactive waste packages, namely *compressible waste, non compactable waste* and *spent ion exchange resins*, intended for the final disposal in the very low activity radioactive waste repository, were prepared,. The WPS were agreed with Radioactive Waste Management Agency (RATA) and State Nuclear Safety Inspectorate (VATESI). The experts of the laboratory elaborated final safety analysis report (FSAR) for *Landfill repository buffer storage.* FSAR submitted to VATESI for approval.

Last year, the Laboratory together with partners from French companies *AREVA TA* and *ANDRA* and Lithuanian partners JSC *Specialus montažas-NTP* and *Pramprojektas* continued the project ***Low and Intermediate-Level Short-Lived Radioactive Waste Near-Surface Repository (Design)*** (2009–2013). 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 Concept Report, Waste Inventory Report and Site Revalidation Report which were submitted to the Contractor and approved. In 2012 Basic Engineering Design report for Near

Dr. R. Kilda and Dr. V. Ragaišis at the meeting with partners at AREVA's headquarters (14 November, France)

surface repository 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: description of waste, long-term safety assessment, waste acceptance criteria and waste package specifications as well as general overview of environment monitoring and repository surveillance. In 2012 preparatory work of technical project was initiated during which the experts will estimate long-term repository safety and will prepare chapters of preliminary safety analysis report. Preparation of environment monitoring program and coordination with the responsible state institutions is foreseen for 2013.

The Laboratory continued the previous research of radionuclides migration from near surface repositories. In 2011 in the scope of the scientific research ***Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing*** (2010–2012) they analysed the migration of separate radionuclides from near-surface repositories in order to evaluate the factors which have the largest impact on the uncertainty of the obtained results. Parameter sensitivity analysis was performed and most significant parameters influencing the radiation impact uncertainty were determined.

In 2012 during the implementation of the above-mentioned budgetary work and the project ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE)*** (2008–2013) of the 7th Framework Programme of the EU, numerical research related to the radiological characterization of the constructional materials of RBMK-1500 reactor, namely irradiated graphite, was continued. In 2012, the modelling of axial neutron flux distribution was continued: the axial activity distributions of the main radionuclides in activated graphite were estimated, and the possible spread of their activity values was analysed regarding the amount of initial impurities. Having obtained the initial measurement results of the activity of several radionuclides in the graphite sleeve of Ignalina NPP Unit 1 reactor, the calibration of the developed models was carried out. Similarly as before, the numerical research was performed using MCNP-5 (LANL, USA) and ORIGEN-S (from SCALE-5 software system) (ORNL, USA) software.

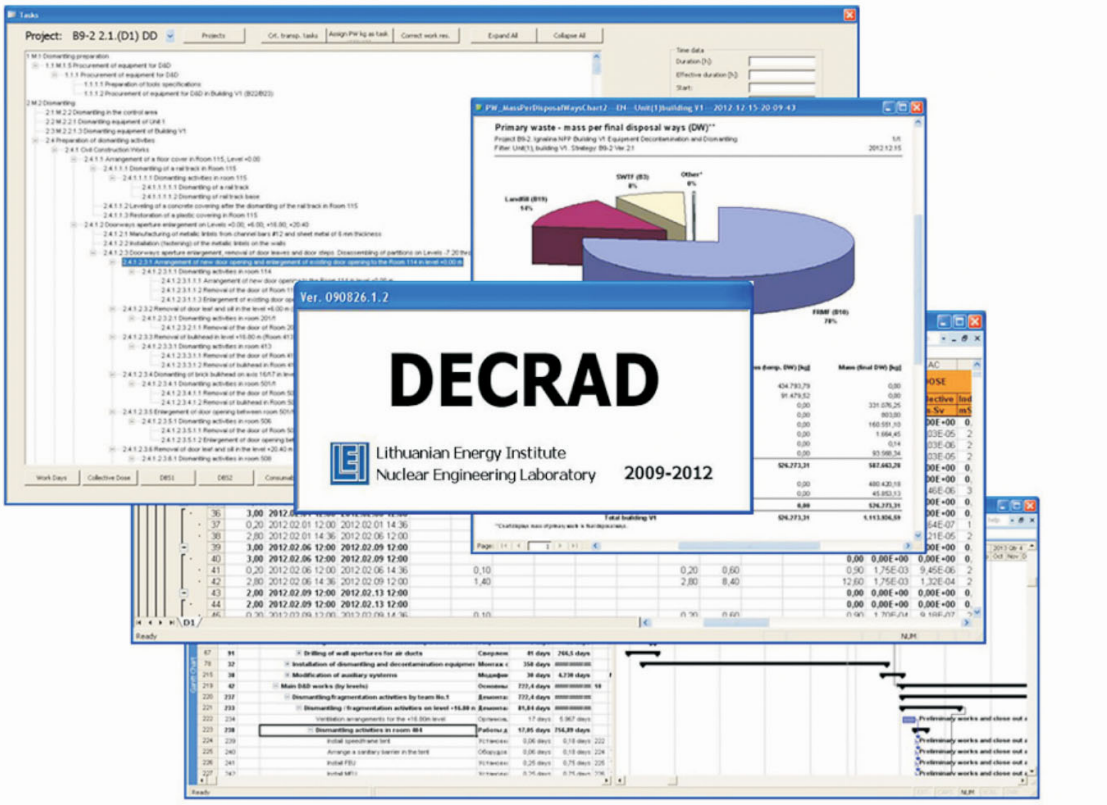
The feasibility study of RBMK-1500 graphite final disposal in a repository was analysed in the scope of ***CARBOWASTE*** project regarding the alternatives of treatment/non-treatment of the graphite. To assess the specificity of long-term repository operation after placing irradiated graphite, numerical models were developed. While performing numerical modelling the release of radionuclides from graphite and their transport through engineering barriers of the repository was evaluated. The developed models of the repository environment were implemented using AMBER software (Quintessa, the United Kingdom). The analysis of radionuclide transport was carried out taking into account the results obtained within the mentioned project, whereas aiming to estimate the relation between waste treatment and final disposal, the relation between radionuclide release rate and maximum radionuclide flux outside the repository engineering barriers was analysed.

During the analysis possible different functioning of engineering barriers was considered and numerical modules of radionuclide migration were developed, when graphite waste is emplaced in the disposal contained without grouting and grounted in cementitious grout, estimating in this way the impact of immobilization in cement material. For further assessment of migration in natural environment numerical models were realized in the environment of software TOUGH (LBNL, USA), and the impact of natural barriers on radionuclide migration was estimated.

EVALUATION OF DIFFERENT FACTORS RELATED TO DECOMMISSIONING OF NUCLEAR POWER PLANTS

In 2007–2010, Lithuanian Energy Institute, as a partner of consortium VT Nuclear Services Ltd (UK) – LEI – NUKEM (Germany), implemented the project ***Ignalina NPP Building 117/1 Equipment Decontamination and Dismantling***. In 2009 the specialists of the Laboratory prepared *Environmental Impact Assessment Report* approved by the authorities, while in 2010 they completed *General Data Set*, *Basic Design* and *Safety Justification Report*; the two latter were approved by the relevant authorities. The researchers of the Laboratory also participated in preparing the *Detailed Design*, which was reviewed and submitted to the contractor. The characteristics of the equipment of building 117/1, waste amounts and their characteristics were analysed and economic assessment of the planned decontamination and dismantling activities was carried out by laboratory specialists. Following the prepared documentation, the INPP started the work of dismantling and decontamination of equipment installed in Building 117/1 on 1 December 2010 and completed them in October 2011.

In 2012, Lithuanian Energy Institute, as partner of consortium Babcock (UK) – LEI – NUKEM Technologies GmbH (Germany), completed the project ***Ignalina NPP Building V1 Equipment Decontamination and Dismantling*** (2009–2012). In 2010 Specialists of the Laboratory completed *General Data Set*; in 2011 they prepared



DECRAD software

Environmental Impact Assessment Report and received its approval from the Ministry of Environment, whereas in 2012, *Basic Design* and *Safety Justification Report* were agreed with the authorities, whereas the *Detailed Design* was completed in 2012. The employees of Ignalina NPP initiated dismantling and decontamination activities of Ignalina NPP building V1.

In 2009, the specialists of the Laboratory developed ***DECRAD*** software intended for 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. In 2012, the specialists upgraded the software code ***DECRAD***. It was successfully applied in the scope of the project ***Ignalina NPP Building V1 Equipment Decontamination and Dismantling***.

In 2012 performing project ***CARBOWASTE*** multi-criteria decision analysis methodology was acquired. The analytic hierarchy process was identified as the most effective method for choosing nuclear equipment dismantling strategies. Nuclear equipment dismantling strategies were developed, whereas a list of qualitative and quantitative criteria, comprised of higher level criteria (waste flows, expenses, duration, safety, technological, environmental and social) and lower level criteria, was developed. Primary data was processed and quantitative criteria values for different dismantling strategies were estimated applying software package DECRAD. The analysis of dismantling strategies and strategies' ranking results were obtained by applying AHP method. The investigations were expanded in previously discussed state budget financed scientific project, where probabilistic assessment of uncertainty of alternative ranking relative weights was carried out as well as sensitivity analysis of alternatives' relative weights.

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

Two alternatives of pipelines dismantling were analysed, the efficiency of respiratory safety measures was estimated as well as their impact on the general effective dose of the sawyer. Computer soft-

G. Poškas and Dr. A. Šimonis at international conference ICRS-12 (02-07 September 2012, Nara, Japan)

ware VISIPLAN (Belgium) was applied while estimating the direct effective dose of the sawyer from radioactive equipment.

In 2012, Lithuanian Energy Institute, as a partner of international consortium (JSC *Specialus montažas - NTP* – FTMC – LEI – ATP (Bulgaria) – INRNE (Bulgaria) – VNIIAES (Russia) started a project ***Evaluation of the Material Backlog and Radiological Inventory of Kozloduy NPP Units 1 to 4***. 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 units under decommissioning.

In 2012 the experts of the laboratory developed database to accumulate project results and provided technical assistance to consortium partners.

Since 2002, the Laboratory is performing fire hazard assessments in the nuclear power plants and other important facilities. In consultation with Swedish experts, the Laboratory specialists assessed the fire hazard of Units 1 and 2 of Ignalina NPP. Fire hazard assessment of some renewed INPP rooms and newly designed INPP SNF and radioactive waste storage facilities were carried out as well. An external fire impact on the new INPP facility 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 report on B19 facility (Buffer storage of the Landfill repository) fire hazard analysis based on detailed project documentation was updated in project ***Installation of very low activity radioactive waste repository (Landfill)***. This report was approved by the authorities in 2012.

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 Labo-

ratory). According to the EIA Report of 2009, positive conclusions of the competent authorities were made concerning the planed economic activity and, therefore, following this EIA Report, the Ministry of Environment has made a motivated decision on the construction possibilities of new nuclear power plant.

The researchers of the Laboratory are participating in the research projects coordinated by IAEA, namely:

- ***Treatment Requirements for Irradiated RBMK-1500 Graphite to Meet Disposal Requirements in Lithuania*** (2010–2014).
- ***Investigation of RBMK-1500 Spent Nuclear Fuel and Storage Casks Performance during Very Long Term Storage*** (2012–2016).

Researchers of the laboratory are participating in four EU's 7th Framework Programme funded projects. Two of them are scientific research projects (they are already mentioned above):

- ***Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste (CARBOWASTE)*** (2008–2013).
- ***Fate of Repository Gases (FORGE)*** (2009–2013).

The remaining two – coordination and support action projects:

- ***New MS Linking for an Advanced Cohesion in Euratom Research (NEWLANCER)*** (2011–2013). 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 2012 national and regional meetings of experts took place in Hungary and Bulgaria, during which the course of activities, results and future perspectives were discussed. The representative from LEI in these meetings presented the overview of Lithuanian science research institutions participation in EURATOM program as well as the results of strength, weakness, possibilities and hazards' analysis performed by LEI experts, national strategies and programs in the field of radioactive waste and spent nuclear fuel management.
- ***Sustainable network of Independent Technical Expertise for Radioactive***

Dr. A. Šmaižys at NEWLANCER meeting at the Hungariane Academy of Sciences (02 April, 2012, Budapest, Hungary)

Dr. A. Narkūnienė and G. Poškas at SITEX meeting at IAEA's headquarters (24 May, 2012, Vienna, Austria)

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. The network also aims at assessing the demand for independent scientific research, recommendations for technical expertise, etc. In 2012 the comparison of the repository safety related requirements, recommendations, technical expertise methodologies were carried out.

MAIN RESULTS

In 2012 the Laboratory (26 employees) completed a state subsidy funded research work ***Probabilistic Uncertainty Assessment of Radiation Impact during the Analysis of NPP Dismantling and Radioactive Waste Managing*** (2010–2012), and also the project ***Ignalina NPP Building V1 Equipment Decontamination and Dismantling*** (2009–2012), in which laboratory experts were participating, was finalised.

Researchers of the laboratory carried out 13 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 presented 7 papers at international conferences (Malta, Belarus, France, Japan and Lithuania) and published 14 scientific articles in the Lithuanian and international journals.

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

MAIN RESEARCH AREAS OF THE LABORATORY:

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

In 2012, 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 long-term institutional scientific research and experimental development program; 14 international projects (6 projects of the EU 6th and 7th Framework Programmes (FP); 3 projects funded by the Lithuanian economy subjects.

1. NATIONAL RESEARCH PROGRAMME *ENERGY FOR THE FUTURE*

In 2012, two projects, financed by the Research Council of Lithuania, were implemented 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 analysis for the Lithuanian energy systems using the methodology developed in the framework of project *Research and Assessment Methodology of Energy Systems Reliability and Its Impact on Energy Security* in 2010-2011 supported by Research Council of Lithuania.

The project is to be implemented by the end of 2014. In 2012 mainly preparation tasks were performed like collection

of initial data, their processing and preparation of models and modeling tools for energy systems. Reliability data for individual systems components as on their basis further reliability and risk analysis for the energy systems will be performed. During reporting period, data on energy systems (electric power, heat supply and gas) and their failures were collected. These data were analyzed and reliability measures were determined for individual systems' components. If new data or other information during the execution of this project will become available - update of reliability parameters is foreseen. From the obtained data and analysis of the results - electronic data bases were prepared. Storage of data in an electronic form will allow to speed-up reliability assessment process as data can be linked directly to the modeling tools.

Aiming at estimating DHS reliability, the main factors which may have influence to the reliability of individual system elements were identified. Also, analysis of the failure causes based on the statistical data was performed and as result the main causes of pipeline failures were identified. In this stage, initial thermal-hydraulic model for Kaunas city DHS was prepared, which will be used to perform thermal-hydraulic heat supply system analysis.

During this project phase the analysis of gas supply failure causes and ageing processes has been performed. Since Lithuanian gas supply system is rather small thus in order to obtain reliable results the collected data were analyzed and compared to corresponding data from other countries (Russia, Western Europe, USA, UK). Following the analysis it was concluded that failure distribution for Lithuanian gas network is similar to the failure distribution of Russian gas network.

Pipeline segments from operated gas pipeline were selected and samples were cut-out for further experimental investigations according to the newly developed methodology. These experimental results will be used in further project stages while performing structural integrity and probabilistic fracture analysis. Obtained initial results will allow continue tasks foreseen in the project work plan in order to perform detailed reliability and risk study of energy systems. The results obtained will be used for Lithuanian energy security study conducted under other project ongoing within national research programme *Energy for the Future*.

In 2012 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 initiated. The objective of the project is to estimate Lithuanian energy security and perform its research in accordance with the methodology developed in Lithuanian Research Council 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 threats evoking biggest social stress and social instability.

2. NUCLEAR INSTALLATIONS SAFETY RESEARCH

The researchers of the Laboratory are participating in advanced international scientific research projects that are aimed at developing new nuclear reactors and solving other relevant issues, related to the nuclear safety. Additionally, the researchers take part in projects that aim at training and sharing knowledge in nuclear energy area with other national infrastructure organizations. These projects are important in strengthening the Lithuanian competence in the nuclear energy field which is necessary for every country owning nuclear power objects (NPPs, nuclear fuel and radioactive waste storage and disposal facilities, etc.).

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

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

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 reactors and nuclear fusion facilities. At present there is no unified safety assessment methodology, whereas deterministic and probabilistic safety analyses employed for safety assessment do not take into account interrelations between these analyses. The performed work is complex, 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 modelling, etc.

In 2012 the aspects of interactions between deterministic and probabilistic safety analyses were identified, the methodology of initial events and their combinations selection was prepared, the overview of new generation nuclear reactors and nuclear fusion installations as well as experiments (PHEBUS, QUENCH) performed for investigation of processes occurring in fuel assemblies during severe accidents was carried out, the list of possible accidents for nuclear fusion installation W7-X was developed, scenarios of hydrogen gas and water vapour release to

the protective shield atmosphere were selected for further analysis. A number of program stages were initiated devoted to research of safety important processes occurring in new generation nuclear reactors and nuclear fusion facilities, and to prepare umbrella unanimous (deterministic and probabilistic) safety assessment methodology.

Research performed during program implementation will greatly contribute to improving the competence of Lithuanian researchers in the field nuclear energy, which is necessary aiming at estimating safety of nuclear power plants constructed or to be constructed both in Lithuania and neighbouring countries in all NPP lifetime stages – selection of NPP, design, construction, operation and its decommissioning, and management of spent nuclear fuel and radioactive waste. 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.

VAE
Visagino atominė elektrinė

Work for Visaginas NPP

In 2012, under the agreement ***Update and Complement of Assessment of Potential Visaginas NPP Construction Sites in Respect of External Events*** between *JSC Visaginas NPP* and LEI, additional research was continued by analysing the following external factors: human induced events, meteorological phenomena and site flooding. The aim of this project is to assess the suitability of potential sites for Visaginas NPP construction following the Nuclear Safety Requirements, newly approved by State Nuclear Power Safety Inspectorate (VATESI) of the Republic of Lithuania, and the updated Safety Requirements of International Atomic Energy Agency (IAEA) as well as taking into account the results of up-to-date research and data. All work is divided into five separate tasks/ topics: Update of Hazards and Events Assessment, Detailed Assessment of Gas Explosion, Description of Possible Actions due to Extreme Situations, Description of Physical Protective Means Application Possibilities, and Assessment of Ultimate Heat Sink Characteristics. In 2012, additional research was carried out by assessing unintentional human induced events, meteorological and flooding hazards, also technical certificate *Survey of Statistical Data and Probabilistic Methods* was prepared, and finally, the initial data and updated final reports of separate topics, agreed with the competent authorities, were submitted to the Client.

At the end of 2012 new short term agreement ***Update, Complement and Adjustment of Assessment of Potential Visaginas NPP Construction Sites in Respect of External Events with the Parties Concerned*** was implemented. According the Resolution No. 83 of the Government of Lithuania "On the procedure for review of NPP construction site evaluation report" issued on 25 January 2012 and taking into account the comments of the parties concerned and mentioned in this Resolution, and after updating simulation models several times and recalculations, the following documents were updated/prepared: *Update of the evaluation of man-made unintended events* (1st part in final report); *Update of the evaluation of meteorological hazards* (2nd part in final report); Technical note *Review of statistical data and probabilistic methods*; Final reports *Assessment of ultimate heat sink characteristics and flooding risks* and *Detailed assessment of gas explosion*.

Research results performed during research may greatly contribute to making decisions regarding specific VNPP construction site and planning its risk management. According IAEA recommendations, after receiving significant information, the analysis of external events should be updated in the future.

SARnet

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

The work of the project ***SARNET-2*** was continued in 2012 (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 at NPP;
- WP5 COOL – cooling of melted core and remaining debris;
- WP7 CONT – analysis of processes in containments of NPP.

While implementing these activities, the researchers of the Laboratory participated in the meetings of ASTEC users and separate working groups. They participated in ERMSAR-2012, which took place on March 20-24, 2012 in Koln, Germany. The meeting was organized by ASTEC developers IRSN (Institut de Radioprotection et de Sūreté Nucléaire) and GRS (Gesellschaft für Anlagen-und Reaktorsicherheit). During the meeting participants of SARNET exchanged the experience on implemented experiments and ASTEC computer code possibilities, application perspectives, recently performed improvements.

On October 3-5, 2012 the overview meeting of SARNET-2 work-package WP5 COOL took place in Budapest (Hungary). This working group deals with the issues of cooling of molten core and remaining debris during severe accidents. During meeting the group activities and future plans were discussed. LEI participate in three WP5 COOL tasks, namely:

- WP5.1 – reflooding and cooling of damaged core;
- WP5.4 – application of research results for reactors;
- WP.5 – analysis of processes in spent nuclear fuel pools.

In these tasks the core heat up and reflooding test performed in QUENCH test facility was modelled using RELAP5 and ASTEC codes. Fukushima NPP Unit IV spent fuel pool was simulated applying ATHLET-CD. Primary water cooling loss accident modelling results were presented. Hypothetical accidents in Ignalina NPP Unit2 spent nuclear fuel pool were simulated. These analyses were performed making a presumption that the pool is filled with fuel assemblies from the reactor core and heat release in the pool is maximal. The current situation in Ignalina NPP Unit 2 spent nuclear fuel pool was analysed as well.

On February 14–15, 2012 meeting of work-package WP7 CONT took place in Bled (Slovenia), where performed activities and achieved results were discussed. LEI participated in two WP7 CONT tasks:

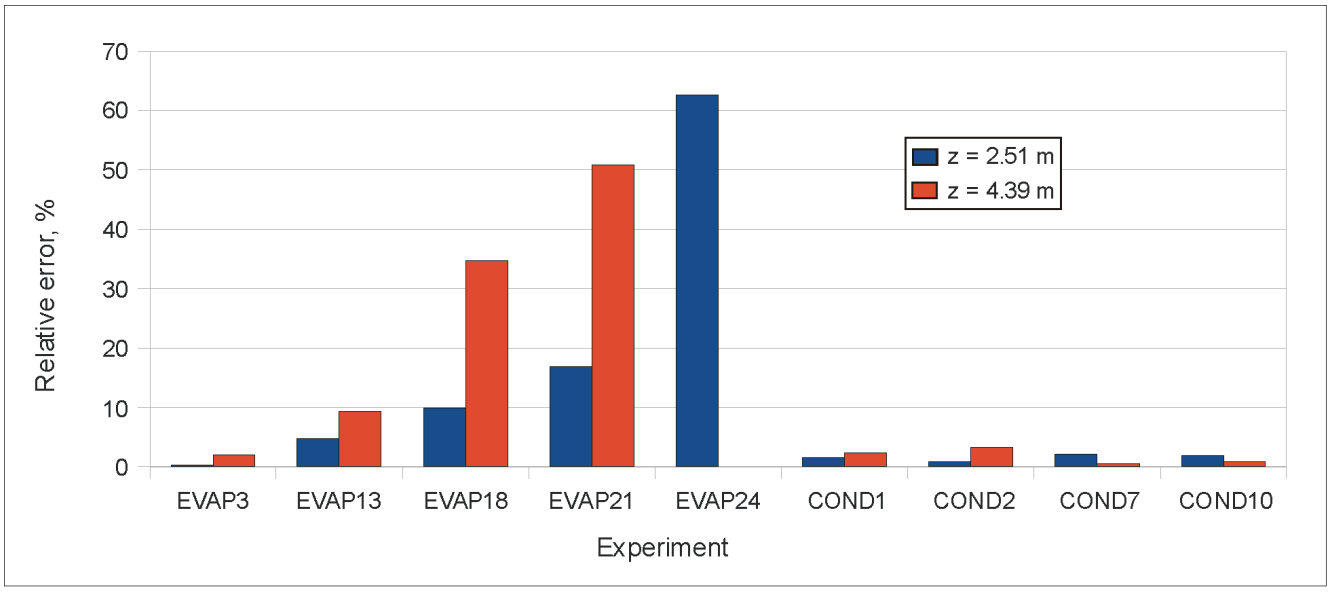
WP7.2 – Hydrogen mixing and combustion in containment, and

WP7.3 – Bringing Research results into reactor application.

The interaction of water droplets and containment atmosphere is a significant research object since in case of hypothetical severe accident water spray systems installed in NPP containment would be used to avoid dangerous pressurisation due to steam release and to ensure homogeneous gas concentration distribution in volume thus preventing from the formation of dangerous local hydrogen concentrations. Therefore when performing the first WP7.2 task *Modelling of containment sprays* experiments were performed in France, meanwhile the remaining project participants, among them LEI as well, conducted simulations using different computer codes (LEI – with COCOSYS).

Total 9 experiments were performed, 5 of them for analysis of droplet evaporation (EVAPi) and the other 4 for analysis of steam condensation on droplet (CONDi). Summarizing performed analyses it was obtained that in the case of steam condensation on the droplets the relative errors are small whereas modelling droplet evaporation is not such accurate. In 2013, it is planned to continue research on the sprays impact on gas mixing in the containment.

Participating in the third WP7.2 task, *Hydrogen combustion* in the containment was analysed. In 2012 research were expanded in analyzing the impact of impurities on hydrogen combustion process. Experiments were performed in ENACCEF facility located in France, comprised of two parts – the 3.2 m length narrow "acceleration tube" and 1.9 m length cylindrical wider part (diameter 726 mm). In the beginning of test combustible mixture is ignited and flame further spread upwards in the facility. Four experiments were selected for benchmark calculations, which differed from each other according impurities part in the mixture. The impurities were comprised of 60% of carbon dioxide and 40% of helium.

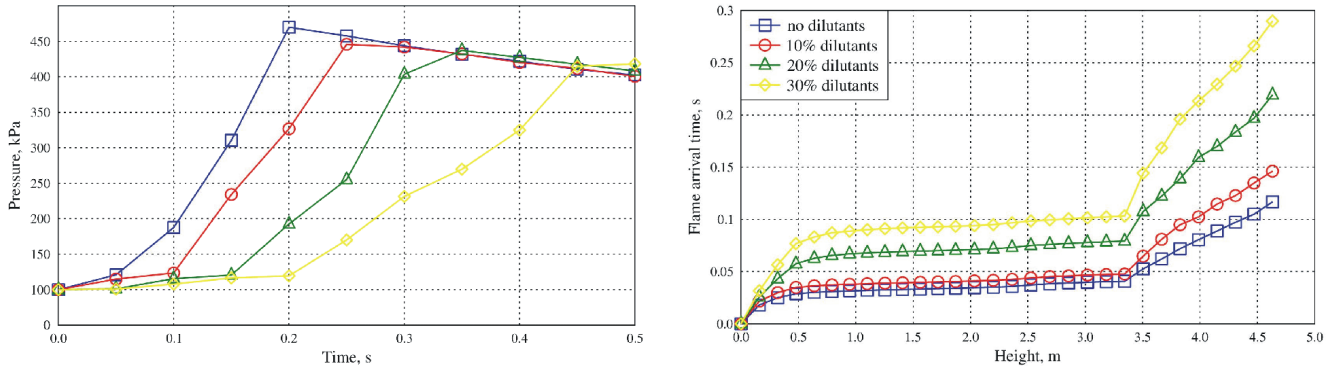


Correspondence of drop size modelling results to experimental data

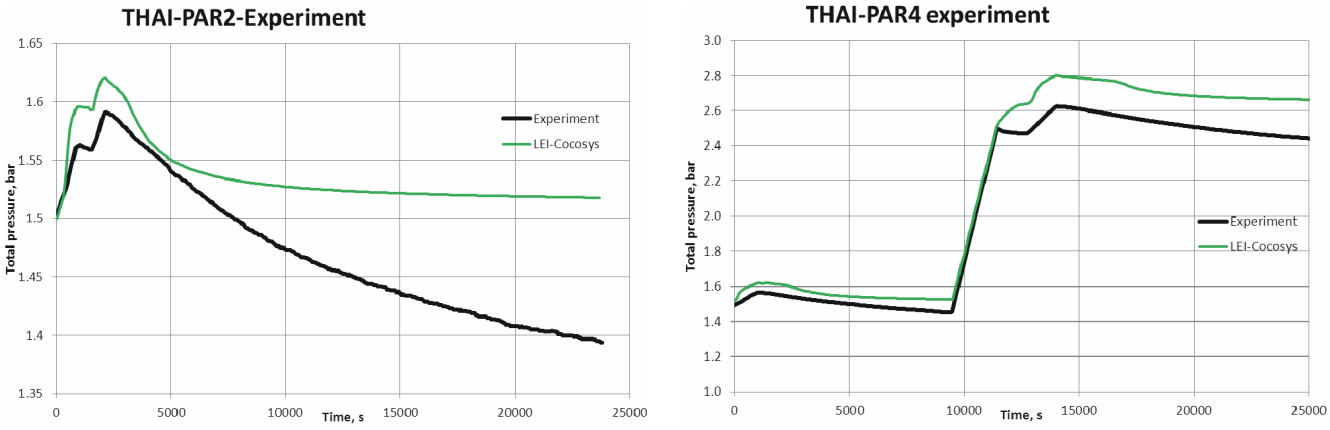
ENACCEF facility

In the analysis it was determined that with the increase of impurities in gas mixture, pressure increases slower during hydrogen combustion, and maximum pressure value is smaller. With the increase of impurities in gas mixture hydrogen combustion velocity is smaller and flame approaches the top of the facility later. Hydrogen combustion velocity during experiments was defined in time during which flame reaches measurements devices present at different height of facility.

