Riga Technical University
Institute of Energy Systems and Environment

Abstract Book

Riga – 2013

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The system's resilience within the infrastructure dimension: a new concept and schematic algorithm for choosing the best recovery strategy

Tatjana Kuzņecova, Francesco Romagnoli, Claudio Rochas, *Riga Technical University*

Abstract – **This study provides the development of a new methodological approach of resilience assessment within the infrastructure sector and the selection of the most effective restoration strategy of a networked infrastructure system, utilizing both quantitative and qualitative methods of assessment. This new methodology was summarized into a general algorithm and applied to the district heating piping system for the city of Salaspils (Latvia).**

This study also comprehends the main aspects to be considered when using the specific resilience metric as a function of time and involving economic components.

Keywords **– Resilience, network analysis, system's functionality, recovery time.**

I. Introduction

The term "resilience" is a relatively new notion [1]. By this time, the resilience concept has not been formulated or applied for any type of systems in Latvia, including energy infrastructure. However, it is strongly necessary to understand to which extent energy systems are able to withstand extreme conditions and how rapidly they can be recovered. This issue is closely connected with energy reliability issues and the efficient use of resources [2].

II. Development of a new methodological approach

The development of an algorithm for choosing the best available combination of segments to be recovered is based on the outcome from Henry and Ramirez-Marquez, where systems are described by so-called Figures-of-merit – the value of the delivery function of a system [3].

The newly developed methodology involves the comparison of restoration strategies based on defined objective function and consequent implementation of numerical values into multi-criteria analysis. The objective function is represented by the average speed of resilience change, expressed by Equation (1):

$$S_{i+1} = 1/n \cdot \sum_{i=0}^{n} \left[(R_{i+1} - R_i)/(T_{i+1} - T_i) \right] \qquad (1),$$

Where:

R - the value of Resilience after the recovery action;

T - time spent to reach the Resilience level R_i;

i+1 – index number of recovery step (e.g. 1st, 2nd, etc.; $i^{max} = n$ - is equal to the total number of segments recovered by the moment of current recovery step).

The methodology was summarized into a general algorithm, which consists of the following main steps: 1. consider the occurrence of some disruptive event; 2. define the system; 3. assume the disruption (hypothetical or real); 4.identify the restoration strategy; 5. analyse combinations; 6. identify the Figures-of-merit (FOM); 7. calculate the following parameters: a) for each recovery strategy - resilience values, recovery time and recovery costs; b) for each FOM - objective function and resilience per unit of costs (C_r); 8. identify the strategies with better character of resilience curve for each FOM; 9. multi-criteria analysis; 10. select the best strategy.

III. Development of a tool for calculations and practical implementation

The proposed theoretical general algorithm, implemented in Java programming language, was used for the assessment of restoration strategies of a real district heating system in the city of Salaspils (Latvia). Different FOMs were proposed for the case of a district heating pipeline system. Taking into account the availability of necessary data, the FOM i) heated area (function dimension); ii) connected people (social dimension); iii) length of functioning pipeline (technical dimension) were selected.

The calculations have been performed for two hypothetical disruption scenarios: i) a particular area is affected by disaster; ii) several random segments are damaged.

The assessment of restoration strategies has been completed in two steps. The first step represents a preliminary assessment, where the best-curved strategy for each particular FOM was determined based on a comparison of the values of the objective function. The second step involves multi-criteria analysis in order to define the best overall strategy where a 5-grade of Likert-type scale was used.

IV. Conclusions

The current research proposes an innovative approach for assessing the recovery strategies within the infrastructure dimension with a major focus on energy infrastructure. The general objective was to develop an analytic tool aiming on providing schematic guidelines to be used after the disaster occurrence.

The developed methodological approach can be used by regional planners, organizers of restoration process and other stakeholders in the situations, when a high level of efficiency in the use of material resources and time resources is necessary.

V. References

[1] Cimellaro G.P., Reinhorn A., Bruneau M. Framework for analytical quantification of disaster resilience. Engineering structures. – Nr.32 (2010), p. 3639-3649.

[2] Wright C., Kiparoglou V. A framework for resilience thinking. Procedia Computer Science. – Nr. 8 (2012), p. 45 – 52.

[3] Henry D., H.E. Ramirez-Marquez. Generic metrics and quantitative approaches for system resilience as a function of time. Reliability Engineering and System Safety. - Nr. 99, 2012, pp. 114–122.

