01

ENERGY AND ENVIRONMENT

RIGA TECHNICAL UNIVERSITY
RESEARCH

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Dear reader,

Nowadays, the need for more effective practical application of knowledge generated at research institutions for public good is growing. The main aim of this journal is to share the knowledge, which has been generated at RTU, published in scientific journals, but yet often not disseminated in a comprehensive way among potential users, such as entrepreneurs, politicians and other interested parties in the entire world. We hope that with the help of this publication entrepreneurs will be able to get new ideas for the development of new products and technologies and researchers from other universities and research institutions will find partners for joint projects. Finally, we hope that this publication will raise interest in engineering sciences among the general public.

This is the first edition in a series of journals, which we plan to publish regularly several times a year. The journals will present opinions of the experts in the field, discuss newest discoveries and technological solutions. Although at RTU research is conducted in almost all fields of engineering science, journal publications will be organised into six thematic fields, which correspond to the most important fields of expertise of our researchers, or so called RTU research platforms: Energy and Environment, Cities and Development, Information and Communications, Transport, Materials, Processes and Technologies, and Safety and Security. Research of numerous RTU institutes and laboratories is reflected in the journals dedicated to these study areas, reflecting their cross-disciplinary character.

The present publication is dedicated to the issues of Energy and Environment. This field is topical in the entire world, and Latvia is no exception. RTU researchers address the entire power cycle, starting with power generation, management and finishing with its usage. Environmental issues addressed by RTU are also closely connected with power engineering, in such a way ensuring sustainability to the developed power engineering solutions.

Despite the consequences of the economic crisis, which hinder the process of business investment into research and result in low funding of research compared to other European countries, RTU continues active work on the implementation of its strategic aims, which set promotion of scientific excellence and facilitating of cooperation with entrepreneurs among the top priorities. These journals will provide opportunity to the general public to follow our progress.

I wish you pleasant reading and hope that you will become a regular reader of our journal!

RTU Vice-Rector for Research
Dr.sc.ing., prof. Tālis Juhna

ENERGY AND ENVIRONMENT

Nowadays, electricity, heating, transport fuel and, respectively, energy supply are indispensable elements of the contemporary life and economic activity. Economic growth, world population growth and urbanization put additional requirements to energy supply systems to ensure safe and high quality energy supply. These systems are becoming more and more complex, the demand for depleting energy resources and the impact on the environment are increasing. Sustainable energy supply has become one of the main challenges faced by the society. Thus, the main tasks in the development of sustainable energy supply systems are the following:

1. *safety and optimal performance of energy supply;*
2. *increase of energy efficiency at all stages of supply;*
3. *increase of the share of renewable energy sources.*

To contribute to the development of reliable and sustainable energy supply systems, within the "Energy and Environment" research platform the scientists of RTU develop technologies and solutions related to the following issues:

- *ensuring stable, high-quality and optimal performance of electricity, heat and transport energy supply systems and their elements;*
- *renewable energy sources, technologies for conversion and storage for use in electricity supply, heat supply and transport systems;*
- *energy efficiency of energy supply chain, i.e., energy efficiency of production, transmission, distribution and end-use sectors;*
- *climate technologies for reduction of environmental impact of energy supply systems;*
- *analysis and planning of energy supply systems considering technical, environmental and socio-economic aspects.*

***To ensure stable, high-quality and optimal performance of energy supply systems**, the scientists of RTU study and develop the monitoring, diagnostic, management, analysis and forecasting technologies and instruments. Examples include diagnostic techniques for power grids, transformers and electric motors, semiconductor converters for electric drives, combustion control technologies in heat energy generation equipment.*

***In the field of renewable energy resources,** the researchers study the methods and technologies for producing biofuel and biogas, and other technologies that enable more efficient use of various bioenergy types, wind and solar energy in energy supply systems. The research results in new technologies, which use the synergy among various forms of energy resources, such as combined use of solar energy and wood pellets in heat supply systems. An important research area is industrial electronics technologies necessary for the development of smart power supply systems and extended use of renewable energy technologies in power supply systems.*

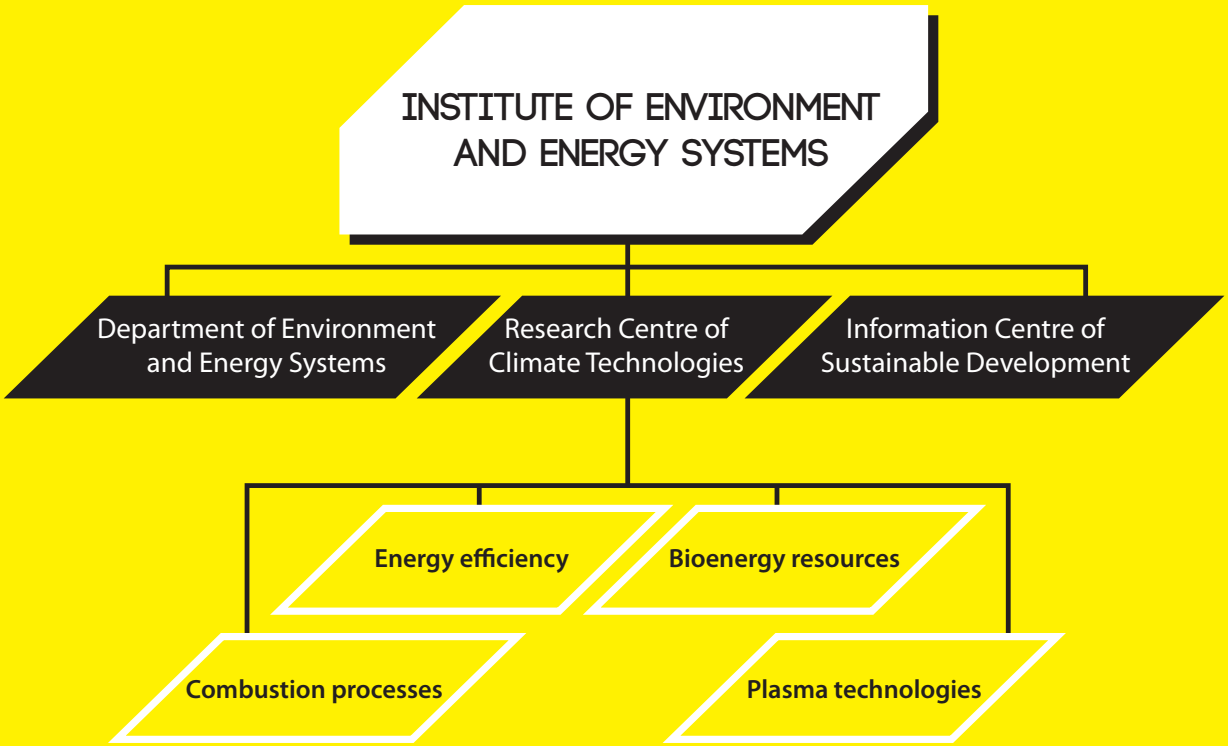
*RTU researchers develop **energy efficiency** technologies for electricity and heat energy generation equipment, transmission systems, i.e., power grids and their components, district heating distribution networks, as well as end-use sectors, industry, transport, households, etc. Considering the fact that exactly the building sector holds a significant share of the national final energy consumption, research is conducted in the field of energy-efficient building construction, for example, heat insulation solutions, in-door climate monitoring and control technologies. Research in the field of industrial electronics allows reducing electrical energy consumption in the industry and other sectors, for example, when creating smart lighting systems. To reduce the environmental impact of energy supply systems, the scientists of RTU study various **climate technologies** aimed at reducing*

emissions from these systems to air, water and soil. Special attention is devoted to the greenhouse gas reduction technologies and equipment, which allow both reducing flue gas emissions from power plants and increasing energy efficiency.

To determine the optimal combination and operation of energy system technologies, the ***methods and instruments for analysis and optimization*** *are developed. These modelling tools are also developed for individual power supply system components, e.g., power grid systems, electrical insulating materials, electric motors, district heating systems and heat supply equipment. In many cases, the analysis tools include not only technical but also socio-economic and environmental aspects in order to achieve comprehensive system analysis results. To determine the potential use of renewable energy resources in electricity supply, heat supply and transport systems, the potential synergy among these energy supply systems is analysed, for example, the use of electrical energy generated by wind power plants in district heating systems for heat generation and electric transport.*

Deputy Vice-Rector for research
Dr.sc.ing., prof. Gatis Bažbauers

CONTENT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Department of Environment and Energy Systems
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Energy efficiency
Bioenergy resources
Combustion processes
Plasma technologies

THIRD GENERATION BIOGAS FROM ALGAE: A LIFE CYCLE PERSPECTIVE

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ABSTRACT

In the light of the latest the Directive 2009/28/EC on promotion of renewable energy sources together with the Food and Agriculture Organization attempt to strengthen and promote studies and researches on 'non-food' energy crops biogas from algae represent a promising source to both substitute fossil-based energy and respond to criticism related to the use of next generation bioenergy systems.

Nevertheless the use of algae as third generation biogas is still related to the evaluation of the environmental and socio-economic impacts within a sustainable perspective.

In this light in this manuscript a comparative life cycle assessment (LCA) has been conducted in order to evaluate the potential environmental impacts of the use of marine macro-algae as feedstock for the production of biogas and its use in a cogeneration unit. The study foresees the identification and quantification of the major environmental impacts in comparison with traditional technologies (i.e. use of natural gas and traditional biogas production system using manure).

Results show that macro-algae can be considered a sustainable source in regard to the use of local sources. Moreover the results show the importance of the potential decrease of the overall analyzed process compared to traditional technologies. The most beneficial environmental effects are related to the impact category of Climate Change and Human Health. This is related to the avoided impacts from the use of external CO_2 sources and the solid fraction of the digestate as fertilizer.

The manuscript highlights as well the need of further and integrated analysis in order to understand the potential use of local sources and the demand on the local market in terms of socio-economic aspect and implementation of specific policy scenarios. In this light the implementation of the dynamic modelling integrated with the LCA methodology for an interdisciplinary design is proposed.

Keywords: *macroalgae cultivation, third generation biogas, biomethane, Life Cycle Assessment.*

INTRODUCTION

The allocation of two-thirds of the global CO_2 emitted is related to two main sectors: power generation and transport. The electricity and heat productions are the main reasons of CO_2 emissions (41% of the CO_2 emissions in the world), where 80% is related to the use of non-renewable sources (oil, natural gas, coal and peat)[1].

Biomass can be considered a real flexible and versatile resource suitable for different applications (heat and electricity production, and the transport sector);

nevertheless, further research is needed to develop this path. Nowadays, the global amount of biomass produced per year provides about 14% of the global energy needs. In this light, it is evident that there is a strong contribution that is given by biomass to the whole world economy, and how biomass represents one of the most available and abundant renewable resources that can be addressed to the production of biogas. Nevertheless, much more attention should be devoted to sustainability related to the cultivation of energy crops: competition for land food crops and land use change has to be avoided. The Food and Agriculture Organisation underlined the need to focus on 'non-food' energy crops for the production of 2nd and 3rd generation biofuels[1].

In this scenario, Directive 2009/28/EC has highlighted that biogas is one of the most promising substitutes for fossil-based energy [1].

Biogas production has increased over the last period. Currently, the production of biogas is principally carried out through anaerobic fermentation of (mixed) cereal crops but still in terms of substrates. More research is needed in order to gather all possible bio-resources. Hence, the need to further explore new feedstock sources for biogas is a fundamental issue and the improvement of know-how about second and third generation biofuel technology production is a natural consequence.

One possible feedstock for the production of biomass is algae (both: macro- and micro-algae)[1].

Algae biomass has photosynthetic efficiency higher (6–8%, on average) than that of terrestrial biomass (1.8–2.2%, on average). This enhances higher CO_2 fixation affording higher biomass production. Algae biomass is easily adaptable to grow in different conditions, either in fresh or marine waters, or in a wide range of pH [1, 5].

The cultivation of algae in open ponds presents the advantage of assimilating carbon dioxide emitted by external industrial sources, using wastewater or other types of biowaste that may supply the proper amount of required nutrients[4].

The direct use of CO_2 is becoming a large factor for increasing the daily growing rate of algae. That means if used as an interface between biowaste and energy production, macro- and micro-algae present a capability to transform negative environmental impacts into benefits for algae growth. In this way, negative environmental externalities are transformed into positive ones[2, 4, 5].

ALGAE TECHNOLOGY DESCRIPTION

Biomass of marine macro-algae represents a good feedstock for production of second and third generation biofuels; the main algae characteristics can be summarized as: higher photosynthetic efficiency, approximately twice that of terrestrial plants (energy crops) traditionally used for the production of 1st generation biofuels[5]; consequent higher capability of CO_2 absorption within bio-fixation processes in respect to terrestrial plants; greater efficiency in the absorption of nitrogen-, phosphate-based compounds during the growing phase; a higher growing rate than that of other terrestrial plants; no land is necessary during the cultivation phase (if cultivated in open ponds on the surface) and no conflict with crops for food production (if the small amount of algae for specific algae-based food is excluded)[5]. If compared with micro-algae, the harvesting methodology for macro-algae requires a higher amount of energy within the whole process.

In this context, the utilization of biowaste can be seen as an excellent source for feeding algae growing in ponds and, ideally, for meeting plant energy supply through renewable energy sources.

The feeding of algae ponds can be conducted with different types of nutrients, among them animal litters (e.g. manure), sludge from wastewater treatment plants (WWTP) and/ or industrial purified water. Nevertheless, the way how the nutrients can be collected is an important issue mainly in relation to sustainability and the optimization of the whole system process.

The use of algae biomass within a scaled-up and automated plant production system seems foreseeable in the near future. In fact, if used within the fermentation process for the production of biogas the limited extension of cultivation (in comparison with terrestrial energy crops), the limitation of machinery usage for harvesting and transportation will be favourable items for the spreading of such a novel type of algae-based technology.

In this context, an LCA methodology for an experimental pilot plant has been conducted in order to evaluate the environmental feasibility performance of the whole system. Two types of technological scenarios have been implemented in the study: one for Italian conditions (using manure as a nutrient for algae feeding) and the second for Latvian conditions (using wastewater from WWTP).

The proposed technology for the production of biogas from marine macro-algae is analyzed based on two different scenarios: the first one in reference to Italian conditions (using poultry manure as inoculums, i.e., base scenario 1) and the second scenario in reference to Latvian conditions (using wastewater from Riga Wastewater Treatment Plant "Daugavgrīva", i.e., base scenario 2).

The basic plant scheme is that one designed for the production of biogas obtained in the plant located in Augusta, and included in the pilot project BioWALK4Biofuels. Figure 1 shows a 3D overview of the whole system; from this view it is possible to understand the main parts that characterize the pilot

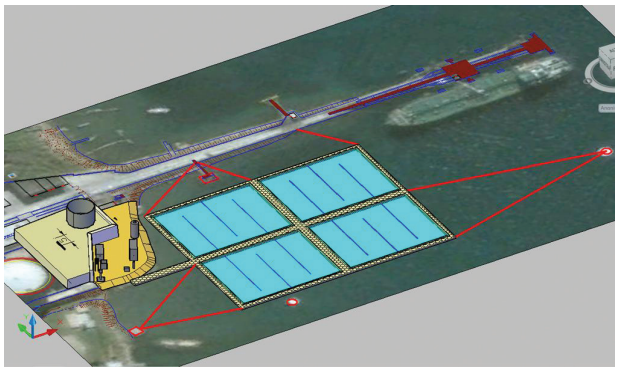

Fig. 1.
3D view of the pilot plant (source: Biowalk4Biofuels project)

plant and its extension. The area (around 670m^2) where the pilot plant will be located with its main components (anaerobic digesters, manure/biomass homogenisation tank, big bag for algae harvesting, screw conveyor from the manure storage, de-nitrification reactor, biogas upgrading cryogenic unit, the adsorption column, the biogas storage, the cogeneration unit) is shown in dark yellow. The anchoring point to stabilize the ponds, through the use of steel ropes, the system against the sea wave motion, can be seen in the red circles.

The area of the installed fours open ponds, devoted to the local available macrolagae growing, presents a total surface of 5000 m^2 and a depth of approximately 0.6m. Within these ponds the correct amount of nutrients and a CO_2 bubbling system is guarantee with an injection system aimed to guarantee the most favourable growing conditions.

Other two parts are foreseen within the final implementation of the pilot plant: the installation of an algae protoplast incubator and the implementation of an upgrading system aimed to refine the biogas in biomethane and a compression unit aimed to produce compressed biogas to fuel vehicles (car or lorry) within a "industrial closed-loop" perspective and a cost-efficient biogas transformation..

Within the proposed system, sea water and fresh water are filled-in to compensate the losses due to the harvesting of biomass (sea water) and the evaporation effects (fresh water). In order to control the cultivation process the open ponds are separated from the surrounding waters with a special membrane made of EPDM rubber.

Algae need carbon (in the form of CO_2) and nutrients for optimal growth. It has been demonstrated that an artificial increase in the concentration of CO_2 in the growth media (e.g., from industrial external sources) increases the algae growth rates by a factor of 1.2-1.8 [4].

Initially, there is supposed to be the preliminary amount of algal biomass (taken from the protoplast incubator, not included in the LCA model) in the ponds. When the biomass reaches the level necessary for production, the planned biogas is harvested.

In the system, part of nutrients is re-circulated directly from the biodigestor and part is supplied directly from sludge of the WWTP process prior a mixing a specific tank with marine water. CO_2 is reused from the exhaust gases of the combustion processes of the cogeneration unit and from an external source related to industrial processes (only for the Italian scenario). This is supplied to the ponds, through a piping system, that allows the creation of moderate turbulence in the ponds preventing the thermal and nutrients stratification and guaranteeing the correct media mixing, the correct light exposure, and bigger availability of nutrients to the growing algae. The harvesting system is performed by the use of the particular textile bag prior transporting the solution of pond water and algae biomass. The bag allows the water filtration to retain the whole biomass that can be collected in the bottom by opening a valve. The algae biomass needs to be clean with fresh water since salinity affects efficiency during the digestion processes. The resulting water will be reintegrated into the system[2, 5, 6].

The harvested algae biomass from the open ponds is pumped in a hydrocyclone for the removal of sand (or directly sends the harvested algae to storage if wastewater is used).

In the next step, the prepared algal biomass together with manure or sludge (from the WWTP) is pumped into the anaerobic digester for biogas generation. The Anaerobic Digestion (AD) system is based on a two-stage bioreactor, in which hydrolysis and acidification steps are separated from the methanization processes in two different bioreactors. The solid part of digestate is used as a substitute for artificial fertilizers. The liquid fraction is reused in the system in the open ponds for algae growing.

In the final stage, the biogas is used to feed the cogeneration unit, where electrical energy and thermal energy are produced and finally upgraded. The energy demand (both thermal and electrical) necessary for the plant is supposed to be provided by the CHP unit.

LIFE CYCLE ASSESSMENT OF BIOGAS FROM ALGAE AND MANURE

Life Cycle Assessment is a good tool within the evaluation both of the environmental burdens and sustainability of specific bioenergy systems [1, 3].

The aim of this LCA is to carry out an environmental assessment of the use of biogas from algae and manure as a biofuel for heat and electricity production in a cogeneration unit (40kW) adopted for Italian and Latvian conditions. The analysis is also performed through comparison with a similar biogas production system based only on agricultural substrate and a fossil fuel based scenario, in which natural gas is supplied to the cogeneration unit.

Definition of Goal and Scope

The goal and scope of the LCA study is to evaluate the potential environmental impacts of the use of marine macro-algae (or seaweed) as feedstock for the production of biogas and its use in a cogeneration unit. The study foresees the identification and quantification of the major environmental impacts (hot spots). The evaluation is also carried out through comparison with a natural gas based system using the same functional unit.

System Boundaries

The function of the system is to generate thermal and electrical energy. The functional unit chosen to represent the system is defined as the total energy produced in the plant during one year equal to 1,1 TJ_{el} and 2,2 TJ_{th} [2, 5, 6.] The amount of algae necessary to guarantee this production phase has been set to a level of 1729 t/year [2, 5, 6] (wet algae mass) for base scenario 1 and 803 t/year [4] (wet algae mass) for base scenario 2.

In regard to base scenario 1, the system (Augusta, Italy) is located in southern Europe in the Mediterranean region, and the Italian energy mix for electricity (medium voltage) has been chosen from the SimaPro database. The site assumed for base scenario 2 is the WWTP "Daugavgrīva" in the Baltic Sea region.

Both systems include the macro-algae cultivation phase,

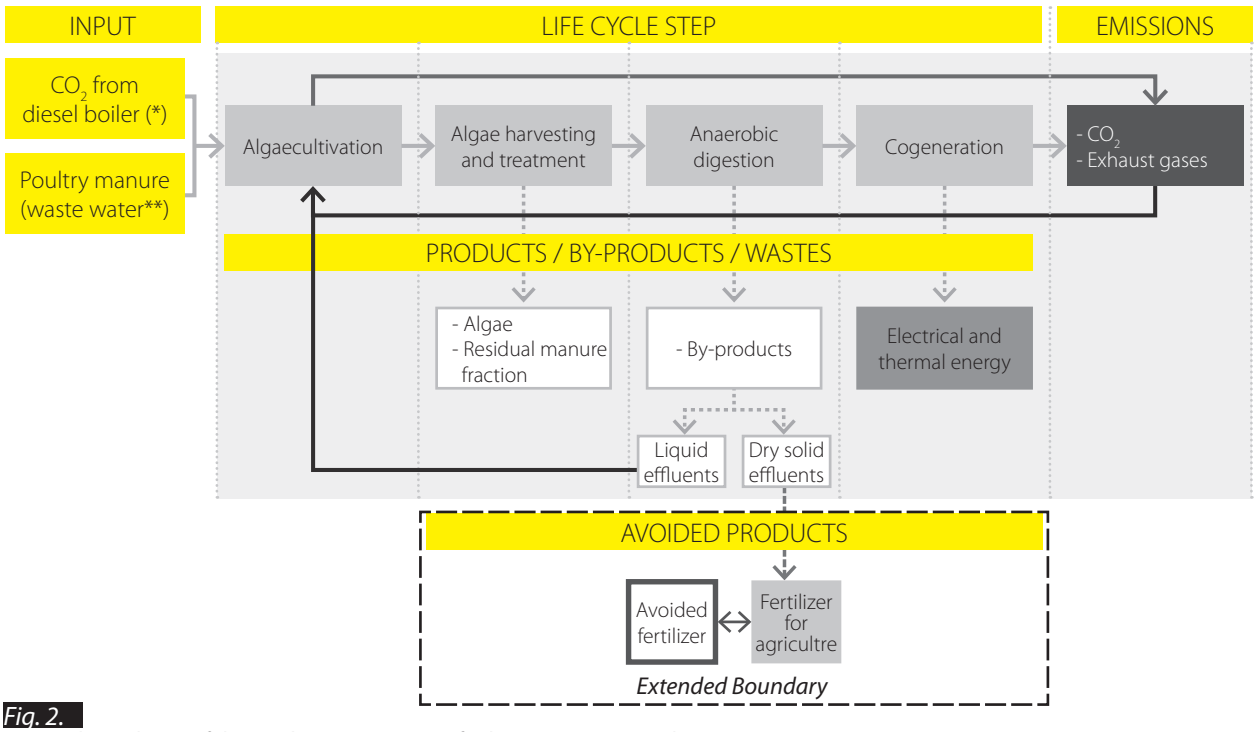

Fig. 2.
System boundaries of the production processes for base scenario 1 and scenario 2

harvesting and treatment, 2-stage anaerobic fermentation units, biogas consumption in a cogeneration unit, as well as by-product management expressed in terms of boundary expansions. Transportation is not shown in these schemes but is taken into account for all the production stages (see Figure 2).

Description and Inventory of Unit Processes

The different stages of the whole process chain have been taken into account in the following steps in order to analyze their contribution towards different impacts:

- algae cultivation – all input and output related to the production of algae biomass, also including the environmental benefits;
- cogeneration unit, represented by the emissions from combustion in the CHP unit;
- energy inflows – all the energy inflows required for all the unit processes in the production chain are taken into account;
- co-product management that takes into account the environmental benefit of the use of co-products in the extended boundary (e.g., the reuse of liquid digestate in ponds and the use of solid fraction as fertilizers);
- materials – all the components necessary for the building up of the plant;
- transportation.

The amount of biogas produced is dependent on the algal biomass. For base scenario 2 during the period from November until April, only sludge biomass is used for biogas production since it is not theoretically possible to cultivate algae during this period (see Figure 3a and 3b).

LCA Results

The results show that the potentially most negative effects (not considering the benefits) are related to the human health catego ry for scenario 1 and climate change

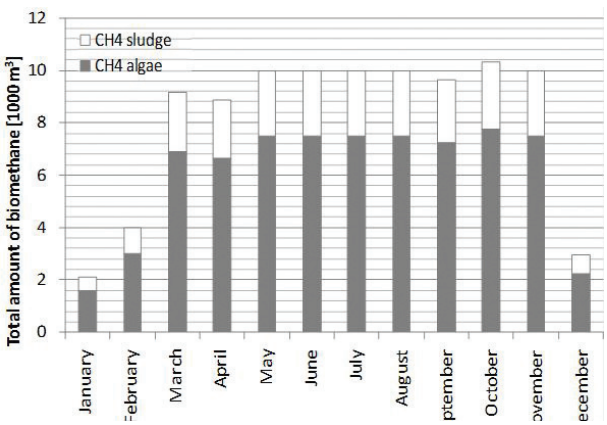

Fig. 3a.
Amount of biomethane in the biogas mix generated from Ulva Prolifera and manure sludge throughout the year [1000 m³] – scenario 1

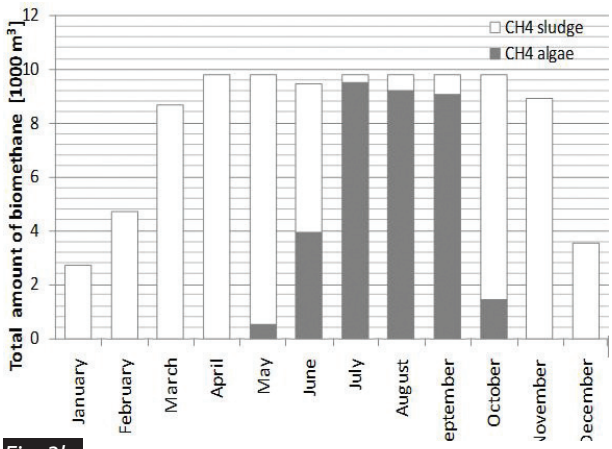

Fig. 3b.
Amount of biomethane in the biogas mix generated from Ulva Prolifera and sludge throughout the year [1000 m³] – scenario 2

for scenario 2 (see Figure 4)[1, 4].

For both scenarios this is directly connected to the emissions from the cogeneration unit not reintegrated in the system. This can thus be considered the main "hot spot" for both models. The difference between the two scenarios can be explained by stressing the fact that for scenario 2 the emissions from the CHP unit can only be reintegrated into the system for the algae growing during the period from May to October. Cogeneration is the most undesirable process from the environmental point of view, followed by transportation and materials needed for building up the plant.

The human health category has a gain of environmental benefits due to the use of the co-products as fertilizer and the CO_2 fixation in the algae biomass for both scenarios. The biggest environmental benefit is associated with climate change, in which the process of algae cultivation and management of co-products accounts for a value of 82% and 18%, respectively, of the total benefit for scenario 1 and for 88% and 12% of the total benefit for scenario 2.

The main environmental benefits are related to the use of by-products and algae cultivation.

The results of the LCA show that:

- macro-algae can be considered a renewable source (based on the energy indicator lower than 1 and for the LCA eco-profile compared to the reference natural gas based system);
- important and substantial GHG reductions can be achieved with macro-algae, but they always involve significant uncertainties;
- macro-algae can be considered sustainable in regard to the use of local sources. Further and integrated analysis is needed in order to understand the potential use of local sources and the demand on the local market;
- the main environmental issues related to sustainability of the process are related to: area occupied by the system, local availability of nutrients (in fact, nitrogen based nutrients are a limited local resource), combination and interaction with other marine species, gaseous emissions, and harvesting sediment disturbance;
- other environmental aspects are related to: use of local species that will not contaminate the local ecosystem, risks of the spread of a monoculture ecosystem (spread of disease), and increase in eutrophication risk due to the amount of algae.

INTEGRATION OF SYSTEM DYNAMICS MODELLING

As previously mentioned, LCA is a good tool to analyse the environmental performances but it is typically a steady-state, rather than a dynamic approach. Moreover, within the increase in the environmental footprint the manufacturing processes and the whole background systems (i.e., supply chains) have started to become more sustainable in terms of economic viability, environmental, and social impacts.

In this light, the idea of integrating within the framework of the dynamic modelling the LCA methodology for an interdisciplinary design facing with economic, social and environmental aspects started to be developed in the last decade.

System dynamics is a computer-aided approach for policy analysis and design in complex dynamic systems. System dynamics is based on the theory of system structures and is utilized to represent complex systems by analysing their dynamic behaviour over time. Since the development of system dynamics modelling approach in the 1950s, it has been applied successfully to a range of complex problems in different areas[1].

The application of system dynamics modelling in strategic energy planning practices began in the 1970s with WORLD models developed in the Massachusetts Institute of Technology (MIT). The MIT study group

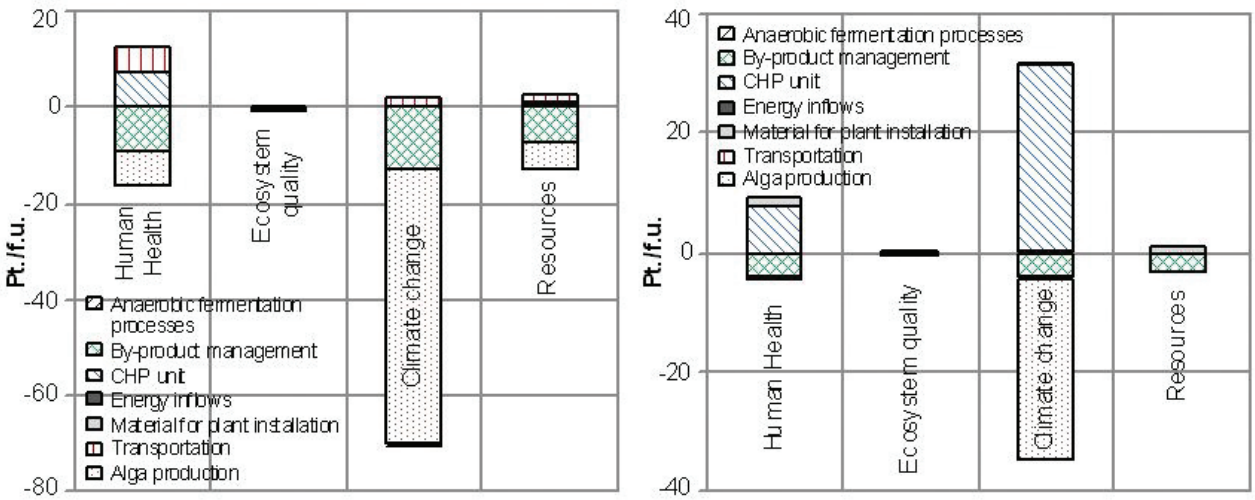

Fig. 4.
Impact assessment for endpoint categories [Pt/f.u.] – base scenario 1 and base scenario 2

forecasted the future developments of the energy sector, analysing interactions between the growth of global population and industrial production and the availability of natural resources[1].

Since then system dynamics has been used for solving complex problems within the energy and environment sectors in many research papers mainly related to the reason that system dynamics model is a way to represent complex systems. In this light, simulation using system dynamics modelling represents a good tool to understand and evaluate how a system is dynamically influenced by different policy scenarios[1].

For this reason, system dynamics modelling has been thought to be integrated into further research to evaluate how strengthen the use of the second generation of biofuel in comparison with the first type and the fossil-based one.

CONCLUSION

The use of algae as source for third generation biogas is recently rising mostly in connection to considering algal biomass as a good solution against the drawbacks of several bio-energy. Nevertheless in order to boost this process questions related to the real sustainability of the use of algae in connection to a cost effective scaled-up system and an appraisal of social-economical from its implementation is still an hot topic within the scientific arena.

Within this manuscript the first outcomes from a Life Cycle Assessment of biogas from marine macro algae have been reported. Results mainly show the importance of the potential decrease of the overall process compared to traditional technologies.

Results show that macro-algae can be considered a sustainable source in regard to the use of local sources. The impact categories Climate Change and Human Health, related to the avoided impacts from the use of external CO_2 sources and the solid digestate as fertilizers, are those where the beneficial effects on using algae as interface between biowaste and energy production is more evident.

The importance of the increase of production yield of algae and a better optimization of the harvesting system is not only evident in terms of reduction of use external biomass input (i.e. decrease the transportation to the plant) and increase of the industrialization of an algae-based biogas system but as well in relation to the sustainability of the process (i.e. area occupied by the system, local availability of nutrients, combination and interaction with other marine species, gaseous emissions, and harvesting sediment disturbance).

ACKNOWLEDGMENT

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REFERENCES

1. Romagnoli, F., *Model for sustainable bionergy production and use, in Institute of Enegy Systems and Environment.* 2012, PhD thesis, Riga Technical University Riga: p. 162.
2. Romagnoli, F., Pubule, J., and Blumberga, D., *Life cycle assessment of biogas production with algae substrate. in 19th European Biomass Conference and Exhibition.* 2011. Germany, Berlin, 6-10 June.
3. Romagnoli, F., Blumberga, D., and Pilicka, I., *Life cycle assessment of biohydrogen production in photosynthetic pro-cesses.* International Journal of Hydrogen Energy, 2011. 36(13): p. 7866-7871.
4. Piļicka, I., Blumberga, D., and Romagnoli, F., *Life Cycle Assessment of Biogas Production from Marine Macroalgae: a Latvian Scenario.* Scientific Journal of RTU, Environmental and Climate Technology, 2011. 13(6): p. 69-78.
5. Romagnoli, F., Blumberga, D., and Gigli, E., *Biogas from marine macroalgae: a new environmental technology – life cycle inventory for a further LCA.* RTU Scientific Journal– Environmental and Climate Technology, 2010. 13(4): p. 97-108.
6. Blumberga, D., Veidenbergs, I., Romagnoli, F., Rochas, C., Žandeckis, A., *Bioenerģijas tehnoloģijas.* 2011, Riga, Latvia, RTU Institute of Energy Systems and Environment. p. 272.