LEI also participated in WP7.3 task *Modelling analysis of passive autocatalytic recombiners*, devoted to compare the specific correlations (designed to model these processes) implemented in different codes. Passive autocatalytic recombiners are one of the means to reduce hydrogen concentration in the containment of NPP. The in-

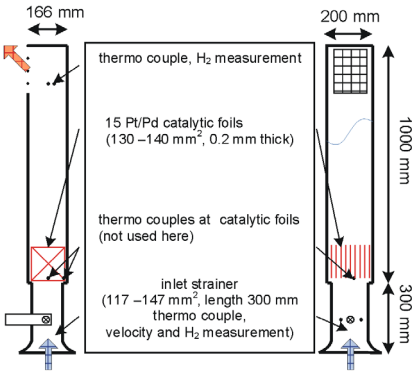


Variation of pressure and flame expansion time in ENACCEF facility (LEI results)



Comparison of measured and calculated pressure during PAR2 and PAR4 tests (LEI results)

teraction of these devices with gas and steam mixture in the containment is one of the most significant tasks when analyzing issues of the containment atmosphere interaction with safety systems. Performing this task two experiments (PAR2 and PAR4) performed at THAI facility were simulated employing AREVA-Siemens manufactured PAR type FR90-150. The hydrogen, air and steam mixture enter this device from the bottom and passes the catalytic plates. During chemical reaction hydrogen burns out on the surface of the plates and turns into steam. PAR4 experiment was longer, during which additional amount of air was supplied to the vessel.



AREVA-Siemens passive catalytic hydrogen combustion facility FR90-150 with additional measurement equipment

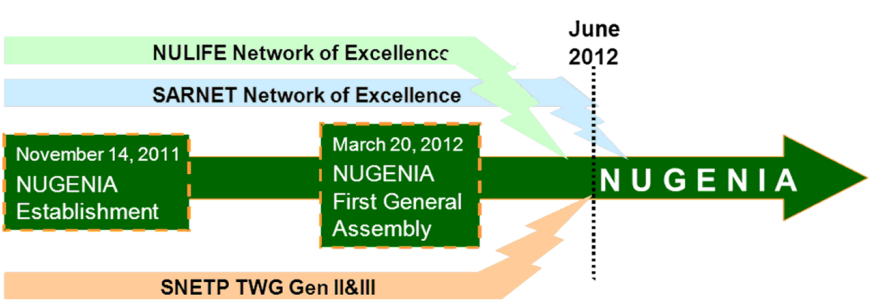
According the obtained results a conclusion may be drawn that using COCOSYS code it is possible to simulate basic processes occurring when hydrogen interacts with passive autocatalytic recombiners, however, the implemented hydrogen recombination models should be updated in the future.

Network of Excellence of Nuclear Plant Life Prediction

In 2012 the activities of EU 6FP NULIFE (***Nuclear Plant Life Prediction***) were completed. The implementation of this project is done by a consortium comprised of 10 organization participants and 27 contract partners, the coordinator – VTT Technical Research Centre of Finland. In 2012 researchers of the Laboratory participated in the activity of Expert group (IA-2) and in the organized meeting. Together with other project executers they prepared the final version of report *Review of Assessment Methods Used in Nuclear Plant Life Management*.

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 technologies, 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. NUGENIA scope of activities covers 7 main technical areas, and includes research directions defined by SNETP *Strategic Research Plan*. Lithuanian Energy Institute is a member of NUGENIA association and together with other ETSON organizations actively participate in all seven NUGENIA R&D areas.



NUGENIA – result of integration – (source www.nugenia.org)

European Technical Safety Organisations Network

The scientists of the Laboratory of Nuclear Installation Safety participate in the activities of the ***European Technical Safety Organisations Network (ETSON)*** since 2009.

Main objectives of ETSON are as follows:

- Form a suitable forum for voluntary exchanges on analyses and R&D in the field of nuclear safety by sharing experiences and exchanging technical and scientific opinions;
- Contribute to fostering the convergence of technical nuclear safety practices within the European Union and beyond;
- Further the planning of nuclear safety research programmes and facilitate their implementation;
- Facilitate the application of the European directive on the nuclear safety;
- Work together in safety assessment and research projects.

LEI and its representatives take active participation in all major ETSON groups. The researchers of the Laboratory

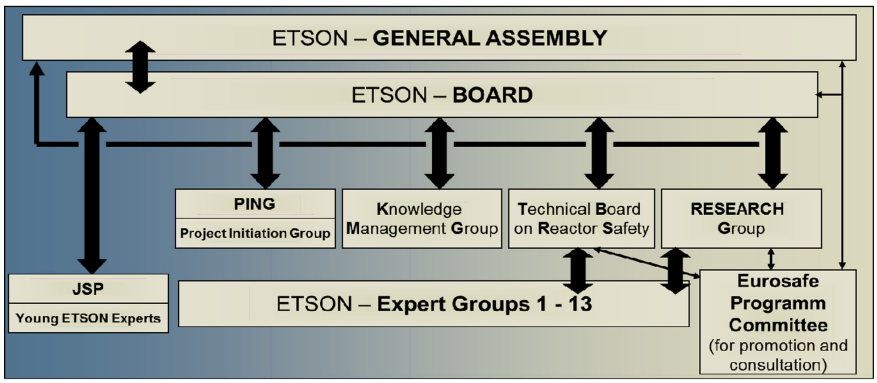
actively participate in the following ETSON groups:

- Operating Experience Feedback, including Incident and Precursor Analysis;
- Mechanical Systems;
- Electrical Systems;
- Severe Accidents;
- Environmental Qualification;
- Safety Fluid Systems, including auxiliary systems;
- Human and Organizational 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.

Recently most active were safety fluid systems, probabilistic safety analysis, severe accidents and thermal hydraulic analyses expert groups. Experts of the Laboratory actively participated in the group meetings and had great input in analyzing available documents and correcting prepared technical safety assessment guides. New version for Technical Safety Assessment Guide *Deterministic severe accident analysis* was prepared, *Safety fluid systems safety assessment guide* is under finalization, and review of different probabilistic safety analysis documents was carried out.

Aiming to activate ETSON activities, to conduct technical program quality review function and provide scientific support to ETSON Board and General Assembly in their decision making processes, in autumn of 2012 ETSON Technical Board of Reactor Safety was established. The first meeting of this Technical Board took place

ETSON General Organisation



in Brussels at Be1V compartments. Representatives from BelV (Belgium), GRS (Germany), IRSN (France), LEI (Lithuania), VUJE (Slovakia) and SEC NRS (Russia) attended the meeting. Most of attention was devoted to coordination of expert groups' activities and discussion of Technical safety assessment guides. Technical safety assessment guides prepared in expert groups summarize best experience of European technical and scientific support organizations (TSOs) and in such way this will be support to individual TSOs in conducting safety assessment reviews. Documents regulating safety assessment review performance, prepared in the expert groups, were discussed at the Technical Board on Reactor Safety. Later, on November 7, 2012 in ETSON General Assembly meeting the following Technical safety assessment guides were approved:

- *Human and organisational factors in nuclear facilities design and modification processes;*
- *Deterministic severe accidents analysis;*
- *Event review and precursor analysis*.

These documents will be useful in performing safety assessment and preparing national nuclear safety regulating documents.

One of major objectives for ETSON Research group is identification of priority scientific research directions in the field of nuclear safety, submission of recommendations for international organizations, such as SNETP and NUGENIA. Thus ETSON contributes to presently prepared documents *NUGENIA Research Roadmap* and *Strategic Research and Innovations Agenda*, influencing EU scientific research policy in nuclear energy. In ETSON research group meetings, which were held in 2012 and where representative of the LEI attended, most attention has been given to the consideration of above mentioned documents. In order to ensure that these documents are expressed ETSON identify research priorities, which are published in a document *Research needs in nuclear safety for gen 2 and gen 3 NPPs,* during the meeting ETSON organizations distributed work pro-

EUROSAFE Program committee in LEI, Kaunas

viding comments for the NUGENIA activities.

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

ETSON actively participate in organizing annual *EUROSAFE* Conferences, which are one of the most significant events organized for nuclear safety. *EUROSAFE* Program committee (EPC) was established with the objective to coordinate the organization of conferences.

Preparing for *EUROSAFE* conference *Towards strengthened nuclear safety* on November 5-6, 2012 in Brussels, one of the meetings was organized in June 2012 in Kaunas, at LEI premises. Representatives from BelV (Belgium), GRS (Germany), IRSN (France), SSM (Sweden), UJV (Czech Republic), VTT (Finland) and LEI (Lithuania) attended the meeting.

At ETSON General Assembly meeting, which took place on November 7, 2012, it was admitted that ETSON Junior Staff Program summer workshop on accident management issues as well as *EUROSAFE* Program committee meeting will be held at Lithuanian Energy Institute on August 25-30, 2013.

Safety Assessment of Innovative Reactors

The 7FP project ***SARGEN_IV*** was initiated in 2012. The objective of this project is to develop a coordinated European methodology, devoted to safety assessment of innovative fast neutron spectrum reactors, planned to be built in Europe. The project is coordinated by the Institute for Radiological Protection and Nuclear Safety (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 three working groups: (1) review of safety assessment methodologies of innovative reactors; (2) application of the European safety methodologies; (3) development the European Action Plan for the scientific research in the field of safety of fast neutron reactor technologies. LEI was coordinating the activity in the Task *Review of available international documents for the safety assessment of Generation IV reactors* in the first mentioned working group. Together with colleagues from Belgian Nuclear Research Center and Polytechnic University of Madrid researchers of LEI performed the review of documents regulating safety assessment of international innovative reactors. In the prepared report the information on modern nuclear reactor safety assessment later were completed by other project participants, adding the experience of creating the integrated fourth-generation nuclear reactor safety assessment methodology.

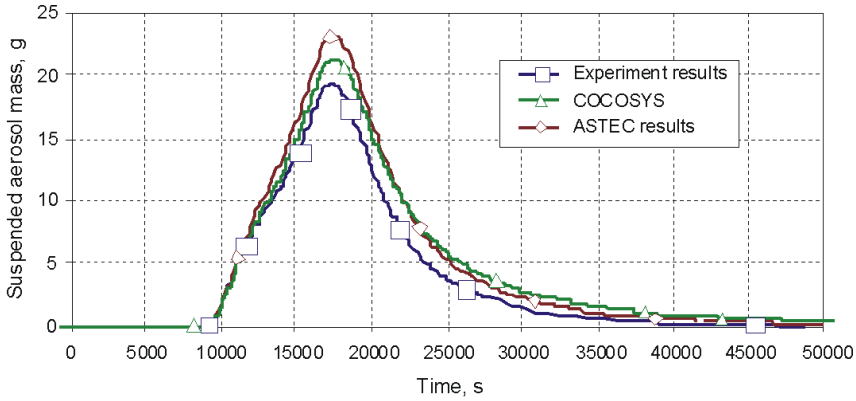
Classification according to generations reflect development of reactors – from the very first nuclear reactors, which are attributed to Generation I to the still developed future reactors, which are attributed to Generation IV. To GEN IV belong high temperature and supercritical water parameter thermal neutron reactors as well as fast neutron reactors. In SARGEN-IV project four prototypes of reactors of Generation IV were distinguished: (1) gas cooled fast neutron reactor, (2) liquid sodium cooled fast neutron reactor, (3) liquid metal (lead) cooled fast neutron reactor, (4) lead-bismuth cooled facility operating as accelerator.

Further continuing SARGEN-IV project LEI participates in conducting the sample application of proposed safety method. As a result, the prepared methodology will be improved, it is also foreseen to prepare recommendations for further research projects devoted to development of different prototypes of GEN IV nuclear reactors. The project to be completed in 2013.

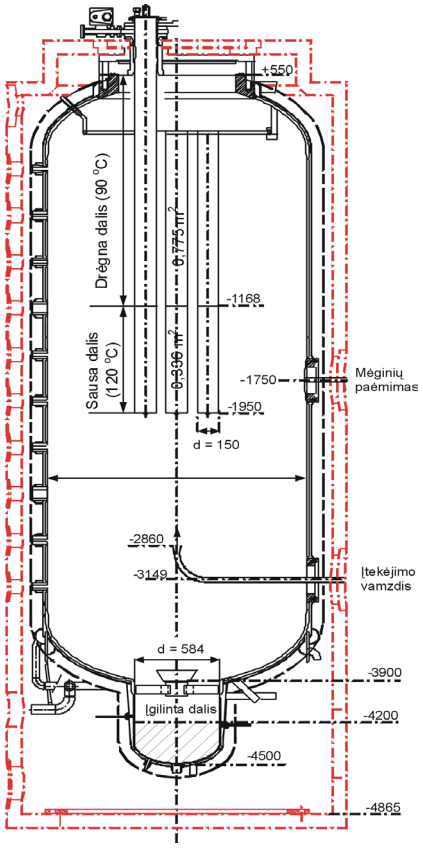
Experts of Laboratory continued activities in ***PHEBUS-FP*** programme, which was finished in 2012. It was one of the largest international research programmes for water-cooled nuclear reactor safety and severe accident research. IRSN (France) initiated the programme in 1988 and coordinated it. Applying COCOSYS code, LEI performed simulations of the phenomena in PHEBUS containment. Aerosol and radionuclides from the damaged nuclear fuel enter the containment via special pipe, directed up towards three condensers comprised of two parts – one part is heated, the other one is cooled. With these condensers it is imitated that in real containment during accident there may exist structures of different temperature. The external containment walls are heated in order to reduce aerosol deposition on them. Different parameters were measured and samples were taken in order to identify the concentration of aerosols in the air. Analogous nodalisation for ASTEC-CPA code was developed in order to estimate the accuracy of calculations performed with COCOSYS code. The obtained results revealed that using both codes more aerosol mass present in the air is calculated than measured, however the aerosol deposition distribution obtained using ASTEC code is closer to the measured.

Distribution of aerosol precipitation

	Containment bottom	Condensers and sump	Containment wall and sampling
Measured FPT2	74.0%	14.0%	12.0%
COCOSYS	86.0%	13.28%	0.72%
ASTEC	82.98%	14.88%	2.14%



Aerosol mass present in containment gas phase



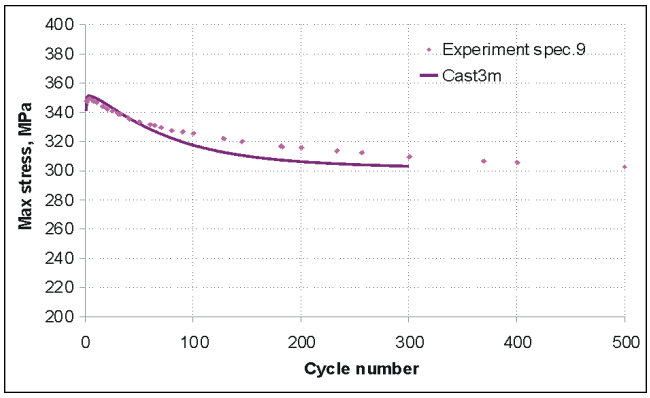
Scheme of PHEBUS containment

MATTER

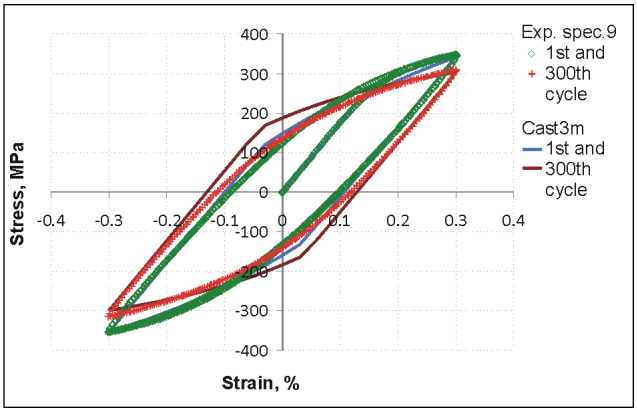
MATerials TEsting and Rules

On 13 December 2010, a new agreement on the EU 7FP project ***MATerials TEsting and Rules*** was signed. This project started on 1 January 2011 and was continued in 2012. The Laboratory of Nuclear Installation Safety and the Laboratory of Materials Research and Testing are participating from LEI side. Its main objective is to carry out detailed research of material behaviour during the operation of GEN IV reactors.

In 2012 research on obtained base P91 steel were performed and fatigue testing methodology was specified. Research of steel baseline properties was conducted and characteristics which are significant for assessment and control of further research were identified. Samples were manufactured and part of fatigue experiments, necessary for fatigue curve formation, were performed. After investigating the welded samples and the fatigue curve, 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 under fatigue behaviour. 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.



Max stress vs. cycle number



Hysteresis loop on the 1st and 300th cyles

Support to Inspecta Nuclear AB, the authorizes third party, in performing PLEX Oskarshamn 2 project expertise

Project PLEX is devoted to NPP upgrade and plant lifetime extension. One of the comprising parts of this project is calculations of piping system structural integrity, justifying acceptability of the systems under new loads (due to power increase) and longer lifetime period. The researchers of the Laboratory participated in this project by reviewing structural integrity assessment reports of Oskarshamn 2 NPP individual piping systems.

International Reactor Innovative and Secure

In 2012, according to the plans for the project ***IRIS International Reactor Innovative and Secure (IRIS***) and the joint agreement between project participants and *Westinghouse Electric Company LLC*, the previously performed research for the preparation of the conceptual IRIS project was summarised and presented in a separate Chapter "Analysis of Emergency Planning Zones in Relation to Probabilistic Risk Assessment and Economic Optimization for International Reactor Innovative and Secure" of the book *Nuclear Power Plants*. IRIS project and the related research of *Westinghouse Electric Company LLC* were completed on 29 November 2010. More than 20 companies and 10 countries participated in the implementation of the project, which took 10 years. During this time, the researchers of LEI participated in the preparation of inter-comparative methodologies and work supervision related to the structural, economic, strength, safety and security research of new reactors. In the recent years, the specialists of the Laboratory of Nuclear Installation Safety have participated in performing IRIS probabilistic safety and economical efficiency analysis and research, devoted to reduce the risk of various external hazards and the uncertainty of the obtained results. As the building of a new NPP in Lithuania is planned, scientific research in this field is relevant for studying the construction of new reactors. The carried on contribution to IAEA technical documentation can be also mentioned as one of the most important activities: Advanced nuclear power plant design options to cope with external events (IAEA-TECDOC-1487) and Small reactors without on-site refuelling: neutronic characteristics, emergency planning and development scenarios (IAEA-TECDOC - 1652). Previously performed research related with IRIS uncertainty and sensitivity analysis in performing economical optimization of new energy sources in Lithuania were published in 2012 journal *Progress in nuclear energy*, in ISI article *Uncertainty and sensitivity analysis for economic optimisation of new energy source in Lithuania*.

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

European Nuclear Safety Training and Tutoring Institute

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

In 2012, ENSTTI organised 4-week summer training (11 June – 06 July) in Germany (GRS). The researchers of the Laboratory gave lectures on the NPP dismantling strategies and particular issues of Ignalina NPP dismantling. 16 participants from Armenia, Belarus, Czech Republic, United Emirates, Jordan, Poland, Lithuania, Morocco, Turkey and Ukraine participated in the summer training.

ENSTTI became even more active since it had submitted applications to IAEA and the European Commission regarding the organization of training, namely *Training and tutoring for nuclear regulatory authorities and their technical support organizations*. In the frame of this project ENSTTI consortium (LEI (Lithuania), IRSN (France), GRS (Germany), SSTC (Ukraine), ENEA (Italy) and VUJE (Slovakia)) conducts activities according task LOT2 *Nuclear Safety Assessment and Inspection*. The training and tutoring is devoted to 15 countries developing nuclear energy: Tunis, Indonesia, Malaysia, Jordan, Belarus, Georgia, Vietnam, Morocco, Philippines, Russia, Ukraine, Armenia, Egypt, Mexico and Brazil. By the year 2014 total 27 one week training courses will be organized within the scope of the project. 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 2012, LEI researchers gave 19 lectures in five training courses, namely:

1. *Thermal-hydraulics and reactor criticality safety*, Bologna, Italy, September 24–28.
2. *Ageing of equipment and mechanical analysis*, Koln, Germany, October 19–23.
3. *Safety of nuclear reactors I*, Bologna, Italy, November 26–30.
4. *Safety of nuclear reactors II*, France, November 26–30.
5. *Assessment of nuclear installations with respect to fire safety*, Koln, Germany, December 3–7.

The first training course *Thermal-hydraulics and criticality safety of reactors* was completely prepared by LEI and ENEA (Italy). During lectures the experts talked about nuclear criticality and its assessment with software packages, thermal-hydraulic processes in nuclear reactors, requirements for thermal-hydraulic analysis and software packages used for such analysis. Also during working class the trainees had the opportunity to simulate the reactor core. During training courses devoted to equipment ageing and mechanical analysis as well as nuclear reactors safety, lectures were given on processes and mechanisms evoking facility ageing, modelling of these processes, specificity

Students and lectors of training course ***Thermal-hydraulics and reactor criticality safety*** *in Brasimone nuclear research centre (Italy)*

of GEN III nuclear reactors, nuclear safety regulating documents, specifics of nuclear power plants' dismantling and Ignalina NPP experience in this field. The trainings on assessment of nuclear installations with respect to fire safety was devoted to familiarize the representatives from different countries' nuclear energy regulatory institutions and their technical support organizations with physical basics of fires, calculation methods and applied computer codes, fire risk and probabilistic safety analysis basics, as well as the practice of fire safety and regulatory institutions' control in different countries.

LEI experts gave lectures on the following topics:

- *Goals of deterministic and probabilistic fire safety analysis;*
- *Fire risk analysis – preparation, results and assessment;*
- *Data exchange between fire hazard analysis and fire probabilistic safety analysis;*
- *Use of fire hazard analysis and fire probabilistic safety analysis and examples of safety improvements.*

Participation of LEI in the mentioned activities enables acquiring experience in organizing similar courses and improving qualification. Such experience may be useful after the beginning of Visaginas NPP construction, when providing qualification for new staff at the power plant and supervisory institutions.

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

In 2012 LEI continuing the co-operation with *RISKAUDIT IRSN/GRS INTERNATIONAL (GEIE)* in the project ***Transfer of Western European Regulatory Methodology and Practices to the Nuclear Safety Authority of Belarus – Institutional and Technical Cooperation with Gosatomnadzor to Develop its Capabilities on the Basis of Transferred Western European Safety Principles and Practices***, organized by the European Commission and *RISKAUDIT*.

Under this agreement, the researchers of LEI take part in the activity of the following four working groups: (1) development of nuclear safety legislation; (2) support of nuclear safety licensing by establishing a regulatory institution and developing its functions; (3) training of the employees at the regulatory institution; (4) training of the employees at the educational institutions of the Ministry of Emergency Situations. In cooperation with the project partners, the specialists of the Laboratory participated in the workshops, organized by different working groups, where they presented international nuclear safety requirements and the experience of the European regulatory institutions and technical support organizations related to nuclear power plant safety assessment and licensing of nuclear objects. LEI was appointed as the leader of the fourth working group and is coordinating the activity of the Lithuanian, Ukrainian and Finish specialists in organizing and running workshops for the employees of the educational institutions of the Ministry of Emergency Situations of Belarus.

In February 2012, the researchers of the Laboratory organized a five-days workshop in Minsk, Belarus. Together with the Ukrainian and Finish partners, they presented the overview of newly published IAEA Specific Safety Guide SSG-18 on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations and the main principles of on-site and off-site emergency preparedness in nuclear power plants as well as public information on accidents. Methodology of preparation of training courses and lecturers' preparation for such trainings (taking into account nuclear safety specificity) was presented. These issues were relevant since the trainees were employees of Belarus Ministry for Emergency Situations who in the future they will have to organize similar nuclear safety trainings in preparing Belarus specialists for elimination of the consequences of nuclear accidents, if it is a case.

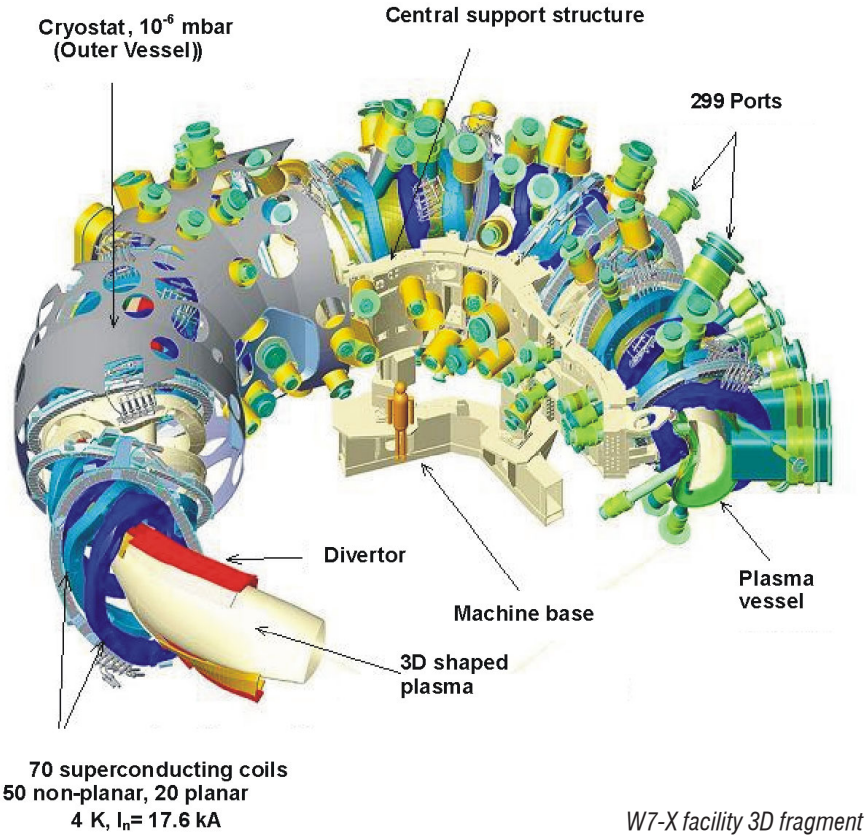
Such support, provided for the neighbouring country, is necessary in order to ensure timely and efficient supervision of the newly-built nuclear power plant in Belarus by its nuclear regulatory institutions, which is especially important not only to Belarus, but also Lithuania (as the plants are going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

4. SAFETY ANALYSIS OF NUCLEAR FUSION REACTORS

Scientific research in the frames of European Fusion Development Agreement (EFDA) 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 with Max-Plank-Institut für Plasmaphysik IPP (Greifswald, Germany) was initiated in 2007 and continues up to now. Fusion test facility Wendelstein 7X (W7-X) is being buit at IPP. In 2012 there was performed assessment of the plasma vessel venting system capacity, probabilistic assessment of divertor cooling system circuit and load scale limit analysis was performed for welding in plasma vessel port AEU30.

On December 2–8, 2012 visit of LEI experts took place at IPP, the objective of which was to discuss the obtained calculation results and specify available design data. During the visit W7-X facility and installed piping were visually inspected.

At present time the installation of all plasma vessel modules is completed, whereas the installation of internal components and peripheral facility is ongoing. Major part of cooling system piping has been installed and tested. It is planned to start W7-X operation in August of 2014. Later, future activities for 2013 were discussed with IPP representatives.