A comparison on renewable electricity support policies in the baltic and nordic countries

Aiga Barisa, Marika Rošā, Dagnija Blumberga, *Riga Technical University*
Reeli Kuhi-Thalfeldt, *Tallinn University of Technology*

Abstract **– The Nordic countries are leading in the exploitation of renewable energy sources the Europe. Meanwhile in the electricity mix of the Baltic States, fossil fuels dominate.**

The paper compares various support policies applied in the three Baltic and five Nordic countries to favor the use of renewable energy sources in power generation. The aim of the research is to find the best pathways for future support policies in the renewable electricity sector in the Baltics taking into account lessons learned from Nordic experience.

Keywords **– Hydro power, renewable electricity, support policies, wind energy.**

I. Introduction

Efforts to reduce greenhouse gas (GHG) emissions are at the top of the European Union (EU) political agenda. As the biggest contributor of the EU's total emissions of carbon dioxide, the energy sector plays an important role in mitigating climate change. The transition of the present non-sustainable energy systems to systems with renewable energy as the standard will take place first and fully in the electricity sector.

Increased use of energy from renewable sources constitute an important part of the package of measures needed to reduce EU GHG emissions and comply with Community and international GHG emission reduction commitments. As outlined in the EC's Roadmap for moving to a competitive low carbon economy in 2050, GHG emissions would need to be reduced by 40% by 2030 and 60% by 2040 to be on track to reach the 2050 target. For renewables, the policy scenarios in the Energy Roadmap 2050 [2] indicate a share of around 30% of gross final energy consumption in 2030. It is estimated that the power sector will play a role of increasing importance in making it possible to achieve a significant level of decarbonization (55-97% by 2050, depending on the scenario).

According to Eurostat, electricity generation from renewable energy sources in the EU has increased from 13.6% in 2005 to 20.4% in 2011. However, in its latest renewable energy progress report [3], presented in the beginning of 2013, the European Commission has concluded that there are reasons for concern about the future progress of renewable energy dissemination in Europe. Current policy initiatives and various barriers limiting renewable energy development reveal a less optimistic outlook for 2020. Member States will need to introduce further measures to ensure that future investments do not decline or delay, and to see that national targets are achieved.

II. Renewable Electricity Support Policies

A. *The Nordic Countries*

The Nordic countries (Sweden, Norway, Finland, Iceland, and Denmark) have made considerable progress in the use of renewable energy sources during the last two decades. A prerequisite for their success has largely been government's strong political position towards a low-carbon economy. In Denmark and Finland, power generation from renewable energy sources is promoted through a premium tariff system based on bonus payments paid on top of the wholesale electricity price. Meanwhile in Norway and Sweden, renewable electricity production is promoted through a common quota system including a certificate trading scheme. Further, subsidies for renewable energy investments are granted in all five countries.

B. *The Baltic Countries*

In Latvia and Lithuania, power generation from renewable energy sources is mainly promoted through a feed-in tariff system whereas in Estonia, a premium tariff on top of the electricity market price is applied. Investment support for renewable electricity installations is available in each of the countries. In Estonia, bioenergy and wind energy installations are especially promoted.

In addition, the Lithuanian Law on Excise Taxes provides exemption from excise tax for electricity generated from renewable energy sources.

III. Results and Discussion

Results show that subsidies and feed-in tariffs (including premium tariffs) are the most widely applied policy instruments to promote the use of renewable energy sources in power generation. Usually all renewable energy sources are eligible for investment support. However, some countries have chosen to support only specific technologies, e.g., Estonia (electricity generation from wind and bioenergy) and Sweden (solar energy). The intensity of the grants ranges from 30% in Finland, to 50% in Iceland and 80% in Lithuania.

Although widely applied, the use of feed-in tariffs is often related to several concerns, e.g., increasing financial burden on the final consumer (especially in countries experiencing a significant increase of renewable electricity generation) and non-transparency of the scheme. For this reason, the intensity of support for each source of renewable energy should be reasonably determined based on cash flow analysis and national needs.

Sweden's example has proven that a high share of renewables in the national electricity mix can be achieved without application of feed-in tariffs but through an efficient renewable electricity certificate trading scheme. Maybe this is the direction the Baltic States should look toward, especially after the integration of the Baltic and Nordic energy markets.