KOPSAVILKUMS

Veikti pētījumi par biogāzes ražošanu no aļģēm, kā daudzsološa fosilo enerģijas avotu aizvietotāja izmantošanu un pētīšanu. Aļģu kā trešās paaudzes energoresursa biogāzes izmantošanai, joprojām nepieciešams vides un sociāli ekonomiskās ietekmes izvērtējums ilgtspējīgā perspektīvā.

Tāpēc šajā rakstā veikta salīdzinoša dzīves cikla analīze (LCA), lai apzinātu iespējamo ietekmi uz vidi, kādu rada jūras makro-aļģu izmantošana biogāzes ražošanā un šādas biogāzes izmantošana koģenerācijas stacijā. Pētījumā iekļauta galveno vides ietekmes jomu identifikācija un ietekmes apjoma noteikšanā, kā arī to salīdzinājums ar tradicionālo tehnoloģiju (t.i. dabasgāzes un tradicionālās biogāzes sistēmu, kas izmanto kūtsmēslus) ietekmi.

Rezultāti rāda, ka makroaļģes var tikt uzskatītas par ilgtspējīgu enerģijas avotu to, izmantojot tās kā vietējo enerģijas avotu. Ir redzams arī kopējais analizētā procesa potenciālās ietekmes samazinājuma nozīmīgums, salīdzinājumā ar tradicionālajām tehnoloģijām. Vislabākie rezultāti ir saistīti ar klimata pārmaiņu un cilvēka veselības ietekmes kategorijām. Tie saistīti ar iespēju izvairīties no ārējiem CO_2 avotiem un digestāta mēslojuma izmantošanas.

Raksts apstiprina nepieciešamību turpināt integrēto analīzi, lai izprastu potenciālās vietējo avotu izmantošanas iespējas un vietējā tirgus pieprasījuma sociāli - ekonomiskos aspektus, kā arī konkrētu politikas scenāriju īstenošanu. Tāpēc šobrīd raksta autori veido sistēmdinamikas modeli šo jautājumu padziļinātai izpētei.

SOLAR AND PELLET COMBISYSTEM FOR AN APARTMENT BUILDING. FROM DYNAMIC MODELLING TO ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

This study focuses on the development and optimization of a new solar thermal energy system, the analysis of a demonstration project and the implementation of fault detection and isolation algortim. The solar thermal energy system has been developed by several commercial partners working in cooperation with Riga Technical University. The basic idea is a solar thermal energy system coupled with a wood pellet system. This is a 100% renewable energy solution for space heating and domestic hot water in multi-family buildings. The system is compact and factory assembled in a standard shipping container. However, potential for optimization exists for the increase of solar fraction, for the reduction of parasitic electricity demand and isolation of developing faults.

The developed methodology for optimization is based on the use of TRNSYS simulation model and multi-correlation analysis. This methodology was approbated by optimizing various operating parameters of the experimental system. To improve reliability and to increase thermal performance of the solar combisystem automated fault detection and isolation system was developed and validated. The programming language of artificial neural networks was used to develop fault detection system. As a result higher thermal performance and reliability of the combisystem was reached.

Along with the increase in energy resource prices and environmental issues, there is growing interest in use of renewable energy sources in heating applications. The development of the experimental solar and pellet combisystem began in 2009; the aim was to build a compact system suitable for apartment buildings located in Northern Europe. To achieve the goal, two industrial partners and three enterprises were involved, as well as the project was supported by the European Economic Area Financial Mechanism. Further performance monitoring and optimization of the combined system was performed with support of the Central Baltic INTERREG IV A Programme.

The solar combisystem is a unit that combines solar collectors and an additional heat source to cover the consumer's space heating (SH) and domestic hot water (DHW) loads. In the initial phase, boundary conditions were set to determine the technological solutions and the choice of an apartment building for successful implementation of the idea:

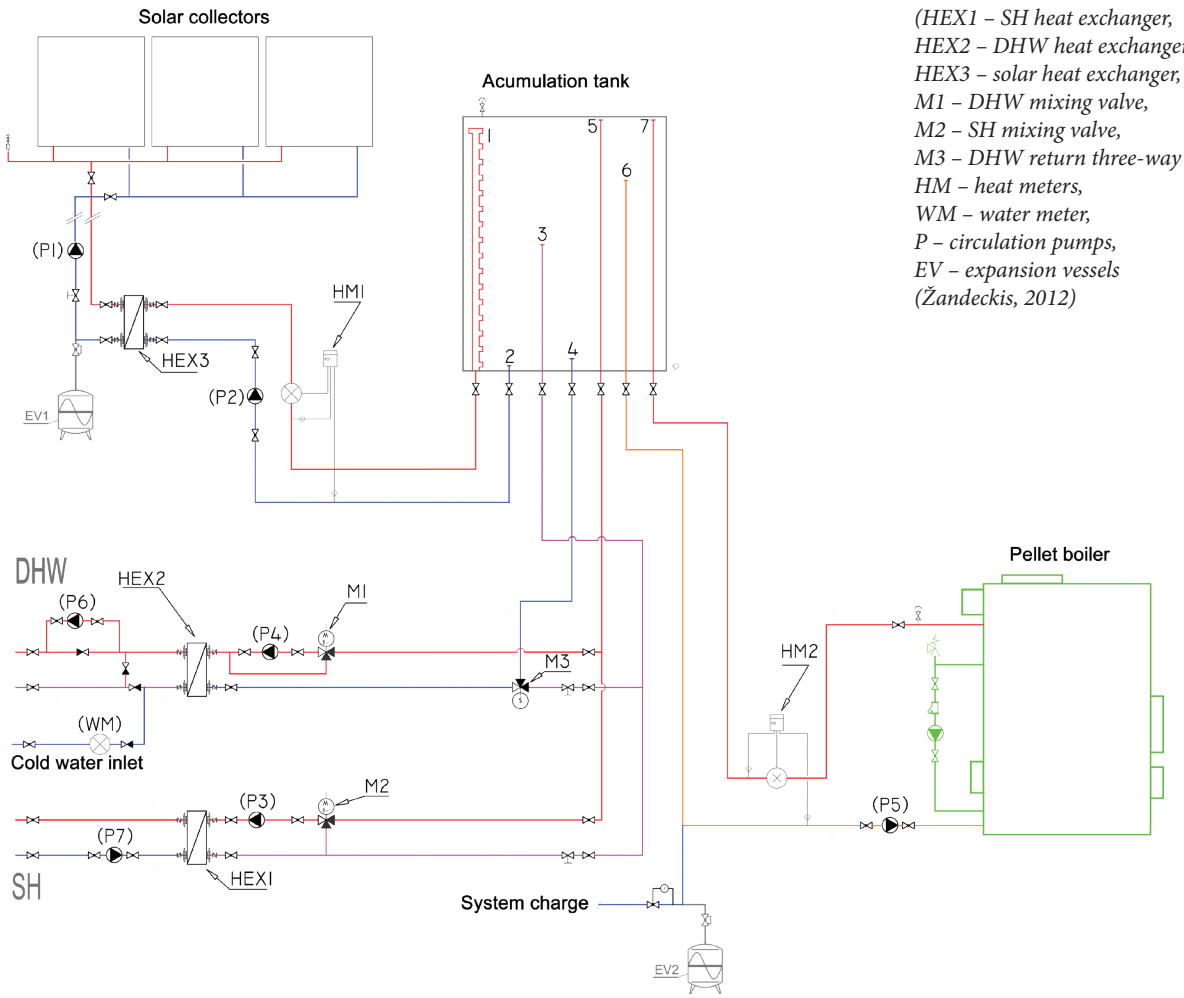
- the system must be compact and modular. Its installation must be possible in buildings without free space in the basement or attic. Time consuming and

expensive building of additions cannot be required;

- a wood pellet boiler must be used as an auxiliary source of energy;
- the system must be able to cover DHW and SH loads for the apartment building. The proper organization of the preparation of DHW is the main condition for the effective use of solar energy;
- the combined system must include all components for heat production, storage and distribution. No additional place in the building for any system components, except solar collectors and pipelines can be used;
- the selection of alternative technical solutions for the system must be based on the results of economical optimization;
- the solar and pellet combisystem must be able to compete with conventional fossil fuel heating technologies;
- the renovated or newly built apartment buildings are more appealing for the installation of a combined solar and pellet system. Otherwise, it is more profitable to invest money in energy efficiency measures (Žandeckis, 2012).

Fig. 1.
Apartment building before renovation (top) and after renovation and installation of the combisystem (bottom) (Žandeckis, 2012)

Fig. 2.
Hydraulic circuit concept of the solar and pellet combisystem (HEX1 – SH heat exchanger, HEX2 – DHW heat exchanger, HEX3 – solar heat exchanger, M1 – DHW mixing valve, M2 – SH mixing valve, M3 – DHW return three-way valve, HM – heat meters, WM – water meter, P – circulation pumps, EV – expansion vessels (Žandeckis, 2012)



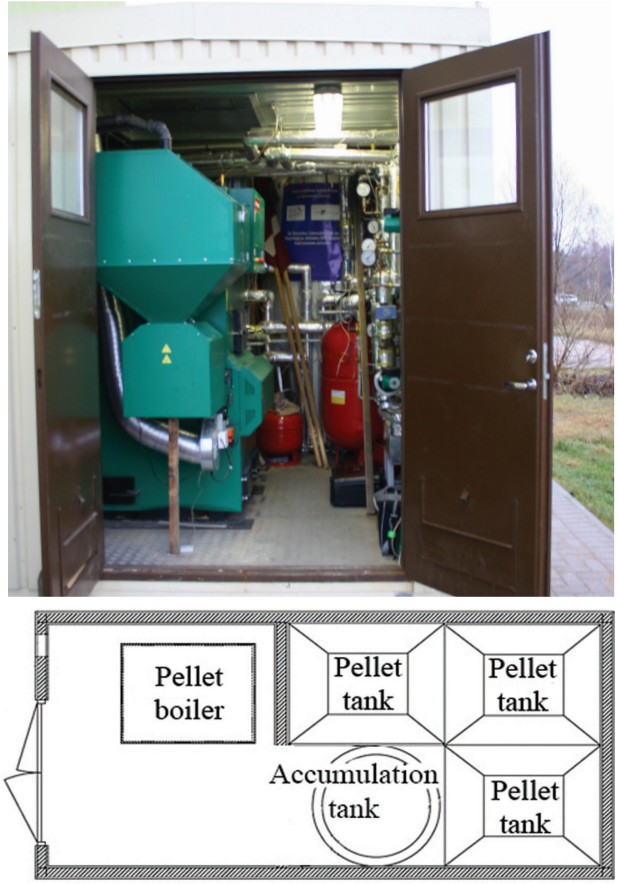


Fig. 3.
Schematic representation of the modular boiler-house with a pellet boiler, pellet storage and accumulation tanks (Žandeckis, 2012)

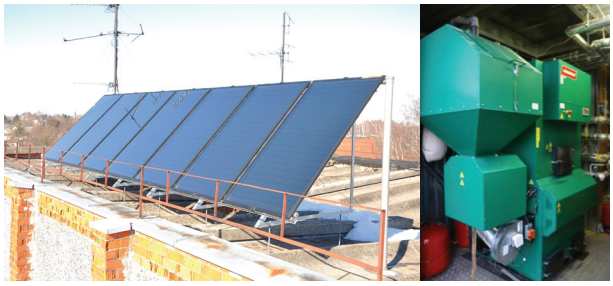


Fig. 4.
Solar collectors ThermosolarŽiar TS300 and pellet boiler Grandeg GD-Turbo100 (Žandeckis, 2012)

On the basis of the results of several studies and project partners' experience and suggestions, some more specific boundary conditions were set:

- a container-type boiler house with standard transportation sizes (6000×2900×3100 mm) must be used for the installation of the system;
- a limited boiler-house size allows for the use of pellet boilers with a capacity up to 150-200 kW, which in turn limits the potential range of consumers. The total energy consumption of 450 to 600 MWh per year could be set as a threshold;
- the use of a container boiler house will allow for the installation of the system components on a factory site. Significantly reducing the time and costs of installation on site;
- the energy gained from solar collectors and the pellet boiler must be accumulated in a joined volume;
- the external heat exchanger must be used for space heating needs, it allows work to be completed effectively with all - high, medium and low - temperature heating systems;
- the consumer's hot water load can vary from 0 kW to 100 kW and up, so external a heat exchanger must be used and hot water recirculation load taken into account;
- the system should be built using flat plate solar collectors. This technology is chosen because it has lower capital and maintenance costs;
- the combined solar system must be designed to match Northern Europe climate conditions (Žandeckis, 2012).

The experimental solar and pellet combisystem was installed at the apartment building at Kr. Barona Street, 2, Sigulda (N 57° 09.410 E 024° 52.194). It is a standard 103 series apartment building with 30 apartments and a total heated area of 1,674.9 m^2.

Based on the DHW preparation and recirculation loads of the building, technological equipment and solutions were chosen, and taking into account the specifics of the building's space heating system the hydraulic concept of the solar combisystem was developed (see Fig. 2.). The concept is based on the five main components: solar collectors with the hydraulic loops, pellet boiler, heat accumulation tank, domestic hot water and space heating loops.

The combisystem is assembled in the modular boiler-house with outside dimensions of 6000×2900×3100mm. Inside, the boiler-house is divided into two parts (see Fig. 3). On the right side it is possible to install tanks for pellet storage and heat accumulation.

Three pellet storage tanks with a total capacity of 12 m^3 were installed in the experimental system. In theory, this volume can be used to store up to 8 tons of pellets, but in practice, depending on the filling strategy it is possible to fill in 5–7 tons of pellets. Pellets may be filled using pneumatic transport or with 500/1000 kg bags.

On the left side of the boiler-house, the pellet boiler and other system components, including the expansion vessels, heat exchangers, pumps, control and monitoring equipment, are installed. From the storage tanks to the boiler, pellets are transported by a pneumatic supply system. The proposed concept of the modular boiler-house allows full factory assembling of the system.

Flat-plate solar collectors ThermosolarŽiar TS300 are used in the experimental system (see Fig. 4). Collectors are oriented to the south with the azimuth angle of 6° and an inclination of 45° to the horizon. In the primary hydraulic loop, 50% (by volume) of propylene glycol and water solution is used as a heat carrier.

Pellet boiler Grandeg GD-100 Turbo produced in Latvia with a maximum output of 100 kW is installed

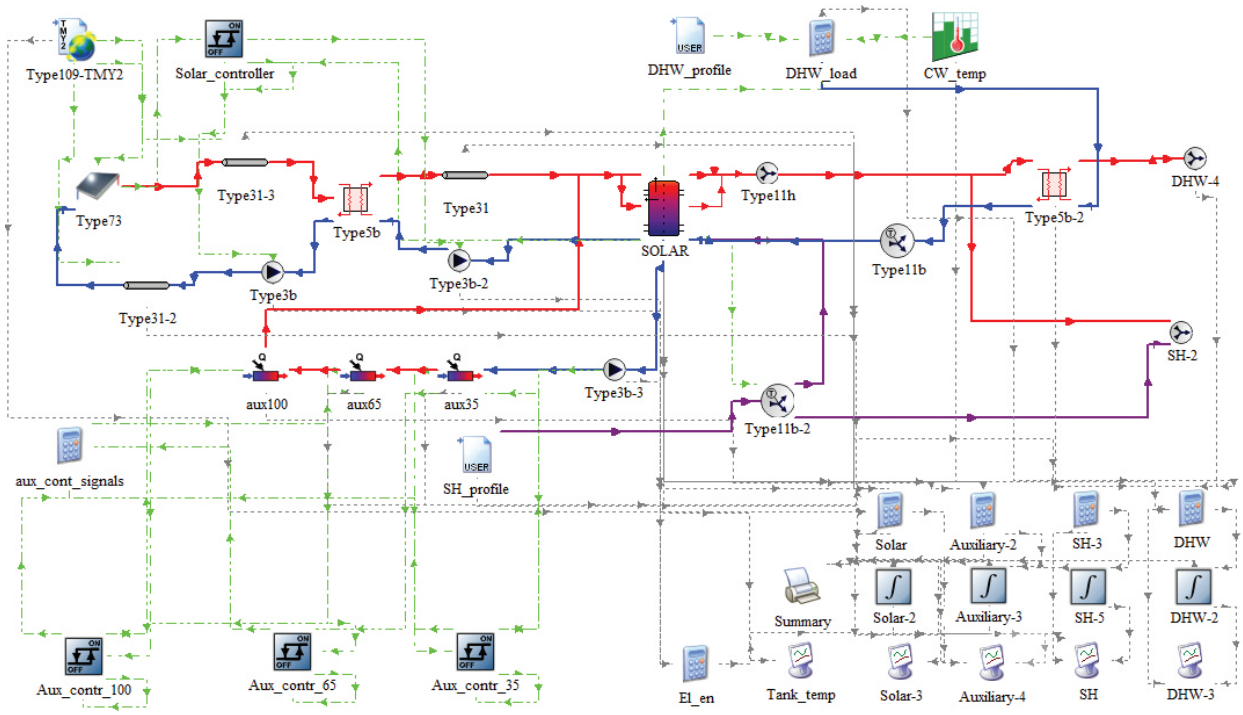
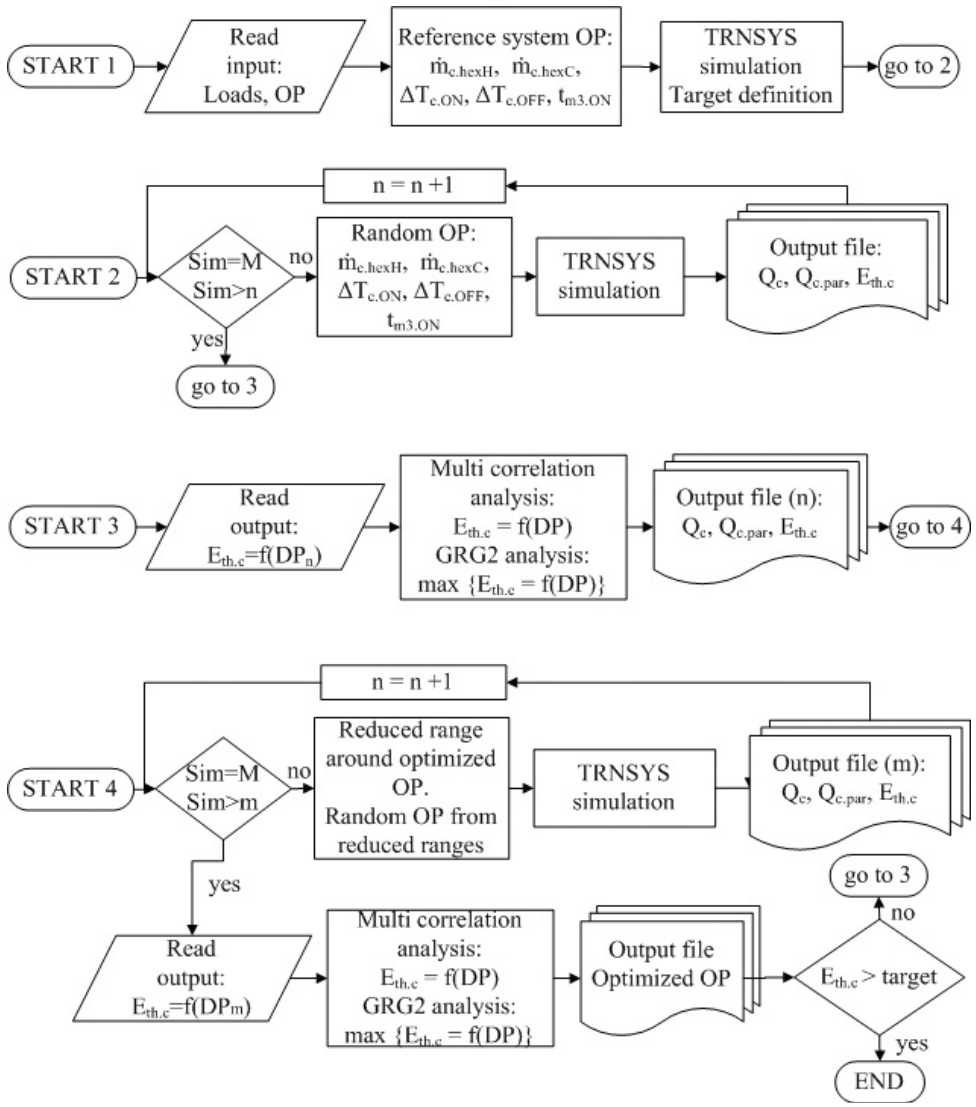


Fig. 5.

Construction scheme of computer simulation model of the solar and pellet combisystem in the TRNSYS Studio sub-programme (Žandeckis, 2012)

Fig. 6.

Algorithm developed for optimisation of the solar combisystem (Rochas et.al, 2012)



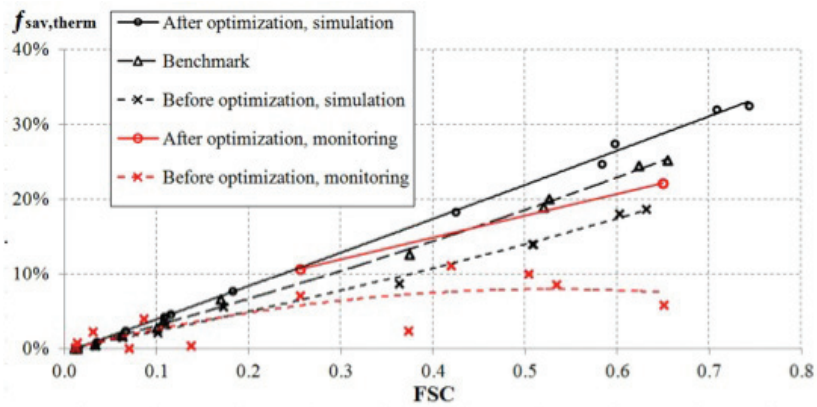


Fig. 7.

The optimization results of the experimental system and simulation model. Changes in solar energy consumption ratio (FSC) and energy consumption reduction ratio ƒsav.th (Žandeckis, 2012)

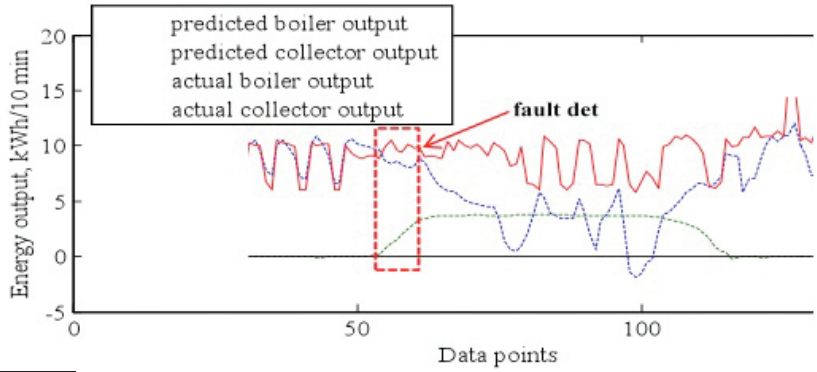


Fig. 8.

Fault detection of a circulation pump malfunctions in solar circuit (Timma, 2013)

in the system (see Fig. 4). The boiler used for the solar combisystem has three power modes. These include 35 kW, 65 kW, 100 kW. The boiler has an overfeed vertical burner with cleaning system, an automatic fuel ignition system, an air blower and a lambda sensor for controlling the air supply. The pellets are fed into the burner by a screw-type conveyor (Žandeckis et.al, 2013).

In the experimental system heat storage tank with the dimensions of 2670x1320 mm and total volume 2.35 m^3. The following dimensions were chosen taking into account free space available in the boiler-house (see Fig. 3). The tank is insulated with 100 mm thick glass wool layer (λ = 0.04 $Wm^{-1}K^{-1}$) and is coated with polyvinylchloride (PVC) protective coating. The ratio of the tank volume to collector effective area is 63 lm^{-2}.

The mathematically determined simulation model of the solar and pellet combisystem was developed in a dynamic transient simulation program TRNSYS 16.1 (Transient Simulation Tool). Software is based on the mathematical description and solution of different system components.

The simulation model developed in TRNSYS Studio environment is presented in Fig. 5. The mathematical structure of the model is fully corresponds to the hydraulic concept of the system (see Fig. 2). However, developed model is flexible and can be used for different concepts and customers.

Based on the results of numerical experiments, the reference system and the benchmark were defined, the economic optimization of technical solutions was carried out and the thermal performance of the experimental system was improved.

In order to improve thermal performance it was necessary to optimize several operating parameters and to find best control algorithms for the system. During the optimization phase set of optimal operating parameters was determined and used for the control of experimental system.

Within the framework this research, a methodology for the optimization of several operating parameters was developed. The developed methodology is based on the use of TRNSYS simulation model and multi-correlation analysis. The developed algorithm of the optimization methodology is demonstrated in Fig. 6, and it is composed of the following steps:

- defining and mathematical expression of a target functions;
- calculation of benefits for the reference system, defining of threshold values;
- dynamic simulation using random sampling of operating parameters between feasible ranges;
- multi-correlation analysis between the outputs from computer simulations and the randomly sampled operational parameters;
- optimization of the regression equation using generalized reduced gradient method in order to identify an optimal combination of parameters with maximal or minimal target function;
- refining simulations with reduced ranges around the optimized values;
- optimization of regression equation for the reduced range and stating of an optimal combination of operation parameters (Rochas et.al, 2012).

The methodology was approbated by optimizing various operating parameters of the experimental system. The optimization results of the experimental system and simulation model are demonstrated in Fig. 7.

Despite the relatively simple construction of solar collectors, failures may occur during their operation. If the thermal output is reduced, the missing amount of heat energy will be compensated by the auxiliary source. In most cases, consumers do not install a proper monitoring system that allows assessing whether the

thermal performance of the system complies with initial plans. Therefore, the aim of the research was to create an automated fault detection and isolation system for solar combisystems that uses artificial neural network programming language (Timma, 2013).

Artificial neural networks have significant advantages over other mathematical and expert system models. Artificial neural networks allow obtaining a mathematical solution to complex problems, where traditional determinant algorithms are exhausted. Artificial neural networks are able to use previously stored information for unsupervised learning and adaption. The obtained results demonstrate that the methodology used in the research allows to increase the performance and operational reliability for solar combisystem. Fig. 8 illustrates the fault detection results in a situation, when the solar loop has malfunctions of circulation pump.

The integration of neural network model is technically feasible for existing and new solar combisystems at little expense. The system's operator is able to remotely and on-line monitor the operation receive information about the performance of system and failures identified. The integration of fault detection and isolation systems allows to decrease the energy consumption of auxiliary source, as well as to reduce amount of harmful emissions during the operation of the system.

REFERENCES

1. Rochas, C.; Žandeckis, A.; Rošā, M.; Romagnoli, F.; Timma, L. 2012. *Applications of informatics and cybernetics in compact solar combisystem for multifamily residential buildings*, WMSCI 2012 - The 16th World Multi-Conference on Systemics, Cybernetics and Informatics, Proceedings, 2: 27-32.
2. Žandeckis, A. 2012. *Modular solar and pellet combisystem for apartment buildings. Experimental research and optimization.* PhD Thesis, Scientific supervisors: Blumberga, D.; Rochas, C. Riga Technical University.
3. Žandeckis, A.; Timma, L.; Blumberga, D.; Rochas, C.; Rošā, M. 2013. *Solar and pellet combisystem for apartment buildings: heat losses and efficiency improvements of the pellet boiler*, Applied Energy, 101: 244-252.
4. Timma, L. 2013. *Application of artificial neural networks for detection of developing faults in solar combisystems.* M.sc.ing. Thesis, Scientific supervisor: Blumberga, D. Riga Technical University and Vilnius Gediminas Technical University.

KOPSAVILKUMS

Pētījuma ietvaros tika izveidota un analizēta jauna saules siltuma sistēma. Sistēma tika izveidota Rīgas Tehniskās universitātes zinātniekiem sadarbojoties ar vairākiem komerciāliem partneriem. Idejas pamatā ir saules siltuma tehnoloģiju apvienošana ar granulu apkures iekārtām. Rezultātā tika izveidots produkts, kas daudzdzīvokļu ēku apkurei un karstā ūdens sagatavošanai izmanto tikai atjaunojamos energoresursus. Sistēma ir kompakta un pilnībā rūpnieciski komplektējama standartizmēra transportēšanas konteinerī. Optimizācijas potenciāls šai sistēmai ietver saules enerģijas īpatsvara paaugstināšanu, elektroenerģijas pašpatēriņa samazināšanu un progresējošu kļūdu izolāciju

Izveidotā optimizācijas metodika ir balstīta uz TRNSYS simulācijas platformas izmantošanu un vairāku parametru regresijas analīzi. Metodika tika aprobēta optimizējot vairākus eksperimentālās sistēmas darbības parametrus. Saules kombinētās sistēmas darbības uzticamības un veiktspējas paaugstināšanai tika izveidota automātiska kļūdu noteikšanas un izolēšanas sistēma. Kļūdu noteikšanas sistēmas izveidošanai tika izmantota mākslīgo neirālo tīklu programmēšanas valoda. Kompleksās optimizācijas rezultātā tika sasniegta augstāka sistēmas veiktspēja un stabilitāte. ◆

LOW ENERGY BUILDING CONCEPTION PROMOTION IN CIVIL ENGINEERING MARKET OF NORDIC EUROPE

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DEFINITION ON NEARLY ZERO ENERGY BUILDING

Buildings in Latvia are characterized by significant potential for energy efficiency that can be gained by implementing building renovation. The average energy consumption for space heating is approximately 180 kWh/m^2 per year. Current average energy consumption is 12 times higher than the consumption of a very low energy house (passive house) or nearly zero energy building (nZEB).

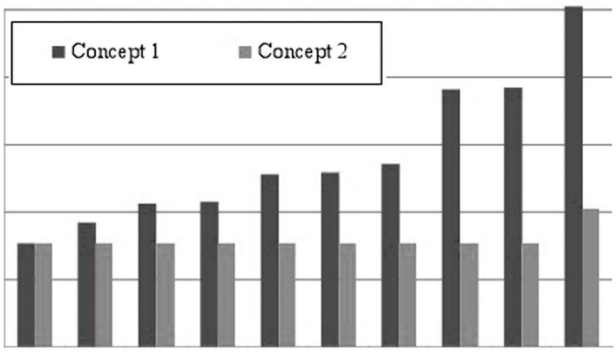
During the NorthPass project the information on local criteria and standards for very low-energy houses currently used in the participating countries has been collected.

The climatic conditions around northern Europe are very different, varying from nearly central European conditions in the south to arctic conditions in the north. Therefore, when planning a very low energy house across these very different conditions, one has to accept:

1. different goals for the space heating energy demand;
2. adaptation of the building to the conditions, e.g., lowering U-values in order to obtain the same energy demand.

Figure 1 shows these two concepts with the resulting space heating demand for a single family house.

The challenge for the very low energy building design in northern Europe is the cold winter temperature and less sun in the winter time compared to conditions in Central



Concept 1: A building meeting the passive house criteria in Copenhagen is moved around North European climate zones.

Concept 2: U-values of a building are modified to meet the passive house criteria in each climate zone. Resulting range of U-values for opaque constructions is 0.04–0.12 W/m^2/K and for windows is 0.56-0.78 W/m^2/K. These values are calculated for a compact single family house with a gross area A = 172 m^2.

Fig. 1.
Space heating demand for a single family house

Europe.

The principles of building a very low energy house in northern Europe can be defined quite simply: One has to try to reduce the heat losses and to cover as much as possible of the remaining losses by heat gains. All this is implemented by optimising the building site, building layout, building envelope and the building services.

Aiming to reduce the consumption of energy in new buildings, a five-step strategy for low energy design is recommended, which was developed within the project *'Cost Effective Low Energy Buildings'* (Dokka 2006):

1. Reducing heat losses (and need for cooling);
2. Reducing electricity consumption;
3. Utilising passive solar energy including daylight;
4. Controlling and displaying energy use;
5. Supplying the rest of the energy demand with renewable energy sources.

The nZEB concept is applicable and utilizable for conditions in Latvia. Utilization of the nZEB concept enables achievement of significant reduction in energy consumption for new building construction, as well as building renovation. Nevertheless, the work for this thesis has determined that while the specifications of particular elements and technologies developed by the Passive House Institute are suitable for Central Europe, they are not directly utilizable in Latvia in order to achieve nZEB energy consumption levels. The indicating decision criteria developed for this thesis evaluate energy consumption for space heating in order to enable an approach to passive building requirements.

To approach nZEB indicators under climatic conditions in Latvia, buildings need to achieve the following indicators:

For the climate in Latvia, the corresponding U value in the case of a private house:

- walls, roof, coverings < 0.08 W/(m^2×K);
- windows < 0.65 W/(m^2×K);
- ventilation heat recovery > 85%;
- building density n_{50} < 0.4 h^{-1};
- maximum utilization of solar energy in a passive manner;
- maximum compactness.

For the climate in Latvia, the corresponding U value in the case of a multi-apartment building:

- walls, roof, coverings < 0.12 W/(m^2×K);
- windows < 0.65 W/(m^2×K);
- ventilation heat recovery > 80%;
- building density n_{50}< 0.4 h-1;
- maximum utilization of solar energy in a passive manner;
- maximum compactness.

It is possible to achieve nZEB indicators (< 15 kWh/m^2 per year) in Latvia.

As the conducted calculations demonstrate, it is very difficult to achieve a smaller peak heating load than 10 W/m^2.

One of the ways to achieve nZEB parameters is to fulfil these very strict parameters. The other way how to reach nZEB is to work at new technological solutions for decreasing building energy consumption. In Riga Technical University such a new technological solution has been developed at the Institute of Energy Systems and Environment. The innovative technological solution includes the use of latent heat of water phase transition and the recovery of the lost energy using low-potential heat sources (such as ground heat).

DESCRIPTION OF THE PROPOSED TECHNOLOGICAL SOLUTION

It is proposed to install a circulating water layer on the external surface of the building envelope. The aim of this water layer is to reduce heat loss through the outer envelope of the building. Despite the fact that the outside air temperature varies and in Latvia during winter it can drop to -30 ^{0}C, the temperature on the outer wall remains constant, which is due to the fact that water is freezing at 0 °C. During the freezing of water large amounts of energy (latent energy) are released, which can be used to reduce heat conduction losses through the building envelope.