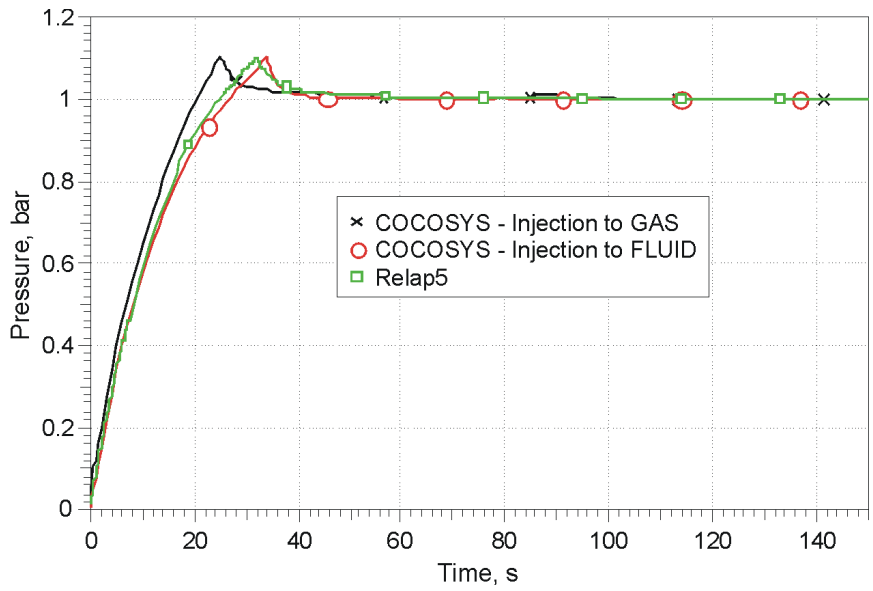
W7-X facility 3D fragment

W7-X plasma vessel safety system reliability

Aiming to check reliability of obtained calculations in W7-X plasma vessel the analysis was carried out using different codes, COCOSYS and RELAP5. After the analysis it was observed that main difference emerges using different water discharge models in COCOSYS code. In 2013 modelling of experiments is to be performed in order to determine which model better defines water discharge to lower than atmospheric pressure environment.

Limit strains of AEU30 Port Welds in the W7-X plasma vessel

Aiming to perform strength analysis for the plasma vessel port welds, the finite element models were developed. During the research, the limit strains of plasma vessel AEU30 port welds at 1 and 6 mm thick welds and in case the weld efficiency factor values (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. The analysis of this ports was performed for specific loading condition and limit scaling factor 3.0 (loading of 300%). According to the results of analysis it is possible to conclude that the stability of all welding between plasma vessel and ports will be sustained at all used loading for analysis. According limit analysis results it was not detected the fact that displacement of the point where loads are applied starts to increase very rapidly and the convergence was never lost during all time of the analysis.

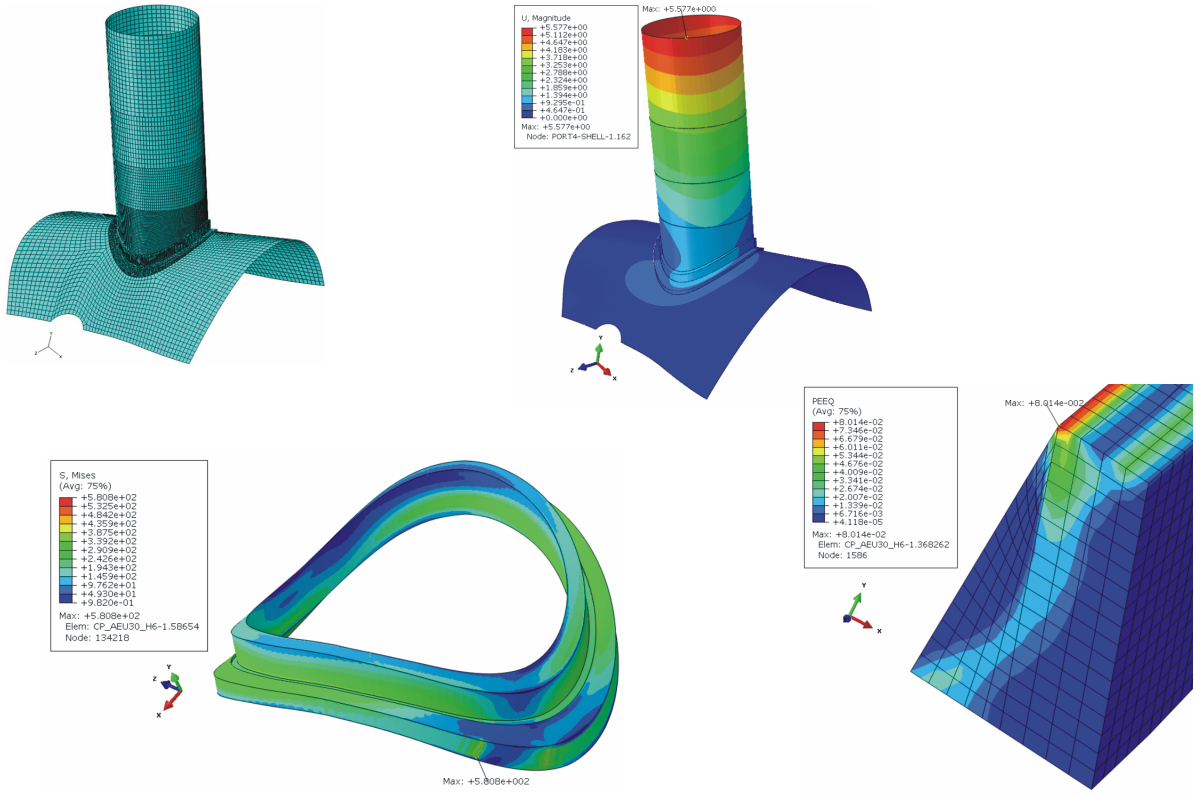


Pressure variation in W7-X plasma vessel. Comparison of COCOSYS and RELAP5 results

The limit analysis results shows that best results was received in port AEU30 with thick welds 1 mm in case the weld efficiency factor value 0.85, but also the acceptable results was received and in 6 mm thick weld in same case the weld efficiency factor. At the thick welds 1 mm the limit stresses are acceptable in case of lower of the weld efficiency factor value, i.e. 0.7.

Reliability, availability and maintainability analysis for W7-X equipment

Employing the reliability assessment methodology the analysis was carried out

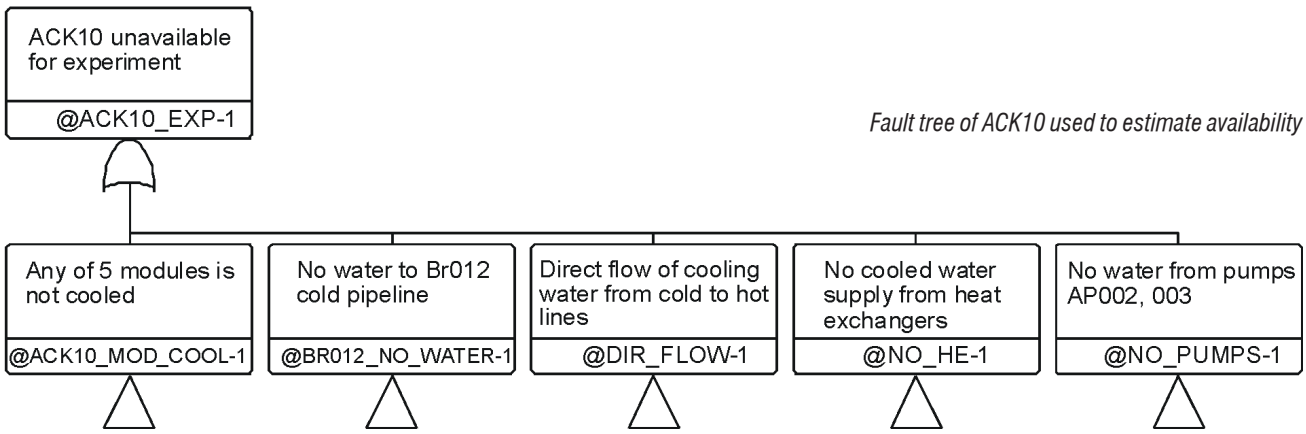


Finite element model of welding connection between the port AEU30 and the plasma vessel with 6 mm gap

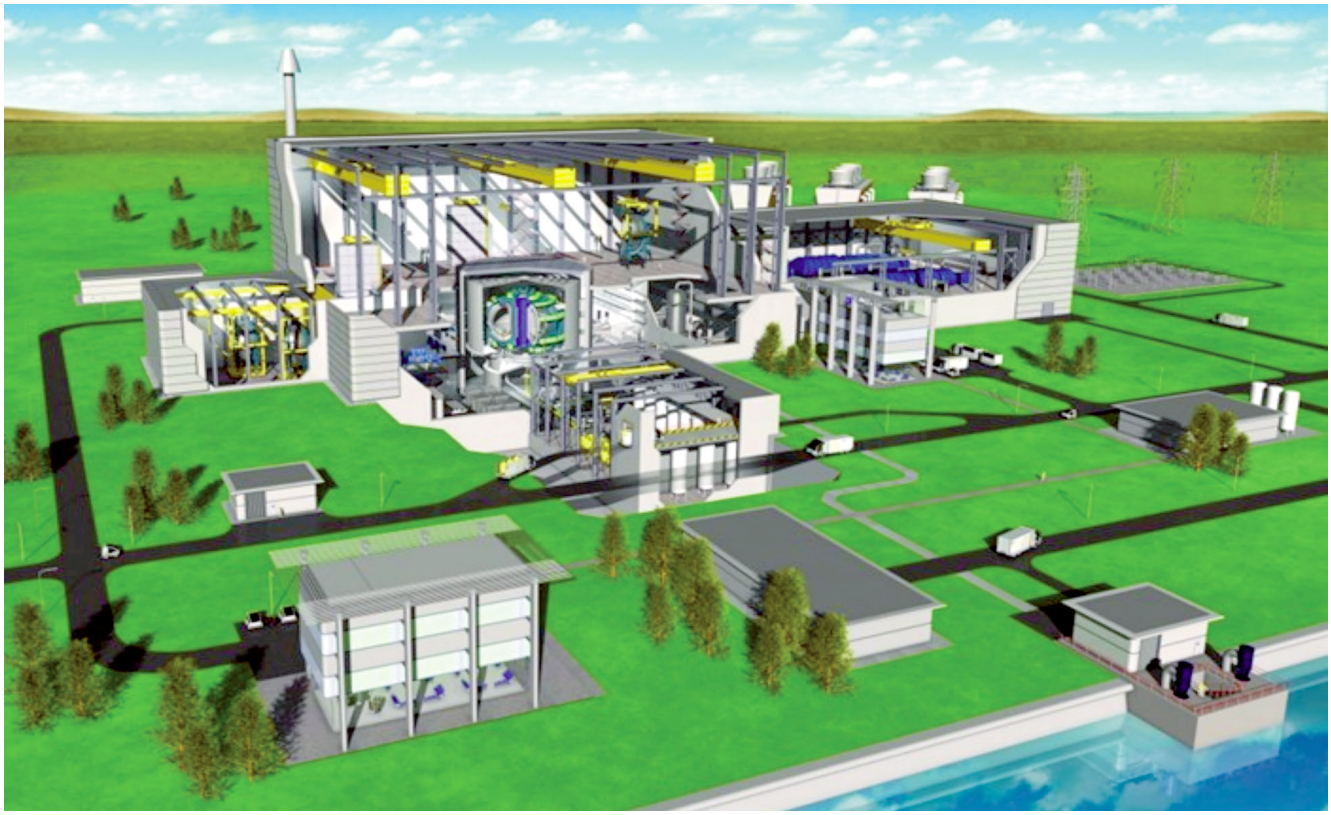
in order to estimate reliability of W7-X facility. Similar analysis methodology is applied for ITER equipment as well. The analysis was performed for divertor cooling system circuit ACK10 considering loss of external energy supply case. RiskSpectrum ® PSA Professional software developed by Relcon Scandpower AB (Sweden) was used during the research.

Reliability model of divertor cooling circuit ACK10 was developed during the analysis, reliability of ACK10 components was estimated, the components which have the biggest impact on system unavailability were identified, the recommendations were proposed how it would be possible to increase reliability of this system. A fault tree was developed aiming to unfold the reasons why this circuit may not be ready for work. After conducting reliability analysis of components it was determined that total ACK10 unavailability is 0.188. Failure of pump AP002 (51%) and unopening of pneumatic valve KA510 (35.1%) have the biggest impact on this unavailability. Compensation measures were proposed which will enable to increase availability of this system, i.e. it was proposed to reduce turn on and turn off cycle number for reserve pump, to ensure planned maintenance, to purchase spare parts, to implement the third reserve pump.

In 2012 EURATOM association signed agreement with European Commission on *Power Plant Physics and Technology Implementing Agreement*, the objective of which is to develop physical and technological



Fault tree of ACK10 used to estimate availability



An artist's impression based on European fusion power plant design. © EFDA

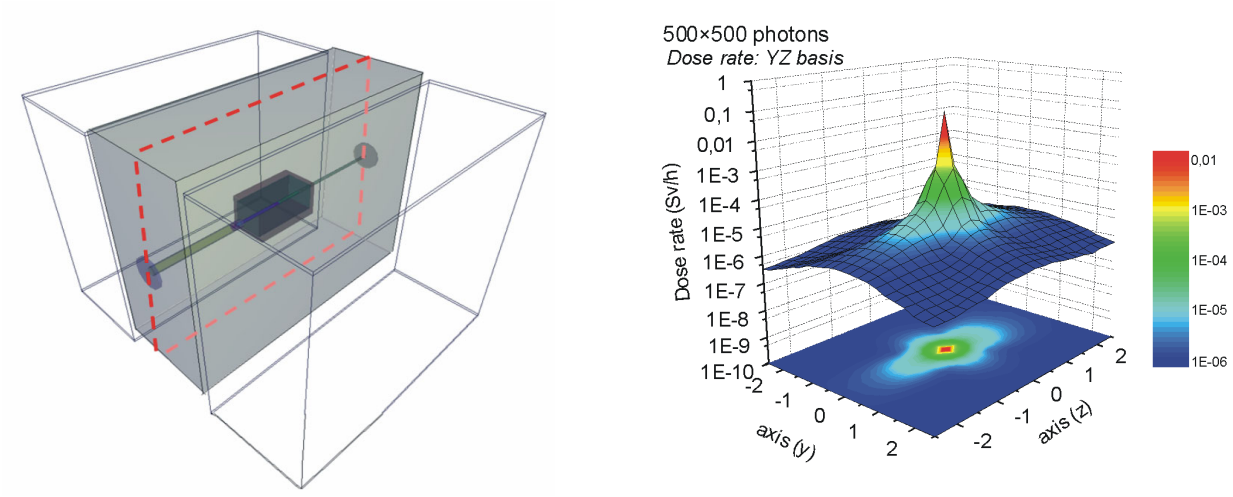
lease for future thermal nuclear fusion power plants and prepare its conceptual design. LEI joined research conducted under the agreement and according to the topic ***Reliability increase and risk minimization of internal plasma vessel components*** implemented the following tasks:

- Expected initial availability and availability growth of the DEMO plant based on historical data;
- Evaluation of RAMI Tools for DEMO.

RAMI (Reliability, Availability, Maintainability, Inspectability) conception is planned to be applied in all DEMO project stages. First of all, there was an objective to identify initial availability and availability increase in DEMO power plants based on historical data. As foreseen, LEI researchers in 2012 reviewed different energy producing European technologies/facilities and analysed how their unavailability assessment may be related with DEMO plans. It was determined that DEMO power plants should achieve the minimum 30% availability. However, if there is an objective to demonstrate the competitive availability of the power plant, it should be in the frame 40%–70%. Besides, after EFDA identification of relevant selected software LEI researchers carried out the comparison of different RAMI software and the overview of possibilities of these software tools, which is very significant for implementation design and research tasks of DEMO power plant. After drawing attention to RiskSpectrum and ReliaSoft software tools, the advantages and its possibilities to be applied for DEMO objectives were demonstrated.

JET research

In 2012 LEI for the first time joined the program related with research carried out in Joint European Torus (JET) facility. The objective of LEI conducted investigations is to model biological shielding models of neutron source and estimate probable dose power leakage. Dose values were estimated and dose maps for neutron and gamma ray cases were developed in order to evaluate dose power leakage into the environment via biological shielding where Cf-252 neutron source is stored. Calculation results are used for dealing with safety issues, i.e. to determine work duration of working personnel nearby source and protect employees from radiation. The obtained results provided important information on the impact on radiation phone depending from the source position in JET facility. This is relevant in planning activities inside and outside of the tokamak. The calculation results provided detailed information on probable dose distribution in the environment in different activity scenarios, they are used in planning activities and selecting means for ensuring safe working environment.

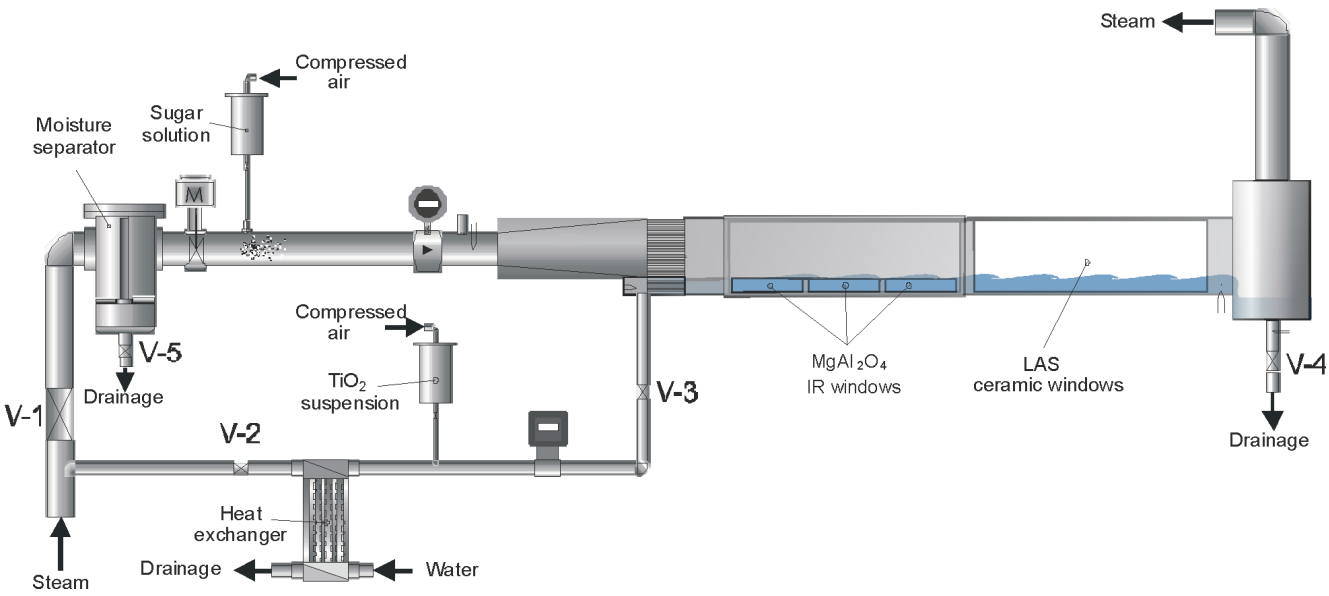


3D model of neutron source shield and gamma dose rate map

5. RESEARCH OF CONDENSATION IMPLOSION

In 2012 the state funded research project ***Research of condensing two-phase flow velocity field in horizontal rectangular channel*** was initiated. The following activities were performed:

1) Measurements of dependence of condensed two phase flow water temperature profiles on condensation intensity were performed employing IR method. Advantages and restrictions of the method were explicated. After analyzing the obtained results and striving for better accuracy of measurements, comparison and wider water flow scope the reconstruction of experimental setup was implemented.
2) 3D-LDV equipment was selected, purchased and tested for the measurement of velocity field. After combining optical and mechanical properties of windows material the experimental channel was reconstructed to allow the widest possible view of the flow for LDV detectors. The necessity of additional seeding of light-reflecting particles in steam and water flows was confirmed under real experiment conditions, and seeding methods were selected.
3) For measuring material concentration profiles the RAMAN spectroscopy equipment was selected, purchased and tested under real experiment conditions.
4) ANSYS CFD Research software was purchased and implemented for modelling and HPC simulation of condensing two-phase flow.



Schematic of experimental bench for two-phase flow

Measurement of temperature field by IR method

3D LDV equipment

6. APPLICATION OF BEST ESTIMATE METHODOLOGY

A three-year state subsidy funded research project ***Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology***, initiated in 2010, was completed in 2012. Laboratory of Hydrology and Laboratory of Energy Systems Research also took part in this project, which is a continuation of previous common work performed by the three laboratories. The objective of this project is to apply the uncertainty analysis methodology in the field of engineering and social sciences and for modelling the hydrological processes.

Developing numerical models by defining marginal conditions of a modelled object and parameter variation limits, measurement results and expert assessments having their own errors are required. Even using most up-to-date methods and software packages it is impossible to avoid uncertainties due to modelling errors. To estimate these uncertainties in nuclear energy field when performing accident analysis the so called "best estimate" methodology is applied. This methodology can also be applied for models describing other physical processes (e.g. hydrological), also performing the analysis of modelling results received in social sciences (for instance, energy economics). The objective state funded project was the application of uncertainty analysis methodology in the field of technical and social science and conducting modelling of hydrological processes. Relevance of best estimate methodology to simulate nuclear fuel assemblies and processes occurring in reactor during severe accidents were demonstrated in final work report. Also applying sensitivity and uncertainty analysis methods for calibration of hydrological models calculation of water bodies balance and conducting analysis for Kaunas city DH development as well as investigating social and economic effects of biofuel usage.

Performing the numerical research in technical systems, the processes taking place during severe accidents in nuclear reactors were modelled. The best estimate methodology RELAP/SCDAPSIM and ASTEC codes, as well as SUSA and SUNSET packages were applied for modelling the experiments carried out in PHEBUS and QUENCH experimental facilities.

Applying best estimate methodology when searching for optimal energy system solutions, a good example would be possibilities analysis of biofuel application for heat production in Kaunas city. Usually such analysis is carried conducting many variant calculation and after that choosing most optimal results. However, due to complexity of analysed task, generation of big number of variants and analysis are very complicated since it takes so much time. In this work, after employing software package SUSA and choosing discounted heat production input as "target function", three approximations were enough. Taking into account the influence of parameters, parameter limits were narrowed when approaching the parameter values corresponding to smaller expenditure. Thus after using best estimate methodology (the uncertainty and sensitivity analysis) purposeful reduction of uncertainties, which influences identification of more optimal solution, was carried out.

Modelling hydrological processes by applying uncertainty and sensitivity analysis it is possible to estimate significance of calibration parameter for each stage of modelling period. Thus it is possible to perform sensitivity analysis of introductory parameters in chosen hydrological

periods during the year since some calibration parameters have bigger impact on floods and high waters, whereas other parameters on the dry period. Calibration of hydrological model of Merkys river reservoir may be presented as such modelling example. Performed research results revealed that with the help of best estimate methodology it is possible to determine which calibration parameters of a model are most significant in individual periods and what impact they have on modelling results. This facilitates the calibration process of hydrological models.

7. ASSESSMENT OF ENERGY SUPPLY SECURITY

In 2012, a three-year state subsidy funded research project ***Development and application of assessment methods of critical energy infrastructure*** was initiated. Its main objective is to develop probabilistic methods for criticality assessment of critical energy infrastructures and apply them for Lithuanian energy system. In 2012 literature review of methods and measures, which are used for modelling and assessment of critical infrastructures, was carried out, classification of methods and measures used for research of critical infrastructures was submitted.

8. 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 continued in 2012. This project is under the implementation of Babcock (United Kingdom), LEI, Nukem Technologies GmbH (Germany) and Ansaldo (Italy) consortium. Its main objective is to prepare an optimal dismantling and decontamination strategy of the equipment (reactor gas circuit, exhaust gas cleaning system, system of reactor repair cooling tanks, ventilation system and emergency cooling system of the reactor), which is located in Ignalina NPP V1 building, as well as to develop all design and safety justification documentation necessary for implementing the project, and to provide support for the Client during the licensing and implementation stages of the project. In 2012 the researchers of the Laboratory finished the preparation of the Detailed Design Documentation and agreed it with 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 NP, this demonstrates confidence of the contractor in work performed in earlier stages, when preparing project documentation and coordinating it with VATESI. Experts of Ignalina NPP 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 2012. The work is carried out in cooperation with *SC TECOS* and JSC 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 2012 the construction of shock-absorbers was improved by selecting optimal parameters for absorbing energy receiving components (pipes). Pilot production of pipe 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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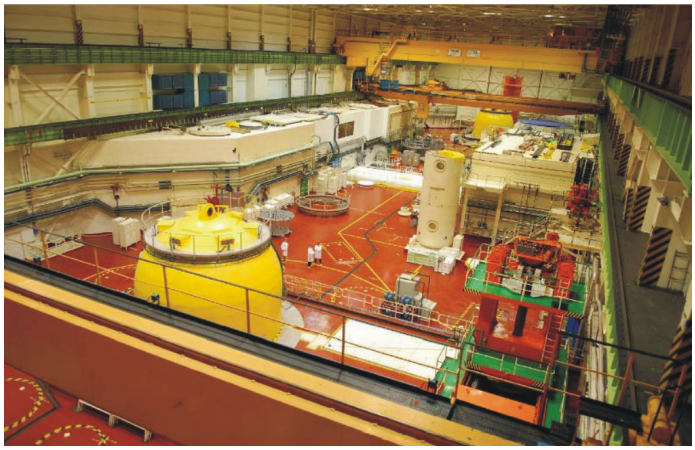
Feasibility Study for the Management of V1 NPP Primary Circuit Components

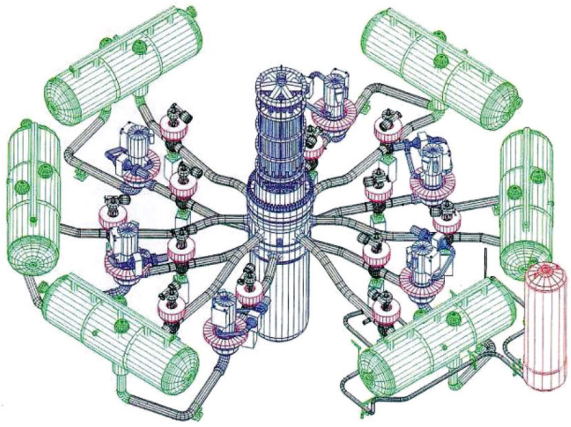
In accordance with decommissioning program for Slovakia V1 NPP two units, in 2012 LEI together with JSC *Specialus Montažas-NTP* and VNIIAES (Russia) initiated the feasibility study, the objectives of which are as follows:

- To analyze, develop and justify alternatives 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 V1 NPP and Mochovce surface storage safety justification reports improvement.

Researchers of the Laboratory participate in this project by selecting decontamination and dismantling versions for primary circuit components, conduct Slovakia and IAEA regulatory documents analysis and prepare proposals for updates of present justification reports. In 2012 initial project documents as well as work implementation methodology, project's quality and risk management plans were prepared and agreed with the Client. Assessment report of V1 NPP primary circuit components and waste management systems valid in Slovakia were submitted to the Client for review.



General view of V1 NPP reactor hall



3D model of primary circuit systems

9. OTHER PROJECTS

Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations

In 2012 experts of the laboratory continued research in EU 7FP international 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 Ambient Intelligence (AmI) features that will enable engineers to collaboratively design energy efficient and ecologically optimal 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 is implemented together with 8 partners from 7 EU countries. Project coordinator – Spain technology research centre *Tecnalia*. From LEI side, the project is coordinated by *Efficient energy consumption research and information centre*.

Project implementation period is 2010-2013. Main objective o f the project is to supplement present design systems of products and processes with new functions, which would enable engineers to design energy efficient and ecologically optimal production processes. At the same time these functions would enable to expand monitoring and decision-making possibilities for already designed and implemented processes. All this would enable to minimize/optimize the impact of production processes and facilities on the environment over the process life-cycle. Producers invest a lot so the products and services to be energy efficient, however there is still lack of Information and Communication Technology (ICT) based systems/measures which would improve design of products and processes taking into account energy efficiency.

One of the main tasks optimizing energy expenditure of production processes is to determine and improve energy consumption characteristics of these processes. This may be achieved by designing with ambient-intelligent (intelligent ICT) based production processes. Such design of production processes would enable energy efficiency control functions.