IV. Acknowledgment

This work was supported by the Nordic Energy Research NORSTRAT project.

V. References

[1] European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'Energy Roadmap 2050' COM(2011) 885/2.

[2] European Commission. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'Renewable energy progress report' COM (2013) 175.

Technological improvement for Paper mill "Ligatne" Ltd.

Miķelis Dzikēvičs, Līga Ozoliņa, Dagnija Blumberga, *Riga Technical University*

***Abstract* - Paper mill "Ligatne" has a lot of options to reduce energy consumption in production. In this research, a way to reduce fuel consumption in this mill was analyzed. The building of a wood chip storage area of 800 m² and shelter was assessed from the economical point of view by calculating discounted payback time, indicators and carrying out a sensitivity analysis. Since the measured moisture level was high, the calculated discounted payback time of the project is 1 to 2 years.**

***Keywords* – Recycled, efficiency, economical, woodchip, storage**

I. Introduction

Being the oldest industrial enterprise in Latvia, the paper mill "Ligatne" has had to overcome a lot of obstacles in its long history, like loss of all equipment during WWI and partly burning down in 1993. It is one of those few companies in Latvia that are looking for ways to become more energy efficient. In this research, data of production, water and fuel consumption were analyzed. The latter was chosen to have higher potential and, consequently, possible improvements for the boiler house were reviewed. The construction of a wood chip storage area with a roof covering it was analyzed to have the potential to reduce the moisture content of wood chips from 50 to 40%, thus reducing fuel consumption by 13.6%. Laboratory measurements of wood chips gave an average moisture level of 51%, justifying the need for a reduction in those levels. The total project cost estimate to build the proposed 800 m² concrete platform with a shelter was found to be 74 thousand LVL. With a discount factor of 7.94%, the discounted payback time is 1 to 2 years.

II. Production scheme

Production processes were looked into to understand links between different parts of the production scheme. Main flows can be seen in Fig.1. – Fresh water, paper, waste water and heat. Additionally, it must be noted, that water production involves wide use of electrically powered machines for paper production, water transport, ventilation, lights and office. Most emissions come from heat and paper production.

III. Data analyses

The available data from production, water consumption and wood chip consumption for steam production were analyzed for the years 2011 and 2012. An analysis of production processes and best available technologies (BATs) in manufacturing recycled paper were carried out.

IV. Methodology

The production scheme was used to find crucial points of interest, where possible improvements could be introduced. Production and consumption data were used to analyze if crucial points can be evaluated. Available data were compared with indicators given from BATs. Economic analyses were carried out for possible improvements in order to calculate the discounted payback time, indicators (NPV, IRR and PI) and a sensitivity analysis.

V. Results

Both water and fuel consumption was greater per ton of produced paper compared to BATs [1]. The option to build a storage area for wood chips was chosen because of the abundance of fresh water and the high level of moisture in the wood chips. The results from the economic analysis justified the choice for improvement due to the short payback time, as well as the low sensitivity for change of capital investment and high sensitivity for change of wood chip price. However, since the existing trend for the price of woodchips is on the increase, high sensitivity for the latter is favorable.

VI. References

[1] About best available technologies: http://www.vpvb.gov.lv/data/files/ippc/bat/LCelulozePapiraRupn.pdf [05.05.2013]