STRUCTURE OF THE SYSTEM

The whole system consists of two separate systems. One system is located on the external facade of the building, it will be referred to as a water layer or a water wall and the other is that part which ensures the recovery of heat through the ground heat exchanger, which in turn will be called a ground loop. These are not the only systems that ensure functioning of the whole system. In the middle of these systems, there is a system that provides heat carrier circulation in the ground loop and on the wall. This system includes components such as a circulation pump and expansion vessel. Expansion vessel is required to compensate for the increase in volume which happens as a result of water changing from liquid to solid phase. The main system, which affects the rest of the system operation, is located on the external facade of the building. Schematically, it can be seen in Figure 2.

The operation of circulation circuit system depends on the losses through walls. The bigger the losses, the faster heat carrier has to circulate through the system components to prevent heat carrier from freezing and to ensure efficient heat recovery.

It is expected that in summer the operation of the system will be different. Heat carrier serves not as a heat source, but as a heat sink. Heat carrier with the accumulated heat from the walls flows to the ground heat exchanger and heat is stored in the ground; thus, the heat carrier is cooled and prepared for recirculating to the wall. Heat carrier can be cooled down to about 8 °C.

Heat losses for a 32 m^2 large wall section with water wall and without it can be seen in Figure 3. When the average heat flow is zero, the indoor temperature and the temperature on the outside wall of the building are

the same. In those areas, where the heat flow is positive, the heat flows through the walls of the building into the surrounding area, which means that there is the need for space heating to ensure the desired indoor temperature conditions. If the average hourly heat flow is below 0, there is a necessity for space cooling. Figure 3 shows that in the case without water wall heat flow peaks during the winter months can be observed. This can be explained by the fact that there is a big difference between indoor and outdoor temperatures.

The figure also shows that in the case of construction with the installed water wall, the heat flow at no time is above 550 W. This is due to the fact that in this case the lowest temperature on the wall can only be 0 ^{0}C. Thus, the temperature difference between the two environments, when the outdoor temperature is -30 ^{0}C, is 18 ^{0}C, which at the current system parameters means that the maximum heat flux is 576 W. Figure 3 shows that if the water wall is installed, it will significantly reduce the energy loss range. This means that it would be possible to design a real building and to predict the maximum heat loss and peak load with a higher accuracy, and thus it should be possible to select the optimum power of the heating system. Each hourly average heat flow multiplied by one hour results in heat loss or gain in one hour. Heat gains and heat losses are counted separately. The results are summarized in Table 1.

The most important result is the heat loss during the heating season, which lasts from 1st January till 15th April and 1st October till 31st December.

EXPERIMENTAL RIG FOR THE WATER WALL TECHNOLOGICAL SOLUTION

Experimental testing of the water wall was performed by setting up an experimental rig that imitates a building with a water wall on one of the surfaces of building envelope.

It is necessary to determine the heat transfer coefficient of building envelope to carry out the analysis of water wall operation. Two heat flux density sensors and seven different

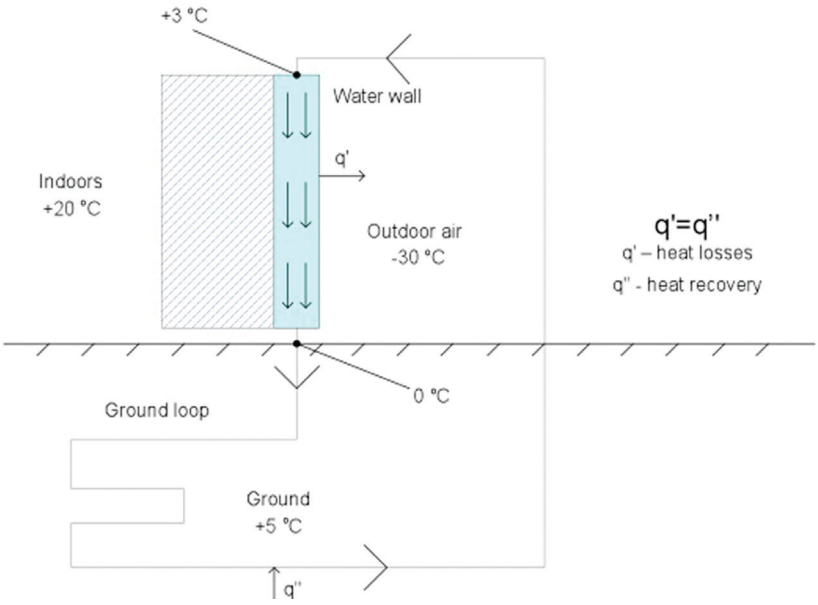


Fig. 2.
Structure of the whole water wall system

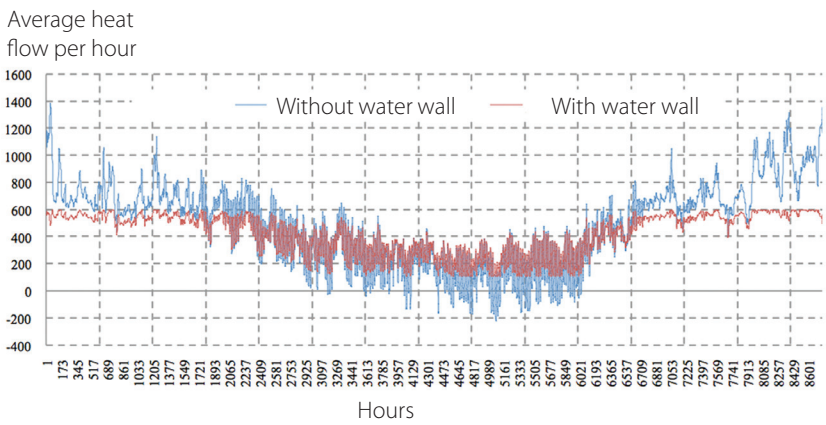


Fig. 3.
Comparison of construction with water wall technology and without it (climate – Gulbene, 2002)

	Without water wall	With water wall
Space heating (whole year), MWh	4.35	3.71
Cooling, kWh	29.29	0
Space heating (heating season), MWh	3.37	2.55
Energy savings in the heating season, %ing season), MWh	24.4	

Table 1
System Performance Comparison in Gulbene in 2002

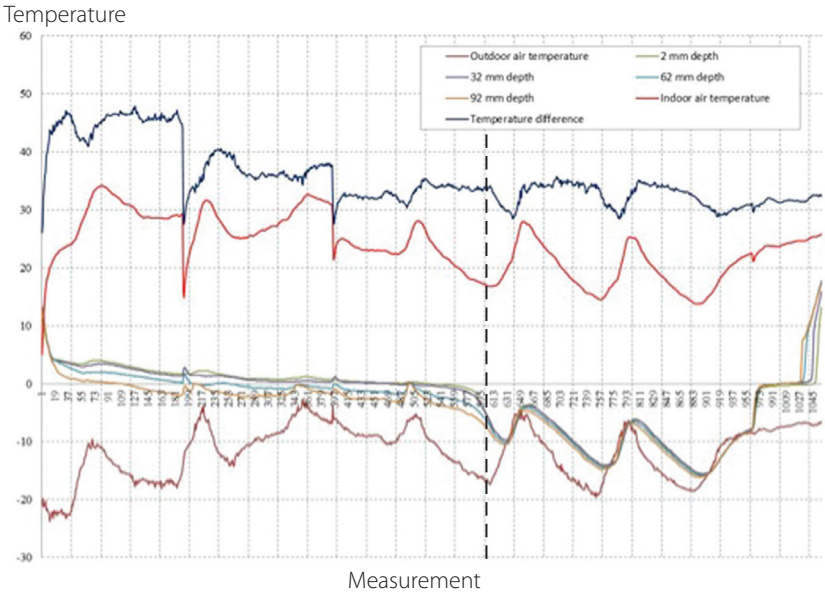


Fig. 4.
The measured air and water temperatures

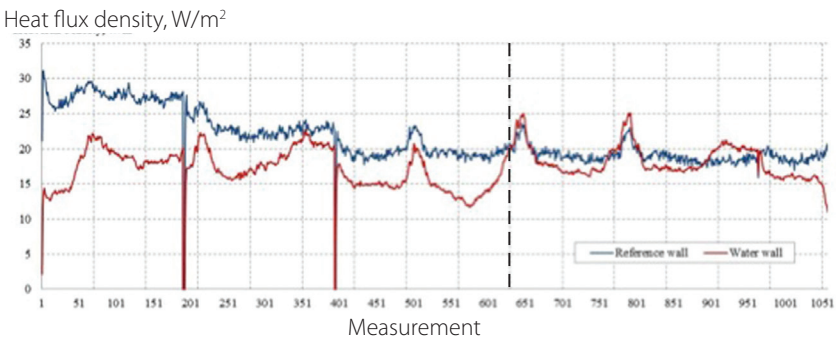


Fig. 5.
Heat flux density measurement results

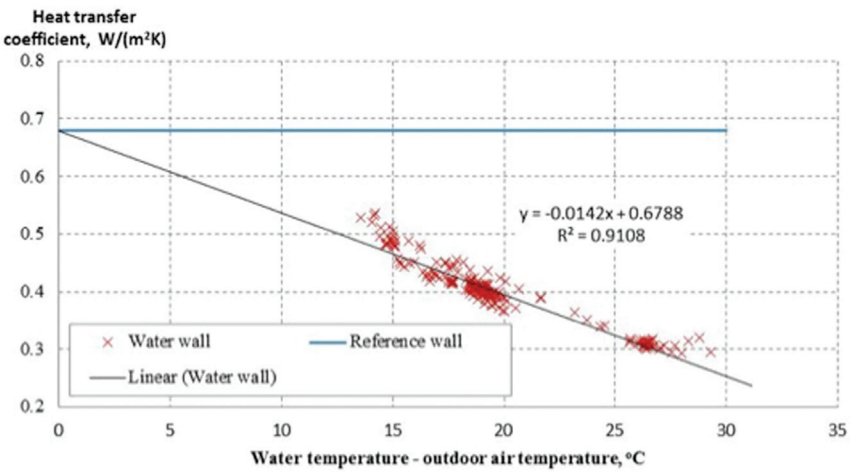


Fig. 6.
The total heat transfer coefficient of water wall depending on the outdoor air temperature

temperature measuring devices were used in the measurements.

To confirm the hypothesis that latent heat of water-ice phase transition can be used in reducing heat conduction losses, heat flux density measurements on the building envelope without the water wall on the outer surface (the reference wall) and with the water wall on the outer surface of building envelope (the water wall) were carried out.

THE MEASUREMENT WITH A FREEZING WATER LAYER ON THE OUTER SURFACE OF BUILDING ENVELOPE

To determine how freezing of water and using latent heat of phase transition affect heat loss from the building envelope, measurements, where the water wall structure was filled with 120mm thick layer of water, were carried out. Measurement results allowed validating the calculation model of the water wall. The measurements were performed from February 6 to February 13, 2012. The total measurement time was 176 hours (7 days 8h). Measurement length was determined by the duration of the water freezing process. It was necessary to ensure that the entire water layer would freeze during measurement. Measurements of completely frozen water wall construction were also carried out.

The measured air and water temperatures are shown in Figure 4.

During the measurement process, the outdoor air temperature was in the range from -2.53 °C to -23.85 °C. Cyclic overnight outdoor air temperature changes can be seen. An electric heater with constant power was chosen to maintain the room air temperature. Therefore, cyclic overnight temperature changes in the observed room air temperature can be seen.

Changes in water temperature show that the water is freezing from the upper layers and gradually freezes into deeper water layers. At the given outdoor temperatures, 56 hours were required for the entire water layer to freeze (vertical water freezing speed– 2.143 mm/h).

When the water layer is frozen, the

ice temperature at different depths converges and no more latent heat is used. At the end of measurement process (beginning from the 960th measurement point) electric water heater was turned on and the ice was melted.

Heat flux densities through the reference wall and water wall during the measurement process are shown in Figure 5.

The measurement results demonstrate that the heat flow in the building envelope with the water wall is significantly lower than in the reference wall (a wall without water on the outer surface), which shows that the water phase transition latent energy can be used to reduce the heat conduction losses through the building envelope in cold climates. When the water is frozen (black dashed vertical line in Figure 2.8.), heat flow in the reference wall and water wall converge, because all the phase transition latent energy is used.

Water wall measurement data can be analysed by not using the water temperature on the surface of the wall, but rather the outdoor air temperature. In this way, it is possible to determine the total water wall heat transfer coefficient, which includes the water layer and the use of latent energy of phase transition for reducing heat conduction losses. By performing this analysis it has been concluded how the total heat transfer coefficient of the water wall changes depending on the outdoor temperature. The heat transfer coefficient for the wall with no water layer is not dependent on the outdoor temperature and it is constant. For the water wall the total heat transfer coefficient varies depending on the outdoor temperature. The lower the outdoor temperature, the lower the total heat transfer coefficient of water wall is. Results of measurements of the total heat transfer coefficient of the water wall are shown in Figure 6.

Figure 6 shows the dependence of the total heat transfer coefficient of the water wall on the outdoor air temperature. The X-axis shows water temperature and outdoor air temperature difference instead of the room air and outdoor air temperature difference. This is done to show that, if the temperature difference is 0 °C, the total heat transfer coefficient of water wall is the same as for the reference wall (a wall without a water layer on the outer surface). The measurement data show a very good correlation between the total heat transfer coefficient of water wall and water temperature and outdoor temperature difference. The total heat transfer coefficient of water wall decreases by 0.0142 W/(m^2 K) if the outdoor temperature is decreased by one degree. The difference between the conventional insulation material with a constant heat transfer coefficient and the water wall with the heat transfer coefficient being dependent on the outside air temperature can be clearly seen. The proposed technology is used in cold climates, because the lower outdoor air temperatures decrease the total heat transfer coefficient of the water wall.

SUMMARY

Building energy consumption is responsible for approximately 40% of EU energy consumption. In countries with cold climate energy consumption for space heating is higher than in such countries as Germany or Denmark. The passive house standard, which in Germany will ensure a building with space heating energy consumption of 15 kWh/m^2 per year, in Latvian climatic conditions will enable to build a building with space heating consumption of 25 to 30 kWh/m^2 per year. Therefore it is important to choose whether we use passive building standard or choose different more strict standard to define nearly zero energy buildings (nZEB). In cold climates it is very hard to reach building energy consumption of 15 kWh/m^2 per year and maximal heating loads of 10 W/m^2. Therefore there is a need for new technological solutions that raise energy efficiency of buildings.

One novel technological solution developed in Institute of Energy Systems and Environment is water wall. Water wall uses latent phase change energy to reduce heat conduction losses from building envelope. This can be done thanks to the fact that water freezes at 0 °C and during this process large amount of energy is released.

KOPSAVILKUMS

Ēku enerģijas patēriņš veido aptuveni 40% no ES kopējā enerģijas patēriņa. Valstīs ar aukstu klimatu ēku apkures enerģijas patēriņš ir lielāks nekā tādās valstīs kā Vācija un Dānija. Pasīvās ēkas standarta ievērošana celtniecībā, kas Vācijā celtai ēkai nodrošina apkures enerģijas patēriņu 15 kWh/m^2 gadā, Latvijā celtai ēkai apkures enerģijas patēriņu nodrošinās 25 līdz 30 kWh/m^2 gadā. Tāpēc ir svarīgi izlemt vai gandrīz nulles enerģijas ēkas definīcijai izvēlēties pasīvās ēkas standartu, vai arī citu stingrāku standartu. Aukstā klimatā celtām ēkām ir ļoti grūti sasniegt apkures enerģijas patēriņu 15 kWh/m^2 gadā un maksimālo apkures jaudu 10 W/m^2. Tāpēc ir nepieciešamība attīstīt jaunus tehnoloģiskos risinājumus ēku energoefektivitātes līmeņa paaugstināšanai.

Viens šāds inovatīvs tehnoloģiskais risinājums, kas attīstīts Vides aizsardzības un siltuma sistēmu institūtā, ir ūdens siena. Ūdens siena izmanto fāzu pārejas latento enerģiju, lai samazinātu siltuma vadīšanas zudumus caur ēkas norobežojošajām konstrukcijām. To iespējams panākt tāpēc, ka ūdens sasalst pie 0 °C un šī procesa laikā tiek atbrīvots liels latentās enerģijas daudzums.

ACKNOWLEDGEMENTS

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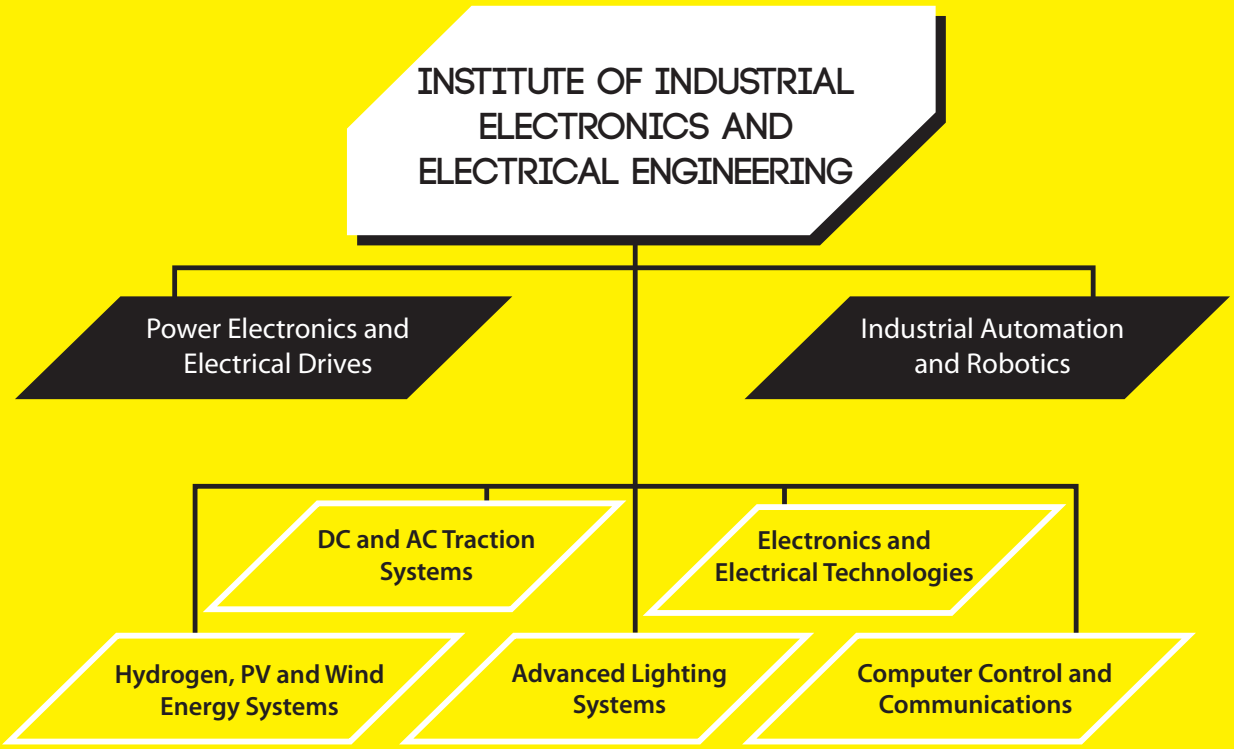
Part of this work has been supported by the Intelligent Energy – Europe (IEE) project Promotion of the Very low-energy house concept to the North European Building Market (acronym: NorthPass)

EIROPAS SOCIĀLAIS FONDS

EIROPAS SAVIENĪBA


INSTITUTE OF INDUSTRIAL ELECTRONICS AND ELECTRICAL ENGINEERING
Power Electronics and Electrical Drives
Industrial Automation and Robotics
DC and AC Traction Systems
Electronics and Electrical Technologies
Hydrogen, PV and Wind Energy Systems
Advanced Lighting Systems
Computer Control and Communications

ON THE INSTITUTE OF INDUSTRIAL ELECTRONICS AND ELECTRICAL ENGINEERING

RTU Rector, Head of the Institute of Industrial Electronics and Electrical Engineering Dr.habil.sc.ing., prof. Leonīds Ribickis

The Institute of Industrial Electronics and Electrical Engineering deals with the design and development of power electronics, power electronics equipment, and high-powered semiconductor converters. We deal with the development, manufacturing, launch and testing of semiconductor control methods, as well as with the research of various control methods.

Alternative energy equipment – wind generators, fuel cells, small hydro power stations, also cogeneration equipment, which is closely connected with it. "Green" invertors, as these electric energy converters are called, are highly necessary as they are essential in manufacturing small, automatic, autonomous and combined power stations and power generating equipment, including microturbines, which run on gas. We are also interested in sun power engineering, as semiconductor converter plates convert direct sunlight into electricity, and we address the issue how to coordinate this process with the consumer.

The situation is similar as regards hydrogen power engineering, fuel cell elements. When electricity has been generated, a question arises – how and at what efficiency rate this energy can be transmitted to consumers. We persistently work on the improvement of this process, in other words, on the improvement of energy efficiency.

The scope of our interests also covers everything that is connected with the performance of mechanical work powered by electricity, which is called electric drive. It is present in all production lines, all vehicles, and robots.

In nature energy propagates and is used in a variety of ways, and we try to learn how. We are still not able to use energy as efficiently as it occurs naturally in all processes, however, step by step we are getting closer.

Nowadays, electronics, equipment, and software are most rapidly developing, old technologies keep quickly disappearing. At present many military and space technologies enter our daily lives. As we know, the first fuel cells, which had been originally developed for spaceships, were used already at the end of 1950s. Of course, at that time they worked as well as they could, nowadays the technology has considerably developed. Also solar cell batteries as autonomous energy source were used already on the first satellites. Talking about solar panels on the roof tops – why not introduce them in Latvia? Solar radiation is everywhere, everything depends on semiconductor element layer, how effective it is, what efficiency rate it has in converting this radiation into electricity. We have been studying these issues for many years. If in Riga sunny sides of all roofs were covered with solar panels, energy consumption of the city would decrease by approximately one third. The only question is how much it would cost to cover these roofs with solar panels. Moreover, solar panels are not eternal, and at present investment payback period for this type of energy source is at least 12 years, which is the shortest time possible. Furthermore, power electronic unit would be necessary to match the harvested energy with the regular network voltage. But as everything is getting cheaper and more efficient, it is possible that it may become reality some day.

Energy will be always necessary. In future every household, may be every individual, will use a personal source of energy. They will be miniaturized, for example, your car will be your power station. Such opportunities and groundwork already exist; most likely, we will see them in the remote future. Our children and grandchildren will get integrated into that system.

Let us meet in the future!

CONCEPT OF LOW-COST ENERGY MONITORING SYSTEM FOR HOUSEHOLD APPLICATION

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Due to continuous development of office and household equipment, the electricity end-consumer profile has changed in the recent years, and increasing number of electricity consuming equipment makes it very hard to identify real electricity consumption of each device. Long-term power consumption monitoring with existing wall plug digital power meters can be an expensive method for consumers with a large number of devices. The article describes a different approach based on the application of a power monitoring system that lowers the costs and price of the needed metering equipment.

Existing dwellings consume about 3 times more energy than it is prescribed in the current Latvian building regulations, which were developed before households became equipped with a wide range of electrical appliances, the classification of average consumption per device type has been changed as well. As the prices for electrical energy are increasing, in the recent years the idea of SmartMetering systems and SmartPlugs got attention from both sides – energy suppliers and consumers, as it could greatly contribute to energy consumption reduction by changing the habits of the consumer, and thus creating more stable power grid in future. It can be concluded that one of the fundamental problems in electrical household is a non-saving energy consumer. In order to solve this problem, the end-user must be informed about his possibilities to save energy, which could be reached by implementing smart metering systems with graphical indicators on screen, or visualization on PC with help and tips for possible solutions regarding energy consumption reduction possibilities of each consuming device.

Existing metering systems in office or household applications have just one electrical energy measuring device, regardless of the fact that there are many energy consumer types - TV sets, music players, fridges, microwaves, washing machines, heaters, boilers, computers, lighting, etc, and without additional metering devices or special calculations proper energy consumption of each consumer device can't be obtained., Digital metering devices, which can be plugged into electrical socket for additional electrical consumption metering, are already available on market for the end-user, but they are very expensive to determine energy consumption for each consumer type, as the average household has at least 8-10 regular electricity consuming devices, and digital metering devices that can be plugged into electrical socket cost around 16-30 EUR. Thus, an investment of 171 to 285 EUR must be made to monitor and determine electrical consumption of each device , which is too expensive for a typical end-user.

This method also doesn't allow monitoring consumption of the lighting system, which possibly has different light sources, such as incandescent bulbs or Compact Fluorescent, and installation of digital socket metering

devices is not possible. Another problem is that a typical end-user doesn't have educational background to properly understand the meaning of W, VA, VAr, kW, kWh, A, V and cosφ values visualized on the digital socket metering device display.

This clearly indicates the need for a much cheaper solution with a more direct and understandable message to the end-user. The metering device should also have small dimensions, so that it could be integrated into the back of the socket or into the luminary chuck (typically E27) (see Fig.1. P_2 load). The main task is to provide energy consumption apportionment between consumers instead of precise energy consumption metering for each consumer type, as the distance between the central measurement point and the monitoring point is less than 100m, the voltage u(t) is practically the same for each consumer, and energy consumption can be characterized by just monitoring each consumer current i(t) value, and the central measurement point, which makes precise measurements of u(t), i(t) true rms values, receives relative current values from the monitoring device via wireless or power line communications, and makes indicative visualization of energy consumption per consumer on display or sends it to PC. 2.5%-5% precision is enough for monitoring task and such precision corresponds to 80 sec or 180 sec consumer state "ON". Energy consumer power typically is within the range from 10W up to 2250W (typical 10A wall plug), consumers have R or RL (also RC) load characteristics, current and voltage graphs are sinusoidal under normal conditions.

In order to get precise measurements and relative current value distribution in the total energy consumption, the central measurement point measuring both voltage and current values must be synchronized with the monitoring measurement point, which measures only current value at the exact point.

Readings from the measuring points are provided sequentially and corresponding counter values are shown as a bar graph at the central measurement point device display. There are no power or energy calculations in-between, so it is possible to use spare clock frequency for other matters. Bar graphs represent energy consumption apportionment between the measuring points.

Shunt was used as a current sensor, and dissipated power in shunt must be taken into account and this fact reduces shunt value and makes it more difficult to read voltage drop on it for low consumer energy (power). Unfortunately, other current sensors like Hall effect (LEM FHS 40-P/SP600) etc. are more expensive, 3-8 EUR, and cannot be applied in this case, as the goal is to get a low-cost measurement device. Shunt resistors like ERJ-M1WSJ8M0U, PMR50HZPJU8L0, or similar, are priced from 0.30-1.00 EUR, which is significantly lower price.

For data processing, storage and computing tasks, a system based on ATmega328 microprocessor and FTDI USB UART chip FT232RL mounted on Arduino Duemilanove board is used. Arduino Duemilanove allows several system developments: USB connection, WiFi and Bluetooth wireless connections as well as Ethernet connections via additional installations on Arduino board. Also small computation is available if it is necessary.

Currently USB connection was chosen to communicate with FileMaker database installed on a PC (any kind of personal computer operating Microsoft Windows or Apple OS X operating system). FileMaker database was chosen due to several advantages, it is well known and has been developing during the last 20 years, it has practically unlimited number of data tables and table fields, which means practically unlimited amount of data that can be easily processed, FileMaker network allows easy communication via the Internet, instant web publishing engine allows viewing the data as well as interacting with the collected data, PHP or XSLT web publishing (web server must be installed), Microsoft ODBC, mainly OpenSource JDBC and OpenSource MySQL connections available. No advanced programming knowledge is necessary to use FileMaker, it has user friendly layout design, advanced Script technique, it allows chart data representing - Gantt, bar or line (possible directly in FileMaker or Google Charts live), one FileMaker installation simultaneously can run several databases - energy consumption monitoring, CRM, people, etc.

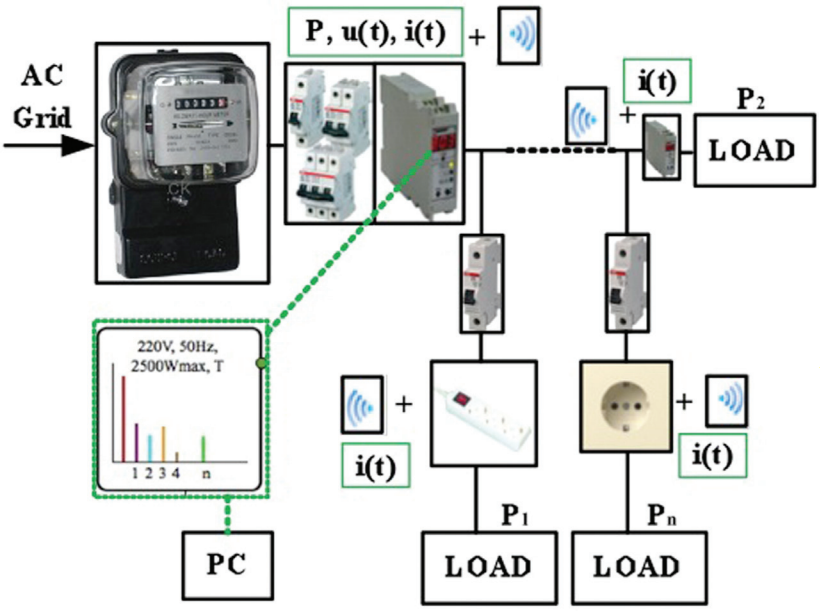

Fig. 1.
Block diagram of energy metering method of the proposed solution.

KOPSAVILKUMS

Rakstā tiek atspoguļota RTU zinātnieku ideja par lētas elektroenerģijas monitoringa ierīces koncepciju, tiek pamatots kādu apsvērumu dēļ šī ideja ir radusies, un dots ieskats par ierīces/sistēmas darbības principiem, kā arī par tās pamatelementiem.

DEVELOPMENT OF COMPUTER CONTROL TECHNIQUES FOR CRITICAL INFRASTRUCTURE

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Intelligent Monitoring of Critical Infrastructure Systems is related to modern ICT tool application. The main objective of the research is to develop innovative intelligent monitoring, control and safety methodologies for critical infrastructure systems, such as electric power systems, telecommunication networks, transport and water distribution systems.

'Critical infrastructure' (CI) according to the definition of Directive 2008/114/EC means an asset, system or its part, which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people. It is clear that modern society cannot function if large portions of critical infrastructure are disrupted or destroyed.

Critical infrastructures and their mutual influence and interdependence have been analyzed. The methods for the evaluation of mutual influence and interdependences of critical infrastructures have been observed. A method that includes establishing evaluation metrics and performance indices of interdependent critical infrastructures, based on their content, services decomposition, expert opinions and risk analysis have been researched.

The study presents an approach to monitor and control critical infrastructures, considering the CI services provided by its own CI, as well as interdependent CI services conditions. In such a way objective measurements that describe the state of each critical infrastructure and services are abstracted by means of common indicators that could be distributed between interdependent critical infrastructures. This approach allows particular infrastructure experts to evaluate the impact brought by other related CI on their CI and on the services it provides.

Let us assume that each critical infrastructure is composed of services that are provided to customers. Services may be self-contained or may depend on other services, which may be provided by the same or by another service provider.

Current risk analysis methods do not provide a way to share risk knowledge between providers forming CI. Usually providers have expertise on risks on their own infrastructure, but not on related infrastructures of other providers. Also, since different critical infrastructures are very divergent in nature, risk data gathered from particular infrastructure cannot be easily interpreted by non-domain experts.

The reference scenario is composed of a high level representation of water utility (Talsi Water), which presents interdependencies with energy provider (Latvenergo CI) and a telecommunication provider (GSM Operator CI). This scenario is demonstrated as an example for validating the risk based methodology. A more complex and realistic representation is not possible due to the lack of the data and the limited scope of this work.

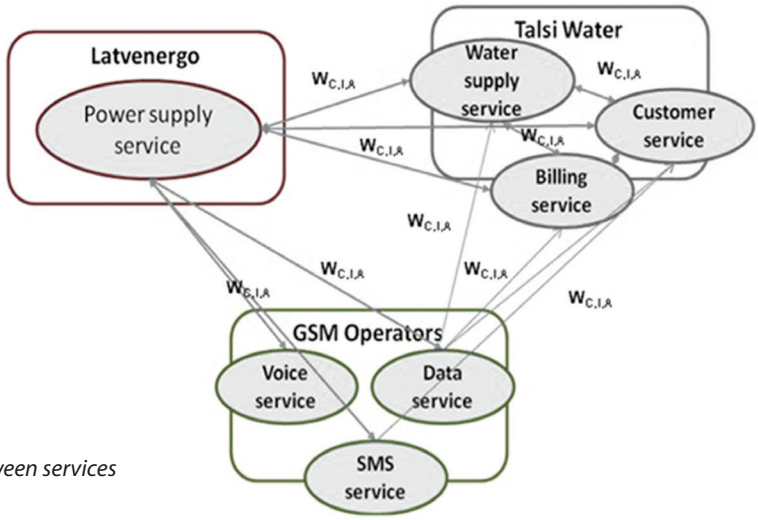

Fig. 1.
Interdependencies between services and services providers.