After implementing the project it is foreseen to develop a common methodology and for present design systems easily applied the following ICT components:

- *Energy dependency selector*, devoted for pre-design analysis and enables to select a tool, which will satisfy manufacturing as well as energy efficiency requirements over the process or product life cycle.
- *Energy monitoring setup* devoted to design and select ambient-intelligence based technologies and other measurement systems, ensuring energy efficiency of implemented manufacturing process.
- *Energy analyser* conducting energy efficiency optimization for manufacturing process and equipment.
- *Energy simulator*, designed to model variants of manufacturing processes and equipment design and to estimate its energy consumption.

In accordance with the second year project implementation program, in 2012 laboratory and early prototypes of DEMI component *Energy Simulator* were expanded and final prototype with implemented all business cases was completed. In addition, using compressed air system design and modelling concept (with partial modifications), the energy consumption estimation in steel heat treatment process was completed. Thus realizing mod-

elling of suppressed air as well as other systems there is an objective to retain a united model configuration and necessary data structure. The implementation of compressed air and other systems/processes was achieved by retaining unified model configuration as well as necessary data structure.

Applying available experience of modelling hybrid systems and acquired new ICT possibilities universal software and with it related modelling methods was developed. These modelling and energy consumption estimation tools operate taking into account *Energy Analyser* system configuration, design requirements and boundary conditions provided through web services. Models reflecting control of different systems and variables of process evolving within those systems as well as varying working conditions were constructed within MATLAB environment by applying automatic modelling and energy consumption estimation tools.

Taking into account project plans in 2012 the following activities were implemented in LEI:

- Development of Energy Simulator final prototype, including:
  - development of DEMI ICT and industrial methodology;
  - energy consumption modelling.
- ICT integration, testing and assessment:
  - demonstration and application scenarios description;
  - assessment of application scenarios.
- Preparation of demonstrators, including:
  - plastic mould cooling modelling demonstration;
  - metal eat treatment modelling demonstration;
  - compressed air system modelling demonstration.
- Exploitation and dissemination development, project management.

Considering one of the DEMI objectives – DEMI software development, in the activity of this project great deal of attention is devoted to cooperation promotion and development of new methods, software and its application methodologies. LEI researchers participating in present project stage may also contribute to information technologies or other innovative projects.

Feasibility Study on Application of Decomposition Methods for Complex Networks

In 2012, LEI continued research in the risk and vulnerability assessment area of critical infrastructures (CI). In the scope of this topic, the ***Feasibility Study on Application of Decomposition Methods for Complex Networks*** was continued under the agreement between the Institute for Energy and Transport at the Joint Research Centre of the European Commission (EC JRC IET) and LEI. Many of the CI infrastructures, especially the ones in the energy sector, are complicated network systems (e.g. electricity system, gas or oil transportation and distribution systems). The analysis of such integrated systems is complicated and requires vast human and technical resources due to its scope. One of the possible solutions to such problem is the application of decomposition method: the problem is divided into simpler problems according to predefined rules and then the obtained results are recombined in order to obtain solution for the initial problem. During the feasibility study, possible application of the decomposition method for analysis of complex networks as well as the advantages and drawbacks of the method were assessed. In addition, an example of possible method application for reliability assessment of large gas transportation network was provided.

10. RESEARCHERS' QUALIFICATION AND PUBLICATION OF SCIENTIFIC RESULTS

In 2012, there were 11 doctoral students in Laboratory of Nuclear Installation Safety who, together with experienced scientists, presented the research results in science research reports. 42 scientific articles were published (including 17 articles in ISI indexed journals) and 36 papers were presented in scientific conferences. The researchers of the Laboratory participated in the events related to nuclear energy and presented papers in all main international conferences, where safe operation of nuclear power plants and physical phenomena occurring in them were analysed. The researchers actively participated in different international and national training courses, IAEA seminars, committee and coordinating meetings, activity of FUSION development committees and other organizations and scientific institutions.

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LABORATORY of ENERGY SYSTEMS RESEARCH

MAIN RESEARCH AREAS OF THE LABORATORY:

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

In the scope of completed state subsidy funded scientific research project ***Development of Multiobjective Decision Making Model and its Application in the Lithuanian Energy Sector***, the multiobjective decision making methodology oriented towards the energy sector was improved. A computerised multiobjective decision making model for the Lithuanian energy sector was prepared. It was applied in the power system by carrying out a comparative analysis of power plants, using different electricity generation technologies, on the basis of the determination of market value. The prepared model enables taking into account the majority of factors influencing the value of the object and assessing their impact on the value of the analysed objects. In the final report of this project, a research of the prepared multiobjective decision making model, intended for the assessment of 4 electricity generation technologies used in Lithuania, was presented by applying the model. To implement the model, the objects of energy sector that use different primary energy resources and different technologies for electricity generation were selected. To be more precise, the objects include Kruonis Pumped Storage Power Plant, Kaunas Hydro Power Plant, Lithuanian Thermal Power Plant and Klaipėda Geothermal Power Plant.

In accordance with the prepared methodology, three computer multiobjective decision making models were determined to identify the impact value of environmental factors for energy sector enterprises. They are based on different multiobjective decision making model instruments: ESIAPVN-SPS, EGTAV-SPS, EGT-SELECT-SPS. Main advantage of the developed systems is that they enable to analyse objectively technologies, to determine the advantages and disadvantages of each of them as well as to identify the significance of factors influencing them. After conducting the assessment analysis of basic electricity production technologies, it was determined that while applying different multiobjective decision making models, the obtained results are almost identical.

Moreover, during the implementation of this project, Dr. J. Šliogerienė, who won the contest of Research Council of Lithuania for post-doctoral placement ***Development of Decision Support System for the Assessment of Energy Production Technolo-***

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

The state subsidy funded scientific research project ***Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology***, implemented together with the Laboratory of Nuclear Installation Safety and Laboratory of Hydrology, was completed. Specific model created in Microsoft Excel environment enabled to generate options of heat production sources development automatically, applying long-term period analysis modulus. This was realized by generating heat production sources implementation years and their capacities as random numbers in pre-foreseen limits. Looking for rational directions for biofuel application in producing heat in Kaunas city, this method was applied for simulation of heat sources implementation years and capacity indicators, automatically generating options out of which, according the objective function, are selected the best. In presented calculation, the objective function corresponds to the sum of discounted heat production costs. In such a way the priority is given to most economically efficient solutions.

Practical application of the model revealed that due to analysed task scope a great amount of options must be generated, whereas their analysis takes much time. Aiming to simplify procedures of calculation and analysis of results, SUSA software was applied, which is usually applied conducting best estimate methodology analysis. In this work best estimate methodology methods were applied and thus the process of identifying rational directions of heat source development was simplified and precipitated.

Scenario of high fuel prices and relatively constant heat demand was applied for research. Since options are generated on the base of random numbers, installed capacities of heat sources forecasted in some part of it are insufficient to satisfy heat demand during peak hours. Aiming to simplify the analysis, an extra fictional technology, which satisfies the lacking capacity demand with high price (9.99 LT/kWh), was introduced. This technology may be interpreted as price for inconvenience caused due to insufficient heat production or as rather high heat price, which could attract investment to additional heat production source.

Methodology of Germany company GRS and SUSA software were applied in this analysis. The methodology was chosen due to the following reasons:

1) the amount of calculations does not depend on the amount of investigated parameters, whereas all parameters change randomly, depending on indicated distribution limits and distribution law. Thus, more parameters can be investigated since necessity to choose in advance a parameter which may be more important or less important is not required;
2) this methodology estimates the sensitivity of parameter uncertainties on final results, which enables to range the parameters and to determine where accuracy should be increased (this is particularly relevant when improving a model), wishing to obtain more narrow limits of uncertainty of final result;
3) GRS uncertainty calculation methodology is different from other methodologies in the fact that ranging is result of analysis, but not predetermined. This enables to analyse the uncertainties and sensitivity of only one initial value containing parameters as well as value of a set containing parameters;
4) the amount of calculations depends on necessary probability of statistical tolerance limits and necessary confidence interval, whereas least amount of calculations is estimated according Wilk's formula.

Years of heat source implementation and its capacity limits were considered as potentially possible uncertainties, which influence modelling results. Modelling result in this case is the above mentioned function – total sum of discounted heat production costs. The smaller total production cost, the more optimal is a set of heat source implementation years and installed capacity. It was considered that variation values of all parameter in chosen intervals are equally probable and the law of parameter distribution in interval is even. Applying SUSA software the sets of heat sources implementation years and their installed capacity were generated. For the analysis with twofold statistical tolerance limit (the tolerance limit of obtained analysis results with at least 95% probability, accepting at least 95% confidence interval), according Wilk's formula, at least 93 calculations with different sets of parameters should be conducted. In practice, applying SUSA software, 100 parameter sets were generated, whereas applying the model created in the Laboratory of Energy Systems Research to each of them target functions– discounted sums of total heat production costs were determined. With the first approach it was determined that total discounted costs in the system over the period 2010–2030 change in the interval from 2.49 to 3.59 billion LT.

SUSA software enables to determine Spirman range correlation coefficient, i.e. enables to investigate the impact of parameters introduced into the model on mod-

elling results (the objective function). Spirman range correlation coefficient reveals total impact of specific parameter and its interrelation with other parameters on the analysed result. It is determined that the impact of parameters is of different sizes and it is both positive and negative. The bigger value of sensitivity coefficient of parameters in absolute size the more significant is the parameter and it has bigger influence on modelling result. On the basis of this research, the parameters, which have the biggest impact on the target function, were selected: capacity of combine cycle gas turbine unit (CCGT) at Kaunas CHP, heat supply line from Lithuanian Thermal Power Plant, capacity of gas turbine at Kaunas CHP, capacity of gas boilers which are planned to be built by *JSC Korelita*, *JSC Filana*, etc. Aiming to obtain optimal solution (to reduce total discounted cost in heat supply system), first of all, attention should be drawn to parameters, which have the biggest impact. After selecting sets of heat sources implementation years and their capacity with the smallest total cost, in the second stage, variation intervals of the parameters having the biggest impact on the target function were narrowed. One hundred of new parameters sets were generated with SUSA package. After finding discounted sums of general heat production costs, it was determined that minimum of total discounted costs in the system is reduced to 2.397 billion LT. Narrowing the limits of most significant parameters once more and after conducting calculations for one hundred newly generated parameters sets, the minimum of total discounted costs in the system is reduced to 2.379 billion LT. Thus purposeful reduction of uncertainties enabled to determine an optimal solution.

The project ***Development of Methodology for Optimal Integration of Future Technologies into Energy Sector*** of the national scientific programme ***Energy for the Future***, implemented in co-operation with the experts of Laboratory of Regional Energy Development and Laboratory of Systems Control and Automation, is especially important for justifying the competence of the scientists of the Laboratory. In the final stage of the project, a methodology of optimal integration of future technologies into the energy sector, including the stages of planning, installation and operation, was prepared. The methodology is based on principle of common modelling of the country's energy sector and the country's economy long-term development which is realised by combining a hybrid energy-economy model with mathematical model of comprehensive analysis of the energy sector future development. Such modelling allows to perform complex assessment of future technologies impact not only on the energy sector and environment but also on the overall national economy and to ensure at the time optimal scale for implementation of analysed technologies and their usage over the planning period. Aiming to ensure optimal integration of future technologies the priority on stages of their implementation and operation should be given for creation of non-discriminatory legal and economical environment for future technologies as well as for establishment of objective support means. The goal of such principle of future technologies integration is to harmonise activities in the energy sector and other economic sectors so that maximal discounted social wellbeing is achieved during the analysed long-term period. It is greatly depended on the amount of the general value-added that may be created in the country and the funds allocated from the national GDP for ensuring the wellbeing. The maximization of social wellbeing could by partially substituted by the maximization of consumption or minimization of expenses on the development and operation of the economic sectors.

Aiming at public benefit by integrating future technologies into the energy sector, support schemes often are necessary on the stage of their implementation seeking to motivate separate economic subjects so that by serving their own interests they would target their activity towards satisfying the needs of the society. Within the framework of this project detailed analysis of support schemes experience in other EU countries is performed as well as documents which regulate development of the energy sector in EU-27 and Lithuania are carefully analysed. Optimal integration of future technologies should satisfy the interests of sustainable development of the society. Therefore possibilities and areas for application of multiobjective decision making mechanisms as well as external costs of energy technologies and methods of their assessment are discussed in details in the final report.

Most attention in the final report is given to detailed mathematical description of hybrid energy-economy model, submission of mathematical modelling solutions of specific processes (stochastic operation nature of technologies, updating and conservation of facilities, energy efficiency increase, energy consumers' behaviour, elasticity of energy demand, etc.) occurring in the energy sector and poorly investigated in the energy sector modelling practice. Detailed description of methods for common application of the detailed energy sector development mathematical model and hybrid energy-economy model is presented also. The properties of smart networks which have influence on the integration of other future technologies into the energy sector, possibilities of mathematical representation of smart networks in the energy sector development model are analysed. Modelling methods were developed and analysed, considerable part of information necessary for such analysis was collected and summarized.

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

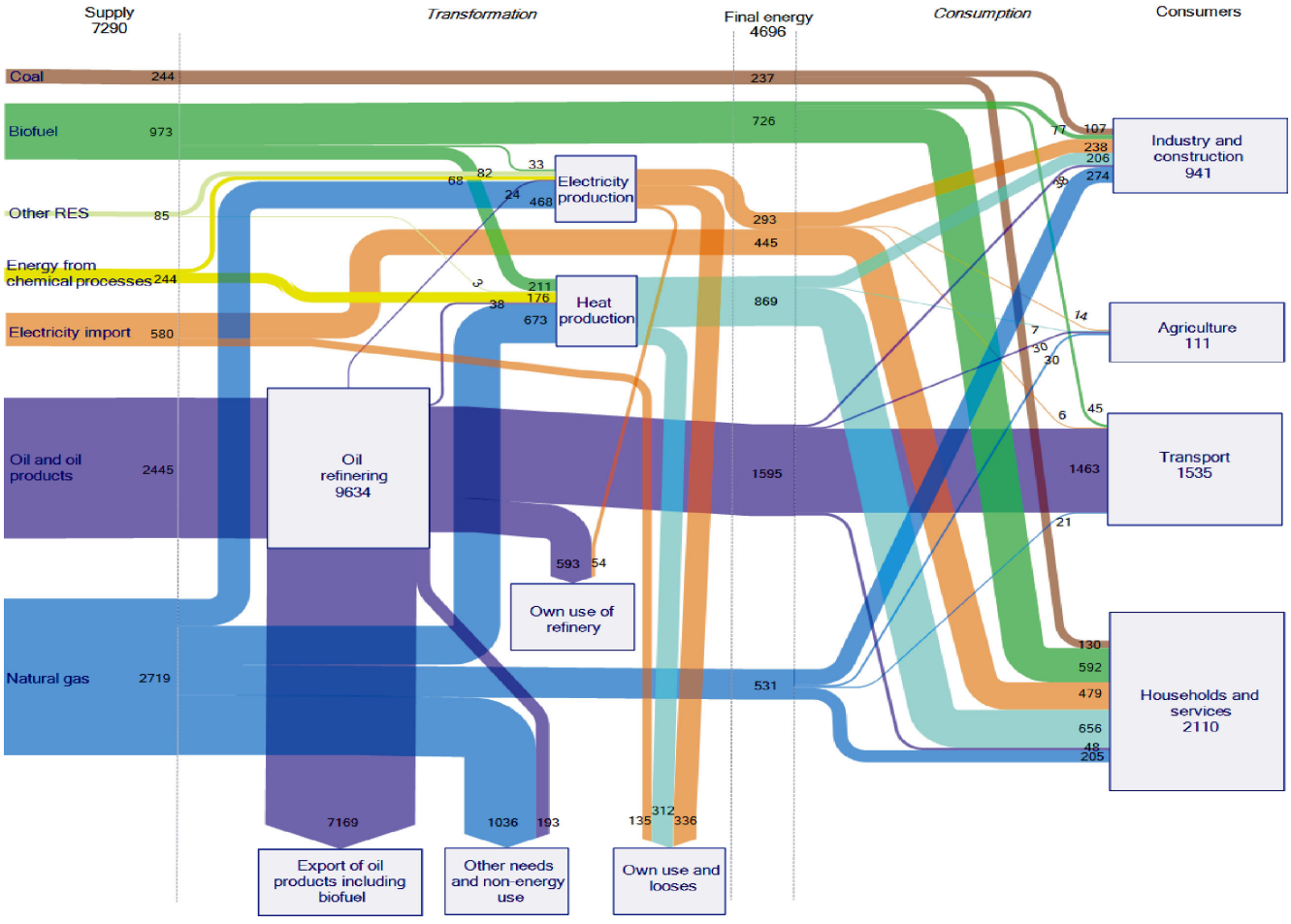
In 2012 project ***Economic and sustainability analysis for energy sector development*** was implemented in co-operation with the experts of Laboratory of Regional Energy Development and Laboratory of Systems Control and Automation.

In the long-term programme an ambitious objective is set to solve the following tasks:

1) to develop 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 to 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 the State and municipalities, to evaluate the efficiency of support measures already applied and proposed;
4) to investigate possibilities of synchronous operation of Lithuanian electricity system with ENTSO-E, taking into account the perspective development of generating capacities.

While implementing the second task, most of attention was given to the development of complex modelling base of the energy sector development. Most significant changes in the Lithuanian energy sector were discussed; comprehensive analysis of energy development trends was performed for Lithuania, EU countries and the largest world countries. The energy information system of technical and economic indicators required for energy demand forecasting and optimisation of the energy sector development was renewed and supplemented by new data.

The following general internal and global changes are significant to justify directions of the energy sector development: after final closure of Ignalina NPP, methods of primary energy and electricity provision are drastically changed; natural gas which may be imported from only one source currently is the main fuel in the



Scheme of basic Lithuanian fuel and energy flows in 2011

Lithuanian primary energy balance; the European Commission approved the Baltic energy market interconnection plan which open new possibilities for the integration of the Lithuanian energy systems into European energy systems, however, financing sources and terms for construction of interconnections are still not approved; very high heat and electricity prices for final consumers evoke a lot of social problems; very strict requirements for Lithuania are raised by the EU directives: 2010/31/EU on the energy performance of buildings, 2010/75/EU on industrial emissions and 2012/27/EU on energy efficiency.

In accordance with analysis of energy and economic indicators available at the Lithuanian Statistics data base, other data bases of the EU countries and international organizations, trends in changes of indicators, which define sustainable state energy sector development, are determined: the intensity of primary and final energy in Lithuania is reducing more rapidly than in most EU countries; indicators defining role of RES such their share in the primary energy balance, share of green electricity in the gross electricity consumption and share in the gross final energy consumption have been significantly changed.

Implementation of the project ***Assessment of potential for greenhouse gas emission reduction in households in Lithuania*** (project leader D. Štreimikienė) supported by the Lithuanian Research Council is going successfully: energy consumption and greenhouse gas emissions in the household sector are analysed, basic social-economic and technological as well cultural factors influencing emission of greenhouse gas in this sector were identified.

SCIENTIFIC RESEARCH WORK FOR THE NATIONAL ECONOMY

Under the agreement with ***JSC Projektų centras*** scientific research work ***Preparation of separate parts of plan for offshore liquefied natural gas terminal development in Klaipėda harbour Smeltė peninsula*** was implemented. When implementing this scientific work, analysis of current conditions of the Lithuanian energy sector was performed, forecasts of the future final energy demand were prepared, natural gas demand was estimated taking into account rational scenarios of the energy sector development; distribution of natural gas consumption in the state's territory was analysed; analysis of natural gas transmission network modelling results is also submitted in the final report, possibilities for efficient use of liquefied natural gas terminal were determined as well as possible limitations of gas supply.

Use of liquefied natural gas cannot be separated from transmission infrastructure, thus a very significant part of this analysis is devoted to modelling of liquefied natural gas supply regimes and natural gas transmission networks as well as calculations of technical regimes. Basic strengthening options for gas pipe systems (without network strengthening, strengthening of line Gargždai-Kuršėnai and line Jurbarkas-Klaipėda) were modelled in the study and necessary investments were estimated.

Complex modelling of natural gas supply enabled to determine possibilities for state's provision with natural gas, usage of liquefied natural gas terminals and loads' subdivision, depending on future demand of natural gas and scenarios of network strengthening. It was determined that construction of 700 or 800 mm diameter gas pipe instead of planned 400 mm diameter gas pipe Jurbarkas-Klaipėda would allow to increase, the load of natural gas terminal up to 4.2-4.6 billion m^3 per year. In this case, even in a case of gas supply interruptions from Russia, all country's demand could be met from the liquefied natural gas terminal.

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

Dr. I. Konstantinavičiūtė also participated in the Lithuanian Greenhouse Gas Emission Account assessment review executed by experts of United Nations Framework General Convention on Climate Change secretariat. She was granted the Note of Honour from the minister of Environment G. Kazlauskas for conducted responsible work during the review.

Under the agreement with the Ministry of Environment, a scientific research ***of National Greenhouse Gas Emission Inventory in the Energy Sector*** was carried out. Lithuania following the requirements of the United Nations Framework General Convention on Climate Change, the Kyoto Protocol as well the EU Directives 280/2004/EB and 2005/166/EB has an obligation to perform each year the National Inventory of Greenhouse Gas Emissions in Energy Sector which are not controlled by the Montreal Protocol.

Inventory of greenhouse gas emissions covers all types of gases evoking greenhouse gas emission phenomenon: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6), according corresponding categories of sources and absorbents. The gas account is prepared in accordance with general methodology recommended by Intergovernmental Panel on Climate Change (IPCC) and covers all investigated

period from 1990 to reporting year.

IPCC experts who analysed the National Greenhouse Gas Emission Inventory prepared in 2011 recommended to use national emission indicators for identifying the amount of greenhouse gas in the energy sector. Aiming to ensure the exact account of emitted greenhouse gas emissions in the Lithuanian energy sector and in other branches of the economy from fuel combustion, a thorough analysis of emission indicators was carried out in this research, on the basis of which recommended values of national emission indicators were submitted.

The analysis of greenhouse gas emissions occurring from fuel combustion, trends of their changes as well as structural changes enabled to identify the most important types of fuel, i.e. to identify the types of fuels, the assessment of national emission indicators of which is the most significant aiming to improve significantly reliability of account.

In particular important part of this research is a detailed comparative analysis of emission indicators applied in the EU countries. For such analysis 14 EU countries were selected, the experience of which could contribute to account of greenhouse gas emissions in Lithuania. These countries apply three types of emission indicators, namely: standard, national and facility level. The performed analysis revealed that most EU countries have set national emission indicators for the fuel types, which are dominating in general structure of consumed fuel, as well as for local fuels, whereas for the remaining fuels they apply standard emission indicators. Some countries (Sweden, Germany, Finland and Austria) have assigned national emission indicators for most types of burnt fuel. While performing the comparative analysis of emission indicators, most attention was given to those sectors of economy and fuel types which are most specific for Lithuania. While performing the comparative analysis, emission indicators applied in the EU countries were compared with standard values recommended by IPCC, thus aiming to identify the limits of emission indicator values rather than deviations from the standard one.

Detailed analysis of reports provided by energy facilities participating in the Lithuanian greenhouse gas turnover pollution marketing system revealed that emission indicators of the energy sector for corresponding fuel types may be specified based on „bottom up approach" methodology, i.e. by using data of separate facilities, which for identification of CO_2 emission indicators apply the third or the second b stage. While preparing account of national greenhouse gas, in Lithuania in the case of certain facilities specific emission indicators identified at the facility level may be applied and thus ensure low uncertainty of calculations.

The results of different Lithuanian scientific studies devoted to the analysis of greenhouse gas emissions from fuel combustion in the energy sector and other branches of economy, are summarized in the final report. In accordance with the carbon dioxide values, identified during research in different institutions, and their comparison with values recommended by the IPCC it was determined that:

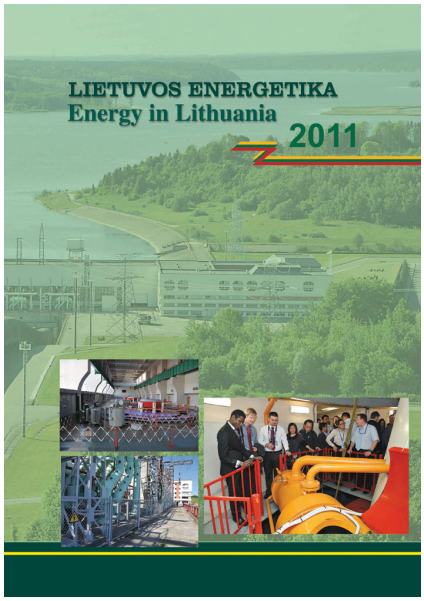
1) CO_2 emission indicators for basic fuel types, identified during investigations conducted in Lithuania, are similar to the standard ones;
2) emission indicators assessed for certain types (peat, lignite, orimulsion, etc.) differ almost twice.

While preparing national inventory of greenhouse gas emissions, in a case of certain energy facilities, emission indicators which are assessed at corresponding facilities level, for example, at Quality research centre laboratory of SC *Orlen Lietuva* and Central calibration and experimental laboratory of SC *Lietuvos dujos* should be applied. They are supplemented with the results of laboratory research carried out at Laboratory of heat equipment research and testing in Lithuanian Energy Institute for basic fuel types burnt in the Lithuanian energy sector. Taking into account research results, national CO_2 emission indicators for basic fuel types (gasoline A-95, liquefied oil products, jet fuel, diesel fuel, gasoils, natural gas and firewood) used in Lithuania are specified and defined.

Based on detailed analysis performed in the research, values of national emission indicators were proposed according IPCC categories and corresponding fuel types burnt in Lithuania. Expert assessment of emission indicators uncertainty was conducted at aggregated level of sectors and fuel types, taking into account international experience. Performed research by no means will contribute to preparation of annual reports of national greenhouse gas emissions.

As an order of the main national energy associations (***Lithuanian District Heating Association, Lithuanian Biomass Energy Association, Lithuanian Electricity Producers Association*** and ***Lithuanian Energy Consultants Association***), the annual publication of statistical data ***Energy in Lithuania 2011*** was published. It presents the up-to-date information describing tendencies in the development of the Lithuanian energy sector and its branches in 2008-2011 as well as detailed energy balances and the recent key indicators of the national energy sector, which are also compared with Estonian and Latvian indicators. It presents also data about greenhouse gas emissions in 1990 and 2010 and their structure according to the sectors in Annex 1 countries to the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

The comparative economic and energy indicators in 2009 and 2010 (GDP, energy consumption per capita, energy intensity, etc.) in the EU countries, largest world countries and countries of the Orga-

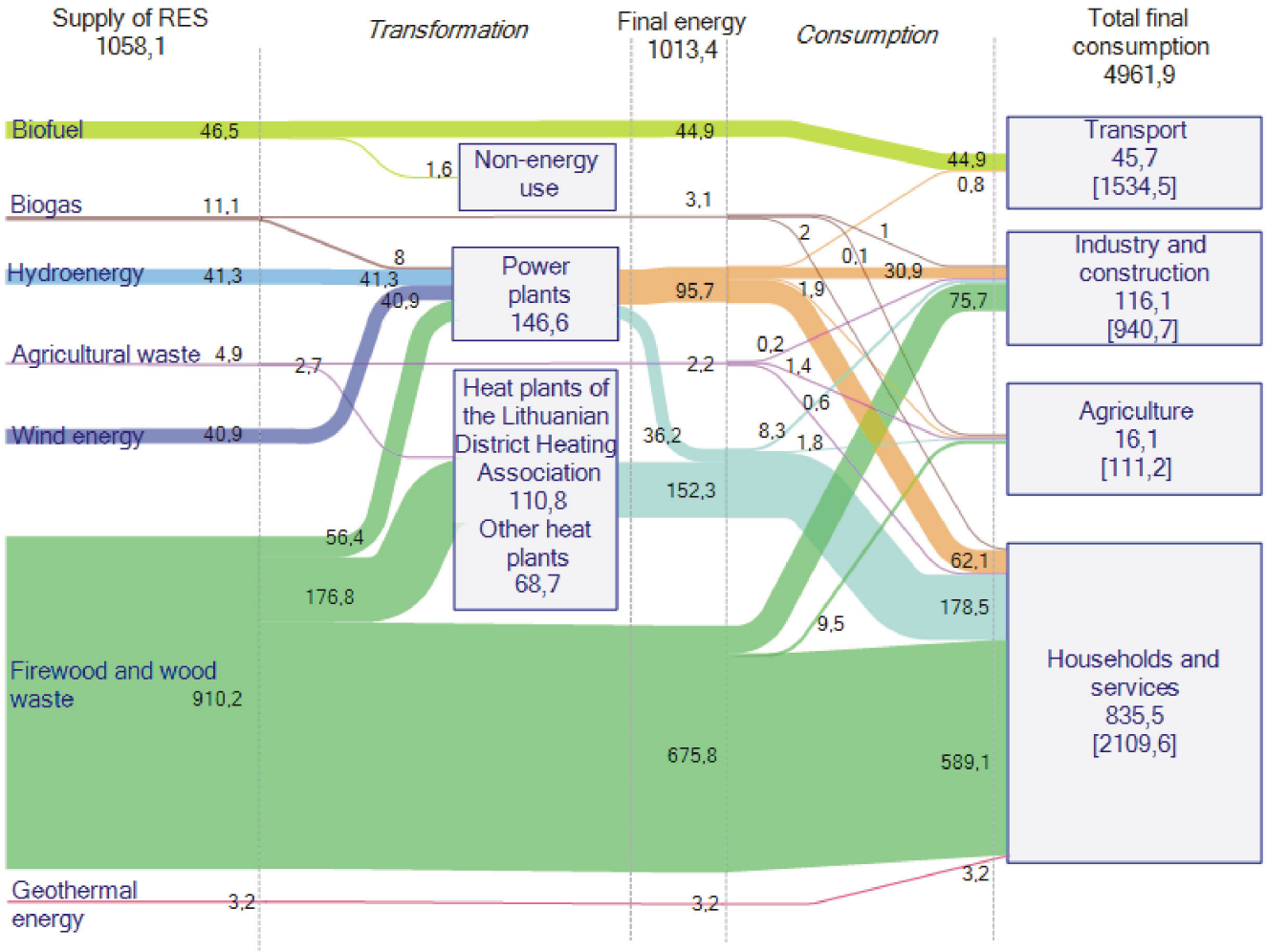


nization for Economic Cooperation and Development are presented in the publication. These comparative indicators were prepared following methodology of the International Energy Agency. According to this methodology electricity consumption does not include transmission and distribution losses, but the total final consumption includes non-energy use.