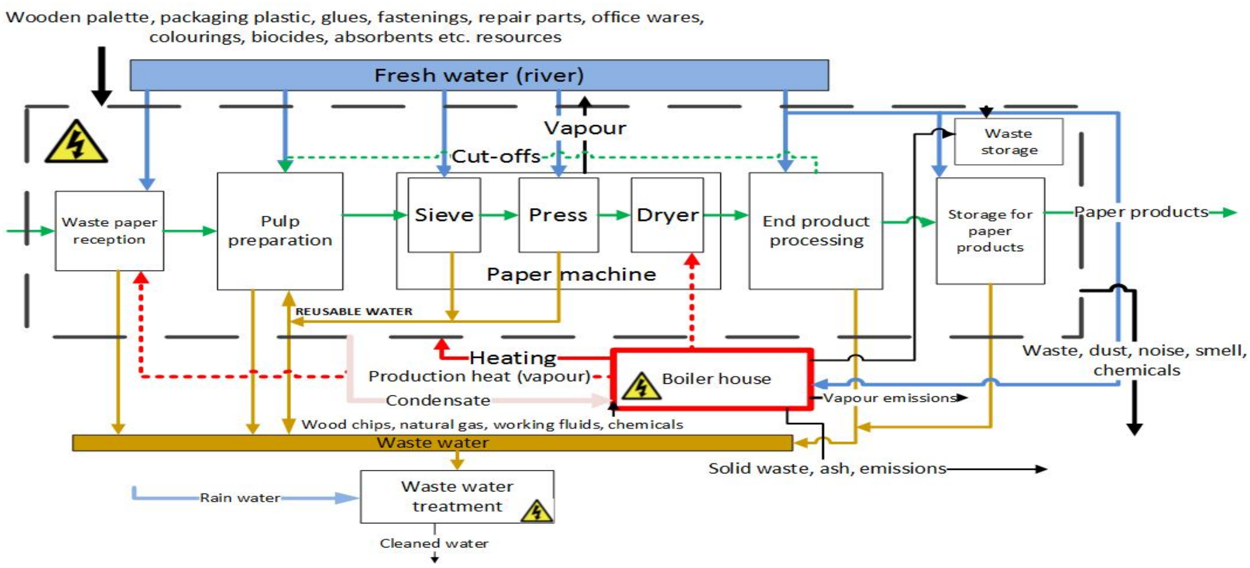

Fig. 1. Production scheme for paper mill "Ligatne"

Energy efficiency in Latvian state prisons and possible measures for energy conservation

Gatis Žogla, Kristaps Kašs, *Riga Technical University*
Artūrs Biedris, *Ltd. Ekodoma*

***Keywords* –energy efficiency, cost reduction, energy efficiency measures, prisons.**

I. Introduction

Energy efficiency has been put on the forefront of the EUs energy policy [1] as an effective measure of reducing dependency on energy imports and stimulating internal economic growth. In Latvia all prisons are state funded, therefore this paper focuses on the current state of prison energy efficiency and possible solutions for improvements in this regard.

II. Energy consumption analysis

In this paper, energy consumption analyses for Riga Central Prison (RCP) and Jekabpils Prison (JP) are presented. The energy consumption analyses were carried out in the framework of the E-seaP project, which is supported by the Intelligent Energy Europe program. The E-seaP project is aimed at promoting the introduction of energy efficiency measures in prisons on all levels – not only by increasing the energy efficiency of equipment and buildings, but also by promoting awareness among prison management, general staff and prisoners. In this paper, the area of emphases is the energy consumption of prison buildings and measures for energy consumption reduction.

The methodology of energy consumption analysis consists of:

- building and energy system survey;
- technical staff interviews;
- measurements and necessary data gathering;
- data analysis, building energy performance calculations.

The total primary energy consumption in prison buildings can be seen in Table I. The total heating area of RCP is 32 140 m^2 and its maximum capacity is 2 500 prisoners, JP has 15 210 m^2 of heating area and maximum capacity of 700 prisoners. At the time of the survey, there were 1 600 prisoners in RCP and 583 prisoners at JP.

TABLE I
TOTAL ENERGY BALANCE OF THE BUILDINGS

	Riga Central Prison, MWh, (kWh/m^2)*	Jekabpils prison, MWh, (kWh/m^2)*
Heating	4624 *(143,9)*	3408 *(224,1)*
DHW	4025 *(125,2)*	268 *(17,6)*
Transmission heat loss	2069	919
Boiler heat loss	1825	1531
Electricity	2256 *(70,2)*	1356 *(89,2)*
Total primary energy	14799	7481

*energy consumption unit in brackets is kWh/m^2, energy consumption unit shown without brackets is MWh.

Each prison presented in this study consists of several buildings which are located in closed territories. The technical condition of the surveyed prison buildings in most cases is below average. In both cases, building facades in some areas are damaged, which can lead to more sever damages in the future, if no corrective measures are undertaken. The overall heat loses from the buildings in prisons can be seen in Table II.

TABLE II
OVERALL HEAT LOSES IN PRISON

Heat losses through:	Riga Central Prison	Jekabpils prison
• ventilation	31%	23%
• building envelope	28%	28%
• ground	9%	11%
• roof	15%	22%
• windows	12%	12%
• doors	2%	2%
• thermal bridges	3%	2%
Total heating energy	4624 MWh	3408 MWh

Each prison has its own heating system with individual boiler houses. RCP has 2 gas fired boilers and JP has 5 coil fired boilers. The heat energy from boiler houses in both prisons is used for DHW preparation and space heating.