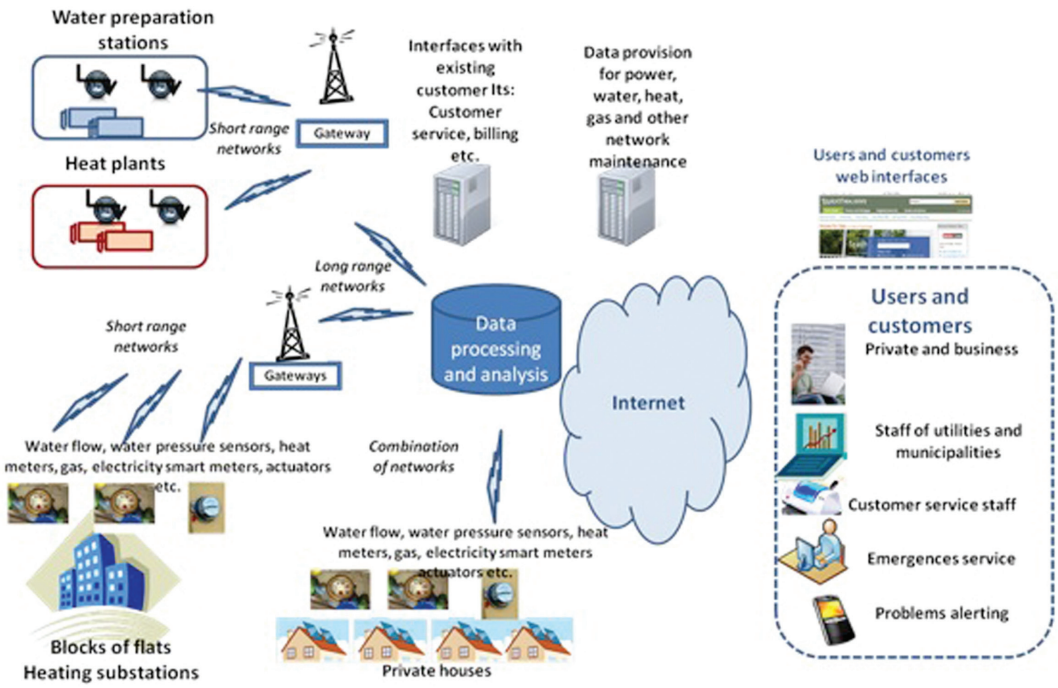

Fig. 2.
Infrastructure Overview

Risk analysis of Talsi Water CI has identified critical services and interdependencies shown in Fig. 1.

Preliminary research activities implemented on water distribution system showed that most of the water utilities in Latvian cities account for losses about 20%. In other cases such losses may exceed 50% and more. Heat losses are between 12 to 15%.

Usually losses are included into the overall cost calculation, and – as a result – into the clients' bills. For example, one municipality owned water utility in Latvia with 10,000 inhabitants estimated a loss around 1.1 million €. The project "Smart Meter" implemented by four Latvian and Lithuanian partners intends to develop a self-service subscription solution for wireless capturing of real-time data from a scalable phycical infrastructure. The consortium will demonstrate how e-services can improve water distribution services; reduce future costs of sensors and equipement.

The solution for two-way data communication between sensors installed on water or heat distribution network and a decentralized backend system will be implemented. The architecture of such a network is covered by a distributed system architecture, where low-cost and ultra-low-wireless energy radio to Ethernet gateway are applied.

The proposed solution is a Local Metrology Networks (LMN) connected to gateways, which provide data connectivity enhanced with application service equipments.

The solution enables operational time without battery replacement of at least 8 – 10 years being extremely energy efficient and possibly using energy harvesting techniques.

The need for low cost is related to the value of the network contents, its structure and quality. Compared to high-value long-range pipeline systems for oil or gas, which are highly monitorized, public water networks are not. In the Baltic States and the majority of post-socialist countries financial resources for modernization of infrastructure are even more restricted than in other regions.

The development of LMN includes also research of application of radio grid system as a basis, estimation of data volume, design of application data format, and evaluation of controllers, transceivers and software to applied, power needs, working regime, and antennas.

KOPSAVILKUMS

Šajā darbā tiek prezentēta pieeja, kas ļauj uzraudzīt kritiskās infrastruktūras (KI), apsverot servisu stāvokli, kā arī mijiedarbojošos servisu stāvokli. Pētījuma laikā tiek izanalizētas kritiskās infrastruktūras sistēmas un to savstarpējā ietekme un atkarība. Ir apskatītas metodes, ar kurām var vērtēt kritiskās infrastruktūras savstarpējo ietekmi. Pētījumā ir izklāstīta pieeja, kas ļauj uzraudzīt un kontrolēt kritiskās infrastruktūras, apsverot KI sniegto pakalpojumu stāvokli, kā arī savstarpēji saistīto KI pakalpojumu stāvokli. Tādēļ mērījumi, kas apraksta katras kritiskās infrastruktūras stāvokli un pakalpojumus, tiek abstrahēti par vienotiem parametriem, kas varētu būt izplatīti starp savstarpēji atkarīgajām kritiskajām infrastruktūrām. Šāda pieeja ļauj konkrētas infrastruktūras ekspertiem novērtēt citu saistīto KI ietekmi uz savu KI un uz tās sniegtajiem pakalpojumiem. Izstrādātais risinājums kritiskās infrastruktūras stāvokļu kontrolēšanai paredz divvirzienu datu apmaiņu starp sensoriem, kuri uzstādīti ūdens vai siltuma sadales tīklos, un decentralizēto „backend" sistēmu. Piedāvātais risinājums ir Lokālais metroloģijas tīkls (LMT), savienotais ar vārtejām, kuri nodrošina atbilstošu datu savienojumu ar lietojumprogrammu servisu iekārtām.

RESEARCH AND DEVELOPMENT OF COMMUNICATION MEANS FOR INTELLIGENT DISTRIBUTION GRIDS WITH DIMMABLE LED LAMPS

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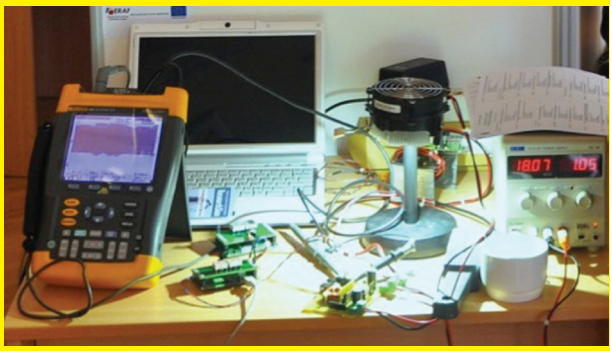
The problem of rapidly growing global energy consumption is very topical. As it has been previously discussed, lighting is quite important for the consumer due to the fact that it consumes one fifth of globally generated electrical energy. As a result, various technologies are introduced helping to stop the increase of energy consumption in this sphere, at growing number of illuminated objects.

Rapid development of solid-state lighting (SSL) sources and implementation of luminaries with light emitting diodes into indoor and outdoor illumination systems create the need and possibility for smart lighting control approaches, such as reduced lamp's luminous output (dimming), when no object is registered; or even object following lighting, when illuminated path is moving synchronously with the object. These techniques also require introduction of communication technologies making lighting network "smarter" and realizing self-controlling features.

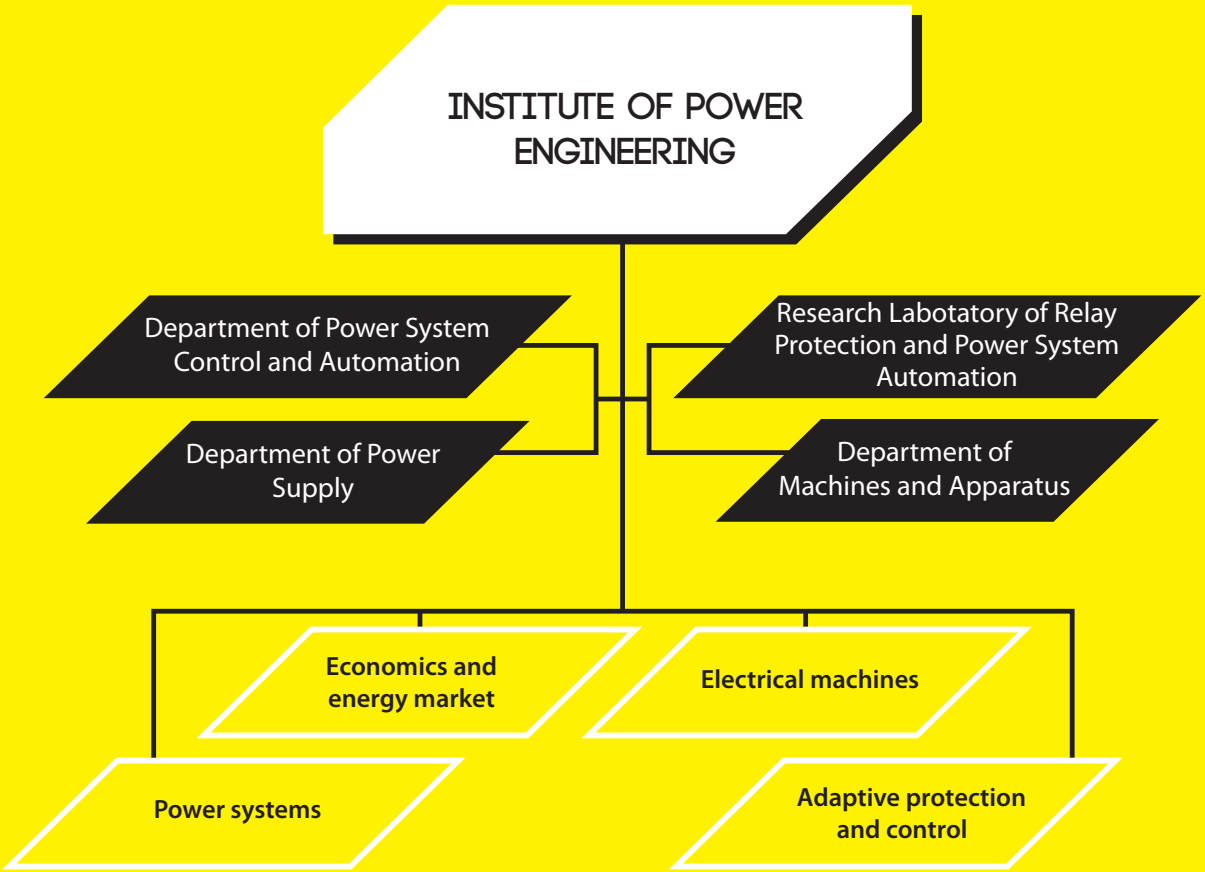
All these initiatives bring us to dynamic illumination, for which LED is the best suited choice, due to its linear character of light output dependence on driving current of LED, thus there are no such negative effects as long warm-ups typical for gas discharge lamps. Besides, SSL has good potential to overcome any other lighting technologies in perspective, comparing efficacy and price, within next 10 years.

Lighting control systems that are currently available on the market vary from simple wall switches to complex microprocessor-based dimming systems that are often networked with other building automation systems. Smart lighting systems can offer features such as light harvesting, optimized lighting levels, dynamic lighting output based on sensors, and dynamic or on-demand color shifting. Smart light fixtures can communicate impending failures that help to reduce maintenance costs. This makes it possible for each individual lighting fixture to operate autonomously. Based on the illuminance information that flows through the network, individual control devices apply to optimal algorithm and exert control autonomously, facilitating the optimum lighting pattern.

Therefore, it is reasonable to continue experimenting with this kind of smart lighting grids. Future works will be mainly focused on power configuration, lighting/sensor/combined node development, communications and protocols, as well as elaboration of advanced control methods. ◆



Testing the prototype of ballast control system for LED luminaire


INSTITUTE OF POWER ENGINEERING
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Economics and energy market
Electrical machines
Power systems
Adaptive protection and control

TOPICAL TRENDS IN THE DEVELOPMENT OF TRANSMISSION NETWORK

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ABSTRACT

Transmission networks are facing an investment challenge due to the limited capacity of the existing power lines. Thus, there are several approaches for solving the posed problem, firstly, the use of new advanced technologies; here the interest is in the overhead line thermal monitoring systems, which are generally designed on the basis of the existing methodologies by using the limiting conditions for the determination of the ampacity of power lines. This study presents a comparative assessment of the measured and calculated conductor temperatures as well as line sagging. Secondly, there is one more advanced technology – the application of High-Temperature Low Sag conductors (HTLS). The purpose of such study is to evaluate conductors of conventional core designs like AS, ACSR and composite core designs like ACCC and ACCR on the basis of the technical and the economic criteria, and to establish which of these conductors would be preferable for upgrading the existing network. Thirdly, construction of the new overhead lines, which is associated with several legal, technical and economic problems, should also be mentioned as one of valid solutions. Therefore, the concept of multi-objective optimization of the selection of an optimum transmission line route as well as designing a line using Pareto approach by minimization of the invested capital costs and maxaimization of the net present value needs to be revealed. The obtained results of all the above-mentioned methods are based on design cases of real line as examples and reviewed in this paper.

Keywords – Design engineering, efficiency, estimation technique, power transmission, parameter estimation, transmission line.

INTRODUCTION

Since the significant increase of electric power transmission and consumption; the considerable impact of renewable energy sources and the impact of important power players such as the Russian Federation, which is expected to increase its generation capacities by the construction of a nuclear Power Plant (NPP) in Kaliningrad, the Belarus and Visaginas NPP in Lithuania as well as the liberalization of the electrical power market are being influencing reasons of development and expansion of the transmission grid (see Fig. 1).

On the one hand, it becomes necessary to implement new transmission line projects in the operation of the network. For example, the construction of the "Kurzeme Ring" – an energy infrastructure project in Latvia, with the main purpose of establishing the interconnection Latvia – Estonia – Sweden for improving power supply reliability in the Baltic countries [1]. However, the low level of capital investments in the building of new power lines reduces the

chances of achieving the desirable objective.

In the designing of overhead lines one of the powerful tools of minimizing the total invested capital or maximizing the net present value (NPV) [2] taking into account several restrictions is multi-objective optimization. In this case the numerous restrictions, impacting factors and conditions as well as the random and uncertain nature of these factors must be taken into account for solving the task of the optimal design of power objects, in particular, transmission lines, despite the fact that solution of the problem became more complex. For simplifying the design of ovaerhead high voltage lines (OHLs), powerful software has been developed [3, 4].

On the other hand, it is possible to use the existing infrastructure of the transmission grid with maximum extension of new technologies as well as implementation of the efficient technical approaches into the existing power line systems with less economic investment and a high degree of technical security. There are different solutions for implementing this concept. Firstly, there is the use of advanced transmission technologies, which are utilized

Fig. 1.
The new electrical connections

towards the integration and implementation of the Smart Grid, for example, underground and submarine XPLE cables; Gas Insulated Line (GIL); High Temperature Low Sag (HTLS) conductors as well as the Flexible Alternating Current Transmission System (FACTS); High Voltage Direct Current (HVDC); real-time technologies and impacting technologies like electricity storage solutions[5]. Secondly, there are more classical methods for reaching the maximum use of the existing overhead lines, for example, reconstruction of the overhead line for a higher voltage, replacing the existing conductors by ones with a larger cross-section, installation of series and shunt compensations equipment, using modern insulators[6], effective towers[7], control devices for the power network.

This study deals with the obtained results from the following activities:

1. testing the main OHL parameters such as conductor temperature and sag, which is based on a real line design case under different actual weather conditions;
2. evaluating the profitability of replacing the traditional type design conductor by a HTLS conductor based on technical and economic criteria;
3. presenting the optimization design method for power lines, which is partially based on a stochastic approach and game theory criteria used for the final decision-making.

In total, all the above-mentioned activities reflect the possible effective solutions for the development of transmission network. Let us consider each of these activities in detail.

TESTING THE TRANSMISSION LINE PARAMETERS

There is a need for developing a more flexible operating network with less economic investment. In this case, the interest is in the real-time technologies, namely, Dynamic Thermal Circuit Rating (DTCR) [8]. DTCR is software that delivers real-time information about a transmission circuit's operating condition to assist in increasing and optimizing power flows [9]. The software determines dynamic circuit ratings by evaluating all equipment ratings on a circuit and finding the most limiting ampacity for each rating scenario.

For implementing the DTCR systems, it is necessary to detect the initial operation algorithm, on the basis of which a real-time monitoring system can be developed, of course, using an appropriate computation method of thermal rating determination, for example, such as IEEE Std 786-2006 [10], IEC 1597 [11] and MT 34-70-037-87 [12]. The concept of each method is generally based on such main elements as conductor temperature, conductor sag and weather conditions (ambient temperature, wind speed and direction, humidity, absorptivity and emissivity) as well as taking into account the impact of these parameters on the permissible load current of a particular power line [13]. Thus, one of the key parameters in the implementation of DTCR systems as well as the operation of the transmission lines is conductor temperature.

The implementation of DTCR software based on transmission line sensor systems information for real-time operation makes it possible to monitor overhead transmission line sag, temperature, and local ambient conditions. There are two common ways for monitoring conductor temperature:

1. direct monitoring entails the direct measurement of conductor temperature, which is, however, inconvenient for the operation of a line;
2. indirect monitoring entails thermal rating calculation methods, which use the measurements of the key parameters that impact the allowable conductor temperature.

Since the DTCR theoretical principles are based on several thermal rating determination methods, it is necessary to select the accurate and appropriate approach for determining the thermal line rating as well as such a key parameter as conductor temperature. Otherwise, the incorrectly calculated ampacity may cause line outages,

insufficient operation due to significant conductor temperature as well as increased sag.

In general, the framework of the evaluation process of the thermal rating methods can be presented in four main steps:

1. when we know the electrical current carried by the conductor and the ambient conditions then we can calculate conductor temperature; of course, it cannot exceed the permissible conductor temperature value adjusted by conductor physical characteristics (the technical documentation of the conductor manufacturer has to be considered);
2. when the conductor temperature is found, it is necessary to estimate conductor sag and clearances to the ground or to the crossed objects as well as parameters of electrical and magnetic fields, which have to be in the area of allowable standard values;
3. the next step is to determine the permissible load current of an examined conductor taking into account all previously computed parameters;
4. finally, correction of operation mode can be performed, if it is necessary.

This section presents the obtained results of testing of thermal rating calculation methods based on indirect conductor temperature monitoring (see Fig. 2) by way of comparing the measured and calculated conductor temperatures as well as the conductor sags. One case of experimental measurements under a certain model of existing power line is presented as an example.

For measuring line parameters, special monitoring equipment was used such as thermovision equipment, which measures the conductor temperature [14] (see Fig. 3 a), the thermohygrometer, which measures the ambient temperature and humidity (see Fig. 3 b) and a pocket weather tracker for measuring wind speed (see Fig. 3 c).

Since a model of thermal ratings evaluation is adopted, all the necessary input parameters based on the measurements are known, the conductor temperature as well as the conductor sag estimation results are presented below.

Fig. 4 presents a comparison of conductor temperatures both measured (Tm) and calculated (T_C) at several wind speeds. Thus, the Tm, which is 17°C, is compared with the T_C, which are defined according to the particular thermal rating method. The diagram shows that the largest difference in the measured and calculated conductor temperature values is observed when using the IEEE Std 738-2006 method (T_C = 23.4°C), then there is the IEC1597 approach (T_C=20.3°C), which has a lower difference percentage, and the last one is the MT 34-70-037-87 method (T_C=17.1°C), which has almost identical values as the measured temperature.

Fig. 5 shows the comparison of conductor sag based on the calculated conductor temperatures at the given comparative methods. The diagram shows that the maximum conductor sag – up to 3.8 m – is observed in the case of using the IEEE Std 738-2006 calculation method due to higher calculated conductor temperatures; by contrast, the smallest conductor sag, 3.6 m, is observed, when the MT 34-70-037-87 thermal rating approach is used. It is obvious that the difference of conductor sag in the case of different methods is very small – only up to

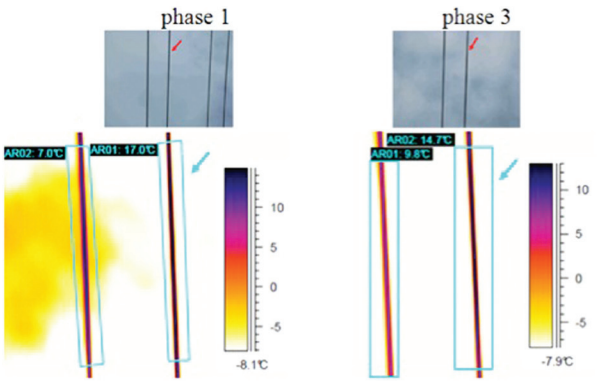

Fig. 2.
The experimental results of conductor temperature measurements for the span between the towers No. 1 and No. 2 for the examined case

a) b) c)

Fig. 3.
Monitoring equipment: a) thermovision equipment; b) thermohygrometer; c) a pocket weather tracker

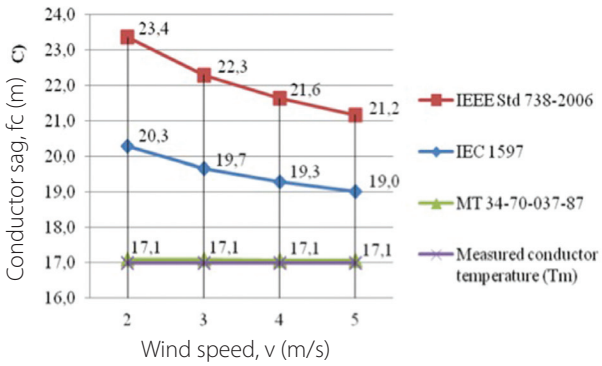

Fig. 4.
The conductor temperature for the examined case of the existing line

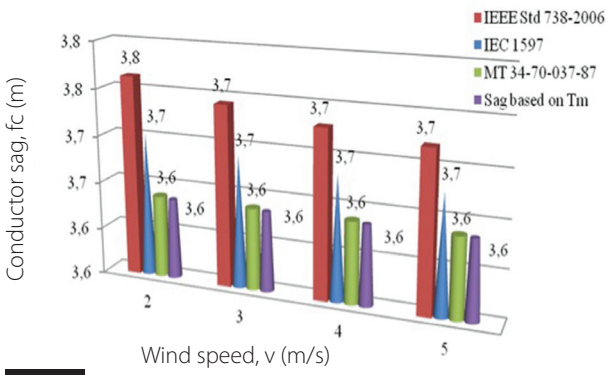

Fig. 5.
The conductor sag for the examined case of the existing line

Installation of a conductor									
AS-240/32		242AL1/ 39-ST1A		"Casablanca"		"Glasgow"		"Hawk 477"	
Mechanical limitations									
Allowable conductor tension, N									
σ_{max}	119.2	σ_{max}	107.8	σ_{max}	144.2	σ_{max}	176.5	σ_{max}	136.3
σ -	119.2	σ -	107.8	σ -	144.2	σ -	176.5	σ -	136.3
σ_{op}	79.5	σ_{op}	58.9	σ_{op}	96.1	σ_{op}	119.7	σ_{op}	91.2
Spans, sags and ground clearance, m									
L_{wind}	403.6	L_{wind}	400	L_{wind}	425.4	L_{wind}	409.3	L_{wind}	403.4
L_{weight}	414.3	L_{weight}	400	L_{weight}	446.1	L_{weight}	476.3	L_{weight}	445.8
L_{cl}	436.5	L_{cl}	411.8	L_{cl}	533.3	L_{cl}	585.9	L_{cl}	487.4
F_{cl}	12.3	$F_{cl.}$	13.6	F_{cl}	8.6	F_{cl}	5.5	F_{cl}	9.8
C_{cl}	8.0	C_{cl}	8.0	C_{cl}	8.0	C_{cl}	8.0	C_{cl}	8.0
Thermal limitations									
Permissible conductor temperature, ºC									
70		80		120		120		240	
Permissible capacity, A									
2 conductors per phase	1210	2 conductors	1260	1 conductor per phase	922	1 conductor per phase	852	1 conductor per phase	1293

Table 1.
Comparison of Different Conductor Types

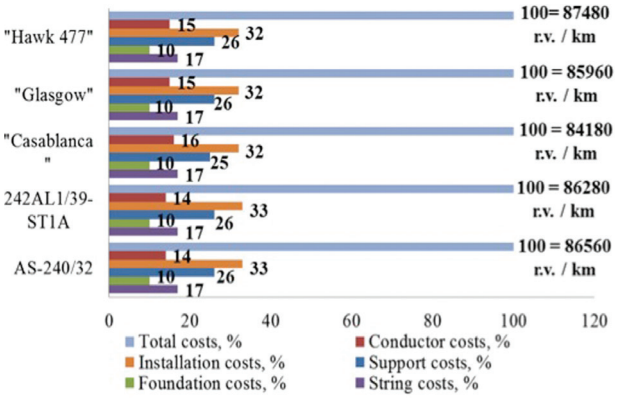

Fig. 6.
The particular overhead line consruction costs

Alternatives	Optimistic scenario 2	Pessimistic scenario 2
	NPV11||E11	*NPV11||E11*
V10	4.7 // 6.9	5.4 / 5.0
V17	6.2 // 7.1	5.33 / 5.6
V19	6.7 // 8.0	5.7 / 7.3

Table 2.
Expected Worth of Net Present Value and Restriction Indicators Ri

20 cm – in spite of a noticeable difference in conductor temperatures.

EVALUATION OF THE PROFITABILITY OF HTLS

The task set for the proposed activity is to consider the profitable opportunity of replacing the traditional type conductors – Aluminium Conductor Steel Reinforced (ACSR) – with HTLS conductors [15] as well as increasing the operational efficiency and reliability of the grid with the purpose of enlarging the efficient investments in the transmission grid.

The evaluation of the described suggestion was based on an existing Latvian power line as an example.

There are five different conductor types, which are taken as the basis for the simulation task. The "Casablanca" and "Glasgow" conductors are of the Aluminium Conductor Composite Core (ACCC) type [16]; "Hawk 477" is of the Aluminium Conductor Composite Reinforced (ACCR) type[17]; the AS-240/32 and "242AL1/39-ST1A", which are of the ACSR type [18].

The technical efficiency of the examined conductors was based on two main aspects, the mechanical and thermal limitations (see Table I).

Firstly, the mechanical limitations are discussed. Table I shows that the wind spans (L_{wind}) are the decisive spans of all the presented conductor types for the arrangement of towers. For example, L_{wind} of AS-240/32 type conductor is 403.6 m, which is the worst parameter as compared with the clearance span ($L_{cl.}$), which is 436.5 m, and the weight span (L_{weight}), which is 414.3 m. For other conductors, this comparison has the same behaviour. The conductor "Casablanca" is preferable, because the maximum allowable wind span is 425.4 m, which is by about 25.4 m more than in the case of using "242AL1/39-ST1A", or by about 21.8 m more than in the case of using "AS-240/32" and "Hawk 477", and by about 16.1 m more than in the case of using "Glasgow", if all the other conditions remain the same.

The largest sag is observed in the case of an ACSR type conductor "242AL1/ 39-ST1A" (13.6 m), which is by 8.1 m more than in the case of "Glasgow" (5.5 m), because of a smaller wind span (Lwind) of "242AL1/ 39-ST1A" – 400 m.

Secondly, the thermal limitations like the capacity of the line and the permissible conductor temperature are described.

As a result, it can be concluded that the HTLS conductors like ACCC and ACCR have the maximum permissible conductor temperature compared with the ACSR and AS conductor. In this case, the installed capacity of 850 A is provided with one conductor per phase for ACCC and ACCR as compared with the AS and ACSR (see Table I). Therefore, the higher the permissible conductor temperature, the higher the capacity that can be transmitted over a particular overhead line, of course, without worsening the electrical parameters. For example, if the conductor "Casablanca" is used, then its permissible conductor temperature is 120°C and as a result it provides 922 A for one conductor phase.

The total investment for the construction of an examined overhead line (see Fig. 6), in the case of using the traditional type conductors "AS-240/32", "242AL1/39-ST1A" and

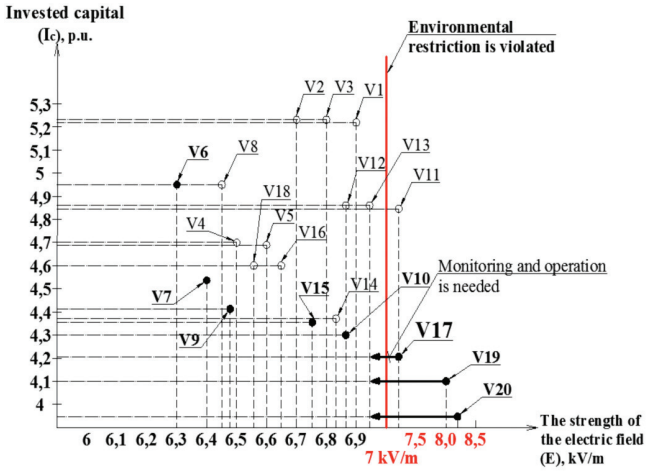

Fig. 7.
A diagram of Pareto set for the combination variants

ACCR – "Hawk 477", turned out to be higher than the costs of constructing a power line, when using the HTLS conductors "Casablanca" and "Glasgow". The difference between "AS-240/32" and ACCC conductors ("Glasgow" and "Casablanca") is about 2.8%, as compared with ACCR ("Hawk 477"), where it is 3.9%. However, the total costs of a line using "Casablanca" is the optimum variant, because of minimum total investments – 84180000 r.v., then goes "Glasgow" – 85960000 r.v., then there are the AS and ACSR conductors, and the last one is "Hawk 477" conductor of ACCR type with the total costs of 87480000 r.v.

As a result, for these initial data of the particular line model, the economic efficiency of using conductors with composite core is observed in the case with the ACCC conductor – "Casablanca".

The high price of the ACCC and ACCR type conductors also play a principal role; in the simulation task, it was taken to be about 2.5 times higher as compared with the traditional conductor type. If the price is reduced, the application of HTLS conductors could be more productive.

OPTIMIZATION OF TRANSMISSION LINE PARAMETERS

The need to construct a new transmission line can be revealed based on the forecasts of the economic development for some geographic regions. If there is a prediction of new loads or an increase in the existing loads, new generation sources, inability to supply the demand of electricity by using the existing network, a decision concerning building a new line can be taken. Due to the impact of the uncertainties, there is a need to consider several scenarios, for instance, for the load increase ratio. After selecting the development scenarios of the power system, numerous alternatives are examined with the purpose of choosing the optimization parameters.

Thus, to achieve the best technical and economical solution of the transmission line design, a large number of optimization variables need to be taken into account. In the last decades powerful software tools are used [3-4], which provide an opportunity to form a significantly smaller initial set of the competitive alternatives.

Let us consider an example of using the described methodology of optimization of the transmission line design based on a real project, which will be implemented in Latvia.

After searching the optimum solutions by using the software for OHL design, 20 alternatives were selected, formed by implementing the different combinations of the examined towers and conductors. Therefore, the following groups of combinations were selected: V1 and V10; V11 and V20 mean that there are the traditional type conductors for both 110 kV and 330 kV circuits; V6…V9; V16…V19 – there are the HTLS conductors for both 110 kV and 330 kV circuits; V2…V5; V12…V15 – there are conductors of the traditional type with a combination with the HTLS conductors for 110 kV and 330 kV circuits (see Fig. 7).

Fig. 7 reflects the optimum solution results of two-objective optimization by implementing Pareto approach [19], where IC (p.u.) is the invested capital and E (kV/m) is the strength of the electrical field. As a result, the competitive variants are V6, V7, V9, V10, V15, V17, V19 and V20.

The resulting values of the optimization criteria are summarized in Table II (only competitive alternatives are left for further consideration). An analysis of the table reveals the following:

1. if the "classical" problem formulation, namely, maximization of the NPV, complying with all the restrictions, is used, one of the alternatives – V10 – would be chosen. The final decision would be taken by using one of the criteria.
2. if the constraint violation is allowed one of the alternatives V17 or V19 should be chosen.

CONCLUSIONS

In accordance with the above-presented technical solutions for the development of the transmission grid, the following results are acquired:

1. Concerning the testing of the conductor temperature and sag – it can be concluded that the difference between the measured and calculated values of conductor temperature for the particular thermal rating estimation methods is observed due to several reasons, namely, the utilization of different empirical techniques of the examined calculation methods, the complexity of these methods, the impact of the uncertain nature of the lading reserve of the temperature rise of the conductor in the thermal rating estimation methodologies, the conservative current limitations without taking into account actual line loading. In spite of the existing difference in the measured and calculated conductor temperatures, all the examined estimation methodologies are quite accurate due to the fact that the maximum difference of the conductor sag values is only 20 cm. Thus, the most appropriate method must be chosen for calculating the ampacity of a line, based on which new advanced technologies can be developed, such as real-time thermal monitoring systems.
2. The comparative assessment of conductors with conventional core designs like AS and ACSR and composite core designs like ACCC and ACCR shows that the HTLS conductors may offer several technical advantages like long-term reliability, higher capacity,

a low sag-tension property, easy and quick design and installation as well as economic efficiency due to lower total construction investments as compared with conductors of the traditional type.

3. The problem of optimization of the design of transmission lines is a multi-criteria optimization task with a large number of state and decision variables. This task must be formulated by taking into consideration the possible influence of random and uncertain parameters. The solution of such a problem is associated with considerable mathematical, computational and informational difficulties. In this way, utilization of multi-criteria optimization partially based on the stochastic approach provides the possibility to consider even the alternatives with constraint violations, which with some additional measures can represent the most cost-effective solution.

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REFERENCES

1. The Kurzeme Ring. [Online]. Available: http://www.latvenergo.lv/portal/page/portal/english/LET/LET/about_network/KURZEME_RING/
2. King Fahd University of Petroleum and Minerals: Chapter 7 Net Present Value and Other Investment Criteria. [Online]. Available: http://faculty.kfupm.edu.sa/FINEC/mfaraj/fin301/notes/Ch7.pdf
3. The special program "SAPR LEP 2011" description. Modern design System. [Online]. Available: http://www.bsapr.ru/prod/progs/element.php?ID=250 [in Russian].
4. PLS-CADD™ (Power Line Systems - Computer Aided Design and Drafting). [Online]. Available: http://www.powline.com/products/pls_cadd.html
5. A. L′ Abbate, G. Migliavacca, T. Pagano, A. Vafeas, *"Advanced transmission technologies in Europe: a roadmap towards the Smart Grid evolution"*, in Proc. 2011 IEEE PowerTech Conf., pp. 1-8.
6. S. S. Karimi Madahi, M. Hassani, *"Optimal design of insulators of using Artificial Neural Network (ANN)"*, Journal of Basic and Applied Scientific Research 2 (1), pp. 60-64, 2012.
7. G. Visweswara Rao, *"Optimum designs for transmission line towers"*, Computers & Structures, Vol. 57, No. 1, pp. 81-92, 1995.
8. P. Pytlak, P. Musilek. (2012) Selective upgrading of transmission lines using DTCR. In 25th IEEE Canadian Conf. on Electrical and Computer Engineering (CCECE), April 29 – May 2. (pp. 1-4) Canada: IEEE. DOI: 10.1109/CCECE.2012.6335038.
9. Christine Hertzog. (2012) Smart Grid Dictionary TM plus. USA: Delmar, CENGAGE Learning.
10. Standard for Calculation the Current-Temperature Relationship of Bare Overhead Conductors, IEEE Std. 738-2006 (revision of IEEE Std. 738-1993), pp. 1-59
11. Overhead electrical conductors - Calculation methods for stranded bare conductors, IEC 1597.
12. The method of calculation of limit loads for current conditions of the heating wires to the existing power lines, MT 34-70-037-87, 1987 [in Russian].
13. Svetlana Beryozkina, Antans Sauhats, Edvins Vanzovichs, *"Climate Conditions Impact on the Permissible Load Current of the Transmission Line"*, in Proc. 2011 IEEE PowerTech Conf., pp. 1-6.
14. Flir systems, *"FLIR ThermaCAMTM P65. The professional thermographer's choice"*.
15. Dale A. Douglass, Practical application of High-Temperature Low-Sag (HTLS) Transmission Conductors. New Haven, Connecticut: 2004, p.53
16. Home page – Composite Technology Corporation. [Online]. Available: www.compositetechcorp.com
17. Powering the next generation. Composite Technology corporation. January 2007. V8.4 Public NYC. [Online]. Available: http://ctc-energy.com/products/files/block_1/page12_2.pdf
18. Bare aluminum electrical conductors. Home page of *"Sural"* products. [Online]. Available: http://www.sural.com/products/bare/acsr.htm
19. V. Pareto, Cours D'Economie Politique, Vol. I and II. F. Rouge, Lausanne, 1896.