The publication summarises the changes in the national economy and the energy sector. In 2000–2008 the Lithuanian economy was growing rapidly, but declined by 14.8% in 2009. In 2011, the GDP increased by 5.9% and amounted to LTL 80.7 billion (in chain-linked volume) or LTL 26.6 thousand per capita. In 2011, the primary energy consumption increased by 3.3% and comprised 7.29 billion toe, whereas the final energy consumption for energy needs rose by 3.0% and equalled to 4.7 million toe. Furthermore, the final electricity consumption increased by 3.0% and amounted to 8.58 TWh, while the primary energy consumption per unit of GDP dropped by 2.4%, and the final energy intensity decreased by 7.0%.

This publication was prepared in close cooperation with the specialists of *the Statistics Lithuania, Lithuanian District Heating Association,* specialists of energy companies and associations. The information invoked in the preparation of the publication was taken from the publications of the *Statistics Lithuania* (Energy Balance, 2008, 2009, 2010 and 2011), 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***, preparation of a sci-



Scheme of renewable energy flows in 2011

entific research ***Experimental Data Analysis of National Greenhouse Gas Emission Inventory 2013 in the Energy Sector*** started. This National greenhouse gas inventory in the energy sector for the period 1990–2011 was prepared following the methodology recommended by the Intergovernmental Panel on Climate Change.

PARTICIPATION IN THE INTERNATIONAL PROGRAMMES

The experience gained during the implementation of different international projects is universally important for improving competence of Laboratory researchers. In 2012, the project ***Economical-technical Comparative Analysis of the Storage of Nuclear Waste and Carbon Dioxide (CO_2)*** (project leader D. Štreimikienė), coordinated by the IAEA, was successfully completed. The possibilities of carbon dioxide storage and nuclear fuel burial in Lithuania were analysed, economic-technical assessment of possible storage equipment was performed and recommendations were prepared.

3-year duration project ***Analysis of sustainable development of renewable and other energy sources, earth and water use in Lithuania*** coordinated by IAEA was initiated**.** Main objective of the project is to foresee milestones for sustainable development of the Lithuanian energy sector, earth and water use. Usage of RES has influence on sustainable development since it enables to reduce negative environmental impact, stimulates development of national and regional economy, has large impact on energy prices, creates extra working places, etc.

State's energy security (ensuring energy demand for socially acceptable price) is also an inseparable part of sustainable economic and social policy. In the first stage of this research, a principal structure of mathematical model was prepared. Aiming to implement the objectives, it is foreseen to encompass and analyse total chain of energy flows, beginning with the resources and finishing with the use of separate energy types obtained from these resources for satisfying society demands, without leaving apart other, application of non renewable energy resources and environmental impact assessment, taking into account country's commitments to the EU as well as strategic objectives and aiming to provide consumers with energy at possibly the lowest prices. Taking into account the above mentioned criteria, an optimization model using MESSAGE software is being created.

In 2012, analysis of technological processes for growing, collection, transformation and transportation of RES, agricultural products and other possible energy sources was carried out aiming to prepare their modelling methods. The demand for data necessary for modelling and their sources were estimated, certain share of data was collected, analysis of their application for modelling was carried out.

In 2012, researchers of the Laboratory in accordance with agreement with the **Institute for Environmental Studies**, **VU University Amsterdam**, were invited to participate in preparing international project ***Inventory of Estimated Budgetary Support and Tax Expenditures for Fossil Fuels***. Together with experts from other countries they summarized the experience of Bulgaria, Lithuania, Latvia, Cyprus, Malta and Romania, promoting fossil fuel production and consumption. In the final report, submitted to Directorate-General of the **European Commission,** the structure of the energy sectors of six countries was analysed, principles and methods of appraisal tariff and taxation of energy products was discussed, support means for fossil fuel were identified, assessment of support of fossil fuel size was carried out.

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

- By preparing specialists to model scenarios of the energy sector development: in March 2012 in Sudan Dr. A. Galinis as expert delegated by the IAEA responsible for application of MESSAGE model to solve tasks of long-term energy planning, shared his experience in regional modelling training, whereas in October in Indonesia he gave lectures and supervised practical training of specialists who are responsible for preparation of the energy sector development programme in this country.
- By conducting IAEA audits devoted to the assessment of technical cooperation projects, related to planning of the energy sector as well as research of energy economy and environment, in Ghana and Botswana Republic, also audit in Sudan under IAEA programme *Strengthening of Capabilities and Analysis of Energy Economy and Environment* (Dr. D. Štreimikienė).
- By representing IAEA with the report at the 18th UN Framework Convention on Climate Change conference and at the 8th Kyoto Protocol countries' meeting in Doha, Qatar (dr. D. Štreimikienė).
- By performing centralized assessment for France, Monaco, Spain and Romania greenhouse gas emission inventories organized by UN Framework Convention on Climate Change secretariat in Bona (dr. I. Konstantinavičiūtė).
- By accepting for three month training the PhD Candidate from Ghana Mr. Isaac Ennison. During his training the PhD Candidate acquainted with tools and methodologies for technical and

economic analysis of the energy sector as well as with methods of electricity production costs assessment. On the basis of laboratory researchers' experience he prepared a mathematical model which includes energy demand variation curves, renewable energy sources power plants, nuclear power plant and oil refinery plant; he also dealt with modelling and analysis tasks of technical, economic and political parameters of these energy objects. The PhD Candidate during his training prepared two articles which may be published in Lithuanian journals. In his final seminar, when summarizing his own training results, as one of his most significant achievements, had highlighted the fact that based on experience of LEI researchers he had an opportunity to deepen his own knowledge. He is planning to apply new knowledge in dealing with implementation of nuclear energy and other possible energy sources in Ghana.

Isaac Ennison (on the left) has a discussion with the researchers of the Laboratory

Year 2012 was significant in improving the qualification of Laboratory researchers:

- On the 15th of June junior research associate V. Bobinaitė defended her doctoral thesis in social sciences ***Factors, Methods and Model of Wholesale and Retail Electricity Prices' Forecasting***.
- PhD Candidate Vidas Lekavičius on the 24–25th of June participated in the 2nd Edition of the International School of Input-Output analysis in Bratislava (Slovakia), where he completed module *Dynamic econometric Input-Output Modelling* . On 20–31st of August he was improving his qualification at training courses *National Long-Range Nuclear Energy Strategies* organized by the IAEA in the Argonne National Laboratory, the USA. He found it useful to familiarize with new tools and methodologies applied for planning of energy systems, and in particular with INPRO methodology, applied for the assessment of sustainability of nuclear energy development.

In 2012, the researchers of the Laboratory participated in the conferences in Austria, Belgium, Estonia, Ghana, Italy, Katar, Portugal, Sweden, Slovakia, Sudan, S. Korea, Germany and other countries, where 21 paper was presented. The researchers of the Laboratory published 20 scientific articles in Lithuanian and international journals and proceedings of international conferences (4 of them in publications that are included into the list of Information Sciences Institute).

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LABORATORY of REGIONAL ENERGY DEVELOPMENT

MAIN RESEARCH AREAS OF THE LABORATORY:

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

OBJECTS AND TASKS OF THE RESEARCH

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

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

The attention is currently focused on the technological advancement which notably outpaces the implemented state, organizational and fiscal measures. Balancing all promotion measures to make them versatile, rather than single-targeted, is also an important task. At present, many countries are forced to alter the economical promotion policy, because the increased technology supply has generated the interest of businesses and investment due to the applied favourable energy purchase costs. However, an uncontrolled development of such technologies would increase energy production costs which are paid by all energy consumers. The justification of promotion preconditions and measures requires assessing their benefits and long-term usefulness regarding different aspects, which would serve as the basis for the development of economic, regulatory and organizational promotion system. The main objective in justifying the scope of promotion measures is to estimate or otherwise determine their public benefit which reveals itself through energy supply security and reliability, affordability to all consumers, solution of urban and rural social issues, averting negative environmental impact and other benefit which may be exposed both national (e.g. improvement of foreign marketing balance, high GDP development in energetics) and local level (e.g. improvement of employment, production expansion in regions).

Nevertheless, the assessment of expedience and impact of promotion measures is still a new area in Lithuania; thus, searching for solutions requires following the international-level or indirectly related research and methods enabling a more versatile assessment of the measures. This holds for both the assessment of future usefulness of technologies, and the applied organizational and regulatory forms

of the measures. The effectiveness of various regional or urban programmes, use of waste energy, regulation of emission, energy efficiency and eco-labelling schemes of devices, equipment or systems as well as buildings must be analysed following a general assessment methodology.

The scientific problem is related to the objective assessment of the public benefit due to the RES development capable of revealing the advantages which could not be disclosed by assessing financial benefits and solving the environmental and social problems at the same time. Single-criteria identification of solutions is usually impossible since the problem itself is diverse. This requires versatile knowledge which could be systemized and purposefully disseminated. Exceptionally regulatory measures in the society may be treated as realisation of interests of EU bureaucrats and certain lobbyist groups.

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

In 2012 the economic and social benefit assessment of promotion measures, based on life-cycle costs method, escaped external costs and social benefit was prepared. Assumptions were analyzed in which way different RES technological solutions could be promoted by developing sustainable development scenarios for cities.

Dr. Habil. V. Klevas performed economic justifications for RES demand promotion. Together with researchers from the Faculty of Economics and Management of

Kaunas University of Technology he initiated a long-term institutional economic research program for 2012–2013. On 16 11 2012 the first working meeting of program *Long-term competitiveness challenges for Lithuanian economy* took place. During the meeting the proposals and insights were submitted by the Lithuanian Bank Council deputy Raimondas Kuodis, Vilnius University professor Rimantas Rudzkis and LSC vice-chairman Rūta Marcinkevičienė.

Another program implemented together with six Lithuanian higher schools (Vilnius University, Vilnius Gediminas Technical University, Mykolas Romeris University, The General Jonas Zemaitis Military Academy of Lithuania, Aleksandras Stulginskis University and Vytautas Magnus University) was initiated in autumn 2012. During the first working meeting program implementers discussed the objectives and future activities.

In Lithuanian state budget financed program *Long-term competitiveness challenges for Lithuanian economy* the researchers will aim to determine competitive danger of new booming world economy centers for traditional technologies based-production in Lithuania, to investigate the interrelation of higher technologies and innovations expansion in economy sector with business units, the shock impact of credit market.

Besides, researchers will analyse and propose improvement measures for resources distribution and use in public sector, will aim at identifying structural changes of human capital, work resources in state economy sector taking into account migration impact and considering world economy trends. At the end of the program recommendations will be submitted as well as methods according which macroeconomic processes will be assessed and their impact will be simulated.

INTERNATIONAL COOPERATION

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

In 2012 the Laboratory continued the project ***Regions Paving Way for a Sustainable Energy Europe (ENNEREG),*** financed by the European Union. 12 European regions, supporting the initiative of the Covenant of Mayors and participating in the project, initiated the implementation

of the energy and environmental protection goals set by the European Union, i.e. to reduce carbon dioxide emissions by 20%, increase the share of renewable energy sources up to 20% of final energy consumption, and improve the efficiency of energy consumption by 20%.

ENNEREG project is represented by 12 European regions, in Lithuania this is Kaunas region. Alongside with main pioneer-region, in 2011, another Lithuanian twin-region was involved into the project, that is Šilutė municipality, which joined the initiative of the Covenant of Mayors and which had difficulties in implementing the responsibilities of sustainable energy planning.

The project working group is responsible for helping to update and specify the Sustainable Energy Action Plan, also by contributing to dissemination of sustainable energy ideas in Sustainable energy day organized by the municipality. During the implementation of the project a detailed overview of Šilutė municipality energy sector was performed, expansion possibilities were evaluated, on the basis of which a plan of sustainable energy development till year 2020 was prepared. The project representatives also provided training on sustainable energy planning basics to municipality representatives. During the project Šilutė municipality sector profile was created on website, where latest news on sustainable energy development in the region are provided: **http://regions202020.eu/cms/home/replication/silute-municipality/**

LEI working group actively participated in helping Šilutė municipality representatives to organize Sustainable Energy Day in Šilutė on 17 05 2012. The project participants prepared material for sustainable energy lecture, which took place in all municipality high-schools for senior classes' pupil. During the conference which took place at the municipality, LEI representative presented a report on the importance of sustainable energy planning.

In 2012 the working group encouraged to more actively apply heat and energy saving actions in dwelling-houses. On 10 03 2012 during meeting with Eiguliai society representatives, the discussion was related with thermo-vision application and thermo-vision investigation of apartment houses. On 15–18 03 2012 at exposition *Namų pasaulis 2012* the possibilities of heat and energy saving in buildings were presented to visitors as well as considerable amount of useful educational material.

During the project sustainable energy development projects are collected and prepared, which later were presented in other EU regions as examples of good experience. One of such examples was Birštonas town as an eco-town example at the conference, which took place on 22 May 2012 in Poland (Poznan).

Project partners actively participated both in international activity and in Lithuania. On 08 11 2012 we represented Kaunas region in ENNEREG seminar, which took place along with Fedarene **(European Federation of Agencies and Regions for Energy and Environment)** general assembly in Bilbao (Spain).

Project partners also visited scientific research center, which specializes in energy and environmental innovations research.

In 2012 international conference ***Covenant of mayors and up-to-date initiatives of the European Commission – to improve heating sector and energy efficiency of buildings***, which was organized by Panevėžys city municipality together with

Training of Šilutė municipality representatives on 17 04 2012

Sustainable energy day in Šilutė municipality on 17 05 2012

EK Intelligent Energy for Europe technical support initiative *ManagEnergy*. The representative of ENNEREG presented a report on the experience of sustainable energy planning in Kaunas region.

All the material related with regions can be traced on: **www.regions202020.eu.**

The material devoted to region societies may be found in Lithuanian language as well on:

http://www.regions202020.eu/news/secnews-1-lt/

ENNEREG booklets for energy consumers

NEW BUSINESS OPPORTUNITIES FOR SOLAR DISTRICT HEATING AND COOLING

In July 2012, the laboratory joined new project ***New Business Opportunities for Solar District Heating and Cooling (SDHplus)***, which was initiated by the EU partners and it's duration is 36 months and is the continuation of previously implemented IEE project ***SDHtake-off***. 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 countries.

Partners from the first project provided decision makers with necessary knowledge, recommendations, possible support schemes in developing solar district heating plants. The successive project *SDHplus* is directed towards wider application of solar district heating plants in district heating network and meeting heat demand in buildings.

The obejctives of SDHplus project is to foster wider application of solar energy in district heating by:

- Describing and promoting examples of successful solar energy integration into solar district heating power plants systems;
- Developing and implementing new pilot business models in solar district heating power plants, taking into consideration the fact that district heating uses renewable energy sources, the application of which in buildings is considered as measures increasing energy efficiency;
- Developing and implementing new market strategies in solar energy district heating sector (such as, the green tariff, engross models).

Meeting with Eiguliai society on 10 03 2012

Responses to visitors questions in the exhibition ***Namų pasaulis 2012*** *on 15–18 03 2012*

Presentation of Birštonas as ecologic town development in conference in Poznan (Poland) on 22 05 2012

Inspection of experimental energy efficient building in Bilbao (Spain) on 09 11 2012

Expected project results:

- New SDH business models and SDH marketing strategies open up new opportunities for DH suppliers and other stakeholders and thus create a relevant contribution to the market growth.
- Show cases are created for integrating SDH into various specific district heating solutions. These show cases respond to the market barriers of DH stakeholders (e.g. combination with CHP, high costs).
- SDH markets develop in the newcomer countries ES, FR, HR, LT, PL, SI. It is estimated that they can reach a capacity of 500 MW^{th} until 2020.
- High level dissemination activities, in particular the international SDH workshops and visit tours to new SDH plants.

Presentation at Panevėžys city conference on 04 12 2012

Presently approximately 130 solar power plants are operating in Europe, the capacity of which is higher than 350 kW. 40 power plants in this number have the nominal capacity higher than 1MW. High capacity power plants with storages are developed to meet day's heat demands in dwelling houses. In European countries solar heat is transferred into coolness. In Denmark and Germany solar power plants with seasonal heat saving storages are continuously developed.

Four experienced countries participating in the project develop solar power plants in the following directions:

- Sweden combines solar power plants with biomass applications in heat network, whereas final consumer producing heat supplies it to city's DH network. 7 MW solar collectors installed on earth in Kungalv town heat up 1000 m^3 capacity storage.
- Denmark integrates solar collectors into local DH network. 13 MW solar collectors are installed on ground heat up a 10 thous. m^3 capacity storage.

***SDHplus** participants at solar collectors installed in Germany*

- German solar collectors are installed on the roof of houses and heat up dwelling houses and transfer heat surplus to seasonal heat storage. In Neckarsulm town 4 MW solar collectors are installed on the roof of dwelling houses and connected with 63 thous. m^3 capacity storage.
- In Austria SDH for town's DH network is performed by energy services company (ESCO). In Graz town 1 MW solar collectors are directly connected to town's DH network.

Solar energy heat is not currently used in DH network in Lithuania. This project will enable to promote knowledge on possibilities to use solar energy in DHN and applied technologies. Despite the fact that the intensity of Solar in Lithuania is lower than in South European countries, the experience of Nordic countries shows that in this climate zone this may be a good alternative to biomass as well as fossil fuel, taking into account that for the same amount of energy to be collected from biomass requires approx. 30 times higher earth surface, whereas estimated heat production costs (in Germany) amount to 40 EUR/MWh (~ 13.8 ct/kWh).

More detailed information on: **www.solar-district-heating.eu.**

Another project related to district heating sector is ***Ecoheat4Cities*** was to be completed in 2012. Its long-term objective is DHC development in the future perspective of increasing sustainability aiming at justifiable systems, appropriate consultations regarding efficient decision making, integrating RES and energy efficiency measures. A more specific aim was to eliminate non-technological obstacles: the lack of knowledge and objective system indicators that impede the use of DHC potential.

District heating and cooling (DHC) is an effective and environment-friendly means to provide heating and cooling services to the consumers, commercial in-

DHC scheme of Denmark city Breadstrup

Solar collectors on the territory of DGC enterprise

Solar collectors installed on the roof of dwelling house

63 thous. m³ capacity storage of collected solar energy

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

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

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

Project's website:

http://ecoheat4cities.eu.

MAIN APPLIED RESEARCH OF THE LABORATORY

The implementation of Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings encompasses regular control requirements or regulation of alternative measures for heating systems in building with heating boilers with capacity larger than 20 kW as well as air conditioning systems with capacity larger than 12 kW, which should be implemented by member states.

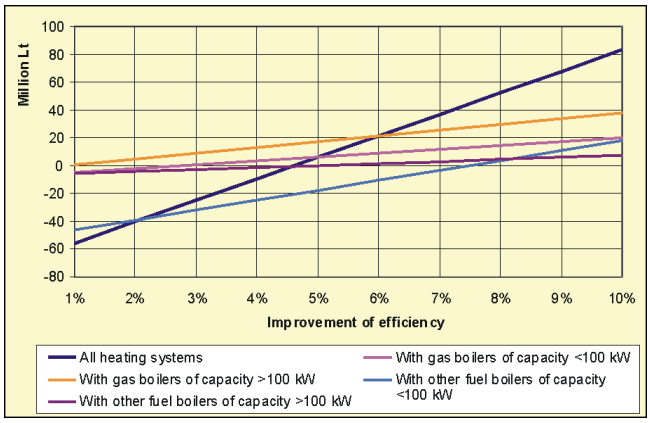
In accordance with the order of the Ministry of Energy a study was performed at the Laboratory, where economic expedience of such regular assessments,

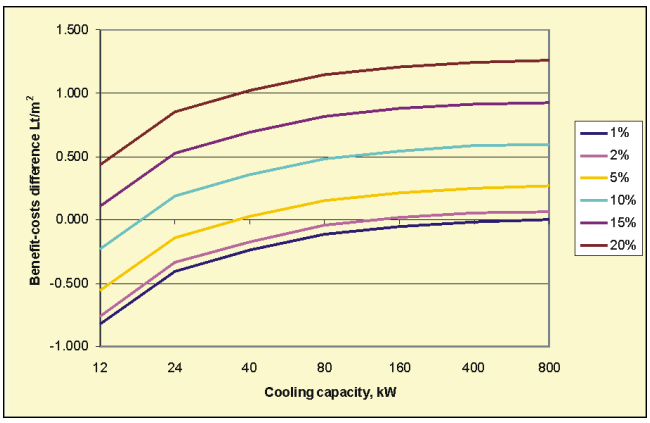
Ecoheat4cities *information for DHC enterprises and town city planners on the benefit and merits of the system labeling and recommendations for their improvement*

based on control expenses and forecasted control benefit due to more efficient operation of engineering systems and saved energy resources of these buildings was evaluated. Alternative measures for regular control were proposed on the basis of studies results – notification of buildings' owners, questionnaires-forms, the use of which would enable to get adequate results for regular checks, which demands lots of expenses.

Another important part of this work – review and correction of present control methods as well as changes proposed taking into account new edition of energy efficiency directive as well as Commission Regulation (EC) No 1516/2007 of 19 December 2007 establishing, pursuant to Regulation (EC) No 842/2006 of the European Parliament and of the Council, standard leakage checking requirements for stationary refrigeration, air conditioning and heat pump equipment containing certain fluorinated greenhouse gases.

Provided corrections and appendixes of methods are confirmed by corresponding Lithuanian regulations.



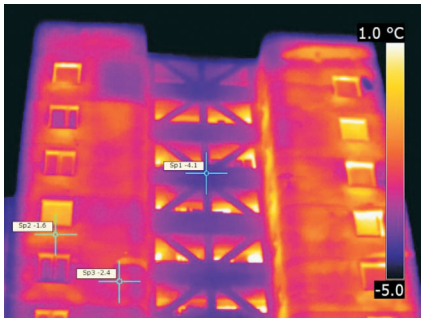


Results of checking costs-benefit analysis for regular heating and air conditioning systems

SERVICES PROVIDED BY THE LABORATORY

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

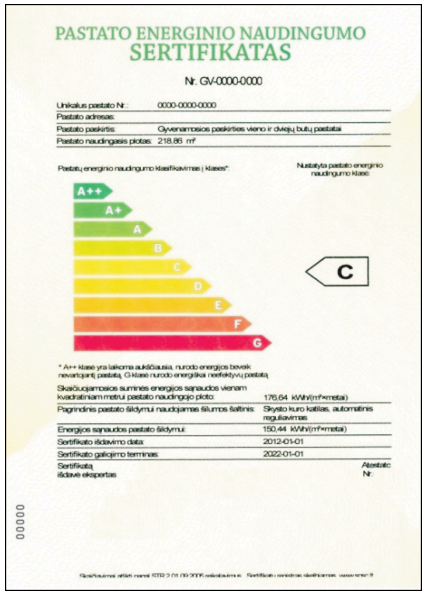
Thermo-vision is a non-contact measuring technology for surface temperatures based on measuring heat radiation intensity. This type of research is applied for investigating and maintaining dwelling houses and industrial buildings, incl. roofs, piping, electrical installation, chimneys and mechanical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



Thermo-visual research

Certification of energy efficiency for buildings

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


PASTATO ENERGINIO NAUDINGUMO
SERTIFIKATAS

Nr. GV-0000-0000

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

Pastatų energinio naudingumo klasifikavimas į klases*:

Nustatyta pastato energinio naudingumo klasė

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

C

* A++ klasė yra laikoma aukščiausia, rodo energijos beveik nevartojantį pastatą, G klasė rodo energiškai neefektyvų pastatą

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

00000

Certification example of energy efficiency for building

PHD STUDIES

On 8 January 2013 a PhD Candidate E. F. Dzenajavičienė has successfully completed the defence of doctoral thesis ***Research of Efficient Biofuel Use for Sustainable Development of Municipal Energy Sector*** . This dissertation was certified.

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

DISSEMINATION OF SCIENTIFIC RESEARCH RESULTS

V. Klevas prepared and published one section from the Monograph. One article is submitted and reviewed in the journal, included into ISI list, 1 article is published and two more are submitted in scientific journals, registered in international scientific information data bases.

In 2012 the researchers of the Laboratory participated and presented papers in local and international conferences; in total, 5 papers were presented in the Lithuanian and 5 in international conferences. Since the researchers pay much attention to educating the scientific and technical community and society on relevant energy issues, they composed 2 science-promotion articles and several leaflets. Researchers of the Laboratory perform scientific research, advisory activities and provide services in accordance with the contracts with Lithuanian public institutions, companies and organizations.

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LABORATORY of RENEWABLE ENERGY

MAIN RESEARCH DIRECTIONS OF THE LABORATORY:

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

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

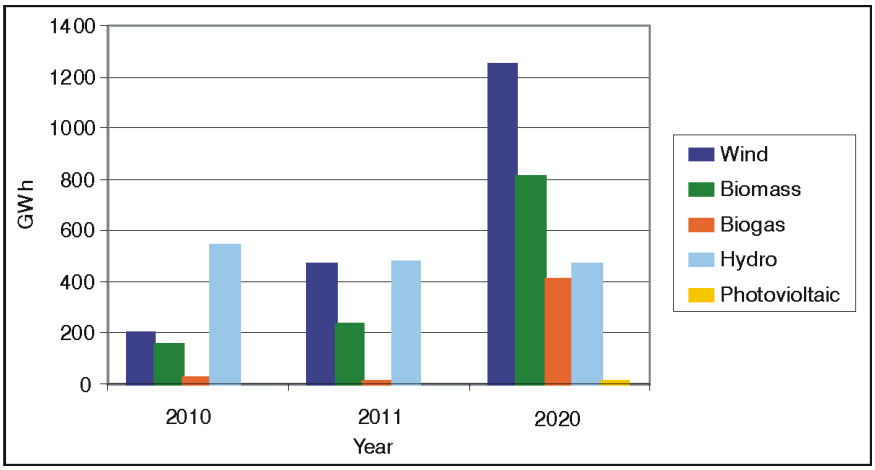
To implement the requirements of the European Parliament and Council Directive 2009/28/EB, and *Strategic Energy Technology* Plan, the Lithuanian National Energy Strategy provides for a notable increase in the use of renewable energy sources (RES) for energy production. Till 2020 the share of RES in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

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

Research of application and intensification and development possibilities in Lithuania of small scale wind power plants and solar energy systems was initiated in 2012. Measurements of wind parameters on the seacoast and mid Lithuania are performed during the project. The impact of meteorological conditions, surface roughness and terrain on wind power plants' operation was estimated. Methodology to predict WPP power by neural network application was described, it will enable to connect physical and statistical forecasting methods and to enhance the accuracy of forecasts. Technical possibilities of solar thermal energy production systems were analysed under different year periods. Taking into account hot water demand, efficiency of systems of hot water preparation with flat and vacuum collectors was analysed.