Buildings in both prisons do not comply with the National Building Code [2] in Latvia which indicates, that the building envelopes are outdated and should be improved to maintain structural integrity and reduce energy consumption. In addition, the low efficiency of the heating system and the use of more expensive fuels indicate high running costs. To reduce the institutions' yearly running costs and CO_2 emissions, a series of energy efficiency measures have been assessed. The main energy efficiency measures can be seen in Figure 1.

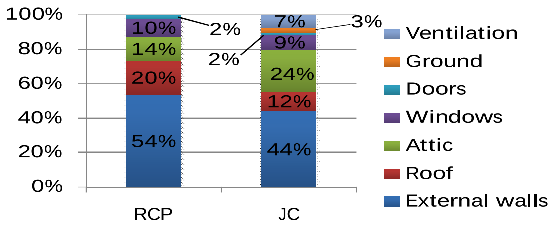

Fig.1. Heat energy loss reduction through different building components

A total heat energy consumption reduction of 1973 MWh can be reached in RCP and 1955 MWh in JP.

III. Conclusion

By implementing a series of energy efficiency measures and by realizing fuel conversion projects from fossil fuels to renewable energy resources, it is possible to significantly reduce the running costs of the reviewed institutions. The next steps are associated with the preparation of project proposals to provide for the implementation of energy efficiency measures.

V. References

[1] Communication from the Commission to the European Council and the European Parliament – an energy policy for Europe. Commission of the European Communities, Brussels, 2007

[2] Latvian Building code LBN 002-01 „Outside construction heat engineering of buildings"

Cleaner production assessment in dairy processing company

Ieva Pakere, Līga Ozoliņa, Dagnija Blumberga, *Riga Technical University*

Abstract – This research analyzes cleaner production opportunities in a dairy processing plant located in eastern Latvia. In the study, the technological process of milk production was analyzed and an analysis of data was made in order to assess the environmental aspects of company. As a result, the environmental indicators were compared with the reference values specified in Reference Document on Best Available Techniques (BREF) in order to identify possible improvements.

***Keywords* – Cleaner production, dairy processing, best available technologies**

I. Introduction

The industrial sector is one that has great impact on the environment. It has been stated that the manufacturing and construction sector accounted for 16.5% of CO2 emissions in the European Union in 2007. Almost 7% of all emissions are emitted by the food, beverage and tobacco industries [1]. Implementation of cleaner production guidelines can be a way to reduce a company's negative impact on the environment, as well as to reduce the costs related to energy and resource consumption, waste and waste water treatment etc.

The milk processing industry is well developed and it is one of three main food industry sectors in Latvia. In this research, a particular dairy processing company was analyzed in order to improve the company's environmental performance. The company is located in Eastern Latvia. It can be classified as a medium- size factory as it processed almost 11 thousand tonnes raw milk in 2010. In comparison, the largest milk processing company in Latvia processed almost 110 thousand tonnes raw milk in 2010.

II. Technological Process

A. *Produced milk products*

The company studied produces 13 different main types of dairy products-pasteurized milk, kephir, yoghurt, sour and sweet cream, light cream, milk curd, processed cheese, smoked cheese, curd snack, sugar pastry, and mayonnaise. The share of products by production volume is shown in Fig.1.

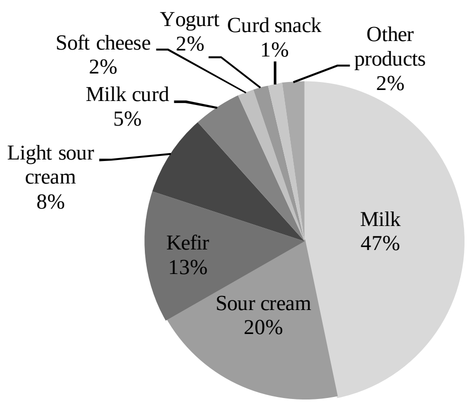

Fig.1. Division of the main products in 2012

As it can be seen in Figure 1, almost 50% of the company's production constitutes milk; other main products are sour cream, light cream and kefir. Products like yogurt, skimmed milk curd, different kind of cheese etc. are produced less.