KOPSAVILKUMS

Elektropārvades tīkli saistībā ar esošo elektrolīniju ierobežoto jaudu un enerģijas pieprasījuma izmaiņām sastopas ar nepieciešamību pēc rekonstrukcijām un ievērojamām investīcijām. Pastāv vairākas pieejas izvirzītās problēmas risināšanai. Pirmkārt jāmin jauno progresīvo tehnoloģiju izmantošana. Šeit interese vērsta uz gaisvadu līniju termiskās kontroles sistēmām, kuras pamatā tiek projektētas, balstoties uz esošajām metodikām, izmantojot ierobežojošos nosacījumus elektrolīniju pieļaujamās slodzes strāvas noteikšanai. Šajā darbā sniegts izmērīto un aprēķināto vadu temperatūru, kā arī vadu nokares salīdzinošs novērtējums. Otrkārt minama vēl viena progresīva tehnoloģija – augsttemperatūras mazas nokares vadu (HTLS) izmantošana. Pētījuma mērķis ir vadu ar tradicionālā tipa konstrukcijas serdi (piemēram, AS un ACSR tipa), kā arī vadu ar kompozītmateriāla serdi (piemēram, ACCC un ACCR) izmantošanas iespēju novērtēšana. Pētījums veikts, balstoties uz pamatotiem tehniskajiem un ekonomiskajiem kritērijiem. Treškārt kā viens no pamatrisinājumiem jāmin jaunas gaisvadu līnijas būve, kas saistīta ar vairākām juridiskām, tehniskām un ekonomiskām problēmām. Šo problēmu atrisināšanai projektējot līniju un izvēloties optimālo elektropārvades līnijas trasi, izmantota daudzkriteriālās optimizācijas uzdevumu atrisināšanas pieeja, minimizējot investētā kapitāla izmaksas vai maksimāli palielinot pašreizējo neto vērtību un ņemot vērā tehnisko un juridisko ierobežojumu izpildi. Iegūtie rezultāti balstās uz reāliem līniju projektēšanas gadījumu piemēriem. ◆

VIEW ON GLOBAL CLIMATE CHANGE

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ABSTRACT

Based on the available facts the view of the existing in climate change tendencies is given. Previously, the flows of the world's rivers were investigated and the correlation with the cycles of solar activity was revealed. Similar correlation has been found for global temperature changes. To separate processes' periodic components in order to compare different processes the discrete wavelet transform was employed. The long-term cycles have been established by analyzing the data of the glacier ice cores. Against the background of global heat balance the influence of heat release by infra-red radiation and the role of convection are shown as well as information on how this process is affected by carbon dioxide gas is provided. Such an analysis, to a definite extent, would allow speculating on the possible character of future climate changes.

Keywords – climate change, solar activity, carbon dioxide

INTRODUCTION

Nowadays, the global climate change is one of the "hottest" issues. In the course of our research into the annual water flows of the rivers it was revealed that these flows depend on the solar processes [1]. Furthermore similar dependence takes place with regard to the temperature deviations during the time when such parameters have been recorded. The solar processes contain a great variety of mutually overlapping frequencies, research into which is of considerable interest.

To separate the frequencies in order to compare each of them with the corresponding temperature deviations the discrete wavelet analysis has been used. A practically determinate relationship between these parameters has been revealed [2]. Naturally, analogous relationships are peculiar to the long-term periods. The notion of these relationships can be obtained from the glacier data. These data show that in every millennium short-term extreme temperature rises and falls occur and correspond to the analogous solar processes.

The authors estimate, against the background of global heat balance, the influence of heat release by infra-red radiation, considering also the convective heat transfer to the troposphere and stratosphere. The transparency degree of the absorption window for carbon dioxide is of special interest. The radiation measurements confirm that the primary radiation in this zone is practically absent and only secondary radiation is present for the heat from lower layers of stratosphere, which is delivered here by convection. Elucidation of this question affects essentially the attitude to the growing specific weight of carbon dioxide in the atmosphere.

SOLAR CYCLES

In the previous works [1, 2] dedicated to the peculiarities of the annual flows of world's rivers it was established that these flows depend on the activity of solar processes. Therefore, in this work the relationship between the activity of solar processes and the observed global temperature change has been investigated.

As it is known, the data on solar processes have been recorded since 1700. Their character expressed in the Wolf numbers is seen in Fig.1. It is clear that the process of the kind contains a big number of cycles with different periodicity, which should be investigated.

For this purpose the spectral analysis based on the discrete wavelet transform (DWT) was employed [4]. According to this method the initial process (signal) is divided into several components using special filters [4]. In the first step the detailing component D_1 is isolated using the high frequency filter but the approximating component A_1 using the low-frequency filter. In the next iteration A_1 is again divided into two ones D_2 and A_2, thus performing decomposition of the signal into components. As a result, the complete set of approximating and detailing components is obtained. By summing up components of a process the initial signal can be reconstructed (Fig.2).

The discrete wavelet transform of solar activity for the different frequencies or cycles is shown in Fig.3.

The well-known 11-year solar cycle refers to level d_3. The 30-year and 80-year cycles are also known and correspond, respectively, to d_4 and d_6. The top view shows the longest cycle a_8 – a fragment resembling a half of the semi-period, which is of particular interest. If such a cycle exists, its duration can be 1000-1200 years. We cannot verify this directly, since the available data are insufficient. At the same time, although we cannot look over the "brink" directly, we can try to solve this problem based on another approach.

VARIATIONS IN THE AVERAGE TEMPERATURE ON THE EARTH

To establish the relationship between the temperature deviations and solar activity data of the global mean surface temperature anomalies are used [5]. As it is seen in Fig.4, in the period of 1850-2007 it began increasing in 1910. Further, from 1940 to 1980 it was decreasing and then again increasing, reaching the maximum in 1998.

The results of the DWT analysis related to the temperature and solar activity variations are shown in Fig.5.

In this figure it is seen that in 1910 the temperature phase for periods up to the century cycle changed to the opposite. This could be explained by the phenomenon of re-magnetization.

It may, possibly, explain the temporary temperature fall in the 1950-1980-ies, when the centenarian and smaller cycles of the solar activity came into anti-phase. The relationship between the temperature change and solar activity phases is now gradually – within about 50 years

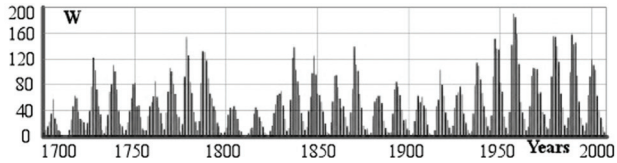


Fig. 1.
Solar activity expressed in the Wolf numbers [3]

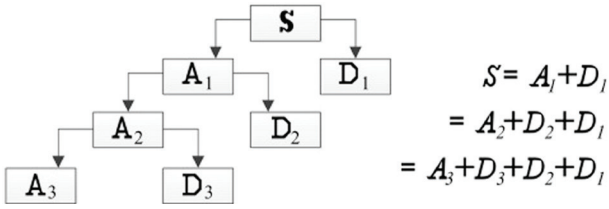


Fig. 2.
The structure of signal reconstruction

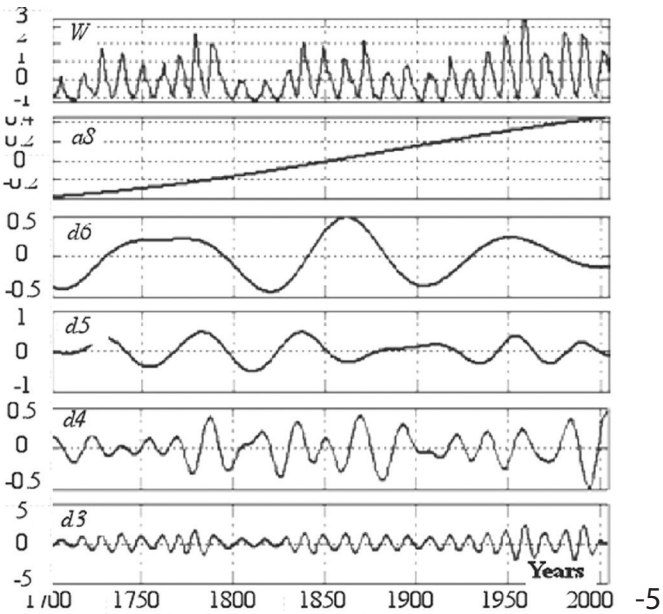


Fig. 3.
The discrete wavelet transform of Solar activity (300 years)

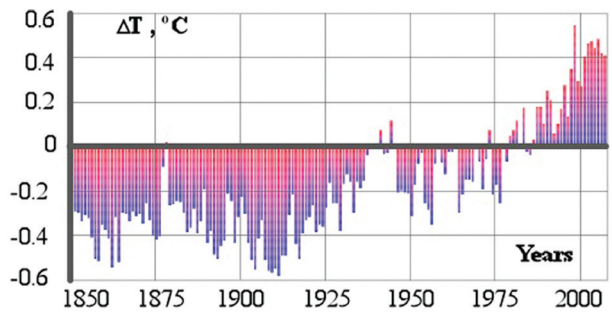


Fig. 4.
Global mean temperature anomalies relative to 1961-1990

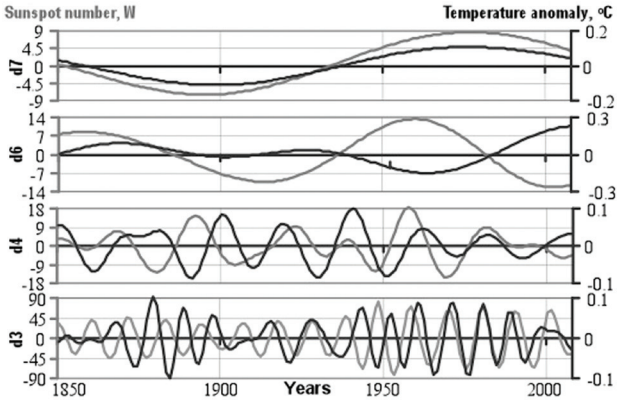


Fig. 5.
Comparison of DWT components (solar activity – grey lines, and global temperature changes – black lines)

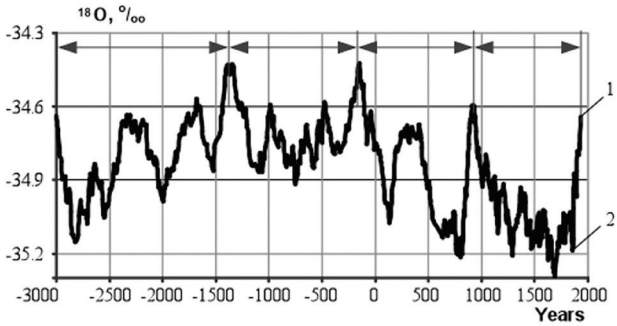


Fig. 6.
Distribution $\delta^{18}O$ of in the upper layers of GISP2 ice cores

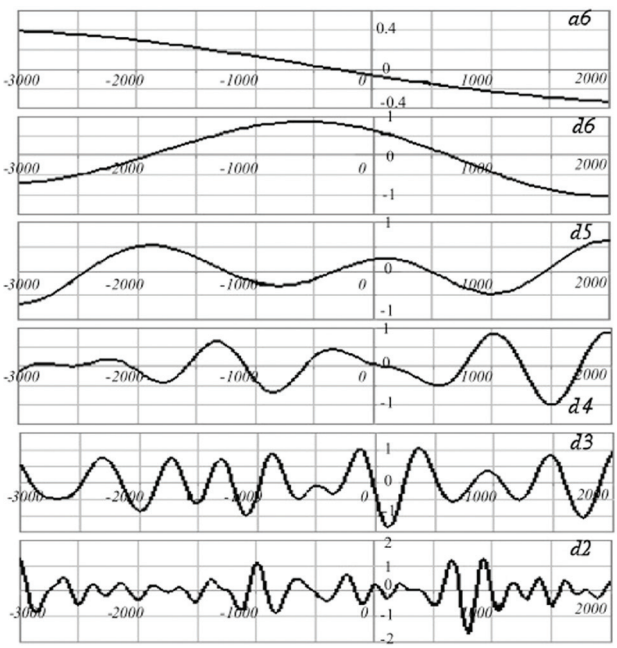


Fig. 7.
The wavelet analysis of 5000-year period

– returning to the in-phase state. It is difficult now to understand this phenomenon completely; therefore this should be the subject for further investigation.

GLOBAL TEMPERATURE VARIATIONS IN 5000 YEARS

The notion of relationships between the solar activity and the global temperature changes in the long-term perspective can be obtained from the data on the Greenland and Antarctica glaciers based on the analysis of palaeo-atmospheric molecules [6, 7]. It is known that a glacier is the pressed snow, which at its re-crystallization is transformed into ice. In the millennial ice cores the annual layers are separated from each other by summer and winter sediments, which have different structure, density, and dust composition. In the stage of ice formation the air becomes stored in bubbles. Analyzing paleo-atmospheric air molecules a linear relationship between the specific weights of isotopes and paleo-atmospheric mean temperature was found [7]. Thus, for example, a 1 ‰ decrease in $\delta^{18}O$ indicates a 1.5 ˚C temperature fall. A good correlation between these values is found also in other investigations, which provides grounds to consider the glacial cores of Greenland as a natural monitor of temperature fluctuations.

Fig. 6 presents the GISP2 ice core data (Greenland) for the last 5000 years; the values are smoothed in 50 years[7]. The points 1 and 2 at Fig. 6 correspond to temperatures changes ΔT_1=0.1˚C and ΔT_2=–0.55˚C in Fig. 4 [2].

As it is seen in Fig. 6 in every millennium short-term (on a geological scale) alternating extremal temperature rises and falls occur. These data convincingly show correlation to the historical and archeological facts. Thus, for example, there was an extreme temperature fall in 2000 years BC when an ancient Egyptian kingdom completely disappeared due to a humanitarian catastrophe. The temperature rise in X century is to be referred to the time of Vikings'expedition to Greenland and Vinland. Also the temperature decrease during XIII-XVII (small ice period) is clearly seen. Now, we are experiencing a next in turn temperature rise.

The wavelet descrete transform for 5000 years is shown in Fig. 7.

The lower curves characterise relatively short cycles. The upper part shows relatively slow temperature variations. The behaviour of temperature variations explains the character of the fragment that resembles a half of the semi-period for 300 years presented above (Fig. 3), which, as was suggested, can have a period on the order of 1000 years. It should be reminded that we are living during the interglacial period that is approaching the end.

GLOBAL HEAT BALANCE

The global heat balance regulates the climate change and is determined by the solar energy streams (by Stefan–Bolzmann's law).

As it is known, the Earth receives heat from the Sun mainly in the visible light and short-wave infrared (IR) regions. Through space the heat can only be transferred by electro-magnetic radiation. Since the atmosphere ozone layer inhibits the solar ultra-violet radiation, and

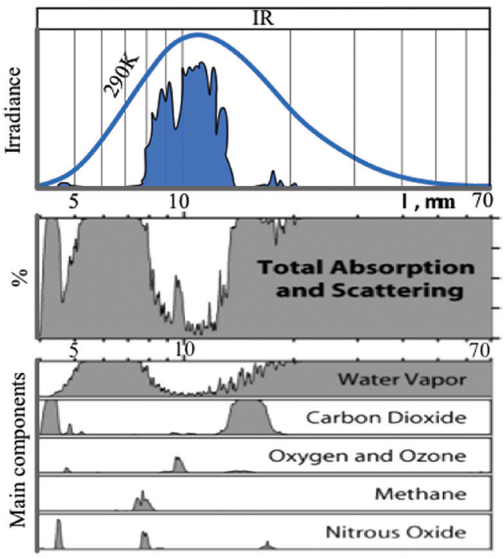


Fig. 8.a

a – intensity of global IR radiation; b – total absorption and scattering at different wavelengths; c – absorption bands for the main greenhouse

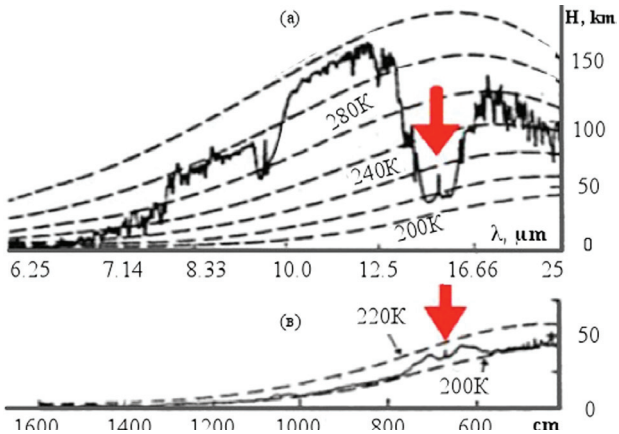


Fig. 9.

Radiation reflection recorded by satellites over Sahara (a) and in polar zone (b) (05.05.1970).

the global surface reflects to the space a portion of visible light (albedo), the Earth receives only about 70% of the solar energy.

A portion of received heat (about 30%) is reflected from the surface of the Earth by infrared radiation (Fig. 8).

This radiation is partly absorbed by greenhouse gases in the absorption zones (or windows; Fig. 8 b), whose effect depends on their saturation.

Water molecules in the atmosphere are dominant in greenhouse gases. In the vapour state their heat absorption is approximately 70%, and absorption by clouds – 20%. The rest 10% fall on other heat absorbing molecules existing in the atmosphere. For water molecules they are saturated in a wide region in which the atmosphere becomes practically opaque so only about 8% from the range remains transparent [2].

It is known that the average global temperature is equal to 288 K (+15 °C). To ensure such a temperature, another portion of heat (about 32%) is carried away with convection by vertical atmospheric air streams (obeying Newton's law). In contrast to IR radiation, the convection flows are distributed uniformly over the whole infra-red radiation range, bypassing the windows for greenhouse gas absorption. This portion comes to the lower layer of the stratosphere not containing water vapour molecules (the temperature is about – 55 °C), from where it is dissipated in the space by the secondary infra-red radiation [2]. The convection creates negative feed-back, which stabilizes the processes of temperature changes on the Earth reducing them by half.

CARBON DIOXIDE

From the carbon balance it follows that the main proportion of the circulating carbon is in oceans (about 98%); while in the atmosphere, its amount is only about 2%. With a temperature rise, the carbon dioxide is released off from the ocean to the atmosphere. At a temperature fall, the excessive carbon dioxide returns into the ocean, although with some delay. Consequently, the cause of variations in the CO_2 amount in the atmosphere is temperature as the primary factor, while the effect – the amount of carbon dioxide in the atmosphere that is released from oceans [2].

From Fig. 8 we can see that the transparency of the carbon dioxide absorption zone is doubtful. There is a relatively narrow absorption window 14–16 μm, which is situated in the region with reduced window saturation of the water molecules.

From the data of measurements performed in 1970 with the help of satellites (Fig. 9; the arrow points to the CO_2 absorption zone for the wavelengths of 14-16 μm) it follows that the primary radiation in the absorption zone at the CO_2 amount of 300 millionth fractions is practically absent and the temperature is sharply decreased to 218K (-55 °C) corresponding to the conditions in the lower stratosphere layers. The heat is delivered to this height with the vertical convective masses of air flows. Possibly, the CO_2 absorption zone is practically opaque for radiation.

The global temperature increase was studied by Dr. Heinz Hug (Germany) [8], who considered the problem applying a physical model under laboratory conditions. It was found that even at a doubled amount of carbon dioxide in the atmosphere, the temperature would increase only by 0.17%.

CONCLUSIONS

The global temperature change is primarily dependent on the character (cyclicity) of solar processes. The mean global temperature of ~15˚C is ensured by a 62% reflection of the heat obtained from the Sun. A half of this heat reflected with the infrared radiation through the transparency zone, which is saturated with greenhouse gases in compliance with the Stefan-Bolzman law. The remaining heat is transported to the periphery of atmosphere via convection with powerful air streams by-passing the zones of absorption for greenhouse gases in compliance with

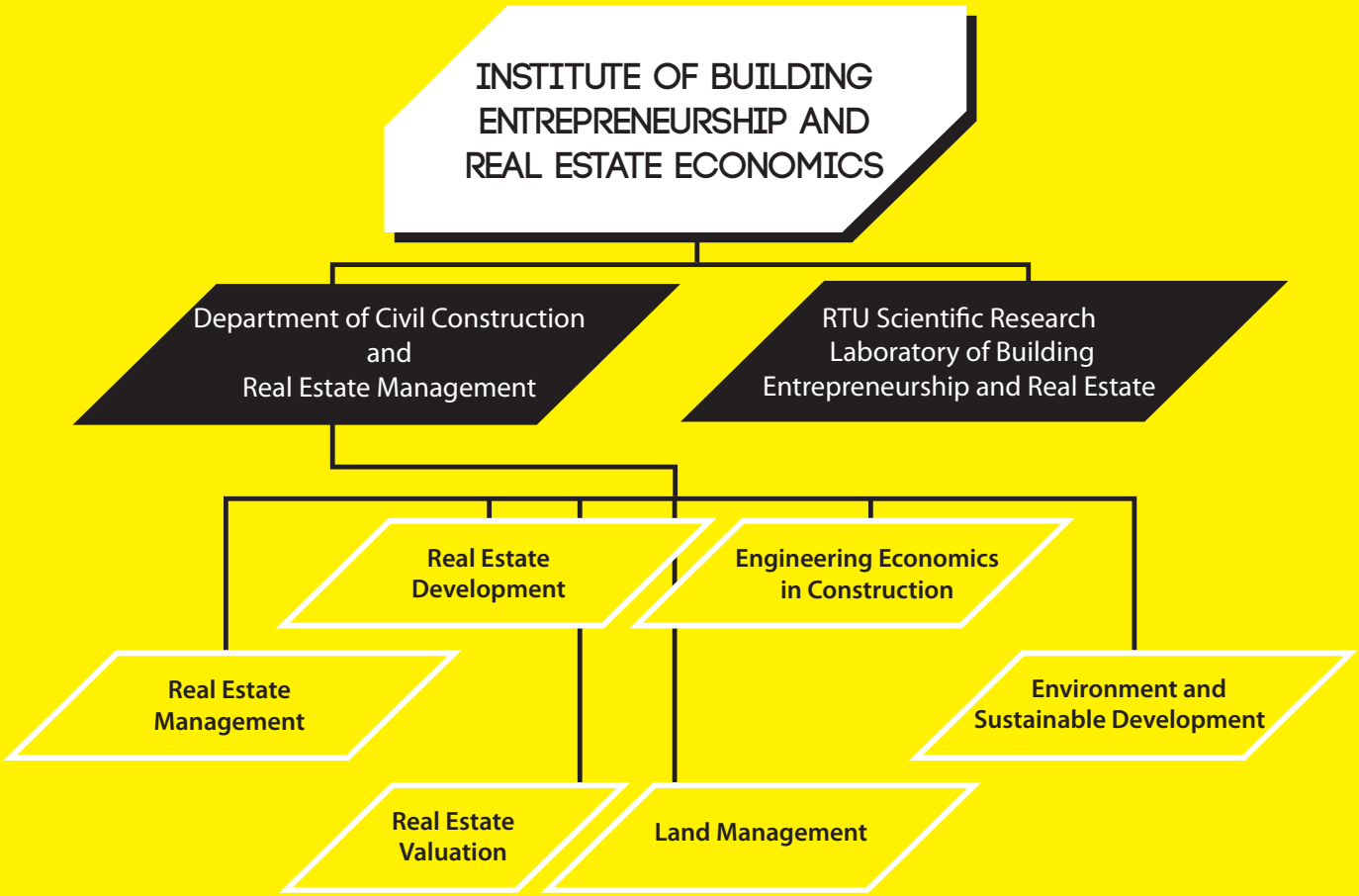
Newton's law. The rest remaining heat leaves this cooled and rarefied environment and goes to space in the form of secondary radiation of the corresponding wavelengths. The temperature variation with a growth in the specific weight of CO_2 in the atmosphere is insignificant owing to the flatness of this dependence caused by saturation of the process at which the absorption zone becomes practically opaque for radiation.

REFERENCES

1. Barkans J., Zicmane I. "Peculiarities of annual flows of World`s rivers" (with D.Zalostiba participation (8.3.Ch.)), *World Energy Council, Nacional Committee of Latvia. Riga: RTU,* 210p. (2005).
2. Barkans J., Zalostiba D. "On the global climate change". *Riga, RTU Publishing House,* 89pp. (2010).
3. Data of sunspot available at ftp://ftp.ngdc. noaa. Gov /STP /SOLAR_ DATA /SUNSPOT_ NUMBERS/ YEARLY.PLT
4. Polikar R. "Introduction in the wavelet transformation", *Iowa State University,* 50 p. (2003)
5. Data of temperature anomalies available at http://www.cru.uea.ac.uk/cru/data/temperature/hadcrut3gl.txt
6. Epstein S. "Variations of the $^{18}O/^{16}O$ ratios of fresh water and ice", *National Academy of Sciences. Nuclear science Ser.*, Report 19, p. 20-25 (1956).
7. Chumichow S.A. "Climate of golocen", *Institute of low temperature science. Hokkaido Unversity, Sapporo Japan* 060-0819 (2002)
8. Dr. Heinz Hug. "The climate catastrophe - A Spectroscopic Artefact", available at http://www.john-daly.com (1998)

KOPSAVILKUMS

Klimata izmaiņu problēma šobrīd ir pasaules uzmanības centrā. Balstoties uz pieejamiem faktiem, ir pētītas un parādītas klimata izmaiņu tendences. Pētot upju caurplūdumus, tika pielietots diskrētais veivlet-pārveidojums, kas ļāva atklāt šo parādību ciklisku raksturu. Salīdzinot to ar Saules aktivitātes analīzes datiem, atklājās interesantas likumsakarības. Analoģiska pieeja izmantota, analizējot temperatūras izmaiņas. Garāko ciklu noteikšanai tika izmantoti ledāju urbumu dati. Pētot Zemes siltuma bilanci, tika konstatēts, ka temperatūra ir atkarīga no Zemes siltuma atstarošanas, kas notiek ar radiācijas un konvekcijas palīdzību praktiski vienādās daļās. Noskaidrojās, ka siltuma atdeve no Zemes ar radiāciju ir ierobežota ar siltumnīcas gāzu absorbcijas logu caurlaidību, turklāt, ogļskābās gāzes logs ir gandrīz necaurlaidīgs, līdz ar to ogļskābās gāzes pieaugums praktiski nevar ietekmēt temperatūras pieaugumu. Savukārt konvekcijai šādu ierobežojumu nav. Izmantojot šo analīzi, varētu spriest par iespējamām nākotnes klimata izmaiņām.◆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Real Estate Development
Engineering Economics in Construction
Real Estate Management
Environment and Sustainable Development
Real Estate Valuation
Land Management

INFLUENCE OF DEVELOPMENT OF LAND USE OBJECTIVES ON THE ECONOMICS OF LATVIA

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ABSTRACT

Topicality of the research refers to the analysis of development of land use objectives and their interaction in implementation of the functional objectives of different sectors of national economy. Usually the changes in the structure of national economy sectors are studied, as well as the composition of the value added, according to the types of economic activity, is analysed. However, the relationship of the activities of respective economic sectors with the functionally indispensable territories in Latvia has not previously been studied. The main findings of the study clearly show the interrelation between land use objectives and activities in particular sectors of national economy.

Keywords: Land use, Real property market National economy

INTRODUCTION

Land resources include both the surface and underground layers, as well as man-made improvements and naturally occurring objects, in a particular area, for instance, forests and water resources. Thus, the *land use* refers to utilization of the useful features of the land. Results of the scientific research in respect to the use of land resources for the public needs, in general, refer to the land management framework [1, 2, 3, 4, 5]. Within this framework the issues of land use are studied and the effectiveness of land use for the purpose to increase the efficiency is evaluated.

The land use objective indicates the purpose for which the resources of a particular area can be used, as well as to the functionality for which the land area is needed. The land use is planned by carrying out the spatial development plans, thus substantiating the best and most efficient land use that leads to the largest possible benefit gained from the particular area. However, the contribution of each sector of national economy or the value added of the total GDP of the country is linked to the implementation of the functional objectives of the industry in a particular territory.

According to the definition of the Central Statistical Bureau of the Republic of Latvia (CSB), the gross value added (GVA) is calculated and expressed in monetary terms as the difference between the initial release of goods and services and the value added by the middleman [6]. Its calculation is based on the data collected by the CSB and other public institutions. The analysis of the components of GVA, according to the types of economic activity and its changes over the time, makes it possible to trace the changes in the structure of the sectors of national economy and to compare the development progress of

particular territories [7]. Identification of the land plots, which are necessary for functional purposes for each type of activity, is related to the real property market research, analysing the dynamics of demand in the relevant market segments.

After the year 2000, there are significant changes in the economy of Latvia, which are reflected in the main indicators of the economic situation. During this period, the dynamics of the development of different economic sectors is influenced by various socio-economic and legal aspects.

The *aim of the study* is to identify key objectives of land use and in line with their development, within a foreseeable period of time, to describe the impact of this development on the development of the sectors of national economy. To reach the aim of the study, the land use objectives are classified according to their functionality; the structure of the national economy and dynamics of the development of respective industries are assessed, as well as the impact of the land use on the development of particular sectors of national economy within the foreseeable period of time is evaluated.

During the study, the following *research methods* were used: statistical analysis, mathematical analysis, and inductive–deductive data analysis. *The land-use categories* that are determined in the local spatial plans and detailed plans were collected and analysed within the framework of the study. The land use objectives are related to the corresponding real property market segments and analysed by using a uniform classification of the land use objectives for the country. Thus, the functional adequacy of the land use objectives to the structure of the national economy sectors, or more precisely – to the types of sector activity, is identified.

THE IMPORTANCE OF LAND USE OBJECTIVES

The benefits gained due to the land use planning and implementation of the plans cannot be unequivocally applied to the calculation of real property market value per area unit – the potential economic benefit, because in the land use planning, different needs of the population, resources available in particular area, the environment, long-term development perspective and other factors are evaluated. However, the land use objectives have some relevance or correlative link with the real property market and its value, which is supported by the content of data analysis. On the one hand, the land according to its purpose of use is the basis for economic activities performed by the inhabitants, but on the other hand, in respect to the objectives set and value determined, people pay taxes for using the land.

United Nations Economic Commission for Europe (UNECE) emphasizes that the tax imposed on land and real estate is an important source of revenue for the budget of public administration entity [8]. Taxes have major impact on the activities carried out by local governments in order to ensure the decentralization regarding issues of land use. Exploring the experience of foreign countries, it can be concluded that tax revenues account for 70 – 90% of local government budgets. In addition, taxes are not considered only as a source of revenue for the budget, but more widely - as a *'fiscal planning tool'* [9], facilitating production goals, providing land for construction purposes, reducing speculations with land, mobilizing of the land market, and finally organizing the particular land use.

To assess the impact of the development of land use objectives on the national economy of Latvia, within the framework of this study, mutually attributable classifications have been identified. *Classification of Land Use Objectives* (CLUO) represents *land use categories* that are determined in the local spatial plans and basically corresponds to the object segments of real property transactions. *Statistical Classification of Economic Activities* (NACE) corresponds to the statistical classification of economic activities of the European Community [7, 10].

CLUO includes: 1.agricultural, forest, water and nature reserve territories, where the construction is not the primary purpose of the land use and can be referred to the NACE types of activity (A, B); 2.manufacturing building sites refer to C and D; 3.commercial building sites refer to G, H, J, K, O; 4.public building sites are applicable to L, M, N; 5.residential building sites to F; 6.technical building sites – to I, E. The framework of such analysis allows determining relevant sectors of the national economy for using the land for appropriate purposes (see Fig. 1). *Classification of Land Use Objectives* from 2-6 refers to the territories in which the construction is the primary purpose of the land use.

Evaluating the afore-mentioned classification and analysing their mutual influence, it can be concluded that the real property market in the long-term run will be considered as a function of the national economy, but the 'construction' – as a function of other economic sectors. Thus, 'construction', unlike other industries, characterizes the supply. Construction of residential buildings is linked to consumer demand, which characterizes the type of demand.

THE INTERACTION BETWEEN REAL PROPERTY MARKET AND NATIONAL ECONOMY

Land use planning and the essence and importance of real estate market explain the fact that the *land area necessary* for functional use in each of the types of economic activity is related to the real property market research, analysing the dynamics of demand in the respective market segments and identifying the price per unit of land area. Assessing the information provided in Review of 2010 regarding the base of cadastral value and its modifications[11] and the base of cadastral value of land for different target groups of land use, it can be concluded that the highest average base value in the country is for *commercial construction sites.* After analysis of the collected and accumulated official market information on real property transactions in the relevant market segments, it can be assumed that the most valuable land is in the territories designated for commercial construction sites. Consequently, in the areas of this market segment higher tax revenues can be obtained and greater potential

for creating value added can be expected.