1 kW wind turbine designed to investigate perspectives of small wind power

Experimental small scale wind power plant on the roof of LEI



Available and forecasted electricity production from different types of RES

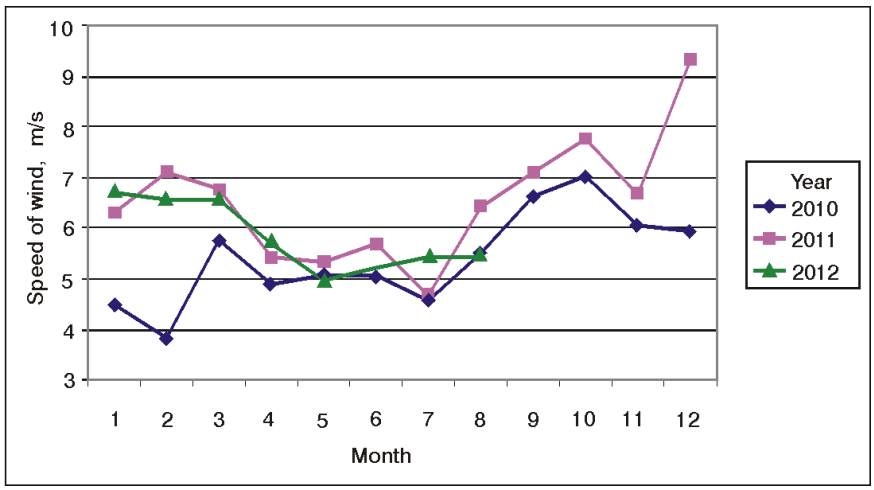
plants under Lithuanian conditions was installed on LEI roof. Next year it is planned to additionally install 3 photovoltaic modules of different types aiming to analyze the perspectives of household supply with electricity.

In 2012 long-term institutional scientific research and experimental development program project ***Research of RES application for efficient energy production and environmental impact*** was initiated. During the project it is planned to investigate scopes of RES sustainable application development, using experimental research to justify efficiency of innovative solid biofuel application technologies for heat production in small and medium power facilities, energy production and consumption efficiency and environmental impact influencing factors. Analysis of sustainable consumption of individual RES for energy production is carried out in the laboratory as well as research of development possibilities.

Regularity patterns of variation of wind velocity profiles were analysed and research of their impact on wind power plants was carried out. According to up-to-date statistical data the resources analysis of biomass fuel and alternative fuels usage for energy production was carried out. Technical-economical assessment of RES usage according to individual types of RES was performed. Scientifically justified RES consumption scopes in heat, biogas and electricity production were identified.

Research and modelling of wind flow characteristics variation in the Baltic Sea coast and other state regions and short-term wind power prediction

It was determined that in different country's coastal region areas the regularities of WPP capacity factor variation are analogous. This reveals that wind flows in the coastal region are correlated. The conducted measurements in one chosen



Wind speed at 65 m height in Klaipėda region (Giruliai)

area enables to accurately estimate wind energy parameters in other areas.

Data of period 2010–2011 reveals that average annual wind velocity at 65 m height fluctuates approximately 18% (in 2010 – 5.4 m/s, in 2011 – 6.6 m/s).

Research revealed that west direction winds prevail in the Baltic coastal region. The highest wind speeds prevail during winter time, the lowest – during summer. Wind velocities also vary significantly during 24h: in the daytime wind velocity is higher than during the night.

Performing the activities of scientific research and experimental development in 2012 a 50 m height meteorological tower as well as wind velocity, direction and atmosphere physical parameter measurement equipment were purchased using *Santaka valley* funds. The tower is constructed in Kaišiadorys district and is designed to investigate wind conditions in the state mid region. Wind velocity is measured at 10, 30 and 50 m heights, whereas direction – at 50 m height. The first measurement results reveal that average wind velocity in July-September at 50 m height reached 5.12 m/s. Like in coastal region, the regularity pattern of wind velocity increase during the daytime was observed.

50 m height meteorological tower in Kaišiadorys district

Measurement data are used to improve the methodology of short-term wind speed prediction for wind farms. Data is compared to numerical weather forecast model data used by Hydrometeorological Service, correlations are carried out using physical and statistical methods and errors are calculated.

RESEARCH OF DEVELOPMENT POSSIBILITIES OF SOLID BIOMASS FUEL PREPARATION AND COMBUSTION TECHNOLOGIES

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

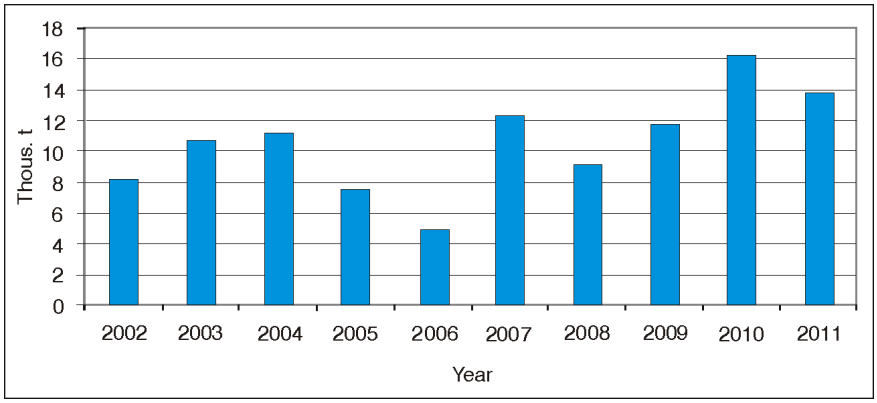
The main resources of biomass include wood waste (forest cutting, wood processing and construction waste) and agricultural waste (straw). Solid biofuel may be used as a raw or processed product (briquettes, pellets, wood chips, sawdust).

The use of solid biomass in central heating supply (CHS) system

The Lithuanian District Heating Association and Biofuel Producers and Suppliers Association have an ambitious goal: to increase the share of RES and other local energy resources in the balance of fuel for heat production up to 70% of the total primary energy till 2020. In order to achieve

Development of fuel structure in DH system

	Year							
Fuel type	**1998**	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2011**
				%				
Natural gas	52.5	80.3	75.5	83.6	79.6	77.0	74.4	73.1
Heavy fuel oil	44.1	17.2	18.7	5.6	4.4	4.1	4.6	2.7
Renewables	2.0	2.0	5.0	10.0	14.0	17.7	19.3	22.4
Other fuel	1.4	0.7	0.8	0.8	2.0	1.2	1.7	1.8



Straw fuel consumption in 2002–2011

this aim, it is necessary to develop an additional network of biomass power plants having the capacity of about 1560 MW; the required investment amount to about LTL 1.1 billion. Currently fossil fuel prevails in the Lithuanian heating sector, whereas natural gas and fuel oil comprised the major share of total fuel until 2003 and the use of wood and sawdust increased since 2004.

Implementing regulations of the National energy independence strategy and EU directives it is expedient to increase the share of RES and other local resources for DH production and at the same time to reduce greenhouse emissions. Therefore it is proposed to construct 1000 MW capacity biomass power plants. Major wood fuel source for all large and medium biomass boiler houses is forest cutting waste, the potential of which has not been exploited enough. In recent years approximately 10% of forest cutting waste have been used in Lithuania.

Big potential of heat energy production lies in agricultural waste (straw), which comprises approximately 4 million of tones in Lithuania. Approximately 500 thous t of straw may be used for heat energy production, however, only 3% of this amount is used.

RESEARCH OF BIOGAS AND BIOFUEL PRODUCTION PROCESSES AND ENVIRONMENTAL ISSUES

Biogas

The Laboratory has been carrying out the research of anaerobic technologies of liquid organic waste processing for many years. It was determined that the rational use of these technologies could result in successful solution of many e*nvironmental, energetic, social and agricultural issues* related to the reduction of environmental impact caused by industrial activity of companies. The environmental effect purports the fact that organic materials are effectively (up to 40–60%) decomposed in bioreactor under anaerobic conditions. This reduces the negative effect on the environment of processed sewage.

Different organic liquid waste is processed in 6 biogas power plants, presently operating in Lithuania. Landfill biogas extracted in 6 landfills is used as fuel in cogeneration power plants of total 6.62 MW_{el} capacity.

Having removed CO_2 and other extraneous admixtures, biogas has recently been supplied to the natural gas networks or

Biogas power plants operating in Lithuania

	Capacity of biorectors, m^3	Processed raw material	Electric power, MW	Thermal power, MW	Year of start
AB *Kauno vandenys*	10 000	Sewage sludge	0.75	1.05	2000
UAB *Utenos vandenys*	2×1000	Sewage sludge	0.275	0.440	1999
AB *Rokiškio sūris*	800	Food processing organic waste	0.50	0.33	2003
AB *Aukštaitijos vandenys*	3200	Sewage sludge	0.33	0.35	2007
UAB *Kurana*	n.d.	Grain	4.0	2.4	2008
AB *Klaipėdos vanduo*	n.d.	Sewage sludge	0.654	n.d.	n.d.

n.d. – no data

Biofuel production amounts in 2005–2011

Year	2005	2006	2007	2008	2009	2010	2011
Bioethanol production thous. t	7.2	9.9	14.9	17.1	24.5	39.3	20.9
Biodiesel fuel production thous. t	7.0	10.3	24.8	64.6	104.7	89.2	79.9

used as alternative fuel for transport in many countries. The Laboratory carries out exhaustive integrated assessment of biogas power plant efficiency by analysing the experience gathered in the Lithuanian and European power plants.

Biofuel

One of the biggest final energy consumers is transport sector, where 40% of total country's energy is consumed. Biggest part of fuel raw material in transport sector is comprised of imported oil products since local products could comprise only 4% of total country's oil demands. The analysis of relevant legislation, and biofuel production and consumption suggests that a great deal of difficulties will emerge in the implementation of the obligations of Lithuania to the EU regarding the goals of using biofuel in transport sector (to use 15% of total amount of consumed fuel till 2020, and 20% till 2025) if no additional economic and organizational measures are taken. It was determined that bioethanol should be substituted for synthetic methanol used for biofuel production, which would enlarge the amount of RES used in the area of biofuel consumption.

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

PARTICIPATION IN INTERNATIONAL PROGRAMS

In 2012 international project ***Solutions for Biomass Fuel Market Barriers and Raw Material Availability (EUBIONET III)*** of Intelligent Energy Europe Programme was completed.

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

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

INTERREG international projects carried out in the Laboratory in 2012:

- *Public Energy Alternatives: Sustainable Energy Strategy for Regional Development (PEA). 2010–2013.* (Baltic Sea Region Programme 2007–2013);
- *Wind Energy in the Baltic Sea Region 2 (WEBSR2). 2010–2013.* (South Baltic Cross-border Co-operation Programme 2010–2013).

The scientific research project ***Public Energy Alternatives: Sustainable Energy Strategy for Regional Development (PEA)*** is implemented by 21 partners from 6 countries of the Baltic Sea region. Among them: 11 governmental institutions, 7 scientific research institutes and 3 coordinating partners. Lithuania is represented by the fol-

Opening of Wind energy information point

lowing 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.

Project activities create an opportunity to collect and spread knowledge and experience in energy field as well as encourage the sustainable district development by cooperating on different levels, planning developmental guidelines and taking into account the attitude towards regional development. The aim of the project is to find appropriate means for reducing the costs of public utilities by using alternative energy sources. The main result of the project was the development of sustainable regional energy strategy and its implementation in one of the regions.

The scientific research project ***Wind Energy in the Baltic Sea Region 2 (WEBSR2)*** analyses the legal basis for the development of wind energy and economic, technical and social issues impeding its development. Additionally, the problems, related to the accumulation and storage of energy generated in wind power plants, are addressed. Having assessed the existing obstacles, recommendations for the enhancement of energy development in Lithuanian and the EU countries were prepared and provided to the municipalities, investors and project developers. Its aim is to provide objective, science-based information about wind energy technologies, their impact on the environment and public health in seminars, lectures, excursions, training courses and other events. WEIP will also collect and provide wind power project developers and investors with information about the Lithuanian legislation, project funding possibilities, economic conditions, environmental impact and social aspects.

Wind Energy Information Point

Wind Energy Information Point (WEIP) was established on 4 May, 2012, the aim of which is to provide objective, science-based information about wind energy technologies, their advantages and disadvantages, to promote scientifically based society's attitude towards rational application of wind energy resources. Partial financing for WEIP establishment was received by implementing international project *Wind Energy in the Baltic Sea Region 2*. Feasibility studies of wind energy projects, assessment and modelling of factors conditioning wind power plants' impact on the environment and public health are carried out in WEIP, consultations on wind energy project preparation and legal basis issues as well as seminars are organized for industry and energy specialists, businessmen, lecturers, and students. Other activities are also implemented: lectures and practical trainings for students, competitions and excursions are organized.

SCIENCE PROMOTION ACTIVITY

In 2012, during the implementation of international projects in the field of RES, scientific ideas were spread to promote the society to take interest in the variety of RES technologies and possibilities of their practical application. Researchers of the laboratory made presentations in public seminar *Green energy. Myths and reality* regarding possibilities of wind energy and biogas application. Presentations on RES development in the country were made in international conference *Diversity of renewable energy sources* in Anykščiai town and in conference *Kaunas society – towards sustainable energy: renewable energy sources and efficient energy usage in Kaunas city.*

*Seminar **Obstacles for wind energy development in Lithuania**, 4 May 2012. Speaker – representative of LR Ministry of Energy V. Sankauskaitė*

Practical activities with students

In 2012 when implementing international project ***Wind Energy in the Baltic Sea Region 2*** two seminars on wind energy issues were organized. In the first seminar, obstacles for wind energy development in Lithuania were discussed, whereas in the second seminar, the small wind energy development perspectives were analysed. Participants of seminars – businessmen, representatives of municipalities, public health centers and science enterprises, students, potential investors, representatives of communities.

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

In 2011 the researchers of Laboratory published 1 article in scientific publications with citation index in ISI WoS database, 1 article was accepted for publishing. 3 articles were published in scientific publications, registered in international scientific information databases, 1 presentation paper was published in the international conference proceedings. 4 science promotion articles were published. Research results were presented in 2 international and 4 national scientific conferences. The monograph *Vibration of tubes in Heat Exchangers* by V. Katinas and other co-authors was translated into Chinese language.

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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.

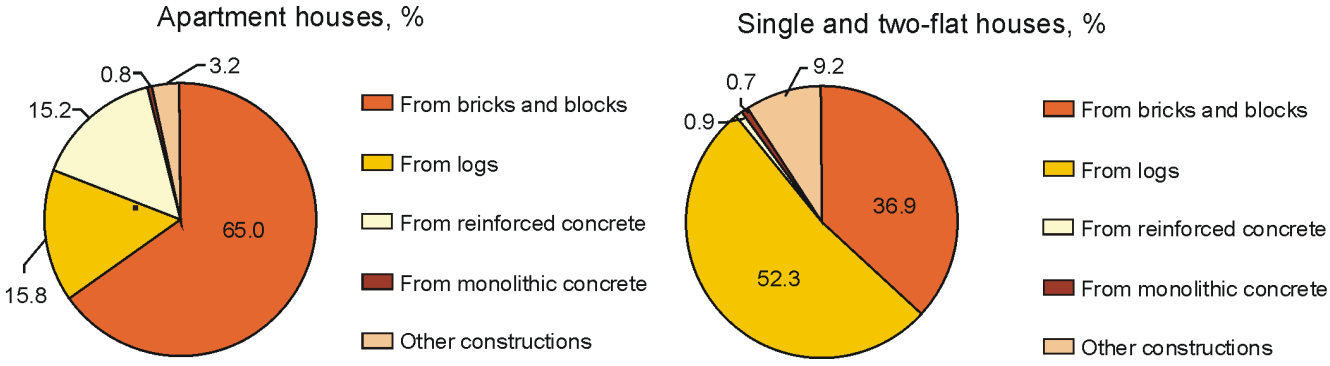
RESEARCH OF ENERGY PRODUCTION AND CONSUMPTION EFFICIENCY IN LITHUANIA

In 2012 a state funded research project ***Investigation of new generation heat pumps' application for heat production*** was initiated.

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.

Aiming at more efficient energy use, reduction of CO_2 emissions, increase of renewable energy use in the European Union, the EU Parliament and Council approved new Directive namely: 2009/28 EC

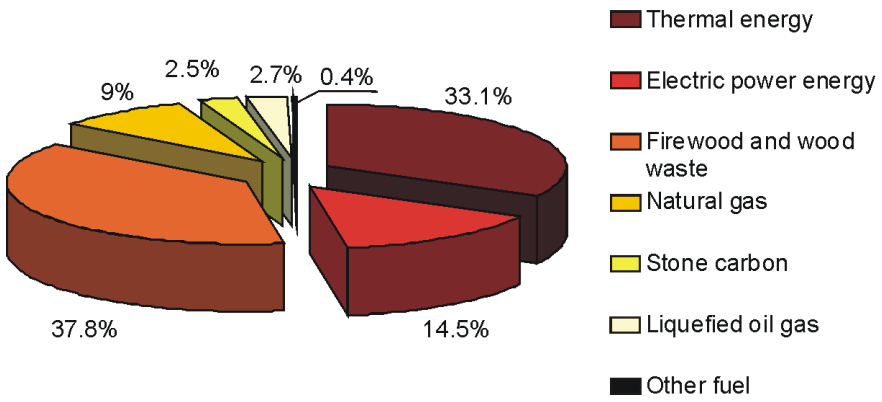


Distribution of dwelling houses in Lithuanian according the type of wall constructions

on the Promotion of the Use of Energy from Renewable Sources and *2010/31/EC on* Energy Performance of Buildings (PEND). Implementing the latter directive the EU Commission promotes that no later than 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 heating pumps, thermal energy devoted to heating buildings in the field of production.

There is a long-lasting discussion in Lithuania on geothermal heating using heating pumps. The amount of implemented such heating technologies in Lithuania increases. However, one of the factors preventing from more rapid implementation of such technologies in Lithuania is too high heat consumption in buildings, which at present time in dwelling houses amount to 120 kW/m^2 per year, whereas in single apartments and public buildings this number is even bigger.

In case of such big heat consumption, the application of heating pumps from the economic perspective is not very attractive for radiator heating systems in buildings. From 2020 under implementation of the EU Directive 2010/31/ES (PEND) consumption of thermal energy in buildings will be particularly reduced and will amount to 15 kWh/m^2 per year. Under such conditions the up-to-date thermal energy production technology may become heat production using heating pumps. This would fundamentally enable to reduce fossil fuel consumption and greenhouse gas emissions. Preparing for the mentioned period



Fuel and energy consumption in household according types, %

it is necessary to expand scientific research, pilot projects, applied research works devoted to implementation of heating pumps in Lithuania. For this purpose the increase of know-how of specialists working in this field is necessary.

Statistical data and its analysis on single-apartment houses (1–2 apartments), multi-apartment houses (3 and more apartments) and other purpose buildings present in Lithuania by 01.01.2012 are submitted in the performed work. It is revealed that main area of buildings' sector is occupied by single-apartment houses. They amount to 439767 houses (total area – 53 481 976 m^2) or 64.2% from all present building number by 01.01.2012. Multi-apartment houses comprise 37 379 buildings (total area – 51 917 557 m^2).

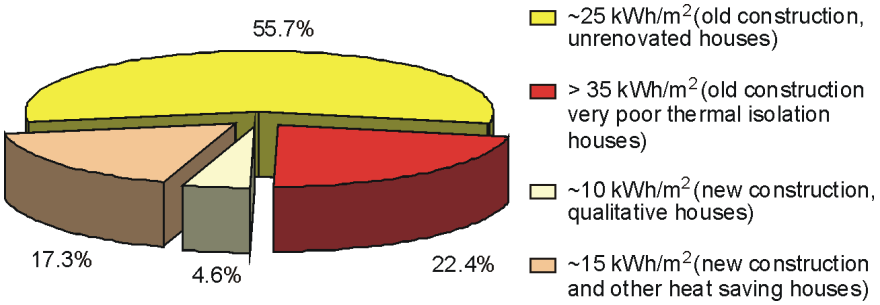
Total area of these buildings is similar: 53.5 mln m^2 single-apartment buildings and 51.9 mln m^2 multi-apartment buildings. The volume of buildings is also similar: ~199 mln m^3 single-apartment houses and 200 mln m^3 multi-apartment houses.

Most Lithuanian buildings (~95%) were built in 1995 in pursuance of the construction technical requirements of that time. According these requirements, buildings are distinguished for very bad thermal isolation due to which energy consumption in them is very inefficient. Only from 1991–1995 the microclimate requirements for buildings began to be more rigid for newly built buildings. Present amendment STR 2.05.01:2005 to construction technical regulation (Official Gazette, 2011, No. 26-1292), which came into force on 04. 03.2011 increased the requirements for thermal resistance of external separation screens of buildings for up to 5 times (to $R_{atitv.}$ = 5.0 m^{2}K/W) and approached, for instance, Swedish requirements for buildings, built in Southern part of Sweden.

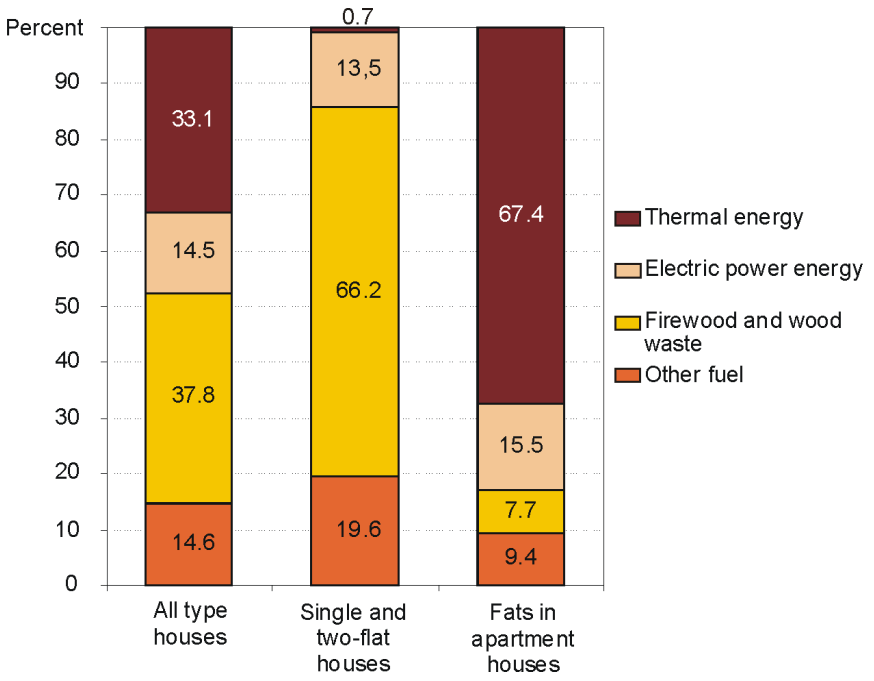
The performed analysis of thermal energy consumption in buildings revealed that average heat consumption in multi-apartment houses amount to 120 kWh/m^2 per year. Heat consumption in single-apartment houses and public buildings is even higher.

Basic fuel share for DH thermal energy is comprised of natural gases (73.1%) and RES – 22.4% (93% of which is biomass).

Review on EU and Lithuanian law acts, regulating freon usage, design and



Percentage distribution of apartment houses according consumed heat amount per month, %



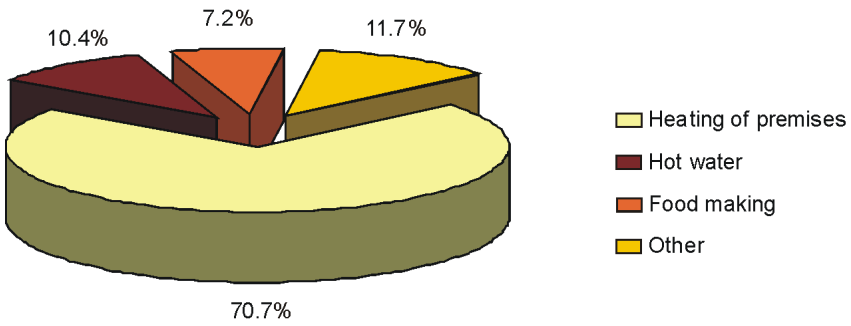
Average fuel and energy consumption according house type

production of heating systems with heating pumps as well as the qualification requirements for physical and juridical persons who install and maintain these systems is presented in the report. Besides, promotional measures for heating pumps implementation in Lithuania, foreseen in Renewable Energy Law of Republic of Lithuania (Official Gazette, 2011, No. 62-2936) and in the Order of the Minister of the Environment of the Republic of Lithuania of February 10, 2011 *Regarding maximum subsidies approval for low scope projects, financed from the specific Climate change program assets* (Official Gazette, 2011, No. 20-972) are submitted.

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 aerothermal, 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.

EU and Lithuanian law acts regulating the construction of passive and almost null energy buildings are discussed in the report. Thermo-dynamic analysis of compressed heat pumps (using freons and natural origin cool transmitter R744) is submitted.



Fuel and energy consumption in household according appliance direction, %

PARTICIPATION IN INTERNATIONAL PROJECTS

In 2012 the international project ***Product and Process Design for AmI Supported Energy Efficient Manufacturing Installations (DEMI)*** was continued. It is partially financed by the EU 7th Framework Programme for Research, Technological Development and Demonstration Activities. The period for the implementation of the project is 2010–2013.

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

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, are going to be developed:

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

In 2012 during the implementation of the project, currently functioning industrial processes and product design systems were updated with the mentioned ICT components. In 2012, 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%.

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

In 2012, the Energy Efficiency Research and Information Center and the Laboratory of Renewable Energy together with 21 partners from 6 Baltic Sea region countries (Germany, Estonia, Lithuania, Latvia, Poland and Finland) continued the implementation of the international project ***Public Energy Alternatives – Sustainable Energy Strategies as a Chance for Regional Development*** **(PEA)** of *Baltic Sea Region Programme 2007–2013*. The period for the implementation of the project, which is partially financed by the EU (European Regional Development Fund), is 3 years.

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

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

The participants of the EU Baltic Sea Region programme PEA and moments of their activities in 2012

Booklet of the EU Baltic Sea Region programme PEA project

of the region. The investments realised during the project gave an excellent example of using the alternative energy potential in the region.

In pursuance of the aims of the project in 2012 there was a close cooperation with Ignalina NPP Regional Development Agency, representatives from JSC *Eksponentė* as well as Ignalina, Zarasai and Visaginas municipalities in preparing NPP region sustainable development strategy and discussing future action plans of municipalities. A brochure was prepared in Lithuanian language on the EU Baltic Sea region program. LEI representatives participated in project implementers' workshop visit in Sweden and Denmark, got acquainted with the possibilities to increase energy consumption efficiency as well as up-to-date technologies of alternative energy sources (biofuel, water, wind, solar). The results of this visit are presented in journal *Thermal Engineering* 2012 No. 2 (Vol. 51).

Theoretical and technical potential of final energy from RES were identified and strength, weaknesses, opportunities and threats (SWOT) analysis for RES potential in INPP region was performed. Project's website was created: **http://www.lei.lt/_img/_up/File/atvir/pea/index.htm** .

Action Plans devoted to the implementation of Regional Energy Srategy for Ignalina, Zarasai and Visaginas municipalities were prepared.

According to the topics of the research carried out in 2012, 2 seminars were arranged, the results of the studies were introduced in 5 scientific articles and 2 scientific papers were presented in scientific conferences.