B. *Milk production process*

As pasteurized milk production constitutes for the largest proportion of the products produced by the company, a more detailed explanation of the technological processes for milk production is described further in the text.

The raw milk is transported to the company in tanks which are washed after they are emptied by using technical water and cleansing agents. Around 20-30 liters of raw milk is delivered everyday, which is purified by using fabric filters, cooled and stored.

The stored milk is then pre-heated through heat exchange with hot pasteurized milk. This process allows to save energy and is one of the company's possible cleaner production achievements. The pre-heated milk is then separated and normalized with low fat milk. After the normalized milk is pasteurized- heated up to 90-95 degrees by using steam. The necessary heat is generated in the company's boiler house, where there are two steam generators with a capacity of 0.75 MW each and a steam boiler with a capacity of 1.5 MW. The boiler house provides heat for industrial processes as well as for space heating during the heating season. The fuel used in the boiler house is natural gas.

The next process is cooling when milk is rapidly cooled to 4-6 degrees. For all cooling processes, the so-called "ice water" is used. Preparation of the ice-water is based on a heat exchange between the cold water and refrigerant, which, in this case, is freon. Cooled milk is than packed, labeled and stored until distribution to the retailers. In each of these processes, different environmental aspects can be determined.

The equipment is washed every working day by using special detergents and disinfectants. Drinking water from the city water supply is used for cleaning purposes. In order to reduce the used amount of water, the cleaning in place (CIP) system has been applied. The system consists of a water tank and cleaning solution tanks (alkali and acid). The waste water from the production and cleaning process is discharged in a municipal sewer.

The production process of the different products differs widely and different resource and energy flows can be detected.

III. Data Analyzes

In order to evaluate the company's efficiency, data analyses were done. Data about the electricity and natural gas consumption, water and wastewater, as well as the production volumes and raw materials in 2010, 2011 and 2012 were collected from the company's representatives.

One of the main values describing the dairy production process is the received raw milk volume. In 2010, the company processed the most, but in 2011-the least raw milk. The processed milk volumes differ from month to month- more milk is delivered in the summer, and less in the period from September to April which is due to lack of suppliers.

The necessary energy in the dairy production company has been provided by using natural gas for steam production in the boiler house. Electricity is bought from the electricity supplier Ltd. "Latvenergo". Fig. 2 shows the changes in natural gas consumption from 2010 to 2012 on a monthly basis. The dairy company does not monitor the data separately in the administrative and production facilities, so only the total consumption in the company is analyzed.

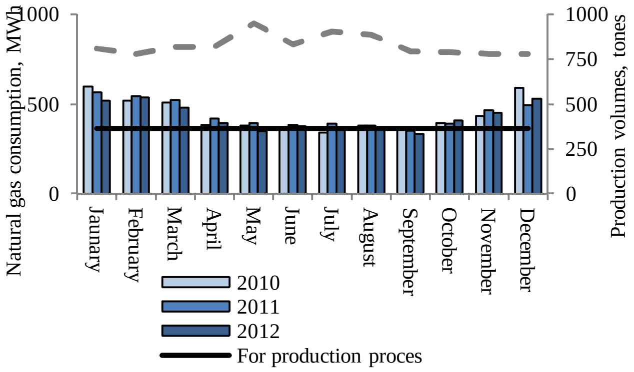

Fig.2. Natural gas consumption in 2010-2013 and average production volumes

Fig.2 shows that there are significant differences in natural gas consumption during the summer and winter periods due to space heating in the administrative facilities in the winter. By using yearly data, it is determined that the natural gas consumption for production processes is around 360 MWh a month. Figure 2 also shows that natural gas consumption does not change as rapidly as the production volumes. This is the opposite for electricity consumption, as it increases when more raw milk has been processed.

In order to compare the energy consumption of the particular company studied with other dairy production companies, it is necessary to evaluate the specific energy consumption for one litre raw milk processing. The specific energy consumption in this dairy in 2012 was 0.67 kWh/$l_{raw\ milk}$. The reference values stated in BREF is 0.07 to 0.2 kWh/$l_{raw\ milk}$ [3], which shows a potential for improvements in the particular dairy company.

The specific energy consumption correlates with the raw milk processed (see Fig. 3). When the production volumes increase, the specific energy consumption decreases and the dairy can work more efficiently and reduce the specific energy costs.