Due to the implementation of the objectives of the land use the real property market is facilitated. Whereas, very often, as the result of real property transactions initiative is created to actualize the objectives of land use. Real property market responds to the development of a particular sector of national economy – the price and occupancy of the area is increasing. Supply responds by promoting construction, land use transformations, due to what, an increase in the amount of supply or rapid rise in price, if the amount of particular land use category is limited. Taking into account the afore-mentioned indications, it is possible to assess the interaction between real property market and national economy. This is the basis for a hypothesis that such interaction contributes to the development of land use objectives and real property market and has an impact on national economy by affecting the structure of the concerned sectors. However, during the studies it can be determined how large this impact is. Assessing the features of commercial building construction sites and objects (CLUO – 3.), it can be concluded that these areas in the spatial planning of the territories are being developed as territories of mixed use, in which public building construction sites, office buildings and residential building areas are included. In addition, manufacturing building construction sites, in practice, often have a commercial nature.

DYNAMICS OF THE DEVELOPMENT OF THE SECTORS OF NATIONAL ECONOMY

Development of the sectors of national economy of Latvia can be assessed by analysing the dynamics of GDP and the amount of values in each economic sector and by type of the economic activity. Assessing the volume of GDP at comparable prices of 2000, it gradually over the last 10 years has increased, reaching a peak in 2007. Then, due to the economic crisis the amount of GDP decreased reaching, a minimum in 2010. The GDP changes in the time line also show the largest increase in 2006 reaching 12.2% while the largest decline was in 2009 - reaching 18.0%. According to the forecasts of the Ministry of Finance of the Republic of Latvia in coming years, a moderate GDP growth within the range of 3 – 4% is predicted [7].

In recent years, the GDP structure shown in Figure 1 indicates essentially that the largest proportion of *commercial services* and sales as being stable (G – O) [7]. Thus, it is reasonable to assume that the territories with the land use objective – sites for commercial construction have greater impact on the economy of Latvia.

DEVELOPMENT DYNAMICS OF RETAIL SPACE BUSINESS TRANSACTIONS

Real property market development in the land segment of business object construction sites is best described by the space and price of retail premises. The research of one of the biggest Latvian real estate companies 'Latio' *on the retail space market* [12] refers to the prices or leased retail space in Riga during the period from 2004 till 2010.

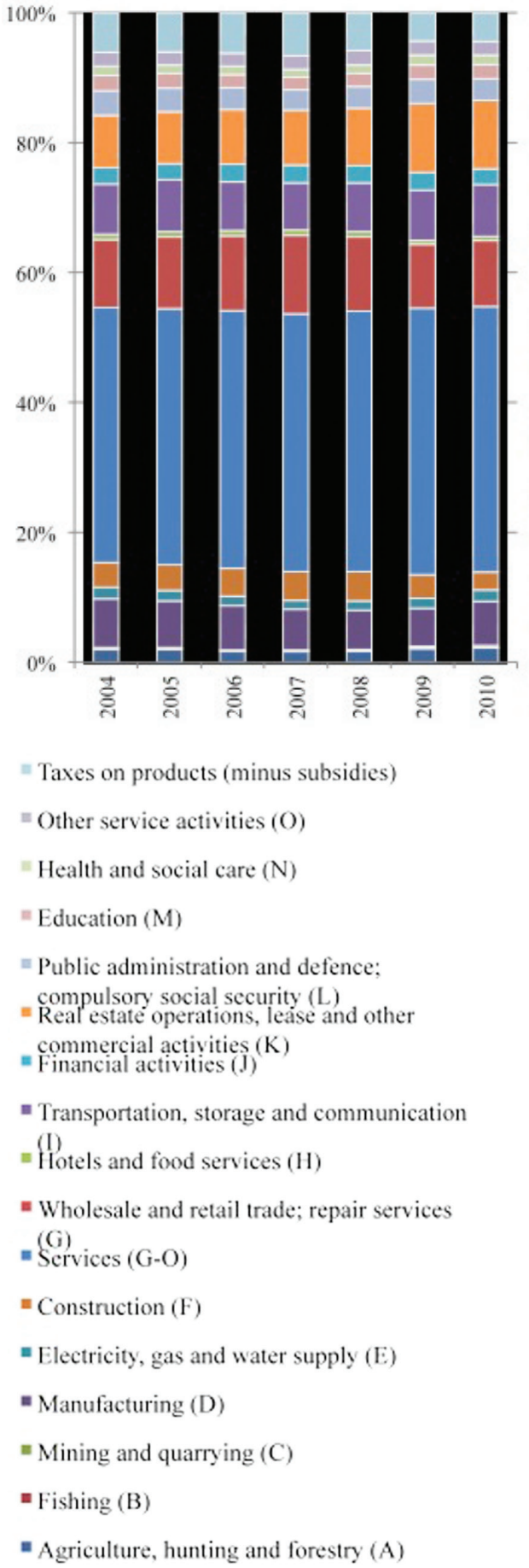

Fig. 1.
Coherence of rental prices of commercial space and GDP

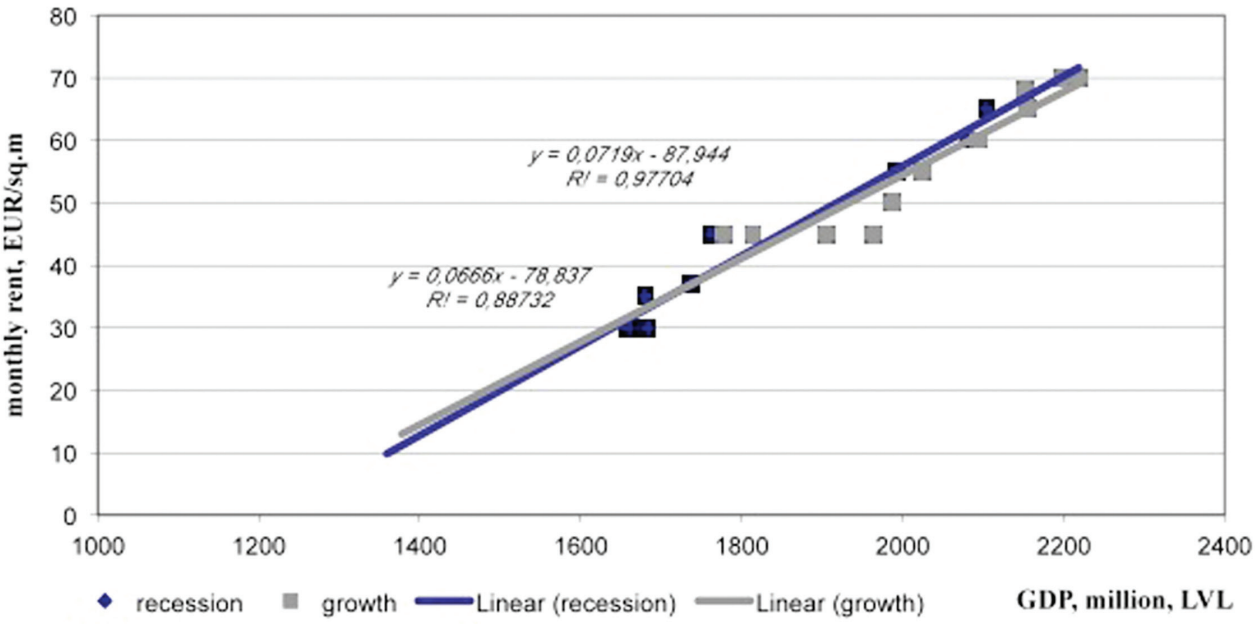

Fig. 2.
Coherence of rental prices of commercial space and GDP

Analysing *retail space* in accordance with the number of inhabitants in Riga, it can be concluded that in the period from 2001 till 2010 it has gradually increased from 120 sq.m. up to 700 sq.m. per 1000 inhabitants. In addition, mainly the newly built premises for retail, which in 2006 reached 150 sq.m. per 1000 inhabitants, were built during the period of rapid growth of country.

By analysing *rental prices* of the best retail space in Riga, the period of growth from mid-2005 until mid-2007 and the subsequent recession period until 2010 are clearly outlined. In the research performed by 'Latio' the optimistic and pessimistic retail space rental price scenario for the period until 2015 is highlighted. Optimistic scenario indicates gradual increase in prices of up to 70 EUR per sq.m., but the pessimistic one shows a gradual increase in prices of up to 45 EUR per sq.m. [12].

By analysing the relationship between *rental prices* of the best retail space and GDP in comparable prices of 2000 (see Fig. 2), it can be seen that there is a linear correlation both in the growth and recession periods, which generally refers to a correlation of the national economy and the land for building of commercial premises.

CONCLUSIONS

The research of the land use objectives and impact of the real estate market development on the national economy of Latvia leads to several important conclusions.

Setting of the land use objectives is considered to be a regulatory tool for the national economy, whereas economic development is proof of the updating of the land use objectives, thus mutual influence or interrelation is identified.

In future the prices of real properties will greatly depend on the GDP, if to be more precise – on the structure of the GDP. Facilitation of sustainable economic development in the longer term has to focus on the real property market as a function of national economy.

Demand for a retail space is related to the value of real property market that affects both the value of the land and the actualization of the land use objectives.

The paper is concerned with the assessment of the development impact of the commercial building sites, but, in a similar way, it is possible to analyse and reflect impact of the development of other land use objectives on the national economy and identify importance of this impact or correlation.

Analysis of different classification types allow to determine the limits and, within its framework, to analyse the elements of interrelation, but consistency in classification in the long term, which would enable to compare relevant data and identify the development trends of related processes, shall be required.

As the value of the premises increases, the land value increases as well – the respective industry contributes to the revenue increase (taxes) in the budget. The growth in budget revenue allows the public sector to develop other territories – the land use categories thus influencing real property value, including construction sites for technical infrastructure, natural areas and construction sites for residential buildings.

Municipalities are required to maintain current information regarding the real property tax amount and % of GDP, both in total tax revenues, as well as in tax revenues by the territories according to the land use categories that would allow to constantly analyse development trends in the territory and facilitate the development of planned territories, by using tax revenues as an important fiscal tool.

REFERENCES

1. G. Larsson. Land management. Public policy, control and participation. The Swedish Council for Building Research *(Byggforskningstradet)*, Stockholm, p. 232, 1997.
2. A. Boruks (eds.). Zemes izmantošana un kadastrs Latvijā [Land Use and Cadastre in Latvia]. *Skriveri Scientific Centre, AUL, State Land Service of Latvia.* Riga, p. 405, 2001.
3. A. Dobele. Use of land resources in Latvia. *PhD thesis.* AUL, Faculty of Economics, Jelgava. 2004.
4. I. Francis. Transformation of the functional structure of the territory of Riga. *PhD thesis*. LU Faculty of Geography and Land Sciences, Riga. 2004.
5. I. P. Williamson, S. Enemark, J. Wallace, A Rajabifard. Land Administration for Sustainable Development. *ESRI Press Academic, Redlands California, USA,* p. 487, 2010.
6. VRAA. Reģionu attīstība Latvijā 2009 [Development of Regions in Latvia 2009]. *Annual Report of the State Agency of Regional Development*, Riga. 2010.
7. CSB. Statistical Database. [Online access]. <http://www.csb.gov.lv>. Accessed: 01.10.2011
8. United Nations ECE/HBP/96. Land Administration Guidelines: with special reference to countries in transition. UNECE, New York, Geneva. 1996.
9. GTZ. Land Use Planning: Methods, Strategies and Tools. Wiesbaden: Universum Verlagsanstalt, p. 237, 1999.
10. European Commission. Eurostat statistical database of EU countries. <http://ec.europa.eu/eurostat/ramon>. Accessed: 01.10.2011.
11. State Land Service of Latvia. Pārskats par kadastrālo vērtību bāzi un tās izmaiņām, 2010.g. [*Overview of the cadastral base values and its changes in 2009*]. <http://www.vzd.gov.lv>. Accessed: 10.10.2011.
12. Latio. Tirdzniecības telpu tirgus Latvijā, salīdzinājums ar Eiropas valstīm [Retail space market in Latvia, European comparison]. *Study of Latio Market analysis unit*, Riga. 2010.

KOPSAVILKUMS

Pētījuma aktualitāte attiecas uz zemes izmantošanas mērķu attīstības analīzi un to mijiedarbību dažādu tautsaimniecības sektoru funkcionālo mērķu īstenošanā. Parasti tiek pētītas tautsaimniecības sektoru struktūras izmaiņas, kā arī tiek analizēts pievienotās vērtības sastāvs atbilstoši ekonomisko aktivitāšu veidiem. Tomēr, iepriekš vēl nav pētīta saistība starp atbilstošajiem ekonomikas sektoriem un funkcionāli saistošajām teritorijām Latvijā. Pētījuma galvenie atklājumi skaidri parāda savstarpējo saistību starp zemes izmantošanas mērķiem un aktivitātēm atbilstošos tautsaimniecības sektoros.

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REVITALIZATION AND DEVELOPMENT OF THE GREEN REAL ESTATE OF RIGA CITY

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ABSTRACT

The general purpose of the scientific paper is to reflect basic research results in the area of green real estate management in Riga City. In the term *"green real estate"* are included parks, gardens, squares, alleys and other green urban open space. Scientific research discussed within the framework of the paper is designed as an observational case study. The main results of the present research are related to the study of the management process of the revitalization and development of parks and open spaces in the City of Riga. Taking into consideration the obtained research results, the conclusions drawn and the elaborations developed, the authors of the paper have developed the recommendations for the improvement of the management of green space of Riga City.

Keywords – development, green space, green real estate management, revitalization

INTRODUCTION

This chapter examines topicality and the scientific aspects of the research *"Revitalization and Development of the Green Real Estate of Riga City"*.

In 2005 the World Health Organisation based on the data provided in the Report of the Millennium Ecosystem Assessment *"Ecosystems and Human Well-Being. Health Synthesis"* attracted public attention to the fact that diverse and friendly green urban open spaces are desirable. This is reflected in high real estate values adjacent to attractive open spaces. There is a hypothesis that green real estate management contributes not only to tangible but also to intangible landscape services such as benefiting human health and well-being. Individual studies report on the benefits of green environment to human health, both physically and mentally, on green open spaces affording ventilation and thermal comfort in urban heat islands, on retention of storm water, on preventing air pollution, and on people using such areas for food and fuel/energy production. Functions that are important for improving quality of life, adapting to climate change and for emergency management related to natural hazards such as floods, fires and earthquakes are essentials elements of the green real estate governance [1]. According to Diedrich Bruns *(Diedrich Bruns – deu.)* thus, green open space would contribute to resilient societies. However, there is little proof that substantiates such hypothesis and much research is needed to better understand such complex relationships [2]. A leading author on sustainable development Herbert Girardet considers that public spaces and parks form a crucial feature of liveable cities. Unlike in many 19th-century cities, frequently insufficient space is kept aside for them.

Too often, attractive, safe and well-maintained spaces are located in privately owned, enclosed shopping centres. Yet public parks are important for people from whose lives the experience of green space and biodiversity has gone missing [3]. Enrique Penalosa *(Enrique Peñalosa – spa.)*, former mayor of Bogota *(Bogotá – spa.)*, observes that parks and public space are important to a democratic society because they are the only places where people truly meet as equals. Parks are also essential to the physical and emotional health of a city. However, this is not obvious from most budgets, where parks are treated as somewhat of a luxury. Roads, the public space for cars, receive infinitely more resources and less budget cuts than parks, the public space for children [4]. In Enrique Penalosa opinion parks play many non obvious roles in constructing a society. However, one of the most important is to make cities more egalitarian.

Clark and Jauhiainen *(Clark – fin, Jauhianen – est.)* found that the *"greening"* of European cities has been one of the most important widespread and controversial of modern urban developments [5]. The notion of the *"green"* city goes back at least to the seventeenth century, when Thomas Fuller described the English provincial town of Norwich as: *"Either a city in an orchard or an orchard in a city. So equally are houses and trees blended it."* [6]. But it was the nineteenth century, when references to green space in the urban context multiplied. The need for *"zones of open country"* around London was mentioned in the 1820s and *"green corridors"* in the 1880s, and similar phrases were picked up and disseminated in other cities and towns across the continent [5]. Robert Schafer *(Robert Schäfer – deu.)* in *"Parks. Green urban spaces in European cities"* emphasizes, that a city without park is not a city, at least not a modern one. No other open space, be it a square or a boulevard, an arcade or a promenade, is able to do what a park can. Substantial contribution in study of the role of parks in different processes of city development are made by such scientific disciplines as ecology, aesthetics, sociology, anthropology and others. In the parks are concentrated interests of different subjects of society. A great many interests and needs are . The value of a park for a community and stakeholders is undisputed. Controversy arises if a new park is to be created. Everyone wants to have their say even though the financial investments involved is considerably lower than for any run-of-the-mill bridge structure. On the one hand, this is an indication of its status, and on the other, of difficulties surrounding its application [7]. In some cases an economic value of the park as the green real estate comes in front of the institutional and public decisions and activities. Necessity to provide study on the improvement of the management of green space of Riga City *(Rīga – latv.)* goes well beyond the traditional value of parks determines the topicality of the scientific research. In order to achieve the abovementioned aim the following assignments are defined:

1. with the help of the monographic method to discuss the ideas, attitudes and phases of the development of green space in Riga City;
2. using the questionnaire method to focus the attention on the management of green space of Riga City nowadays;
3. with the help of the benefits approach to evaluate managerial aspects of green real estate;
4. using the case study approach to explore the importance of the revitalization and development of green space in Riga City.

The main research results are related to the development of the recommendations for the improvement of the management of green space of Riga City.

RIGA – THE CITY OF GARDENS

This chapter will discuss the ideas, attitudes and phases of the historical development of urban parks and green areas in Riga City in the period from the 13th century until nowadays.

"The garden represents close interaction between civilisation and nature and it is of global importance as confirmation of the original aspects of culture, style, time and creativity," – states the Latvian architect Juris Dambis (Juris Dambis – latv.). Historical gardens and parks in various parts of the cities are important components of Latvia's cultural heritage, and their preservation for future generations will satisfy the interests of both Latvians and Europeans [8]. The famous Latvian poet Imants Ziedonis *(Imants Ziedonis – latv.)* has named Riga: *"The City of Gardens"* [9]. Describing the development of the gardens in Riga, he noted that during the late 19th century a new movement emerged in the public gardens of European cities – greenery based on the principles of the natural sciences. The landscape gardeners of Riga were ready for this. Analyzing the historical development of the green areas in Riga City it is necessary to note, that the first significant town planning measures were the establishment of two the so-called Imperial Gardens *(Государевы сады – rus.)*[10]:

- At Gustavsala *(Gustavsala – latv.)* or Petersala *(Pētersala – latv.)*;
- At the Alexander *(Aleksandra – latv.)* bastions.

Initially the parks were conceived as a part of an ensemble of the Imperial's palaces *(Государевы дворцы – rus.)*, which were to be built in these places. Later, however, the citizens of Riga were able to utilize these parks for their rest and recreation. At the beginning of the 19th century, a plot of land given to the town by the widow of the merchant Vermanis *(Wöhrmann – deu.)* was planted with trees and shrubs. In line with the terms of the gift deed, this park was open to the public. In due course the park expanded and became one of the most remarkable open spaces in the city [10]. The gardens created at the beginning of 19th century were intended for all of society, but the truly public gardens in the city were designed and installed after the Riga Gardens Directorate *(Rīgas dārzu direkcija – latv.)* was established in 1879. Riga's gardens became an urban treasure – a place where people could take walks and relax – and these gardens wisely unified and supplemented the urban space. Overview of the development of Riga's parks and gardens over the course of the centuries is provided in Table 1.

As it can be seen from Table 1, the development of Riga's

parks and gardens has occupied in five specific phases. Riga's public greenery has been the work of several highly prominent gardening artists. From 1880 until World War I, the director of the Riga City Gardens and Parks Georg Kuphaldt *(Georg Friedrich Ferdinand Kuphaldt – deu.)*, who with great skill has reconstructed and improved all of the public gardens of his era. After World War I the public gardens of Riga were very successfully restored by Andrejs Zeidaks *(Andrejs Zeidaks – latv.)*, who installed vast lawns and carefully constructed groups of perennial plants, as well as areas of greenery meant for different groups of visitors[9]. It is necessary to note that Andrejs Zeidaks has successfully launched the development of public parks and gardens also outside the city centre, e.g.,, Ziedondarzs, Moscow Garden and Dzeguzkalns Park. Zeidaks had a seminal influence on the development of green areas throughout Latvia. After World War II the restoration and maintenance of the city's public gardens was largely the work of Karlis Barons *(Kārlis Barons – latv.)*, who designed several parks and oversaw the installation of many squares and street green areas. His lifework is the Victory park in Zemgale *(Zemgales – latv.)* suburb of Riga.

New specific phase of the development of public green space in Riga City has started after Latvia proclaimed its independence in 1991. This period could be characterized by new forms of real estate ownership and management as well as by new landscape planning approaches and materials.

The first phase, from the 13th to the 18th century
Gardens were established in closed territories – the gardens of convents and baronial estates
The second phase, from 1710 to 1860
Riga became the part of Imperial Russia, and the gardening arts developed very quickly: the first Imperial Garden on Petersala Island; the second Imperial Garden; gardens at baronial estates (the Hammer, Benkin and Thoren estates, the White baronial estate with a beautiful park and oak plantation and other locations)
The third phase, from 1860 to the eve of World War I
Suburban areas were developed very rapidly. G.Kuphald began work on the Esplanade *(Esplanāde – latv.)* Vermane Garden *(Vērmanes pārks – latv.).* The green areas of the city's main cemetery. The green areas along the city's canal. The ring of boulevards around Old Riga. The Riga Castle Square *(Rīgas Doma skvērs – latv.).* Jekabs Square *(Jēkaba skvērs – latv.).* Herder Square *(Herdera laukums – latv.).* The green area around the buildings that now house the Cabinet of Ministers and the Supreme Court. Tornkalna Park *(Torņkalna parks – latv.).* New principles of cemetery planning were put in place
The fourth phase, from World War I until 1940
A new landscape in Vermane Garden. Ziedondarzs Garden *(Ziedoņdārzs – latv.)*. Moscow Garden *(Maskavas dārzs – latv.,).* Dzeguzkalna Park *(Dzegužkalna parks – latv.)*
The fifth phase, after World War II
The square at the Riga Russian Drama Theater. The establishment of the Forest Park *(Mežaparks – latv.)* as a place for cultural events and recreation activities (1949). Esplanade (1951). The left and right banks of the Daugava River (*Daugava – lav.).* The green area at the Dailes Theater *(Dailes teātris – latv.).* The green area at the Moscow cinema *(kinoteātris Maskava – latv.).* Green areas in new residential areas. Victory Park *(Uzvaras parks – latv.)*

Table 1.
Overview of the Development of Riga's Green Space [8-9-11]

MANAGEMENT OF GREEN SPACES OF RIGA CITY NOWADAYS

This chapter will focus on the management of green space of Riga City nowadays.

Nowadays Riga is widely known in Europe for its parks, gardens, squares and alleys. In accordance with the Riga City Development Programme 2010-2013 (Rīgas attīstības programma – *latv.*) plantings and natural areas cover almost 25.0% of the territory of Riga. The total area of green urban open space is 7 430 hectares [12]. Green areas are popular places for recreation and sport among the local residents and foreign tourists. Urban open space and parks are an important value of the living environment of the Riga City residents as well as significant element of the structure of the urban landscape. Urban open space and parks are significant elements of the *"green"* real estate of the Municipality of Riga City *(Rīgas dome – latv.)*. There are 30 gardens and parks and 66 squares in Riga that are managed by the municipal limited liability company *"Riga City Forests"* (*Rīgas meži – lav.)*. The organizational structure of the agency is schematically shown in Figure 1.

As it is shown in Figure 1, one of the departments of the municipal limited liability company "Riga City Forests" is responsible for maintaining and restoring existing urban gardens, parks and squares as well as for creating new green areas. The department "Riga Gardens and Parks" consists of three sections – North, East and Pardaugava (Pārdaugava – latv.). For the assessment of the management of green urban areas in Riga within the framework of the research the sociological study was implemented. In framework of sociological research methods main attention was paid to the following audience of the respondents of Riga City:

- Urban residents – 18÷74 years old residents of Riga City;
- Urban development experts – knowledgeable, senior professionals whose daily work and duties related to various dimensions (incl., urban planning and management) of Riga City.

Experts' assessment of the management of Riga City green urban space during the period from 2005 till 2010 is provided in Figure 2.

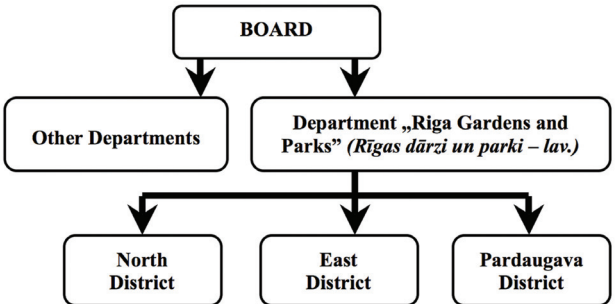

Fig. 1.
Organizational structure of the municipal limited liability company "Riga City Forests" [13]

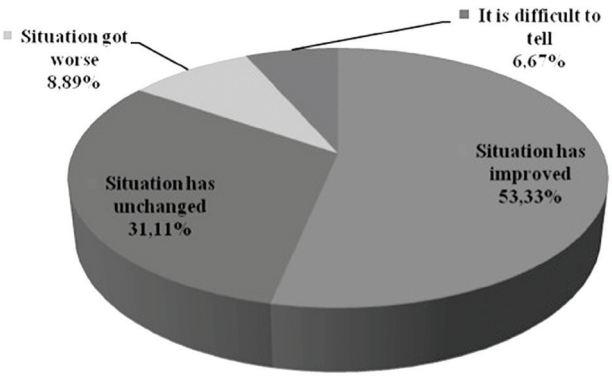

Fig. 2.
Changes in area of management of Riga City green urban space during the period from 2005 till 2010 [Developed by the authors]

As shown in Figure 2, 53 percent of the surveyed urban development experts positively assess the situation in area of management of Riga City green urban space. By contrast, 31 percent of respondents admit that the situation has not changed during the reporting period. About 9 percent of the experts stressed that the situation got worse, but 7 percent could not answer. It is necessary to note that within the survey Riga City residents among other significant impediments of Riga environmental improvement have mentioned the lack of green open space. In the opinion of the urban residents the 8 most topical environmental development challenges for Riga City are the following:

1. Low air quality;
2. Poor waste management system;
3. Low potable water quality;
4. Insufficient waste water management;
5. Retired vehicles, poor technical condition of vehicles;
6. Lack of planting and natural areas (parks, gardens, etc.)
7. Lack of facilitated public beaches.

It is important to note that in order to evaluate improvement of the urban environment and movement towards healthier and even more sustainable living areas, the municipality of Riga in 2009 has applied for the European Green Capital Award. The objectives of the European Green Capital Award are the following [14]:

- To reward cities that have a consistent record of achieving high environmental standards;
- To encourage cities to commit to ongoing and ambitious goals for further environmental improvement and sustainable development;
- To provide a role model to inspire other cities and promote best practice and experiences in all other European cities.

In accordance with the results of the evaluation of Riga City application for the European Green Capital Award of 2010 & 2011, Riga got 8 points out of 13 possible in the indicator area *"Availability of green areas open to the public"*. It means that in relation to other European cities situation in Riga is characterized by medium accessibility of green and blue space. Existing situation in Riga City is

Fig. 3.
Availability of green areas open to the public in Riga City [15]

Distance to Park in Meters	Round-Trip Walk in Minutes	Sales Premium %
~30,0	1,0	24,0%
~90,0	2,5	15,0%
~180,0	5,0	5,0%
~400,0	10,0	Insignificant

Table 2.
Park proximity sales premium [20]

schematically shown in Figure 3.

As shown in Figure 3, there are still territories with the lack of green open space in Riga City. Therefore improvement of the availability of green areas open to the local public as well as amelioration and the management of urban green open space are crucially important for Riga City. Directions of future activities are closely related with the potential social, economic and ecological benefits that green open space could provide to the urban residents, entrepreneurs and tourists.

BENEFITS OF THE GREEN REAL ESTATE

This chapter will evaluate managerial aspects of green real estate and its social, economic and ecological benefits.

In a publication edited by Michael Sorkin *"Variations on a Theme Park: The New American City and the End of Public Space"* is stressed that there are not only significant differences in urban public space between the United States and Europe but also between different European cities [16]. An author focuses his attention on the fact that green open space in the city in the late nineteenth century is not the same as green space in the early twenty-first century – even if we talk about a park that is physically located exactly in the same place. In trying to unravel the processes by which urban, public or green space is made, the following key questions have to be asked: for example, who acts as gatekeeper to whom in urban space, how different notions of space are communicated and represented in the media and broader local discourses, and what is the role of urban space in political and power relationships [16]. Answers on the above mentioned questions could help identify green open space managerial characteristics and aspects. Significant proportion of them is associated with potential social, economic and ecological benefits from green urban areas.

Benedict and McMahon found that green open space provides people with mental and physical health benefits derived from living near nature in the following ways [17]:

- Purify the air in urban areas: they remove nitrogen dioxide, sulphur dioxide, carbon monoxide, and ozone, and store or sequester carbon in wood;
- Provide opportunities for outdoor recreation, from walking to biking. Thus reducing the risk of coronary heart disease, high blood pressure, diabetes, etc.
- Regular physical activity also relieves symptoms of depression and anxiety and generally improves mood;
- Enhance emotional, cognitive and values related development in people.

According to Habermas *(Habermas – deu.)* green space is a vital, dynamic part of urban space. He discusses that it not only has a physical dimension as parks, gardens or wasteland within the built environment, but it also functions as social space. Parks and other green areas are sites of public cultures, social gatherings and informal get-togethers, bringing together various people. In contemporary cities green space offers accessible public space to local communities. Because of its openness, public space of this type is vital for cultural identification and social attachment at the neighbourhood and local level. In this way, with the activity and engagement of urban residents, green space constitutes an important, often neglected part of the public sphere [18]. In this way green open space promotes recurring casual social encounters and the building of social capital.

Having analysed the economic benefits of green open space it should be noted that it is often difficult to express people's love to open space or natural landscapes in the form of money. Benedict and McMahon note that recreational trails, which may be part of green infrastructure plan, also serve to attract people and commercial enterprises that serve them. The flow of tourists and recreational spending produces additional employment and opportunities for existing residents. Multiplier effects enhance the value of natural amenities. Additional incomes are generated from encouraging people who service the tourist industry and retires – from hotel workers, to hospital staff, to taxi and bus drivers – to spend their time and money within the community [17]. *"A community that expects to capture and maintain incomes from tourism and people with non-employment income must structure the economy to maintain the amenities that attract these people," conclude Clyde F.Kiker and Alan W.Hodges* [19].

The world practice shows that green open space – parks, gardens, squares, natural areas, etc. – also increase the value of a real estate. Data of the research on park Proximity Sales Premium implemented by Miller Andrew Ross are summarized in Table 2.

As it can be seen from Table 2, parks increase the price real estate buyers are willing to pay to live close by. For example a park located 30 meters from home could raise sales premium up to 24.0%. If the distance to the park is six time longer the rate of sales premium is only 5.0%. It is necessary to note that in this way green open space provide a very good return on investment for either government or private developers. In addition, Benedict and McMahon stress that many businesses report that access to outdoor recreation and a clean environment are among the most important determining factors when selecting a location. As cell phones, computers, the Internet, and other advances in technology make it easier for businesses to locate away from the commercial hubs and transportation links, such quality-of-life factors will be even more critical to location decisions [17]. Finally, green open space also directly benefits people – providing variety of natural sites for outdoor recreation and nature-based education.

REVITALIZATION OF GREEN REAL ESTATE OF RIGA CITY

This chapter will provide an overview of the plans of revitalization and development of the green open space in Riga City exploring the importance of future activities.

In accordance to the Riga Development Plan *(Rīgas Attīstības plāns – latv.)*, the general purpose for the capital of Latvia is to facilitate Riga long-term development, providing the possibly highest quality of life for all the people working, living, investing into or simply visiting

Riga [21]. In order to achieve an above mentioned purpose Municipality of Riga City has started an ambitious project in 2012. It is aiming to arrange and to revitalize green open space areas in Riga and to provide local residents with attractive green recreation areas within 20 minutes walking distance from their living place.

In general, approximately 2.5 million Latvian Lats *(lats– latv.)* from the budget of the Municipality of Riga as well as 4.7 million Latvian Lats from the European Union funds will be invested into the development of green areas [22]. It is important to note that within the project of the development and revitalization of the green real estate of the Municipality of Riga City a new, broader view of parks, that has recently been emerging, is identified. Chris Walker *(Chris Walker – eng.)*, Urban Institute senior researcher, focused attention on the fact that this new view goes well beyond the traditional value of parks as places of recreation and visual assets to communities[23]. It focuses on how policymakers, practitioners, and the general public can begin to think about parks as valuable contributors to larger urban policy objectives, such as job opportunities, youth development, public health, and community building.

An overview of the planned green real estate revitalization and development activities in Riga City is granted below [22]:

Lucavsala *(Lucavsala – latv.)* **– it is planned to carry out the development of green area, including creation of Lucavsala recreation park and a skate park, lawn installation, arrangement of jogging trail, improvement of the access to the road, arrangement of the beach volleyball court, etc. It is planned to invest into** arrangement of the park about 600 000 Latvian lats. This year, around 300 000 Latvian lats will be invested in the green open space development. The cost of the installation of the equipment for video supervision and lighting installation will be about 77 000 to 98 000 Latvian lats.

AB dam *(AB dambis – latv.)* – the renovation and extension of the covering of the road and pavement, including replacement of the concrete slabs and concrete paving, installation of the road curb as well as arrangement of the playground, etc. It is planned to use such type of coverage for sidewalks that would make them appropriate for skateboarding. **It is planned to invest into development of the dam** from 145 000 to 168 000 Latvian lats. Lighting installation will cost 217 700 Latvian lats. In addition the video supervision would cost approximately 26 000 Latvian lats.