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LABORATORY of SYSTEMS CONTROL AND AUTOMATION

MAIN RESEARCH AREAS OF THE LABORATORY:

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

Power system (PS) is one of the most complicated 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 energy transfers, voltages, currents, active and reactive powers, phase angles and other parameters, and are under the constant variation. The modes should be controlled properly so they would not exceed the allowable parameter limits, and this is the basic task of PS operator. Control is rather complicated procedure even in case of normal operations. Nonetheless, the systems rather often experience the stressed operations, and sometimes – contingencies and post-contingency modes, which should be prevented from going out of control. Uncontrollable operational modes may result in loss of dynamic stability, voltage collapses and lead to partial outages or even blackout of a power system. Systemic and preventive automation with embedded relay protection devices, and multiple digital controllers as well as on-line data transmission systems (linking generators and network substations with dispatching centers) support the operators in control of systems and networks and in protection against contingency-induced failures.

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

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

When preparing the control measures (plans of facility switchover, set-points of automatic devices, dispatching control signals, etc.), the operators rest on the modeling results, i.e. on calculations of operational modes. This is an activity which requires deep scientific knowledge necessary to develop relevant calculation algorithms, estimation methodologies and analysis procedures.

Major changes are currently evident in the evolution of modern PS. Multi-system electricity markets are spreading geographically as well as in their scope, offering a variety of electricity market products (active power reserves and other ancillary services, forward financial transactions). Electricity consumers and small generators are included into electricity market and provision of ancillary services. Electricity becomes more ecological due to increasing share of renewables-based generation, and, maybe, due to expected 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, predominantly those based on ICT. Nowadays the outcomes of their implementation are defined by new concepts such as *smart generation, smart electricity network, smart relay protection, 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 power network 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 extra algorithms and software programmes are installed into controllers, and their functioning should be monitored. The actions of controllers should be coordinated and the controllers "reprogrammed" in order to remove the observed inadequacies.

In 2012, researchers of the Laboratory together with JSC *Energetikos Projektai* performed contractual scientific project ***Feasibility study of renewal/reconstruction of the 6-kV indoor switchgear in ORLEN Lietuva thermal power plant*** (Contractor – JC *ORLEN Lietuva*). Both the technical opportunities were estimated and the solutions for the renewal, modernization and reconstruction of the 6 kV indoor switchgear were developed. Advantages and drawbacks of these competing solutions were specified and discussed. Upon evaluation of actual technical condition of switchgear facilities and taking to account the requirements brought up by the Contractor, six different solutions were chosen as eligible ones for the final decision.

The project was prepared with close regard to the real characteristics of both "external networks" and consumers, and their loads, with the viewpoint to search for optimal solution, including its compliance with the principle of least investments and expenditures. To deal with operational modes of the switchgear under consideration, special mathematical models were developed which reflect not only specificity of this switchgear, but also relevant structures of oil refinery's (JC *ORLEN Lietuva*) power network and Lithuanian transmission network.

The project comprised the following parts:

- description of renewal, modernization and reconstruction solutions with draft electrical schemes and reserving supply paths;
- comprehensive results of power network calculations (loads, flows, reliability, short circuits) obtained using PSS/E software package;
- sketch of electrical facilities layouts;
- technical specifications of major facilities;
- solution's implementation schedules;
- solution cost budgets with estimates of the fourth precision class (-25%/+30%) pursuant to ANSI Z94.0;
- decision on optimal solution.

Technical and economic assessment of proposed solutions was performed in the work and report was prepared, where benefits and drawbacks of solutions were indicated as well as technically and economically optimal version.

This work from previously performed design activities of objects differs in the fact that previously "complex approach" and method were applied.

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).

The project refers to the Lithuanian National Energy Strategy (2012), which envisages the direct current links *LitPol Link*, 1000 MW (with Poland), and *NordBalt,* 700 MW (with Sweden). After construction of these links, Lithuanian PS will be asynchronically connected to Continental Europe and Northern Europe networks, respectively, with subsequent switchover of the *LitPol Link* converter station (in Alytus) to asynchronous work with IPS/UPS power system. In order to adequately model the future static and dynamic processes of Lithuanian PS with these interconnection

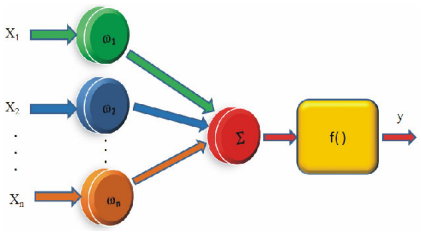
links, it is necessary to extend its mathematical model by submodels ones describing operation of direct current converters. Currently most popular converter technologies are VSC (voltage-source converter) and LCC (line-commutated converter). *LitPol Link* will be provided with LCC technology, while VSC technology is to be embedded into *Nordbalt* link (with considerable contribution to PS stability). Consequently, the VSC and LLC mathematical models were developed, with the structure and parameters adequate to real brands to be installed on aforementioned links.

Furthermore, taking to account the promising future prospects of wind power plants in Baltic region, it is also necessary to evaluate their impact on Lithuanian PS. Therefore new mathematical models of wind power plants were developed, with the focus on 2 major technologies:

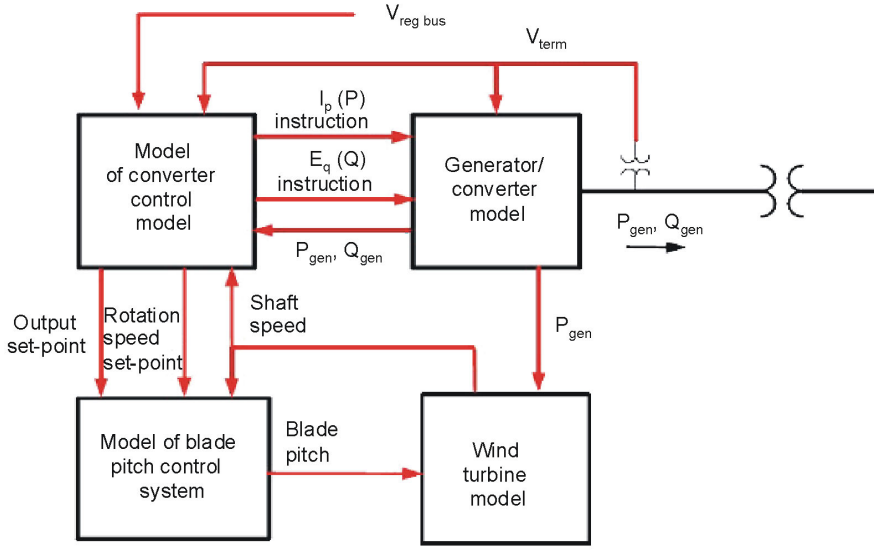
- synchronous generators;
- double-fed asynchronous generators.

In result, models of both categories (direct current converters and wind power plants) were integrated into the mathematical model of Lithuanian PS. The extended model was validated by the test calculations and acknowledged to be suitable for simulation of system's operational modes.

The researchers of the Laboratory jointly with Laboratory of Renewable Energy Sources worked on the state-funded project ***Research of intensified application and development possibilities of small wind power plants and solar energy systems in Lithuania***. The study was aimed at the development of wind power generation forecasting model. The Laboratory's contribution was to develop a statistical forecasting model and a summarization model. The latter yields the coherent summarized forecasts from the outputs of statistical and physical forecasting models. The summarization model was built employing principles of artificial neuron networks (ANN). Therefore the review of literature related to the applicability of ANN for the wind power forecasting purposes was performed in 2012.



Scheme of artificial neuron



Structural scheme of wind power plant model

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF LITHUANIA

As a participant of an institutional long-term scientific and technical research programme, the Laboratory was entitled to investigate the issues related to the project ***Possibilities of Lithuanian power system's synchronous operation with ENTSO-E with respect to the future extension of generating capacities***.

In pursuance of energy independence, main objective of Lithuanian energy policy is to switch Lithuanian PS to synchronous operation with the Continental Europe network (CEN). However, as known, the physical construction of interconnecting links (lines and substations) is not a sufficient pre-condition. The major challenge refers to the problems of sophisticated control of system's operational modes. To solve them, PS operators should be supported by the advanced regulation systems complying with the specific requirements. Within the scope of the task *Collection, analysis and summarization of information on present and future load and frequency regulation sources (regulation reserves)*, the analysis focused mostly on the currently available Lithuanian generation sources. The sources were ranked in the list of significance basing on the generation and other technical characteristics. These characteristics were meant to have a relevant contribution into load and frequency regulation. They include, notably, the start-up duration (from the "cold" state) of a generating unit, the droop range and its change-over step, the widths of insensitivity zone dead-band zone of a regulator.

Using the characteristics as mentioned above, the conformity of Lithuanian generation sources to the CEN requirements was thoroughly assessed. The assessment revealed that the major problems within the scope of this task are related to

insufficiency of the primary regulators. Namely, they have too wide insensitivity zones (Kaunas Heat and Power Plant, Vilnius Combined Heat and Power Plant-3, units #2 and #7 of Lithuanian Power Plant). These zones should be narrowed in the nearest future thus eliminating the major obstacle for Lithuanian generators to be run synchronically with CEN.

Within the scope of the next task *Investigation of technical and economical characteristics of frequency and power regulation sources with respect to the specificity of Lithuanian PS*, the analysis focused mostly on dynamic mobility of Lithuanian generating units and their economical characteristics. In accordance with ENTSO-E (European Network of Transmission System Operators for Electricity) rules, primary frequency regulation systems must have adequate dynamic characteristics. A generating unit has to be able to change its power output in proportion to the deviation of control signal from pre-determined one. 50% of required power increase should be delivered within 5 s, the rest 50% – 25 s. The duration of transient process should not exceed 30 s. The investigation proved that dynamic characteristics of Kruonis Pumped Storage Plant and Kaunas Hydroelectric Power Plant comply with ENTSO-E requirements. Other Lithuanian power plants will be investigated in 2013. Awareness of dynamic characteristics of the units will help identify the reserve amounts of primary, secondary-fluctuation, secondary *n-1* and tertiary regulation, respectively.

From the future perspective, successful participation of Lithuanian power plants in load-frequency regulation will be ensured not merely by relevant technical characteristics, but only in conjunction with good economical performance. It refers basically to the thermal generating units whose frequency regulation cost issues were not addressed in Lithuania as yet because the major burden of this regulation is still carried by Russian PS. Aiming at quantification of regulation cost for Lithuanian thermal generating units, the 3 following issues should be clarified, at least:

1) how does the unit's efficiency η depend on two major parameters as unit's regulation range (amplitude) and regulation period, when unit is involved into automatic load and frequency regulation?
2) how is the useful life (longevity) of the unit influenced by its involvement into load and frequency regulation?
3) what should be a fee for the frequency regulation in a power system, taking into account the first two issues and economic loss, if such regulation would be conducted outside Lithuania?

Addressing the first issue, a novel methodology was developed suggesting determination of the unit's economic characteristics that associate efficiency with its regulation range (amplitude) and frequency. The methodology was applied to the unit #8 of Lithuanian Power Plant. The respective calculations lead to the finding that participation in the load and frequency regulation brings down the unit's efficiency and such a decrease is proportional to the standard deviation of generated power.

The obtained results suggest that the participation of thermal power plants in load and frequency regulation could be reasonably required to be technically and economically justifiable. Conversely, a regulation with too high accuracies would cause significant extension of PS operation costs, while lower accuracies may bring down the reliability of PS and quality of electricity supplied.

The outcomes of this research encourage the Laboratory to proceed with investigations on availability of frequency and power reserves in Lithuania, and on their technical and economical characteristics in a coming year 2013.

In 2012, Laboratory's researchers performed several scientific expertises in national and international market. Dr. V. Radziukynas contributed to the energy legal regulation as a member of *ad hoc* group entitled by the Ministry of Energy to prepare the draft of *Rules on Use of Power Networks* (enacted on 2012 06 18). As an external expert, he also evaluated the applications of Kazakhstan researchers submitted for the financial support from US funds. Dr. A. Klementavičius participated in the international expert groups which evaluated quality of study programmes (science branch *Electrical engineering and automation*) in Lithuanian and Latvian higher education institutions.

Research results will be a contribution to long-term institutional scientific and technical research programme ***Economical and sustainability analysis of energy sector development***, which is jointly performed by Laboratory of Energy Systems Research, Laboratory of Regional Energy Development and Laboratory of Systems Control and Automation.

The research results from 2012 were presented in 1 international conference, 1 popularization article, 1 article in the scientific journal (included in ISI list) and 1 article in the book.

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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 activity (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 up-to-date digital modelling systems, the Laboratory solves the following tasks:

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

The Laboratory of Hydrology carries out fundamental and applied research in the field of environmental engineering employing numerous hydrographic, hydrologic, morphologic, meteorological and other data, collected 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 transport processes, and pollution dispersion, hydraulic process model HBV, developed by Swedish Meteorological and Hydrological Institute, as well as geographical information systems ArcGIS. This enables solving the most important environmental issues in the assessment of the anthropogenic activities impact on environment and justifying environmental protection measures.

In the recent decade, the Laboratory has been implementing research related to the assessment of the impact of climate change on water resources. Since 2010, a state funded scientific research project ***Research of Changes of Hydrological Regime in the Curonian Lagoon due to Environmental and Anthropogenic Factors*** (supervisor Prof. B. Gailiušis) has been under implementation. The hydrological regime and water quality of the Curonian Lagoon, which is protected by NATURA 2000, have a great influence on the condition of the Baltic Sea. Water regime of the

Lagoon depends on the meteorological conditions (air temperature and precipitation), rivers flowing into the Lagoon, hydrological regime and the changed permeability of the Klaipėda Strait due to the dredging of Klaipėda port. In order to expand the Port, first of all, it is necessary to find out the possible changes of water balance in the Lagoon in respect of climate change and anthropogenic factors. On the basis of hydrologic and meteorological database, the long-term water balance of the Curonian Lagoon of 1961–2007 was estimated.

To assess possible changes in the water balance of the Curonian Lagoon in the 21st century, it is crucial to forecast water balance elements (the changes of total river inflow, precipitation, evaporation and water exchange in the Klaipėda Strait). The Nemunas inflow is the main source of the water balance income of the Lagoon, thus, a hydrological model of the Nemunas up to the mouth was developed using HBV code and daily data of the period of 1961–1990, gathered in 10 water measurement and 14 meteorological stations.

Using the developed run-off model and data of climate change, the Nemunas inflow into the Curonian Lagoon was modelled for the period of 2011–2100 according to two models of climate change and three emission scenarios (Fig. 1). After analysing forecasted water balance element variation for the 21st century it was determined that in comparison to the reference period, river inflow would reduce by 25.9%, whereas evaporation due to increasing air temperature – by 25.1%, the amount of precipitation would increase insignificantly (up to 3.8%), run-off from the Curonian Lagoon to the Baltic Sea would decrease by 16.6%. When expanding the Klaipėda harbor in the 21st century it is expedient to estimate changes of inflow from the Baltic Sea to the Curonian Lagoon since only due to climate change this inflow may increase by 39.7%.

In 2010–2012, the researchers of the Laboratory, together with the Laboratory of Nuclear Installation Safety and Laboratory of Energy Systems Research, implemented a state funded scientific research project ***Analysis of Processes in Complex Technical, Natural and Social Systems Applying Best Estimate Methodology*** (supervisor Dr. Habil. A. Kaliatka), financed by state subsidies. In 2012 uncertainty analysis of the Merkys river hydrological model was carried out by applying the best estimate methodology.

INTERNATIONAL COOPERATION

Together with scientists from 23 European countries, the researchers of the Laboratory participate in the COST ES0901 project ***European Procedures for Flood Frequency Estimation*** (2009–2013). They perform activities in two work groups, namely *Evaluation of statistical methods for flood frequency estimation* and *Impact of environmental change on flood frequency estimates*. Last year, the common methodology of the work in progress was discussed in two meetings of COST project participants at the same time evaluating the tendencies of flood variation in Europe. On 24-26 10 2012 researchers from EU countries presented COST activity results in international conference *Advanced Methods for Flood Estimation in a Variable and Changing Environment* in Volos city (Greece). This conference was devoted to summarize the activities of COST action ES0901 FloodFreq (the midterm conference). J. Kriaučiūnienė and D. Šarauskienė contributed paper *Flood pattern changes in the rivers of the Baltic States* (Fig. 2).

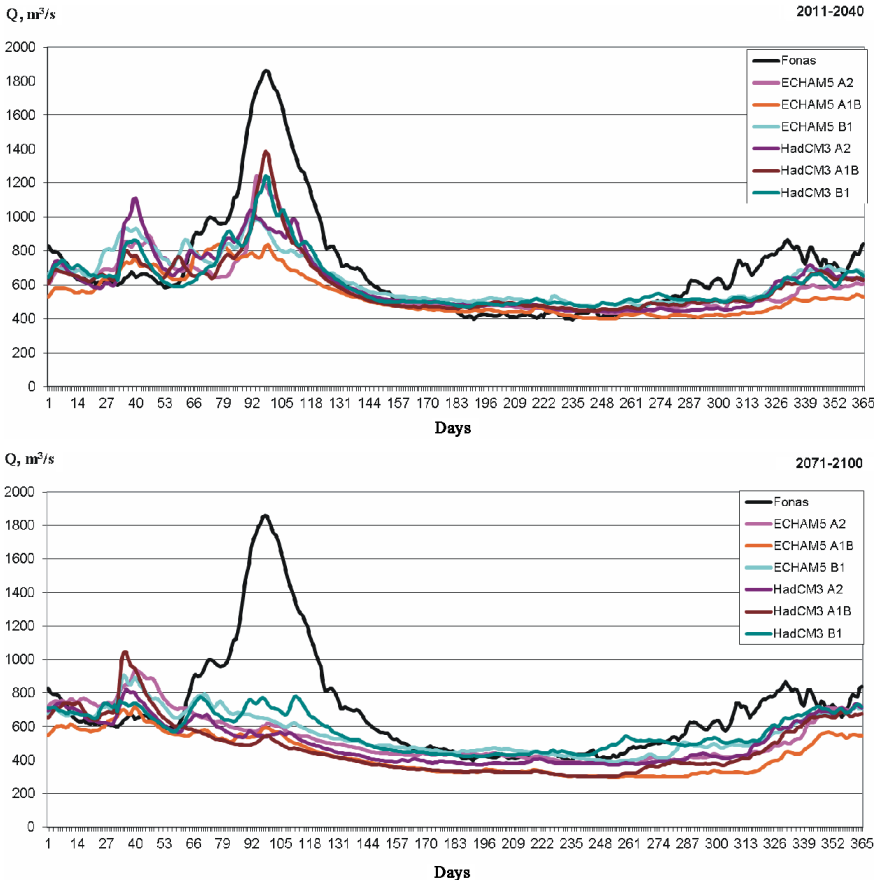

Fig. 1. Forecasted Nemunas run-off at the mouth of the river according to Echam5 and HadCM3 global climate models under A2, A1B and B1emission scenarios for the periods 2011–2040 and 2071–2100

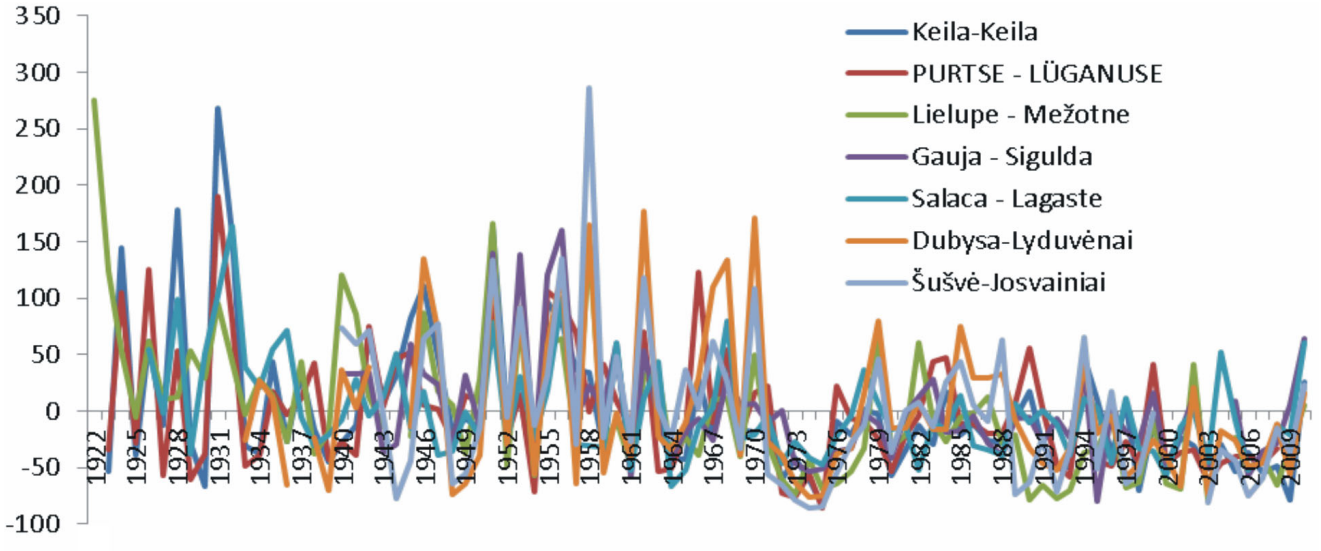

Fig. 2. Maximum spring flood anomalies (%) in the rivers of the Baltic States

***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 XXXVIII meeting of EurAqua members took place on 19–20 April 2012. 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 2010* related to the most relevant aspects of freshwater use and protection.

COOPERATION WITH STATE AND SCIENTIFIC INSTITUTIONS

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 research 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, Lithuanian Health Sciences University and maritime companies, 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 Lithuania marine sector technologies and environmental research*.**

MAJOR APPLIED RESEARCH WORKS

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

- Under the agreement with **Klaipėda State Seaport Authority**, preparatory work for harbour navigation channel dredging, i.e. environmental impact assessment, technical project for dredging and reports on engineering geological research, are being prepared;
- Under the agreement with Klaipėda State Seaport Authority, environmental impact assessment report (EIA) of the Šventoji State Seaport reconstruction is being prepared;
- Under the agreement with ***JSC Sweco Lietuva*** study *PEA (proposed economic activity) impact on the flow and sediment balance of Klaipeda straight, 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;
- Under the agreement with **Nature Research Center** the assessment of Kaunas Hydro Power Plant water body water level fluctuation was carried out.

MIKE 21 modelling system was applied for the evaluation of navigation conditions and the environmental impact of Klaipeda and Šventoji Seaports' development. The most important tasks are the navigation channel dredging, building and reconstruction of harbours.

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

"0" – zero alternative, i.e. present state of the seaport;
"1" – short, 400 m long breakwaters, 6 m deep harbour and 7 m deep entrance channel;
"2" – long breakwaters (800 m), 6 m deep harbour and 7 m deep entrance channel;
"3" – long breakwaters (800 m), 8 m deep harbour and 9 m deep entrance channel.

Modelling of hydrodynamic and sediment transport processes demonstrated that the "1" alternative of the seaport reconstruction meets minimal requirements and has the least impact on the litodynamic processes of the coast. "2" alternative would result in erosion of the shores in both southern and northern sides of the port (Fig. 3). Finally, dredging of the port ("3" alternative) up to 8 m would increase the impact on the sediment transport processes. In 2012 the coordination of Šventoji seaport EIA with state institutions and foreign countries was performed.

The old Šventoji Seaport

One of the basic planned energy objects in Lithuania is the construction of liquefied natural gas import terminal (LNGT). In 2012 JSC *Sweco Lietuva* performed EIA for this terminal. LEI experts from Laboratory of Hydrology estimated LNGT probable impact on the balance of Klaipėda straight currents and sediments, erosion

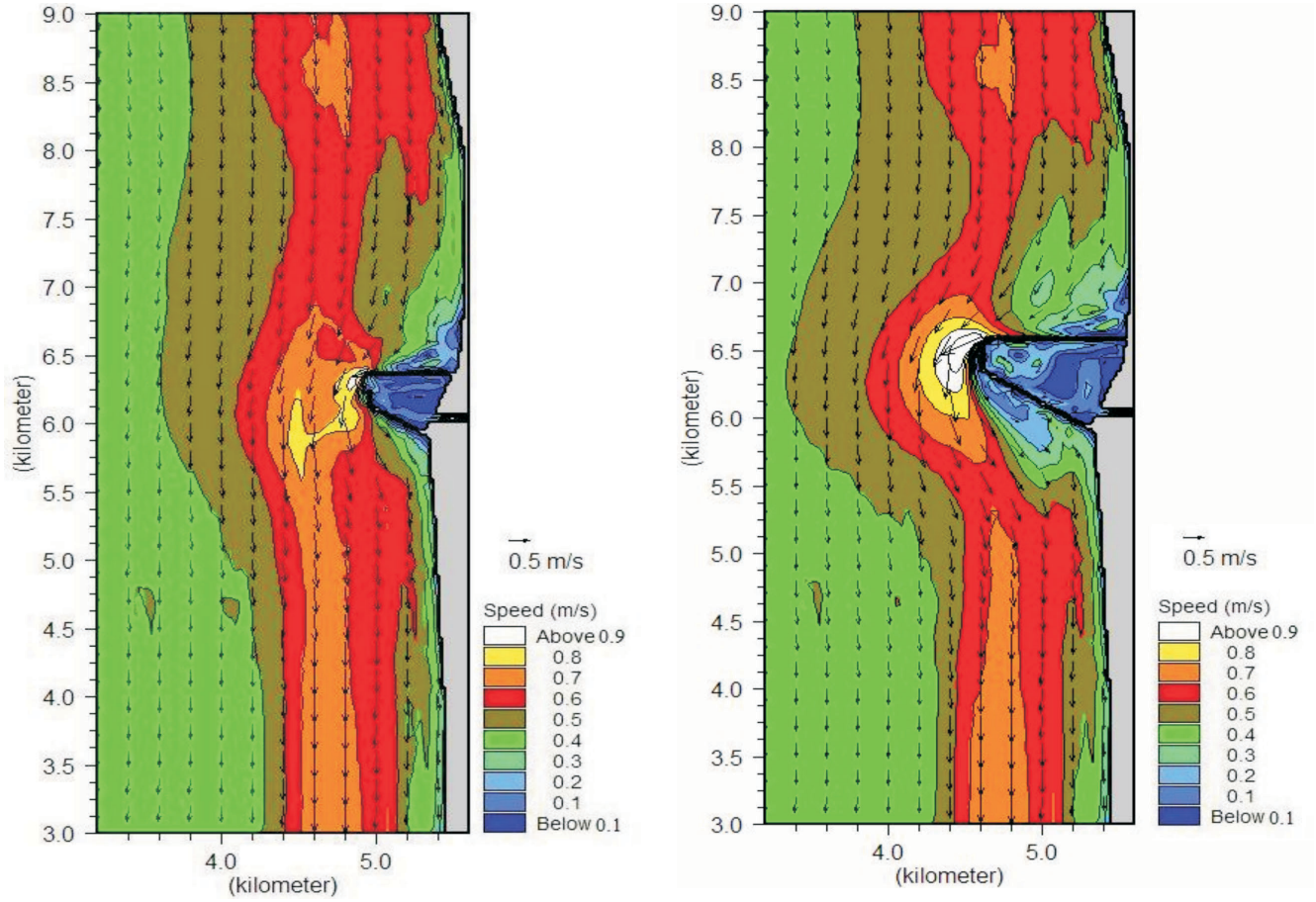

Fig. 3. The structure of flows in Šventoji seaport water area at Northern-Western wind direction 20 m/s: a) "1" alternative, b) "2" alternative

and accumulation processes, bottom changes, and measures to mitigate this impact.

Applying MIKE 21 modelling system the capacity of Klaipėda strait was calculated as well as the structure of flow velocities and sediment transfer for the following alternatives:

"0" – zero alternative, i.e. present state of the seaport (estimated presently performed dredging and widening of straight channel up to 14.5 m);

"1" alternative – dredging works of straight were performed preparing the turning place of LNG transportation ships (14.5 m deep) and terminal place (16 m deep). These are construction period conditions the duration of which is 1–2 years.

"2" alternative – dredging works of straight were performed according to "1" alternative and LNG terminal was equipped. This alternative reflects operation period conditions.

The installation of LNGT near Kiaulės Nugara during construction (from 0.2 to 0.3%) increases permeability of Klaipėda straight very insignificantly. After constructing LNG terminal permeability of Klaipėda straight diminished to 1.0–1.5%. This change is favourable to the processes of the Baltic Sea and the Curonian Lagoon water exchange, which will be intensified due to deepening of Klaipėda harbour.