The area around Mara pond *(Māras dīķis – latv.)* **– the project involves creation of the recreational zone, reconstruction of the walkways and the greenery at the northwest shore of the pond as well as the construction of the bicycle paths. It is planned to clean the pond, to reconstruct the shoreline, to strengthen embankment and to create habitats. In the area near Marupes Street *(Mārupes iela – latv.)* it is planned to repair walkways, to arrange greenery as well as to reconstruct the playground and sport zone.** Improvement of the recreation zone will includes installation of the observation zone, boat docks as well as placement of the art objects.

Grizinakalns *(Grīziņkalns – latv.)* **– the cover of the walkways will be fully restored as well as the special walkways intended for the navigation of the visually impaired people will de labeled with the special signs.** There will also be cycling paths. The new lighting will be created in the park. It is planned to arrange the stage space at the upper terrace – to install adequate coverage for the necessity to put a mobile bandstand in the case of the different cultural events. In the framework of the revitalization of the park it is planned to reconstruct a walking pool. Children's playground will be greatly expanded. As Grizinkalns can be also used for sports activities, it is planned to create a recreation area with outdoor equipment.

Peace Garden *(Miera dārzs – latv.)* **– during the reconstruction the cover of the walkways, stairs and retaining walls will be restored as well as guides for the tourists will be installed, and benches will be refurbished. In addition the revitalization project involves lighting providing and replacement of the public utilities.** It is planned to restore the children's recreation area and to replant the area, as well as to construct the public toilets.

Ziedondarzs *(Ziedoņdārzs – latv.)* **– within the project of the revitalization of the Ziedondarzs, cover of the walkways will be replaced; the area around fountain will be expanded,** accompanied by lush plantings of roses. New equipment will be installed at the children's playground as well as the large pool for walking will be created. The park will be equipped with new, comfortable benches and lighting system. It is planned to restore the gardener's cottage built in 1928 as well as to install the public toilets.

Project on revitalization of the territory of Grizinkalns, Ziedondarzs and Peace Garden has begun in 2011. It will be completed in 2013. The total cost amount to 5 268 283 Latvian lats including:

- Co-financing of the European Regional Development Fund – 4 478 040 Latvian lats (85.0%);
- Co-financing of the Riga City Council – 790 243 Latvian lats (15.0%).

Plavnieku Park *(Pļavnieku parks – latv.)* **– in accordance with the recommendations of the general public, the Riga City Council continues green open space development activities in the Plavnieki District** *(Pļavnieku rajons – latv.)* **in the area between** Andreja Saharova *(Andreja Saharova – latv.)*, Dravnieku *(Dravnieku – latv.)* and Plavnieku *(Pļavnieku – latv.)* Streets. Within the development activities it is planned to keep maximally the existing birch grove. It is planned to provide a comfortable pedestrian movement, while creating opportunities for a diverse range of recreation. All active recreation zones shall be provided in the areas free from the trees. The pedestrian walkways will be mainly intended at the existing sites, but they will be made wider and more convenient by locating the benches and waste cans. This year it is planned to upgrade 2.8 hectares in the park area. 202 000 Latvian lats are awarded for these activities. Another 40 000 Latvian lats are intended for the lighting installation.

CONCLUSIONS

Research results show that green open space is the important component that forms the quality of life in urban areas. Along with the buildings, small architectural forms infrastructure parks and gardens are the significant elements of the living space. Parks, gardens and squares are significant places of urban public life and specific category of the real estate of Riga City. Revitalization of the existing green open space and development of a new one is a great challenge for Riga City and its inhabitants. It is necessary to note that the Riga City Council has not allocated considerable investments into revitalization and development of green open space at least in the period of the last ten years, but the Plavnieki Park has become the first new park created in Riga City during the last twenty years. Successful implementation of the revitalization and development of the green real estate of Riga will make the city more attractive and comfortable for residents, entrepreneurs and tourists. The planned and implemented green real estate revitalization activities in Riga City are oriented to the diversification of the recreation, sport and social life activities in green open space as well as to the improvement of the environment quality and safety. Smart and well-arranged green open space will allow urban dwellers and guests to enjoy outdoor recreation activities and cultural events at the different corners of Riga City. It is significant to note that with the help of the improvement of the quality of the existing parks, gardens and squares as well with the development of new ones in Riga City, the availability of green areas open to the public will increase. Green real estate management will make effort to improve the urban environment in Riga City and move towards healthier and even more sustainable living areas at the Northern Europe. Thus, Riga City will have more chances to apply for the prestigious European Green Capital Award and to win it. It will spur Riga City to invest in further efforts and will boost the awareness of the green real estate within the city as well as in other cities. The award will enable Riga City to inspire other Latvian and European cities and share examples of good practices in the city governance. This will ensure that Latvian's towns and cities create the new elements of the green real estate to reduce their adverse impact on the environment. Based on the above mentioned conclusions, it is recommended for the Riga City Council within the scope of its competence to promote integration of green open space related issues into all municipal development policies. It is advised to find opportunities for public-private partnership in the area of promotion of economic benefits obtained from green open space. It is recommended for the educational institutions to support nature-based education and for mass media to promote public awareness about the importance of the green open space in the urban environment.

REFERENCES

1. C.Corvalan, S.Hales, A.McMichael, *Ecosystems and Human Well-Being. Health Synthesis. A Report of the Millennium Ecosystem Assessment.* France: World Health Organization, 2005, pp.64
2. D.Bruns, *Resilient Urban Development in Europe – without Green? ELCA Research Workshop Green City Europe – for a better life in European cities.* Bad Honnef, Germany: European Landscape Contractors Association, 2011, pp.59
3. H.Girardet, *Cities. People. Planet. Urban Development and Climate Change.* Second edition. Hoboken, USA: John Wiley $ Sons, Ltd., 2008, pp.169
4. E.Peñalosa, *Parks for Liveable Cities: Lessons from a Radical Mayor. Keynote address at the Urban Parks Institute's Great Parks/* Great Cities Conference, Chicago, USA: 30 July 2001 pp.30-31
5. C.Peter, J.S.Jauhiainen, *The European City and Green Space: London, Stockholm, Helsinki and St. Petersburg, 1850-2000.* Ed., C.Peter, Aldershot, England: Ashgate Publishing Limited, 2006, pp.318
6. T.Fuller, *The Worthies of England.* Ed., J.Freeman, London, England: Allen & Unwin, 1952, pp.716
7. R.Schäfer, P.Sansot, U.Poblotzki, et al. *Parks. Green Urban Spaces in European Cities. Berlin, Germany: Callwey Verlag,* 2003, pp.128
8. J.Dambis, J.Zilgalvis, A.Muceniece, *Vēsturiskie dārzi un parki. Eiropas kultūras mantojuma dienas 2007.* Rīga: Valsts Kultūras piemineklu aizsardzības inspekcija, 2007., 143 lpp.
9. I.Ziedonis (sēr. red.), *Rīga – parku pilsēta.* Rīga: Jumava, 1999., 8.-15.lpp.
10. Municipality of Riga City. Parks. Municipal Portal of Riga. – [Online] Available: https://www.riga.lv/EN/Channels/About_Riga/History_of_Ri ga/Stories /Parki/default.htm [Accessed July 22, 2012]
11. Rīgas Meži. Rīgas dārzu un parku vēsturiskais raksturojums. Rīgas Meži portāls. – [Elektroniskais resurss] Pieejams: http://www.rigasmezi.lv/lv/ Rigas_darzi_un_parki/vesture/Rigas-darzu-un-parku-vesturisks-raksturo jums/ [Skatīts 2012.g. 4.augustā]
12. Rīgas domes Pilsētas attīstības departaments. Rīgas attīstības programma 2010.-2013.gadam. Pašreizējās situācijas raksturojums Rīgas dome, 2010. – [Elektroniskais resurss] Pieejams: http://rdpad.lv/uploads/rpap/Programma_2.dala_Esosa_situacija_lielais.pdf [Skatīts 2012.g. 11.augustā]
13. Rīgas Meži. Struktūra. – [Elektroniskais resurss] Pieejams: http://www.rigasmezi.lv/lv/par_mums/struktura/ [Skatīts 2012.g. 12.augustā]
14. European Commission. European Green Capital. The Expert Panel's Evaluation Work & Final Recommendations for the European Green Capital Award of 2010 and 2011. European Commision, 2009. – [Online] Available: http://ec.europa.eu/environment/europeangreencapi tal /wp-content/uploads/ 2011/05/Evaluation-Panel-Report-Award-Cycle -2010-2011.pdf [Accessed August 22, 2012]
15. Rīgas domes Pilsētas attīstības departaments. Publisko apstādījumu pieejamība. – [Elektroniskais resurss] Pieejams: http://www.rdpad.lv/rpap/rpap_ar_grozijumiem/paskaidrojuma_raksts/paskaidrojuma_kartoshemas/ [Skatīts 2012.g. 15.augustā]
16. M.Sorkin (ed.), *Variations on a Theme Park: The New American City and the End of Public Space,* New York, USA: Hill & Wang,, 1992, pp. 252
17. M.A.Benedict, E.T.McMahon, *Green Infrastructure. Linking Landscapes and Communities.* Washington, USA": Island Press, 2006, pp.57-58
18. J.Habermas, *The Structural Transformation of the Public Sphere: an Inquiry into a Category of Bourgeois Society*, trans. By T.Burger, Cambridge: 1992, pp.305
19. C.F.Kiker, A.W.Hodges, *Economic Benefits of Natural Land*

Conservation: Case Study of Northern Florida, Washington, USA: Defenders of Wildlife, 2002, pp. 24
20. F.Douglas, *Sustainable Urbanism: urban design with nature,* New Jersey, USA: John Wiley & Sons, Inc., 2008, pp. 169-170
21. Rīgas domes Pilsētas attīstības departaments. Rīgas plānošanas dokumenti. Rīgas dome, 2010. – [Elektroniskais resurss] Pieejams: http://www.rdpad.lv/rigas_planosanas_dokumenti/ [Skatīts 2012.g. 25.jūlijā]
22. Rīgas domes Pilsētas attīstības departaments. Rīgas dome sāk vērienīgus parku un skvēru atjaunošanas darbus, ierīkos jaunas aktīvās atpūtas vietas. Rīgas dome, 2012. – [Elektroniskais resurss] Pieejams: http://rdpad.lv/services/Projekti/miera_darzs_/article.php?id=102923 [Skatīts 2012.g. 25.jūlijā]
23. C.Walker, *The Public Value of Urban Parks,* Washington, USA: Urban Institute, 2004, pp.8

KOPSAVILKUMS

Pētījuma rezultāti rāda, ka apzaļumota teritorija ir svarīga sastāvdaļa, kas veido dzīves kvalitāti pilsētas teritorijā. Kopā ar ēkām, maziem arhitektoniskiem veidojumiem infrastruktūras parki un dārzi ir nozīmīgi elementi dzīves telpā. Parki, dārzi un skvēri ir nozīmīgas vietas pilsētas sabiedriskajā dzīvē un īpaša Rīgas nekustamo īpašumu kategorija. Esošo apzaļumoto teritoriju atjaunošana un jaunu teritoriju radīšana ir liels izaicinājums Rīgas pilsētai un tās iedzīvotājiem. Ir nepieciešams atzīmēt, ka pēdējo desmit gadu laikā Rīgas dome nav piešķīrusi ievērojamus līdzekļus apzaļumoto teritoriju atjaunošanai un izveidei, bet Pļavnieku parks ir kļuvis par pirmo parku, kas izveidots Rīgas pilsētā pēdējo divdesmit gadu laikā. Veiksmīga Rīgas zaļā nekustamā īpašuma atjaunošana un izveide padarīs pilsētu pievilcīgāku un ērtāku iedzīvotājiem, uzņēmējiem un tūristiem. Plānotie un īstenotie Rīgas zaļo nekustamo īpašumu atjaunošanas pasākumi ir vērsti uz atpūtas, sporta un sabiedriskās dzīves aktivitāšu dažādošanu apzaļumotajās teritorijās, kā arī uz apkārtējās vides kvalitātes un drošības uzlabošanu. Pārdomāti un veiksmīgi izkārtotas apzaļumotās teritorijas ļaus pilsētas iedzīvotājiem un tās viesiem izbaudīt brīvdabas atpūtas aktivitātes un kultūras pasākumus dažādos Rīgas pilsētas nostūros. Ir svarīgi pieminēt, ka uzlabojot Rīgas esošo parku, dārzu un skvēru kvalitāti, kā arī izveidojot jaunus, apzaļumoto teritoriju pieejamība sabiedrībai tiks palielināta. Zaļo nekustamo īpašumu apsaimniekotājs centīsies uzlabot Rīgas pilsētas vidi un virzīsies tuvāk veselīgākas un ilgtspējīgākas dzīves telpas izveidei Ziemeļeiropā. Tādējādi, Rīgas pilsētai būs lielākas iespējas pieteikties prestižajam konkursam Eiropas Zaļās galvaspilsētas titula iegūšanai. Tas pamudinās Rīgas pilsētu ieguldīt turpmākos pasākumos un palielinās apzināšanos par zaļajiem nekustamajiem īpašumiem Rīgā, kā arī citās pilsētās. Šī titula iegūšana ļaus Rīgai iedvesmot citas Latvijas un Eiropas pilsētas un dos iespēju dalīties ar veiksmīgu pieredzi pilsētas vadīšanā. Tas ļaus Latvijas pilsētām un lielpilsētām mazināt to nelabvēlīgo ietekmi uz apkārtējo vidi radot jaunus zaļā nekustamā īpašuma elementus. Balstoties uz augstāk minētajiem secinājumiem, Rīgas domei ir ieteicams tās kompetences ietvaros veicināt ar apzaļumoto teritoriju saistīto jautājumu iekļaušanu visos pilsētattīstības plānos. Ir ieteicams atrast iespējas publiskā un privātā sektora partnerībai ekonomisko labumu, kuri gūti no apzaļumotajām teritorijām, veicināšanas jomā. Izglītības iestādēm ir ieteicams atbalstīt izglītību, kura paredz iemaņu un pieredzes iegūšanu reālajā vidē un masu mēdijiem veicināt sabiedrības apzināšanos par apzaļumoto teritoriju svarīgumu pilsētvidē. ◆

SUSTAINABLE DEVELOPMENT IN CONSTRUCTION: CONCEPTUAL MODEL AND LATVIA'S CASE STUDY

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ABSTRACT

Science and society, when facing the challenges caused by globalization of economy, devote more and more attention to the matters of sustainable development. Buildings and other construction products provide a material basis to ensure conformity of products manufactured by other economic sectors to the criteria of sustainable development. The society and scientists pay great attention to the outcome of the construction process, its technical, ethical and ecological conformity. Location of constructions, amount of building materials used in construction, their heat engineering and mechanical properties, operational consumption of energy resources, functional conformity of the layout of the premises and interior, and other features are used to evaluate a construction with regard to sustainability requirements. Up to now, less notice is given to matters of sustainable development of the building process both on micro and macro levels. Effective usage of the available resources by construction companies is the "backbone" of sustainable development process of the construction industry. In various phases of the economy development cycle not only the demanded volume and price of construction products are changing. In the period of economic growth, favorable conditions give construction merchants an ability to increase efficiency of the available resources used. That provides the economic and technical basis for competitiveness of construction companies, which is necessary to overcome economic recession caused demand and supply mismatch associated with the decrease in market equilibrium price. For the purpose of maintaining competitiveness in conditions of recession, businesses are forced to implement measures aimed at increasing the efficiency of resource use, which are at their disposal more actively, meeting the main conditions of sustainable development of the national economy.

Keywords — sustainable development; construction industry; efficiency measures; environment; conceptual model

INTRODUCTION

Studies on sustainable development of the construction industry focus mainly on the correspondence of the created construction product to specific sustainability criteria, at the same time failing to analyze in a sufficient detail the use of resources available to construction entrepreneurs as the most important aspect of correspondence of the construction product manufacturing process to sustainable development fundamentals on macro level. The definitions and models developed in this study make a clear distinction between the sustainable construction

process and the product created by this process, which must meet the sustainability criteria defined in the society. This approach is linked to the necessity of expanding the scope of research to cover the questions related to the correspondence of the construction process to the sustainable development guidelines and criteria on both micro and macro levels. Studying the situation in the construction industry in Latvia in the period from 2003 to 2010, intensive economic growth was observed, it was followed by a sharp recession with great changes in the efficiency parameters for the use of resources available to construction entrepreneurs. Rapid decline in the efficiency of resource use was observed in the construction industry. This trend is characteristic of a period of explosive economic growth, while it contradicts the fundamentals of sustainable development. As the recession set in, the efficiency of the use of resources available to construction contractors increased.

The results of the study clearly identify the need to pay greater attention to sustainable development issues on a macro level, allowing the government to develop and implement more efficient measures for developing social, economic and ecological processes in compliance with sustainable development guidelines and criteria, promoting increased efficiency of the use of resources available to a society and reducing the destructive impact of economic activity on the environment.

ENVIRONMENTAL IMPACT OF CONSTRUCTION AND INDUSTRY PRODUCED PRODUCTS

Researchers of environmental and construction processes have found out that environmental impact of construction and construction products is characterized by 37 various aspects, from continuous increase of built-up land area to waste created by constructions and degradation of the environment [1]. According to the study carried out by the US Department of Energy on the construction processes, operation and maintenance of the finished constructions consume 39% of the energy resources used in the country annually, 68% of electric power, 12% of water, and create 38% of the CO_2 emissions in the country [2]. In the United Kingdom various constructions produce about 50% of the state CO_2 emission volume, the constructions consume 50% of the total amount of water used in economic activity and produce 30% of solid waste. The construction industry utilizes 25% of the raw materials consumed in the national economy. 27% of the total CO_2 emissions in the country are produced at homes, and 73% from this amount come from home heating and water heating [3]. In order to reduce the destructive impact of constructions on the environment, scientific studies are conducted in the United Kingdom to find possible solutions in order to design the buildings, which would not emit CO_2 gas into the atmosphere, by 2016. The first experimental zero-carbon buildings, fully absorbing the created carbon dioxide, were built already in 2009 [4].

In different countries construction industry consumes 66% of saw timber cut down in forests, the industry exerts a lot of pressure on consumption of non-ferrous metals. The main worries are caused by increase in the consumption of zinc and copper in construction, as reserves of these materials are estimated to last only for the next 30 years. Amount of metals used annually for the construction needs vary from country to country and ranges from 1 to 8 tons per capita. Metal recycling and repeated use decrease metal consumption by 90% and enable saving up to 70% of the power that is necessary to manufacture the respective amount of metal from metallic ores [5]. About 1.3 billion tons of wastes are produced annually in the European Union, of which 510 million tons can be attributed to construction industry, i.e. 1.13 tons per capita and 1.03 tons per 1000 EUR of the manufactured production. In Latvia, 87% of the hazardous waste produced since 2002 is related to construction industry [6].

In comparison with ES-15 and other most developed countries of the world, the buildings that are built in Latvia have considerably lower power efficiency and the indices of destructive environmental impact are considerably higher. Thus, 5.2 thousand GWh of thermal energy were supplied to households in 2009, of which only 2.7 GWh, or 53.4% of the energy produced by boiler rooms, were used efficiently. Thermal energy losses in heating systems amount to 760.4 GWh, and 1.7 GWh of electric power is consumed inexpediently in households [7]. The utmost losses of thermal energy can be attributed to the low usage efficiency of the supplied energy in the majority of homes. Annual specific consumption of thermal energy in apartments and other types of residences built on the territory of Latvia ranges from 220 to 250 kWh/m^2, but this parameter does not exceed 60-120 kWh/m^2 in homes with high power efficiency [8]. Consumption of thermal energy in passive houses built in Finland is within 20-30 kWh/m^2. For multi-storey blocks of flats of conventional construction built in Finland the consumption of thermal energy does not exceed 70 kWh/m^2 [9]. Finland's experience in construction of power efficient homes convincingly proves that there are reserves for decreasing consumption of thermal energy in Latvia and in many other European countries.

SUSTAINABLE CONSTRUCTION AND EXPLANATION OF THE CONCEPT OF SUSTAINABLE CONSTRUCTION PRODUCT

For the purpose to improve environment protection and to maintain the ability of natural resources to renew, the conception of the so-called "sustainable development" is analyzed. Within this framework, more attention is paid not only to reducing the negative impact of production of various goods and the transport system on the environment, but also to optimization of consumption of goods and services and to increasing efficiency of the resource use. In the set of these measures, a significant role is played by sustainable construction and sustainable buildings. The uncertainty and contradictory nature inherent in the concept of sustainable development gives a favorable ground for wide discussions about sustainable existence and development of the construction industry and the products produced by the industry.

The international construction research organization "Conseil International du Batiment" [10] defines the concept "sustainable construction" in the following way:

"sustainable construction – a process of creating a building that is applicable for the specific purposes and that is environmentally friendly, in operation and management of which high efficiency of resource use is ensured". This definition does not take into account the competence of the construction contractor and the owner of the building in a sustainable building production and in the features of life-cycle of a sustainable building. In construction industry, unlike in other national economy sectors, unique products are produced. Those products completely correspond to the client's requirements that are included in the building's technical documentation. For that reason the above mentioned definition is largely referable to the concept of a sustainable building rather than sustainable construction.

The definition drawn up by the European Commission demonstrates unspecific and superficial approach to exposure of content of the concept of sustainable construction, indicating that "…sustainable construction can be defined as a dynamic of developers of new solutions, investors, the construction industry, professional services, industry suppliers and other relevant parties towards achieving sustainable development, taking into consideration environmental, socio-economic and cultural issues."[11]. The definition proposed by European Commission indicates that politicians are willing to lay responsibility for environment protection issues and achievement of socio-economic development objectives on the shoulders of entrepreneurs. Comparison of operating objectives of an entrepreneur to environmental, socio-economic and cultural development objectives demonstrates a formal approach to the issues of development of sustainable construction.

Considering the significance of the concepts of sustainable construction and sustainable building in development of the construction industry and the entire national economy, and for the achievement of the public socio-economic development goals, and the existing functional, economic, technical and legal differences between these concepts, the following definition of the concept of sustainable construction is proposed:

"sustainable construction is the process of design, placement, production and demolition of a construction product, which ensures conformity of the finished product to the criteria of sustainable development, technical documentation and other laws and regulations with regard to safety and harmlessness of the production process and the finished product, as well as high efficiency of using resources at one's disposal, and a possibly minimal impact on the environment".

The definition strictly differentiates the construction process from the further operation of the building after the construction process is finished and the buildings are transferred to its owner and user. In the definition it is taken into account that the construction industry is included in the regulated area of business activity, construction process sustainability requirements or criteria are set in the respective regulatory enactments.

Preconditions that are included in the project and regulatory enactments for a sustainable building to meet the functional requirements in accordance with the main conditions and criteria of sustainable development during its operation are developed in the construction process. However, it is the owner and/or the user of the building who is economically and ecologically responsible for continuous increase in efficiency of resource use, which are involved in operation and maintenance of a building. It is important to mark a borderline between the builder and the user of the building in the formulated definition of a sustainable building:

"sustainable construction product is a building, in production of which requirements of regulatory enactments are met with regard to safety and harmlessness of the production process, and the included constructive elements and technological solutions enable to ensure high efficiency of resource use and a minimal possible impact on the environment during operation and maintenance of the building, as well as it is in compliance with other criteria of sustainable development".

As it may be noticed, in the definition of a sustainable construction product, emphasis is made on the possibilities created in the construction process, which enable to use resources more effectively and safely with a minimum possible destructive impact on the environment. The requirements included in the definition are combined with other criteria of sustainable development that are changing along with changes in mechanical, physical and ecological properties of construction materials, construction technologies, environment condition and natural resource renewal ability [12]. Exactly the criteria of sustainable development that are included in the respective state regulatory enactments is one of the most relevant aspects in increasing power efficiency of the raised buildings and in implementing other conditions necessary for sustainable development in construction.

MODELS OF SUSTAINABLE CONSTRUCTION AND SUSTAINABLE CONSTRUCTION PRODUCT

Considering the above mentioned definitions, models of sustainable construction and construction products are developed, revealing the existing differences and the options to promote sustainable development of the national economy and the entire state. Taking into account that the general meaning of the concept "construction" includes the construction industry, the public authorities supervising the construction industry, construction entrepreneurs and nongovernmental builders' organizations within the framework of the study the focus is on construction as on a sector of the national economy and on a construction company as on a producer of construction products. In the development of the models, systemic approach is used to tackle sustainable development problems on a local, national, international and global level [12].

As it is shown on the model presented in Fig. 1, the basics of sustainable construction are formed by a national policy of sustainable construction development and the consequent criteria of sustainable development

of the construction industry. Up to now major attention in national construction policy is paid to technical conformity requirements that are included in various standards, construction regulations and other regulatory enactments. It is demonstrated in the model that the criteria of sustainable development of the construction industry take shape considering technical and occupational safety and ecological requirements of construction work. An efficient monetary and fiscal policy is added to them, as it enables the construction industry to retain sustainable development nature, avoiding unreasonably rapid growth and the recession following it. In this case, comparatively high conformity of the total increase in construction product and increase in demand is implemented in the framework of an effective monetary and fiscal policy, thus enabling to maintain slight price fluctuations for the produced construction products and stability of development of the industry.

Sustainable development criteria of construction process take shape considering the requirements that establish conformity of manufacturing process of construction products to technical, social, ecological and economic requirements shown in Fig. 2. These requirements are largely related to the sustainable development policy of the construction industry implemented by the state, and determination of a construction company to participate in processes that are aimed to continuous improvement of working conditions in construction, increase of efficiency of using resources at one's disposal, and retaining of ability of natural resources to renew.

As it may be seen in the model presented in Fig. 3, sustainable usage criteria of various buildings take shape on the basis of sustainable development policy of the national economy. These criteria apply to the possibilities to continuously update the used technologies and to increase efficiency of resource use in the economic activity processes that are performed in the respective building, as well as in operation, reconstruction, renovation and demolition of the respective building. That enables to increase production of goods and services using the resources at the disposal of the national economy subjects and the entire society. A significant criterion of a sustainable building is conformity of the working environment and microclimate to the human physiological requirements. It is aimed to reduce sickness rate of the people employed in construction, and to increase labor productivity and quality. The criterion "minimal influence on the environment" includes the requirements fixed by regulatory enactments regarding reduction of environmentally harmful gas emissions and other waste in operation and maintenance of a building, including construction waste that is produced when the respective building is demolished.

As follows from the models presented in the previous figures, the criteria set for the sustainable development of construction and construction business and usage of sustainable buildings are constantly changing, along with the changes in results of scientific research, development of engineering solutions and technologies, environmental conditions, and considering constantly changing requirements of the clients. With the help of feedback, these aspects and the changes that have taken place in them are included in the policy of sustainable development of the national economy and construction industry in order to timely make the necessary changes in regulatory enactments and to make corresponding corrections in the national monetary and fiscal policy.

Further in the study the main attention is devoted to sustainable development of the Latvian construction industry in relation to changes in efficiency of resource use that are at the disposal of entrepreneurs working in the industry, the trends of these changes in the period of rapid growth and economic recession.

POSITIVE AND NEGATIVE SIDE EFFECTS OF SUSTAINABLE CONSTRUCTION

Experience in sustainable construction development and operation of buildings constructed in accordance with the sustainable development criteria collected from several most advanced countries in the world allows us to make a number of fundamental conclusions in favor of this new trend in construction development. Considering the broad range of sustainable construction development criteria and the extensive spectrum of its effects, in many developed countries such buildings are certified using the U.S. certification system Leadership in Energy and Environmental Design, or LEED. This system includes comprehensive technical, ecological and financial auditing of the building to make sure that the result of the certification process corresponds to one of the 4 types of certificate: basic, silver, gold or platinum. The LEED system evaluates 39 criteria with a maximum of 69 points. The building evaluation is divided into the following categories [13]:

- Correspondence of the location of the building to sustainable development of the environment and the building;
- Efficiency of water use within the building;
- Efficiency rate of energy source use in operation and maintenance of the building;
- Air pollution during the maintenance of the building;
- Safety, non-hazardousness of construction materials used, their impact on the environment, efficiency of resource use during operation and maintenance of the building;
- Microenvironment quality inside the building;
- Applied innovative solutions in the building design, construction, operation and maintenance.

In a 2006 study of a large number of various educational, scientific and health care buildings, the U.S. scientists concluded that the costs of buildings meeting the sustainable development criteria are 0.7 to 6.5% higher than those of conventional buildings with similar functionality. A number of cases were established among the buildings inspected where conventional buildings turned out considerably more expensive than green buildings [14]. A group of companies in the U.S. that devoted attention to sustainable buildings, updating their interior facilities and design to ensure an optimal microclimate for people's health, has managed to save around 250 million

USD in a year. This economic effect was achieved due to increased productivity and quality of work [15].

Studies have shown that the increase in expenses of sustainable building construction differs among countries. In New Zealand, it varies from 2 to 6%; in the United Kingdom, from 4 to 10%; in Australia, from 50 to 204% [16]. An important factor is the reduced power consumption by green houses, which ranges from 35 to 50%. A considerable socioeconomic effect is achieved by properly adjusting indoor microclimate of the buildings. Within retail spaces, where artificial lighting is replaced with sunlight coming through the roof, the sales may increase by 35-40% [17]. Interesting data were obtained regarding the impact of daylighting on the operation of educational institutions. Inside school classrooms where children studied under natural light, math scores grew by 20% and reading skills improved by 26% compared to classrooms where schoolchildren were exposed to artificially lit environment [18].

Sustainable buildings constructed within the European Union allow savings of 3-6 billion euros per year due to 8-25% reduction in episodes of allergy and asthma. Thanks to purposeful reconstruction and renovation works, the syndromes characteristic of "sick buildings" have been reduced by 20-50%: this promotes higher productivity, increasing production by 15-45 billion euros per year. As a result of improvements in work environment and microclimate, the productivity of employees within commercial spaces and industrial structures increased by 0.5 to 5%, providing an economic effect of 30-240 billion euros per year [11]. By 2030, the European Union intends to reach ambitious milestones in sustainable construction. These plans involve reducing energy intensity for construction materials by 30% and reducing production waste by 40% in industries producing construction materials. It is planned to reduce power consumption in operation and maintenance of the buildings by an average of 50%. The technologies available at that time will allow producing the power consumed by those buildings without generating CO_2 [19].

As it may be observed in the European Union and in other developed countries, the sustainable development criteria have been disseminating quickly, annually increasing these countries' output of construction materials that comply

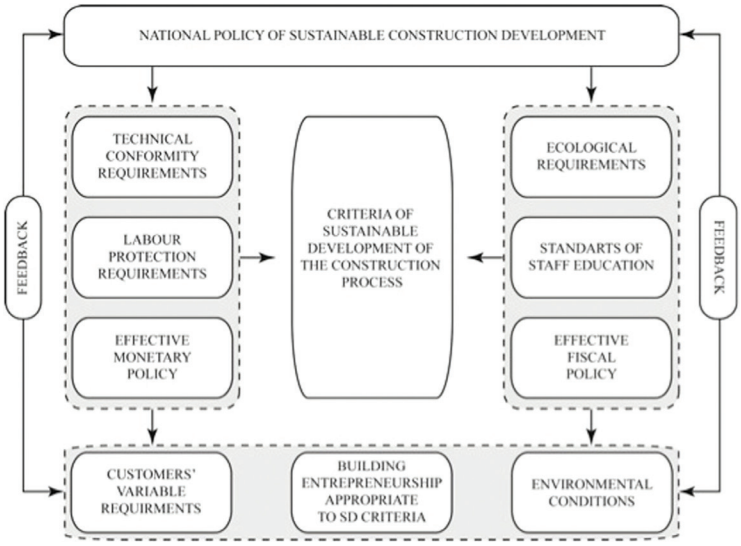

Fig. 1.

Functional model of sustainable development of the construction industry (abbreviations: SD - Sustainable Development)

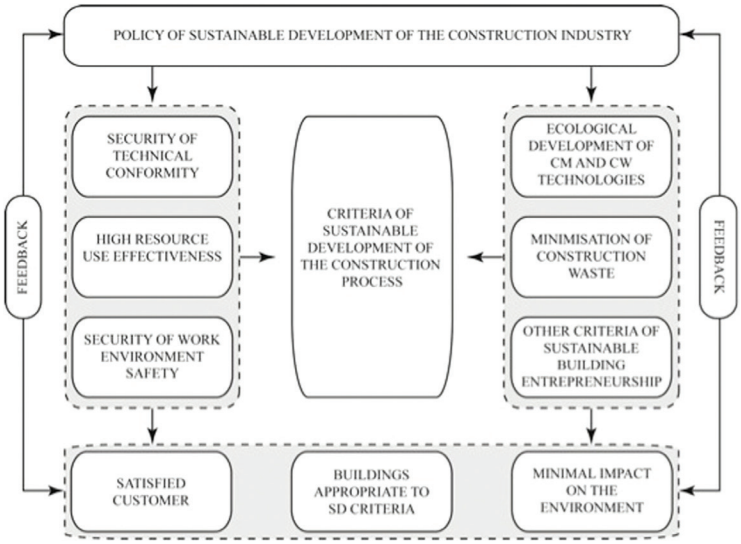

Fig. 2.

Functional model of sustainable development of the construction process (abbreviations: SD - Sustainable Development; CM - Construction Materials; CW - Construction Work)

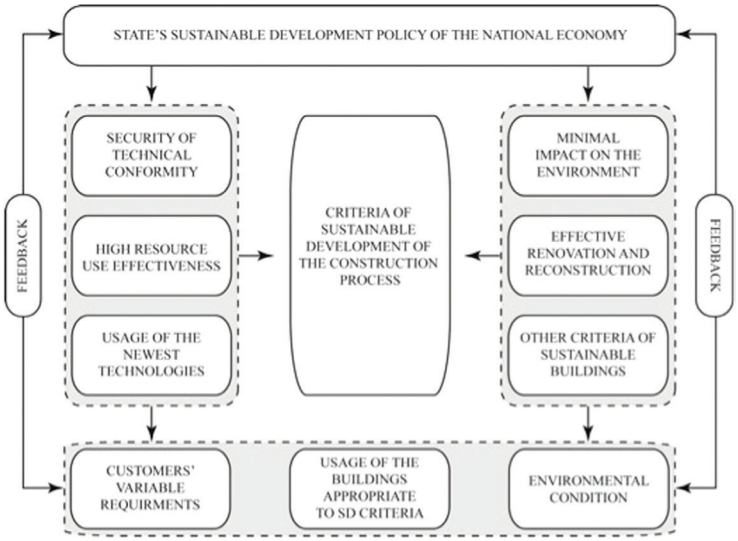

Fig. 3.