LNGT will influence the processes of sediment transfer and accumulation in the water area of Klaipėda State Seaport. After installing LNG terminal ("2"alternative), the accumulation of sediment (sand) transferred in terminal area will reduce (Fig. 4), whereas the accumulation of suspended sediment (sludge) will increase. During LNG construction ("1" alternative) the accumulation of suspended sediment will reduce in comparison to "0" alternative.

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 2012, the researchers of the Laboratory published 3 articles in the ISI WoS database, 3 in the reviewed scientific journals and 3 in science promotion journals. The researchers participated in 6 international conferences. On 13-15 of August 2012 XXVII Nordic Hydrological Conference *Catchment Restoration and Water Protection* took place in Oulu town (Finland). The conference is organised by the Finnish Hydrological Association on behalf of the

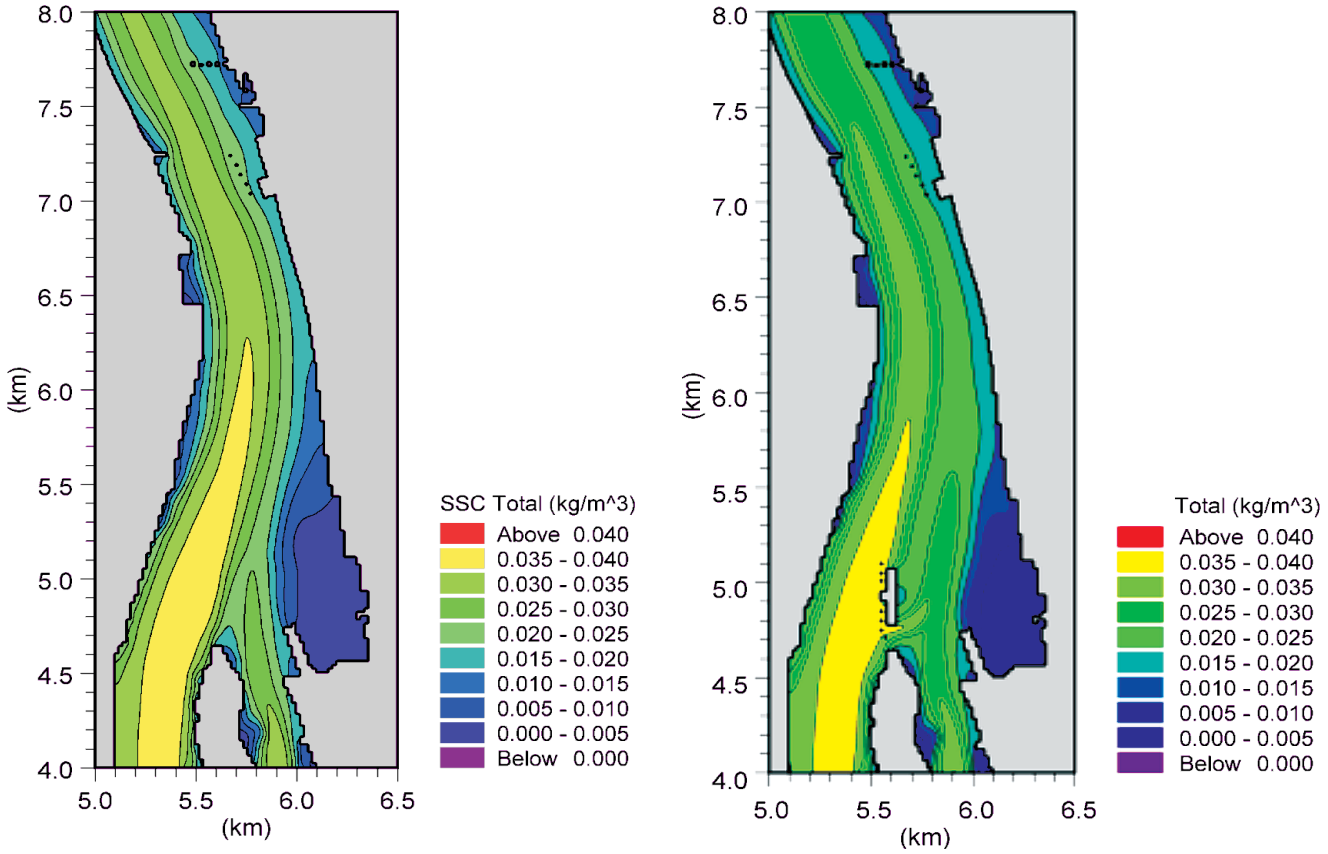

Fig. 4. Distribution of suspended solids (kg/m³) in Klaipėda straight for "0" (a) and "2" (b) alternatives, when a 1630 m³/s discharge flows via straight from the Curonian Lagoon into the Baltic Sea (initial suspended solids concentration is 0.04 kg/m³)

Nordic Association for Hydrology (NHF) and takes place every two years. The conference aims to promote exchange of experience from hydrological research and practice. The main goal of conference is to identify, establish and strengthen collaborations, leading to real partnerships between researchers, decision-makers and managers of water resources. During the conference over 200 researchers presented papers, among which even 10 participants were from different Lithuanian science and studies institutions. Lithuanian Energy Institute was represented by the head of Laboratory of Hydrology Dr. Jūratė Kriaučiūnienė (paper on *Assessment of uncertainty of Curonian Lagoon water balance* together with co-author Darius Jakimavičius) and Dr. Diana Meilutytė-Barauskienė (with the paper on *Identification of high water trends in Lithuanian rivers*, co-author Dr. Diana Šarauskienė). After the conference, an excursion was proposed to Oulu town, visiting the Oulujoki River, where a hydro power plant with fish-ladder is equipped.

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Flash flood in the Oulujuki River and a fish-ladder via which salmons migrate to spawn to the upriver (author of the photos D. Meilutytė-Barauskienė)

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.

The council of LEI YSA. From left: Darius Naujokaitis, Mantas Valantinavičius, dr. Agnė Bertašienė, Tomas Vonžodas, Lina Murauskaitė and chairman of YSA Darius Laurinavičius

CYSENI 2012

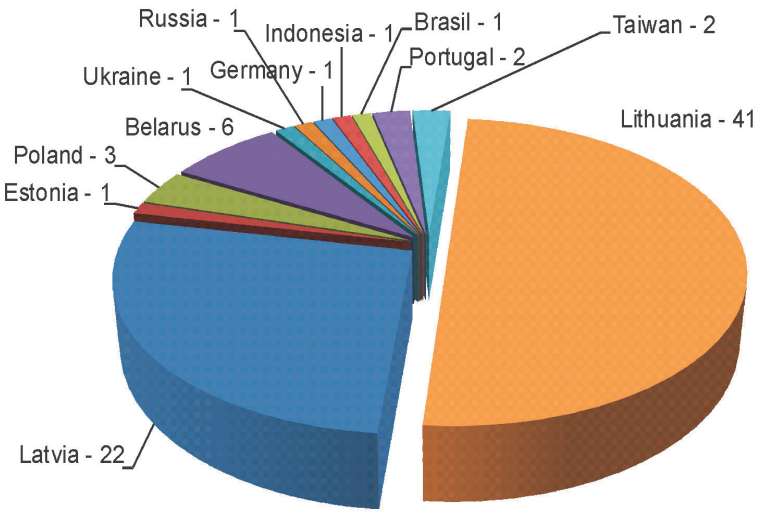
On 24 May 2012, the Institute was bustling with young people: a two-day International Conference of Young Scientists on Enery Issues, ***Jaunoji energetika 2012 (CYSENI 2012)***, began. The conference, which has been organized for 9 years in a row by YSA, this year has attracted a great number of speakers from the Lithuanian scientific and research institutions (Vytautas Magnus University, Lithuanian Institute of Agriculture, Kaunas University of Technology, Vilnius Gediminas Technical University, Vilnius University, Center for Physics and Technological Sciences.

The organizers aim at turning this conference into the foremost annual event for the young scientists, working in the energy field in the Baltic Sea region. The organizers aim at turning this conference into the foremost annual event for the young scientists, working in the energy field in the Baltic Sea region. Thus, many young scientists arrived to the conference from the scientific and research institutions of the neighbouring countries, such as:

- Tallinn University of Technology (Estonia),
- University of Latvia, Institute of Physical Energetics, Riga Technical University , Institute of Silicate Materials (Latvia),
- Institute of Nuclear Chemistry and Technology (Poland),
- A. V. Lykov Institute of Heat and Mass Transfer (Belarus),
- Ufa State Aviation Technical University (Russia),
- A.M. Pidhorny Institute of Mechanical Engineering Problems (Ukraine).

The conference was also joined by the participants from:

- Braunschweig Institute of Technology (Germany),
- Umea University (Sweden),
- Gadjah Mada University (Indonesia),
- Sao Paul University (Brasil),
- Feng Chia University (Taiwan).



Arrangement of the conference participants according countries

Topics of the Conference

The main energy-related topics covered in the conference (82 young scientists from different Lithuanian and foreign institutions presented their scientific papers):

1. Hydrogen and fuel elements;
2. Renewable energy sources and their use;
3. Smart energy networks;
4. Energy efficiency and saving;
5. Knowledge for energy policy making;
6. Research in the fields of thermal physics, fluid and gas mechanics and metrology;
7. Nanosciences and nanotechnologies; research on multifunctional materials;
8. Research on combustion and plasma processes;
9. Global change and ecosystems;
10. Fusion energy;
11. Nuclear energy and radiation protection.

Conference Program

A great number of conference guests was welcomed by LEI Deputy Director Dr. Rimantas Levinskas, LEI YSA chairman Darius Laurinavičius and LEI YSA board member Dr. Diana Meilutytė-Barauskienė.

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

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.

Dr. Rimantas Levinskas, Darius Laurinavičius, Dr. Diana Meilutytė-Barauskienė

Moments from the conference ***CYSENI 2012***

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

1. Mantas Valantinavičius (Lithuanian Energy Institute, Lithuania);
2. Artis Linarts (Institute of Technical Physics, Latvia);
3. Tomas Iešmantas (Lithuanian Energy Institute, Lithuania).

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

1. Darius Justinavičius (Lithuanian Energy Institute, Lithuania);
2. Kuo Hsin Lin (Feng Chia University, Taiwan);
3. Linas Martišauskas (Lithuanian Energy Institute, Lithuania).

The winners were congratulated by LEI Deputy Director Dr. Rimantas Levinskas and LEI YSA chairman Darius Laurinavičius and were awarded the certifications.

Winners of the conference

Apart from the official part, the event included various cultural activities. At the end of the first day of the conference, the guests were invited to have dinner and enjoy a folk dance group *Rasa* performance, which guaranteed good mood of the evening. At the end of the conference, the organizers offered a thematic tour to Kruonis Pumped Storage Plant.

Dancing of the conference participants and guests with folk dance group ***Rasa***

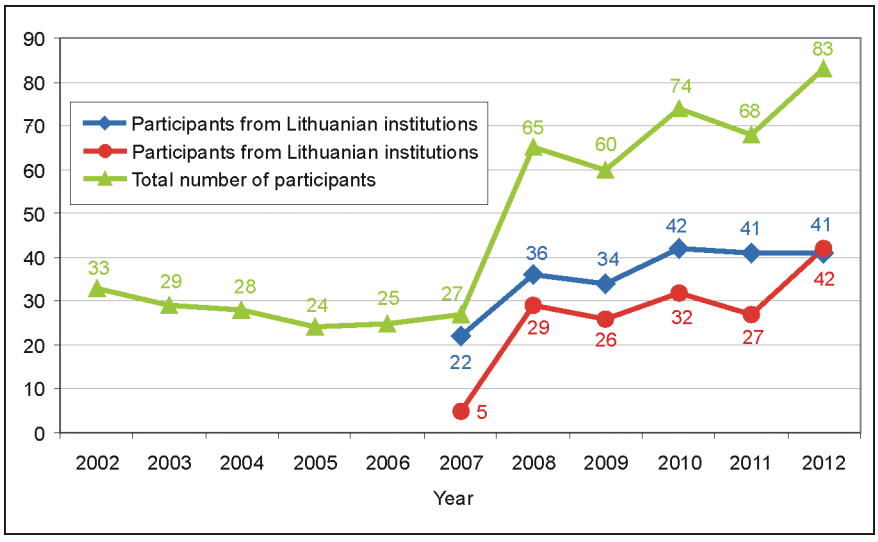
Tour to the Kruonis Pumped Storage Plant

After communicating on scientific topics, finding useful contacts and acquiring new experience the conference participants agreed on meeting at the same conference the next year.

Results of the Conference

95 annotations were submitted to the conference of 2012 and 82 of them were accepted for presentation. Experienced reviewers selected 78 scientific publications suitable for issuing in the conference material from the submitted ones.

One of the most significant conference results is summary of research performed by young scientists, preparation of qualitative scientific publications (each article was reviewed by 2 reviewers and authors themselves) and their presentation to the science society. Scientific publications and annotations prepared by conference participants were published in the conference material (in CD format). Published material will reach main national science centers and libraries as well as some foreign libraries and science centers. While participating in the above mentioned conference young scientists had perfect opportunities to receive reviews on their works, also to learn how to review, to evaluate articles of their colleagues, to get acquainted with topic relevance, importance of obtained results.



Variation of number of conference participants

History

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

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

Deputy Director Dr. Rimantas Levinskas first greets the participants of the Open Doors Day

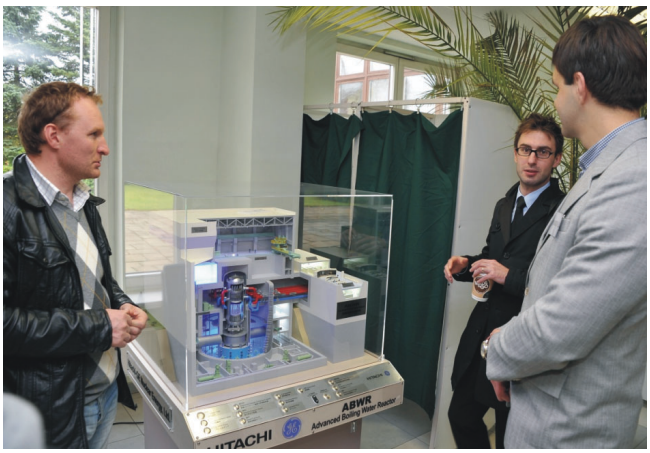
OPEN DAY AT LEI

On 10 October 2012 a traditional event – the open day took place at the Institute. During annual events or individual visits at LEI the society is acquainted with the activities conducted at the institute, with the equipment applied as well as cooperation opportunities. Last year the objective of the open day was to introduce to young society members (school pupil of grades 9–12), who often do not have a clear vision on their future, with the activities and research implemented in the Institute as well as career opportunities in the field of physical and technological sciences. A huge number of participants visited the Institute, particularly the experimental laboratories, where they were greeted by LEI researchers. During the event presentations were made on the institute activities, its administrative arrangement and composition, financial position, implemented projects and future trends.

Deputy Director Dr. Rimantas Levinskas with great delight presented active youth members and young researchers who are provided great perspectives in scientific research work.

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

Extremely active youth during the event had an opportunity to get acquainted with thermal vision technique and measurements, model of wind power plant, which from supplied air flow generated energy necessary to enable to shine the lights. The event participants were introduced with the model of advanced boiling water reactors (ABWR) and its operation principles. They were



Moments of excursions at laboratories

able to test connections linking energy objects by using a pilot model on Lithuanian energy system model. They also got acquainted with information publications on international interrelations and scientific research possibilities, movies on power energy are constantly shown in film studio, its sources and narratives on possibilities and hazards, benefit, efficiency and exhaust pollutant emissions, and its control, which are strictly regulated by EU Directives.

THEMATIC SEMINAR AND LECTURE FOR PHD STUDENTS AND YOUNG SCIENTISTS

Each year LEI YSA organizes seminars and lectures on different topics for LEI PhD students and young scientists. In 2012 one thematic seminar and one lecture took place.

In seminar (Protocol basics) participants were able to get acquainted with protocol basics prevailing in the world at the moment. Seminar was held by Jurgita Vizgirtaitė. While promoting local and international relations with science business partners it is expedient to know basics of communication, which enables to search for new partners.

Two reports were presented at the lecture. One of them – *Nuclear arming* (Andrius Slavickas), the other one – *Intellectual security agreement* ACTA (Anti-Counterfeiting Trade Agreement) (Mantas Povilaitis). The objective of the lecture was to expand world-view on different topics. Scientists should familiar not only with his/her research field but also get to know other relevant fields.

KTU CAREER DAYS 2012

On 21 March 2012 an already traditional event ***KTU Career Days 2012*** took place in Kaunas University of Technology and the representative of LEI also participated in it. For eight years KTU Career Centre and Student Association have been organizing the event which attracts many students from thirteen different faculties of the University, the representatives of the largest Lithuanian enterprises and foreign visitors. Every year the event receives considerable attention from students, professors and the representatives of companies.

This year, 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.

The institute participated in *KTU Career Days* for the eighth time and it proved as an effective means for the Institute in searching for young perspective employees and for students seeking the possibilities of studying and employment. After *Career Days 2012*, 3 KTU students were admitted to doctoral studies and 12 worked for practice.

Young Scientists Association of the Lithuanian Energy Institute

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

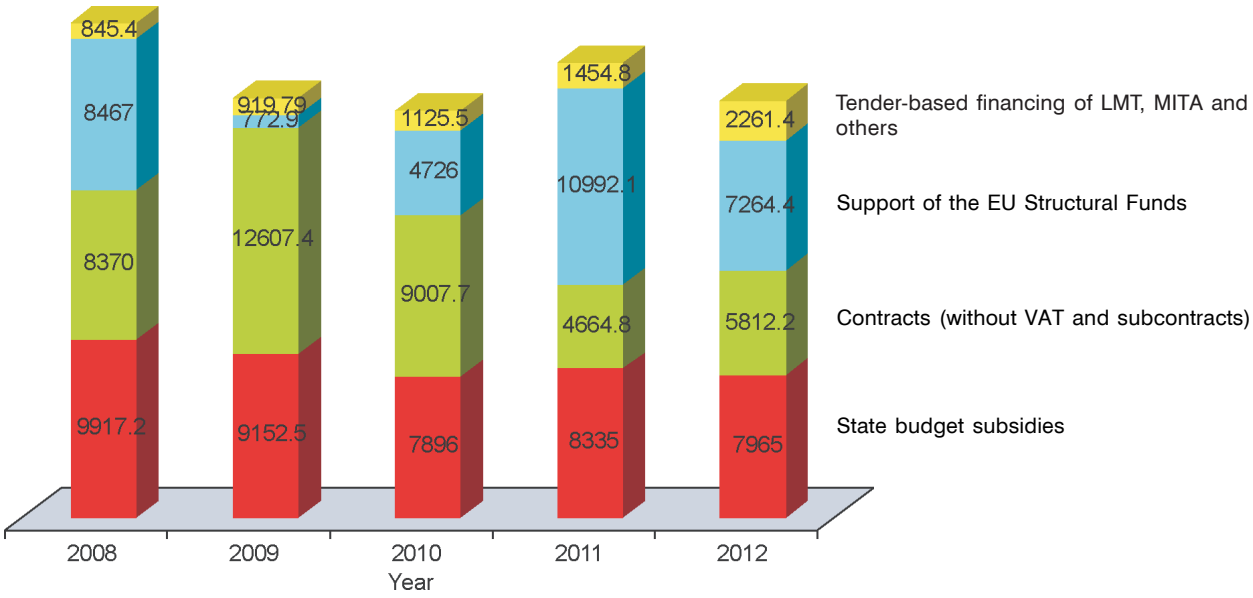
FINANCIAL HIGHLIGHTS

THE FINANCIAL SOURCES OF THE INSTITUTE CONSIST OF:

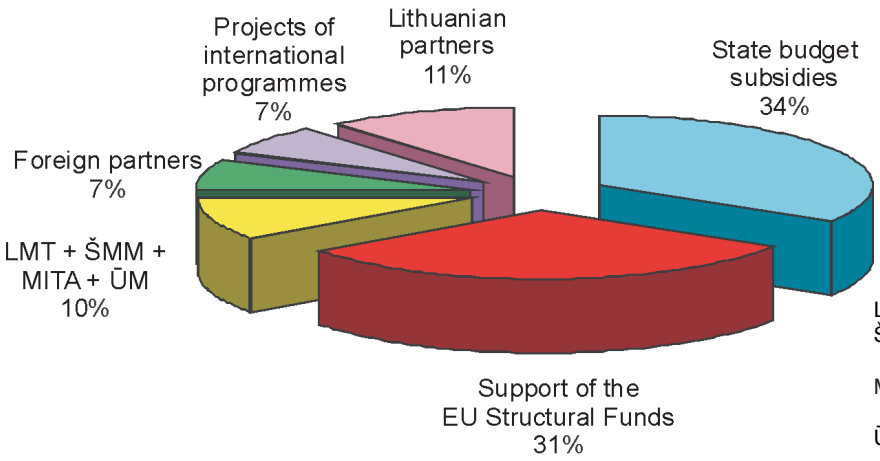
- State Budget subsidies for the implementation of the programmes approved by the Republic of Lithuania;
- Financing received from Lithuanian, foreign and international funds and organizations;
- Financing for scientific research from competitions in programmes;
- Financing received from Lithuanian and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

Structure of Income and Total Expenses (thous. LTL)

	2008	2009	2010	2011	2012
Income:					
State Budget Subsidies	*9917.2*	*9152.5*	*7896.0*	*8335.0*	*7965.0*
Contracts	*8370.0*	*9646.4*	*9356.0*	*6071.0*	*7975.2*
SF Support	*8467.0*	*772.9*	*5403.6*	*10992.1*	*7264.4*
Other Income	*1136.9*	*1155.3*	*99.7*	*95.5*	*98.4*
Total:	*27891.1*	*20727.1*	*22755.3*	*25493.6*	*23303.0*
Expenses:					
Salaries (soc. ins. incl.)	*15650.0*	*13722.0*	*13843.0*	*14273.0*	*13618.0*
Operating Expenses	*5059.0*	*3749.0*	*2432.3*	*3435.0*	*2547.8*
Capital Funds	*9757.3*	*392.0*	*6122.0*	*10863.0*	*7616.4*
Total:	*30466.3*	*17863.0*	*22397.3*	*28571.0*	*23782.2*
Long-term Projects Assets	*2102.9*	*4967.0*	*5325.0*	*2247.6*	*1768.4*

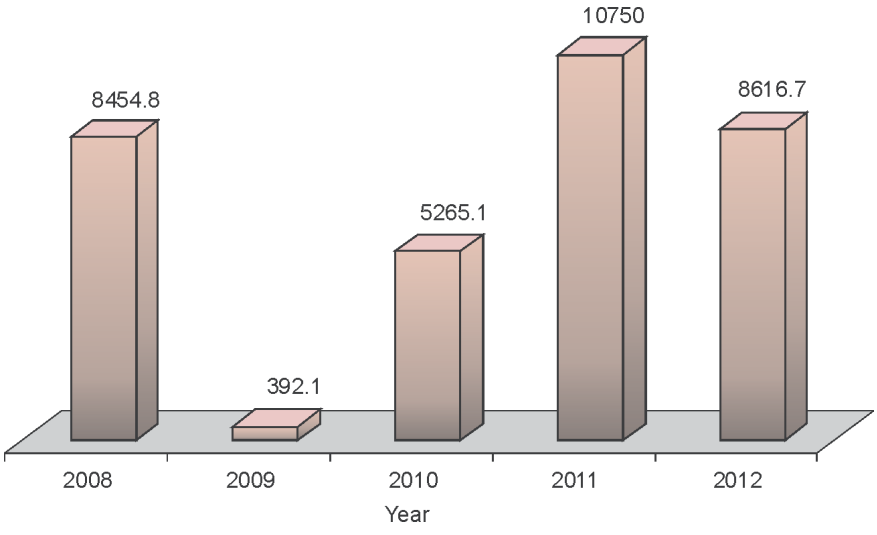


Evolution of financial recourses, thous. LtL



LMT – Research Council of Lithuania;
ŠMM – Ministry of Education and Science of the Republic of Lithuania;
MITA – Agency for Science, Innovation and Technology;
ŪM – Ministry of Economy of the Republic of Lithuania.

The structure of finances obtained from the contractors of LEI for year 2012



Dynamics of assets devoted for equipment purchase, thous. LTL

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

THE MAIN EVENTS in 2012

17 January
Info day of Agency for Science, Innovation and Technology (MITA) ***New possibilities for science and business partnership***

8 February
Visit of representative of Intelligent Technologies Association

10 February
Cooperation agreement signed between LEI and SC *Kauno energija*

21 February
Visit of Dr. James V.A. Abbey (Swansea University, Wales, UK)

21 February
Visit of Shimizu Corporation (Japan) representative

2 March
Visit of Mr. Gintaras Steponavičius, the Minister of Education and Science of the Republic of Lithuania

14 March
Visit of Extraordinary and Plenipotentiary Ambassador to Lithuania H.E. David John Hunt (UK)

22 March
Visit of Mr. Justin Heung, USA Embassy Second Secretary - Consul

3 April
Visit of IRSN (France)representatives to discuss ETSON data base project

6 April

Students from Vilnius University visited Center for Hydrogen Energy Technologies

19 April

Cooperation agreement signed with EC Joint Research Center Institute for Energy and Transport

8 May

Seminar ***The interaction of science, technologies and production for updating of heat routes***

16 May

Seminar ***Perspectives of RES application in Lithuania, energy production from organic waste***

21 May

Visit of HITACHI (Japan) representative

24–25 May

9th International conference of young scientists on energy issues ***CYSENI 2012***

13 June

EUROSAFE committee meeting in LEI

24 July

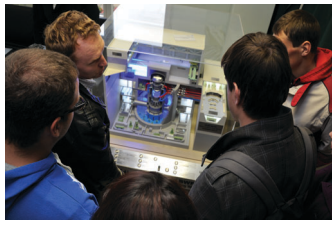
Visit of Lithuanian Consul of Honor Dr. Rafael Jose de Espona and COPISA company (Spain) representative

28 September

Lithuanian Academy of Applied Sciences seminar ***Open access centers: possibilities of application and perspectives***

10 October

LEI Open Doors Day



19 October

Visit of SC *Lietuvos energija* delegation

15–16 November

Conference on Energy Security: Outlook & Perspectives in the Baltic Sea Region

29 November

Visit of representatives from the European Commission, Ministry of Education and Science and Ministry of Finances as well as Research Council of Lithuania

21 December

LEI was granted the golden medal in the competition *Lithuanian product of the year 2012* organized by Lithuanian Confederation of Industrialists

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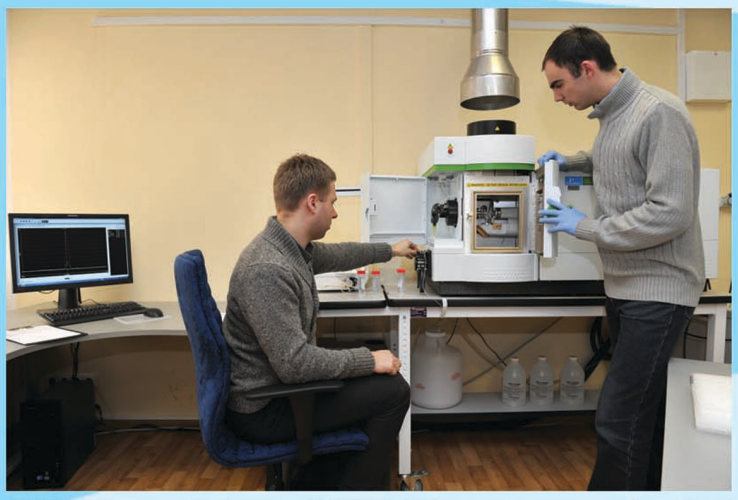

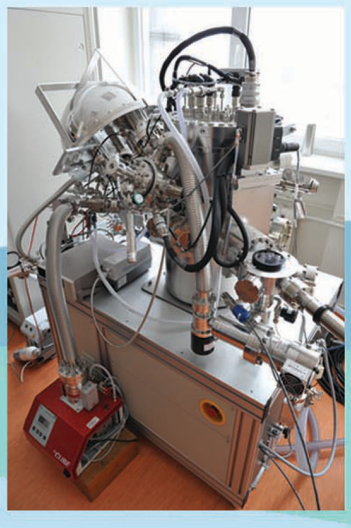

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