Functional model of sustainable development of the construction process (abbreviations: SD - Sustainable Development)

with the sustainable development guidelines. An understanding of the causes and consequences of positive and negative side effects of sustainable construction allows each entrepreneur and member of the public to comprehend their role in promoting sustainable development of construction and the entire country.

CHANGES IN EFFICIENCY OF RESOURCE USE DURING RAPID ECONOMIC GROWTH AND IN CONDITIONS OF RECESSION

The following part of the study is devoted to the most significant aspect of sustainable construction development – changes in the efficiency of usage of available resources in Latvia. A unique situation was observed in the national economy during the last 5-7 years. In the period from year 2004 until year 2008, the value of the goods and services produced in the country increased 2.2 times, but the amount increased only by 30.7% [20], assuming that no fundamental changes in the range of the produced goods and services happened at this time.

The most dynamic changes in the period of time from year 2003 until 2010 took place in the construction industry, causing sharp changes in the efficiency of resource use at the disposal of the entrepreneurs working in the industry. The statistical data and calculation results characterizing the period of rapid growth and recession are presented in Table 1.

Growth of the Latvian national economy in the period of time from 2003 until 2007 was characterized by an unprecedented increase dynamics. Intensity of increase of the value of goods and services produced in the state in the actual prices in this period increased from 11.0% in 2003 to 32.5% in 2007. In the comparative prices the GDP increase is considerably lower, 7.2% and 12.2% in 2003 and 2006 respectively. Recession in the national economy started in 2008 when the volume of the production decreased by 4.2%. Top recession intensity in the national economy was reached in 2009 when the volume of production and product taxes in the actual prices decreased by 19.2%, but in comparative prices – by 18.0%. To evaluate the intensity of fluctuation, fluctuation range index is used – on the level of national economy it reaches 51.5%, which is the highest result in the entire European Union[21] and does not correspond with the basic conditions of sustainable development on macro level [12].

The unprecedented fast increase of internal demand sharply increased profitability in several business sectors and caused resonance of demand in various national economy sectors, increasing demand for construction products and the following supply. Already in 2004, production intensity of the construction product evaluated in the actual prices increased nearly twice compared to 2003, reaching 20.8%, although in the actual prices the increase intensity remained at the level reached in the previous year. The sharpest increase rate was recognized in 2006 and 2007 when the construction product in the actual prices increased by 47.9% and 62.1% respectively, but in the comparative prices – by 21.5% and 15.7%. Therefore, intensity results of the Latvian construction industry beat the growth rate registered in the European Union [21, 22, 23]. The rapid growth was followed by recession of similar nature, which reached its culmination in 2009, when the produced construction product in the actual prices decreased by 40.4%, but in the comparative prices – by 33.6%. Recession trends in the construction industry lasted also in 2010, as the produced construction product volume decreased by 27% and in terms of value by 24%, considerably surpassing the intensity of recession in other national economy sectors in 2010 [20].

Higher rate of increase in production of a construction product in the period of rapid growth was caused by the increasing mismatch between the total demand and supply of construction product. Construction companies, unable to offer the volume of the construction product in demand, raised the sale price, thus ensuring parity between demand and supply. For the maintenance of market balance in the period of time after 2003, price increase of the produced goods facilitated sharp increase in profit of construction entrepreneurs, creating favorable conditions to increase labor productivity and efficiency of using the assets of construction companies. The figures included in Table 2 demonstrate how these favorable conditions were used so that Latvian construction companies could incorporate in their operation the most significant condition of sustainable development and could increase efficiency of using the resources at their disposal.

Volume of resources at the disposal of the entrepreneurs working in the construction industry in 2010 was foreseen by use of statistical data on decrease of resources in 2009 and considering the correlative relation of resources with quantitative changes in the produced construction product. In the calculations of efficiency of resource use at the disposal of entrepreneurs, the negative effect of price increase on efficiency of resource use is reduced to the utmost, but figures of efficiency of construction material use and fixed asset use are affected by structural changes in these resource groups and qualitative changes in content of the construction product.

As follows from the figures presented in Table 2, the resource use efficiency figures included in assets are decreasing as the production intensity of the construction product increases. The efficiency of fixed asset use that are included in the fixed assets and other long-term investments shows a negative increase rate value already in 2003, decreasing by 4.1% in comparison with the level reached in 2003. In the further years of rapid growth, the efficiency of the capital use, being at the disposal of entrepreneurs continues declining, reaching the sharpest decrease of 20.1% and 13.5% in 2005 and 2007 respectively. Along with the recession, capital use efficiency starts to rise gradually. A similar trend, with a more dynamic intensity, can be observed in changes of efficient use of construction materials and other current assets. Already in 2003 this figure declines by 18.7% compared to the previous year level. In the following 2 years, the calculated values in the comparative prices of construction production to produce a unit, value of the utilized construction materials and other current assets in the prices of 2000 sharply increases and in 2005 the increase rate reaches 31.5%. In the following 2 years the

Showing	Changes in intensity of increase of results by years – %								Fluctuation range – %
	2003.	2004.	2005.	2006.	2007.	2008.	2009.	2010.	
GDP in the actual prices	11,02	16,29	21,85	23,32	32,30	9,53	-19,18	-1,50	51,48
GDP in the comparative prices	7,19	8,68	10,60	12,23	9,98	-4,24	-17,95	-1,25	30,19
CP in the actual prices	11,67	20,76	26,64	47,92	62,09	11,26	-40,36	-24,00	102,45
CP in the comparative prices	13,72	13,33	15,46	21,50	15,73	-2,62	-33,57	-27,00	55,07

(abbreviations: GDP - Gross domestic product; CP - construction product)

Table 1.

Period of Rapid Growth and Recession in the Latvian Economy

Figures used in construction	Intensity of changes in resource usage efficiency figures by years – %								Fluctuation range – %
	2003.	2004.	2005.	2006.	2007.	2008.	2009.	2010.	
Fixed assets and other long-term investments	-4,1	-15,4	-20,1	-9,6	-13,5	3,8	6,8	0,5	26,9
Construction materials and other current assets	-18,7	-25,2	-31,3	-23,1	-9,0	7,5	35,5	17,3	66,8
Total assets	-13,7	-22,1	-28,1	-19,7	-10,2	6,5	26,4	11,4	54,5
Labor	-7,83	-2,86	10,74	5,83	-4,26	-2,55	10,14	5,26	18,57

Table 2.

Changes in Efficiency of Using in Construction During Rapid Growth and Recession

intensity decreases, but efficiency of using construction materials continues to decrease. Only upon recession, in 2008 this figure starts to improve by 7.5%, reaching the top value of 35.5% in 2009.

Considering the absolute limitedness of labor force supply and the hard working conditions in construction industry, one of the most important figures in sustainable construction development is increase in labor productivity, which, in its turn, enables to increase the physical volume of the manufactured construction products within a time unit, thus reducing the total production time. As it may be observed from the figures presented in Table 2, changes in labor productivity are of sharply changing character, but the common trend remains the same – as the intensity of the produced construction product increases, the labor productivity decreases. Already in 2003 when the volume of the construction products in comparative prices increased by 13%, labor productivity changed in the opposite direction, decreasing by 7.8%. Even though in 2005 labor productivity returns to the level of 2001 and surpasses it in 2006 by 6% [20], in the following years it decreases again by 4.3% and 2.6% respectively. The positive changes in labor productivity are observed as the recession grows deeper in 2009 when labor productivity surpasses the level of 2001 by 7%, and this trend lasts also in 2010.

CONCLUSIONS

The conducted research on the sustainable development trends of the construction industry in terms of resource usage in the period of rapid economic development and in conditions of recession leads to the following conclusions:

- Studies on the sustainable development of the construction industry focus mainly on the analysis of the conformity of the created construction product to the specific sustainability criteria. At the same time the use of resources available to construction entrepreneurs as the most important aspect of correspondence of the construction product manufacturing process to the main conditions of sustainable development on macro level is not studied in a sufficient detail;
- The definitions and models developed within the study clearly differentiate between the process of sustainable construction and the product manufactured in this process, which must correspond to the criteria of sustainable development established in the society. Such an approach is conditioned by the necessity to expand the research on the issues that are related to conformity of construction process to the basic principles and criteria of sustainable development both on micro and macro level.
- In the period from 2003 until 2010, the intensive economic growth in the Latvian national economy was observed. It was followed by the rapid recession, which was accompanied by sharp changes in the usage efficiency indices of the resources at the disposal of construction entrepreneurs. The period of rapid growth of the economy in construction industry is characterized by sharp decrease in efficiency of resource use, which comes into contradiction with the basic principles of sustainable development. As

recession sets in, usage efficiency of the resources at the disposal of construction entrepreneurs starts to increase. ;

Results of the study clearly indicate the necessity to pay more attention to sustainable development issues on macro level, which would enable governments of the countries with different development levels to develop and implement more effective measures to ensure conformity of socio-economic and ecological processes to the basic principles and criteria of sustainable development, thus promoting the increase in the efficiency of resource use, which are at the disposal of the society and lessening the destructive impact of economic activity on the environment.

REFERENCES

1. Gangolells, M. A methodology for predicting the severity of environmental impacts related to the construction process of residential buildings. *Building and Environment,* 2010, vol. 45, N 3, p. 766-775.
2. *Energy Efficiency Trends in Residential and Commercial Buildings* [Online]. US department of Energy, August 2010 – [Accessed 05.05.2011.]. Available: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/building_trends_2010.pdf
3. *Strategy for Sustainable Construction* [Online]. UK HM Government, June 2008 – [Accessed 05.05.2011.]. Available: http://www.bis.gov.uk/files/file46535.pdf
4. *Zero Carbon home unveiled in Kent* [Online]. guardian.co.uk, February 2009 – [Accessed 05.05.2011.]. Available: http://www.guardian.co.uk/environment/gallery/2009/feb/18/grand-designs-crossway-eco-home-kent
5. *Building construction, the environment and recycling* [Online]. [Accessed 05.05.2011.]. Available: http://www.reciclagem.pcc.usp.br/ingles/td%20paper1.htm
6. *Waste Generated and Treated in Europe 1995-2003* [Online]. European Commission, Eurostat, October 2005 - [Accessed 05.05.2011.]. Available: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-69-05-755/EN/KS-69-05-755-EN.PDF
7. Vanags, J., Ņevoļskis, S. Perspectives for Building Sustainable Apartments in Latvia. In: *International Scientific Conference "Economic Science for Rural Development". Sustainability – Integrated and Sustainable Development; Home Economics and Sustainable Consumption.* Jelgava, Latvia, April 23-24, 2009. Scientific proceedings. Jelgava, 2009, p. 191. – 201.
8. *Enerģētikas attīstības pamatnostādnes 2007. - 2016.gadam* [Online]. Valsts kanceleja, August 2006 - [Accessed 05.05.2011.]. Available: http://polsis.mk.gov.lv/view.do?id=2017
9. *Multi – storey Building – Finish Passive House?* [Online]. 2008 – [Accessed 05.09.2010.]. Available: http://www.passivhusnorden.no/foredrag/Session%201%20-%20Olav%20Trygvason%20-%202%20april%20-%201300/VTT_MERA_PassivHusNorden310308final.pdf
10. Kibert, C.J. S*ustainable Construction: Green Building Design and Delivery.* 2-nd red. New Jersy: John Wiley & Sons, 2008. 423 p.
11. *Accelerating the Development of the Sustainable Construction Market in Europe* [Online]. European Commission: Report of the Taskforce on Sustainable Construction, 2006 – [Accessed 05.05.2011.]. Available: http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/files/construction_taskforce_report_en.pdf
12. Vanags J., Geipele, I., Mote, G. Sustainable Development: the New Approach Inquiry. In: *The 6th International Scientific Conference "Business and Management 2010. Vilnius, Lithuania, May 13-14, 2010.* Selected Papers. Volume I. Vilnius Gediminas Technical University Publishing House "Technika", 2010, p. 518–528.
13. *The Costs and Financial Benefits of Green Buildings. A Report to California's Sustainable Building Task Force* [Online]. The U.S. Green Building Council, October 2003 – [Accessed 05.05.2011.]. Available: http://www.usgbc.org/Docs/News/News477.pdf
14. *The Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption* [Online]. Davis Langdon, July 2007 – [Accessed 05.05.2011.]. Available: http://www.davislangdon.com/upload/images/publications/USA/The%20Cost%20of%20Green%20Revisited.pdf
15. *Is Your Office Killing You?* [Online]. Bloomberg Businessweek, June 2000 - [Accessed 05.05.2011.]. Available: http://www.businessweek.com/2000/00_23/b3684001.htm
16. *Value Case for Sustainable Building in New Zealand* [Online]. New Zealand's Ministry for the Environment, February 2006 - [Accessed 05.05.2011.]. Available: http://www.mfe.govt.nz/publications/sus-dev/value-case-sustainable-building-feb06/value-case-sustainable-building-feb06.pdf
17. Windows and Offices: A Study of Office Worker Performance and the Indoor Environment – CEC PIER 2003 [Online]. Heschong Mahone Group, Inc., 2003 - [Accessed 05.05.2011.]. Available: http://www.h-m-g.com/projects/daylighting/summaries%20on%20daylighting.htm
18. *Daylighting in Schools. An investigation into the relationship between daylight and human performance* [Online]. Heschong Mahone Group, Inc., August 1999 - [Accessed 05.05.2011.]. Available: http://www.coe.uga.edu/sdpl/research/daylightingstudy.pdf
19. *Strategic Research Agenda for the European Construction Sector Achieving a sustainable and competitive construction sector by 2030* [Online]. European Construction Technology Platform (ECTP), December 2005 – [Accessed 05.05.2011.]. Available: http://cordis.europa.eu/technology-platforms/pdf/ectp2.pdf
20. *Latvijas Statistikas datu bāze* [Online]. Latvia's Central Statistical Bureau, [Accessed 05.05.2011.]. Available: http://www.csb.gov.lv/csp/content/?cat=355
21. *The EU-27 construction sector: from boom to gloom* [Online]. European Commission, Eurostat, July 2010 - [Accessed 05.05.2011.]. Available: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-10-007/EN/KS-SF-10-007-EN.PDF
22. *Quaterly Panorama of European Business statistics 3-2008* [Online]. European Commission, Eurostat, March 2008 - [Accessed 05.05.2011.]. Available: http://www.uni-mannheim.de/edz/pdf/eurostat/08/KS-DL-08-003-EN.PDF
23. *Europe in Figures Eurostat Yearbook 2010* [Online]. European Commission, Eurostat, March 2008 - [Accessed 05.05.2011.]. Available: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/CH_04_2010/EN/CH_04_2010-EN.PDF

KOPSAVILKUMS

Veiktais pētījums par būvniecības industrijas ilgtspējīgas attīstības tendencēm resursu izmantošanas

izteiksmē ātras ekonomiskās attīstības periodā un recesijas apstākļos noved pie šādiem secinājumiem:

- Pētījumi par būvniecības industrijas ilgtspējīgu attīstību galvenokārt ir vērsti uz radīto būvniecības produktu un specifisko ilgtspējības kritēriju savstarpējās atbilstības analīzi. Tajā pašā laikā būvniecības uzņēmējiem pieejamo resursu lietojums, kā vissvarīgākais būvniecības produktu ražošanas procesa un ilgtspējīgas attīstības galveno nosacījumu atbilstības makro līmenī aspekts nav pētīts pietiekami detalizēti.
- Pētījumā formulētās definīcijas un izveidotie modeļi acīmredzami atšķir ilgtspējīgas attīstības procesu no šajā procesā radītā produkta, kuram jāatbilst sabiedrībā noteiktajiem ilgtspējīgas attīstības kritērijiem. Šādu pieeju nosaka nepieciešamība paplašināt to problēmu izpēti, kuras saistītas ar būvniecības procesa atbilstību ilgtspējīgas attīstības pamatprincipiem un kritērijiem gan mikro, gan makro līmenī.
- Laika periodā no 2003. gada līdz 2010. gadam tika novērota Latvijas tautsaimniecības intensīva ekonomiskā izaugsme. Tai sekoja strauja recesija kopā ar krasām izmaiņām būvniecības uzņēmējiem pieejamo resursu lietderīgas izmantošanas koeficientos. Straujas ekonomiskās izaugsmes periods būvniecības industrijā tiek raksturots ar strauju resursu lietderīgas izmantošanas samazinājumu, kas ir pretrunā ar ilgtspējīgas attīstības pamatprincipiem. Iestājoties recesijai būvniecības uzņēmējiem pieejamo resursu lietderīga izmantošana sāk palielināties.

Pētījuma rezultāti acīm redzami norāda uz nepieciešamību pievērst vairāk uzmanības ilgtspējīgas attīstības problēmām makro līmenī, kas ļautu dažādu attīstības līmeņu valstu valdībām attīstīt un ieviest efektīvākus mērus, lai nodrošinātu sociālekonomisko un ekoloģisko procesu atbilstību ilgtspējīgas attīstības pamatprincipiem un kritērijiem, tādējādi veicinot sabiedrībai pieejamo resursu lietderīgas izmantošanas pieaugumu un samazinot ekonomisko aktivitāšu kaitīgo ietekmi uz vidi. ◆

INSTITUTE OF HEAT GAS AND WATER TECHNOLOGY

- Department of Heat and Gas technology
- Department of Water technology

BIOTECHNOLOGY FOR CONVERTING WASTE TO ENERGY

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The decrease in global fossil fuels and increasing cost of energy has facilitated the developments in the production of energy from various sources of biomass. To address these global challenges our research is focusing on developing technologies for converting wastes (agriculture, food, wastewater etc.) to energy and fuels. Currently we are running two projects on these issues. In one we develop a new technology to convert agriculture wastes such as grass to fuel, in the second we develop a technology for converting wastes from milk industry to biogas.

BIOFUELS FROM AGRICULTURAL WASTE

During the past decades, the production of ethanol from high-energy crops, starch, lignocellulose and agricultural waste, and the subsequent introduction of ethanol into gasoline has become a common practice. However, the application of vethanol in biofuel still has limitations due to its corrosivity and relatively low blending rate with gasoline. Research in alternative fuels has shown that butanol can be regarded as more advantageous due to its higher energy content, higher blending rate with gasoline and lower corrosivity which enables its transportation via pipelines. Moreover, butanol is naturally produced during the growth of genus *Clostridium* bacteria as a part of acetone-butanol-ethanol (ABE) fermentation where simple carbon sources, like glucose, are converted to valuable fuel. The technology has been known for decades. However, the application of low energy content, readily non-fermentable materials such as lignocellulosic biomass for the biobutanol production is still a challenge. Lately, particular attention in the global biofuel production has been paid to the use of those materials which cannot be used as food.

In the project "The production of a new generation of biofuel – biobutanol from agricultural waste" we have worked on development of simple, environmentally friendly approaches to obtain fermentable sugars from materials not intended for food, for example, hay, algae and agricultural waste, like weeds and giant hogweed (Fig.1).

The technology to release fermentable sugars has been optimized for full scale plants and various high energy and unsafe techniques (steam explosion, acid or base hydrolysis) have been replaced with more simple ones, like, simple boiling and enzymatic disruption of lignocellulosic structures (Fig.2). Moreover, we have worked on obtaining the enzymes from various naturally growing fungi to decrease the manufacturing costs.

Production of biobutanol during ABE fermentation strongly depends also on the potential of the producer-strain and fermentation conditions (T, pH, growth medium). Project research involved the studies on Clostridium efficiency to utilize various hexoses, pentoses, disaccharides and oligosaccharides with and survival during the solvent formation (Fig.3).

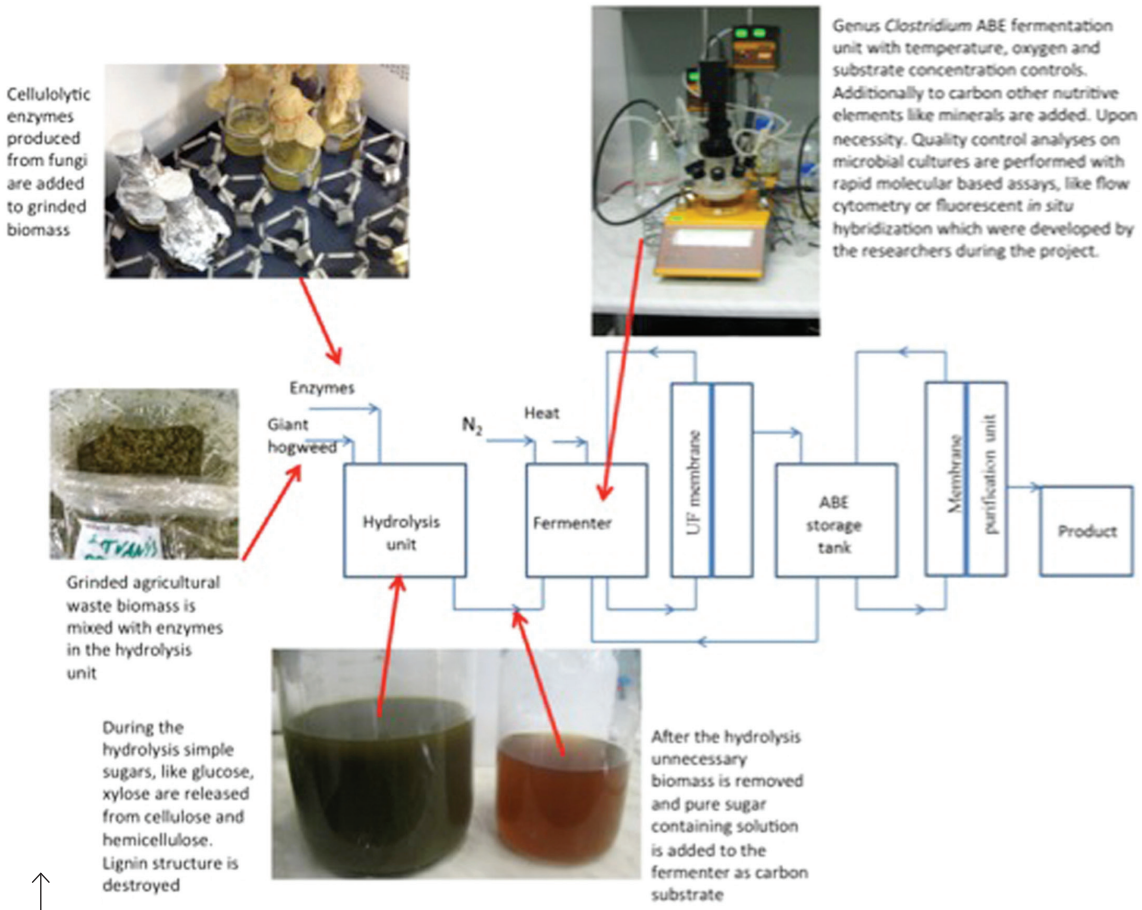

Fig. 1.
Principal scheme for biobutanol production from agricultural waste.

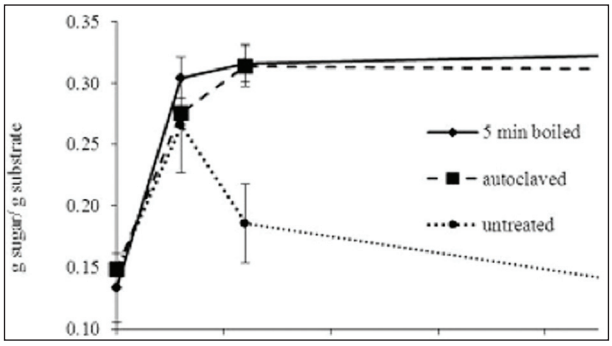

Fig. 2. →
The research has shown that simple boiling before enzymatic hydrolysis releases the same concentration of sugars from giant hogweed as autoclaving in high pressure and elevated temperature for 15 minutes. Source: Latvian Journal of Chemistry, No 4, 2012, 407–414.

In the final stage of the project the prototype of the technology will be developed and the technology will be tested in close to full-scale conditions.

BIOGAS FROM WHEY

The interest and demand for novel renewable energy sources, in particular the production of biogas from agricultural and food industry waste is growing all over the world.

Our group is involved in the research on biogas production from various agricultural and dairy industry waste products. Anaerobic conversion of organic matter into methane and carbon dioxide is a complicated sequence of biochemical reactions involving various microbial species. Thus, the stability and efficiency of the process is controlled by the application of different analysis methods – microscopy (FISH, DAPI, see Fig.4), HPLC, analysis of fatty acids and various elements (such as inorganic carbon and nitrogen) and the analysis of the biogas produced. In addition research on biogas clean-up and enrichment, configuration of reactors and improvement of the inocula

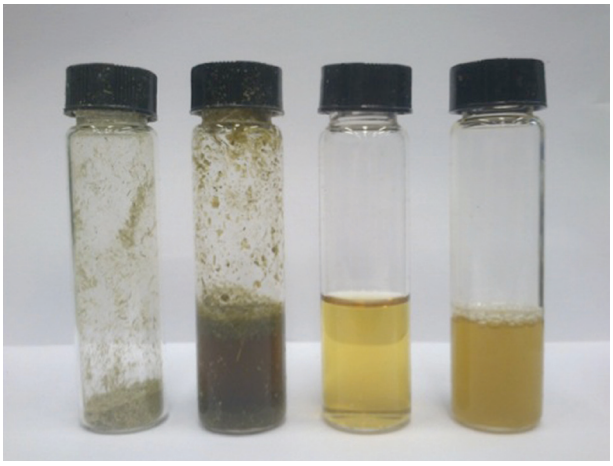

Fig. 3.
Laboratory scale biobutanol production from the grinded biomass (far left), hydrolysed substrate (second from the left) and sterile sugar (third from the left) to biobutanol containing solution (right).

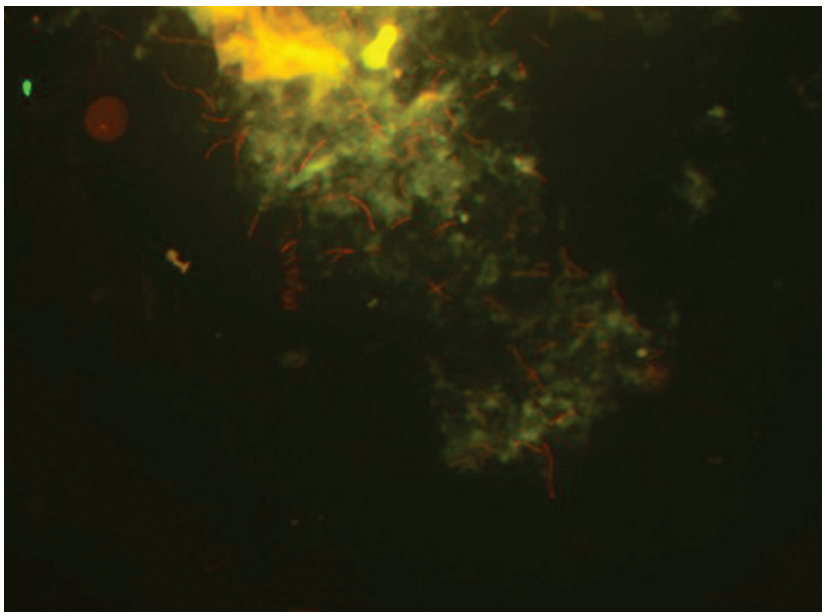

Fig. 4.
Biomass (archaea – red, bacteria – green) for converting whey to biogas

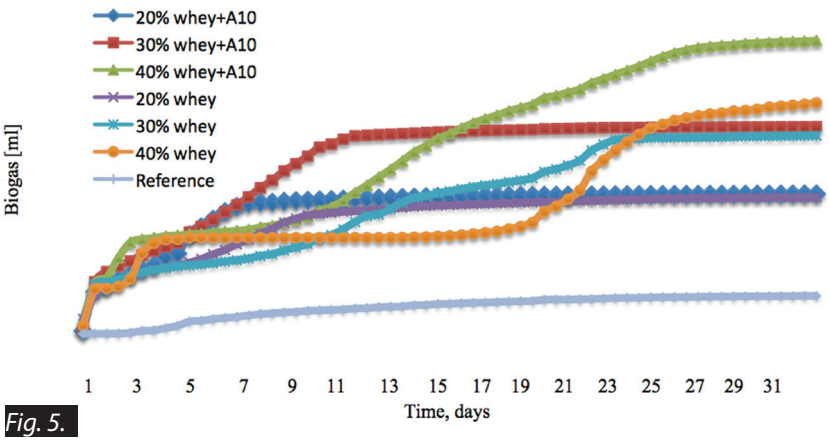

Fig. 5.
The production of biogas with and without the alkaline material (A10) in the presence of various organic loads.

is ongoing.

Current project involves the use of acid whey which is a waste product from cottage cheese production for the production of biogas. The amount of acid whey generated is increasing with every year all over the world. 90 000 t acid whey was generated in Latvia in 2010. Regardless that this material contains high concentration of lactose (4-4,5%), proteins, minerals and other useful elements it is currently non-profitable to process the whey further. Thus, acid whey is considered to be one of the substantial streams of dairy waste.

Due to the high energy value whey is an advantageous substrate for anaerobic fermentation. It is, however, characterized by high organic loading rate, low pH and low buffering capacity which renders this substrate as problematic for use. However, by ensuring the stability of the system and application of correct type of processing, pH correction and supporting the buffering capacity of the system, it is possible to obtain high biogas production rate. Following the optimization of process using 0.4 and 6 L fermentors a prototype with the volume of 100 L is currently being set up to be tested in a dairy industry plant.

In cooperation with Institute of Materials and Constructions research regarding the application of novel immobilizing materials for anaerobic processes is in progress with particular attention to the pH correction and maintenance while fermenting acidic substrates.

Several concentrations of acidwhey (20, 30, 40%) were used to test the capacity of alkaline material to improve the biogas production in batch reactors. The results show that with all the concentrations the addition of material improves the production of biogas, in particular, in the presence of high organic loads (Fig.5).

Within the project a novel approach was developed to deal with the problem of acidification in the fermentation process. As the outcome, a new type of bioreactor will be produced which will enable to carry our fermentation of the whey without the addition of alkaline solution.

KOPSAVILKUMS

Visā pasaulē ļoti strauji pieaug interese un pieprasījums pēc jauniem atjaunojamās enerģijas avotiem, īpaši izceļot biogāzes ražošanu no dažādiem lauksaimniecības un pārtikas atkritumproduktiem.

RTU ŪITK tiek veikti pētījumi par dažādu piensaimniecības un lauksaimniecības atkritumproduktu izmantošanas iespējām biogāzes un degvielas ražošanā ar biotehnoloģijas metodēm. Tā kā anaerobā organisko vielu degradācija metānā un oglekļa dioksīdā ir komplicēta bioķīmisku reakciju virkne, kurā ir iesaistīti dažāda veida mikroorganismi, procesa stabilitātes un efektivitātes nodrošināšanai tiek izmantots plašs dažādu metožu un iekārtu klāsts – mikroskopija (FISH, DAPI), šķidruma hromatogrāfija, taukskābju un dažādu elementu (piemēram, neorganiskā oglekļa, slāpekļa), biogāzes analīze u.t.t. Kā arī tiek pētīti dažādi risinājumi, piemēram, biogāzes attīrīšanā un bagātināšanā, reaktoru konfigurācijās, pieejamo ieraugu uzlabošanā u.tml.

Biodegvielas - biobutanola ražošanai no lauksaimniecības atkritumiem mēs izstrādājām lignocelulozes hidrolīzes metodi, kurā izmanto sēņu enzīmus. Pētījumu laikā tika analizēta dažādu lauksaimniecības atkritumvielu (nezāles, latvāņi) pielietojamība fermentācijas procesā biobutanola iegūšanai. ◆

RTU SUCCESS STORIES

Interview with Antons Adamovičs – CEO of Conelum, Ltd.

Antons Adamovičs
CEO, Conelum
www.conelum.com

Conelum is a company registered in Latvia and is an RTU spin-off, which was founded in 2012. Our team consists of two scientists – Tālis Juhna and Linda Mežule, both of them are outstanding professionals.

The development of EloKIT project began much earlier; scientists had been working on this method for about 10 years, initially with the help of technology they were detecting the presence of micro-organisms in the water. The method is an innovation in the field of microbiological detection, which allows obtaining accurate qualitative and quantitative information in the time period from 30 minutes to 6 hours (depending on the micro-organism), rather than within 24 hours as it is implemented currently by means of Petri dishes.

By exploring the market, we have realized that the technology is of great interest to the food industry, particularly to the companies whose products – meat and dairy products – have a limited period of shelf life. We have met with representatives of many companies operating in the food industry in Russia, Lithuania, Estonia, and Latvia; and our technology has received positive feedback from these companies.

At the end of July we will complete the work on the investment application, and also we intend to establish cooperation with Lithuanian and Russian major processing enterprises.

Cooperation with RTU began in a commercialization reactor – a site where scientists meet entrepreneurs to establish joint ventures. Scientists do not have time for business, so that the task of entrepreneurs is to focus on the commercialization of technology and probably on the acquisition of a larger market share.

Being a biologist myself, I have realized that the project is very close to me; besides, I have obtained education in innovative business development at Skolkovo Startup Academy, so I know how it all works and what to do. Yet we are a small team – 5 people, but as we orient to export, in the course of time certainly a lot more people will be involved.

I appreciate cooperation with RTU, here I have got acquainted with the people with whom I like to work, and I do not rule out the possibility that in the future I may establish another start-up. I am confident that RTU corresponds to the expression 'scientific excellence'. Relations between the university and enterprises have the greatest future especially in Latvia, because in scientific research large amounts of money should be invested that the university can attract to a variety of grants; also human resources with a high level of scientific expertise are involved. The other side is idea commercialization that must be implemented by entrepreneurs. Scientists and entrepreneurs should work together to form joint spin-offs, because this is the future.

RTU Vice-Rector for Research comments on the cooperation, "Signing of the contract is the proof that we are able to create high-quality scientific ideas and the university can successfully participate in the commercialization process. The technology itself is half way to success; a lot of work must be carried out to develop a product in order to meet market requirements, in this process we have realized that it is not always possible to commercialize scientific ideas in the way it has been originally intended; moreover, everything depends on a business approach. I express my sincere gratitude to the Innovation and Technology Transfer Centre of RTU for the support and substantial work undertaken in order to implement the project". ◆