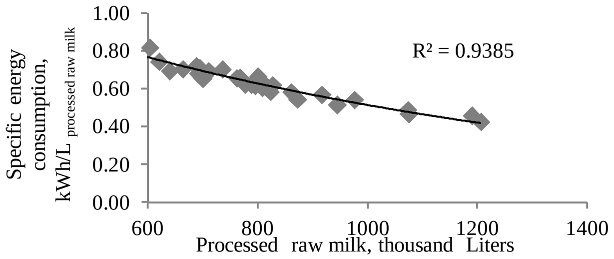

Fig.3. Correlation between raw milk and specific energy consumption

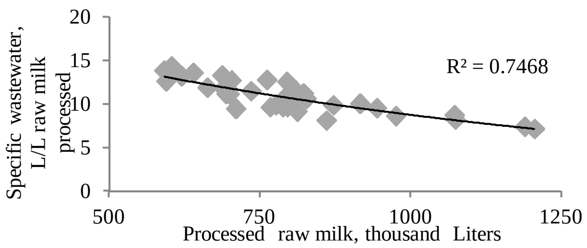

Fig.4. Correlation between raw milk and specific wastewater volume

A significant environmental aspect is the produced waste water and the consumption of drinking water in the company. The amount of consumed water is strongly influenced by the production amount (see Fig. 4).Therefore, it is important to determine the specific water consumption per liter of raw milk processed. An average specific wastewater rate in the particular dairy is 10.8 $l_{wastewater}$ / $l_{raw\ milk}$. BREF indicates that a specific amount of wastewater volume can be reduced to 1-4 $l_{wastewater}$ / $l_{raw\ milk}$ [3]. However, to calculate a more accurate value, the water volumes used for administrative purposes, should be excluded.

IV. Suggested Improvements

As the milk production requires multiple heating and cooling processes as well as regular cleaning, the high energy and water consumption are inevitable aspects. However, after comparing the company's specific energy and water consumption with other dairies, it can be seen that it is possible to use energy and water more efficiently. Some of the possible cleaner production improvements are as follows:

- A more accurate energy and water consumption monitoring; installation of individual meters in production and administrative facilities;
- Scheduling production processes in order to minimize washing needs [3];
- Setting of high-pressure nozzles for floor washing purposes;
- Installation of additional economizers in boiler house;
- Set up of an ammonium plate heat exchanger for pre- cooling of the ice water.
- Installation of a heat exchanger in the cooling chambers to recover the heat generated from stored products.
- Low-potential heat utilization for washing processes.

In the production process it is necessary to cool down the whey. The amount of produced whey is around 1430 tons per year. For pre-cooling purposes the cold drinking water is used which heats up from 8 to about 40 degrees. This warm water is then mixed with waste water which is inefficient resource use. The warmed cooling water can be defined as a low potential energy because it cannot be used directly for heating purposes.

A more efficient way to use this warm water would be to store it and use it for cleaning the administrative facilities. It has been calculated that such improvement would reduce energy consumption by 80 MWh. This would also result with savings of natural gas by around 9000 m^3. The warm water from the whey cooling could replace the water used for cleaning and it could save around 600 m3 of clean water.

All these improvements would reduce the costs and around 3000 LVL can be saved per year. The installation of the storage tank is a relatively inexpensive cleaner production action and can pay off in less than 3 years. Thus the following action can be considered as worthwhile to implement in order to reduce environmental impact, and to save financial resources.

V. References

[1] European Commission, EU Energy in Figures, Emissions by Sector, Available online: http://ec.europa.eu/energy/publications/doc/statistics/ext_co2_emissions_by_sector.pdf [08.08.2013]

[2] European Commission, Reference Document on Best Available Techniques in the Food, Drink and Milk Industries, 2006

[3] J. Berlin , U. Sonesson b, A.Tillman, A life cycle based method to minimise environmental impact of dairy production through product sequencing, Journal of Cleaner Production 15, pp 347-356, 2007

Cleaner production in a small scale dairy processing company

Krista Kļaviņa, Līga Ozoliņa, Dagnija Blumberga, *Riga Technical University*

***Abstract* – In this study, a small dairy processing company's environmental performance is evaluated. The company's facility is surveyed and the accounting data collected, processed and evaluated. Overall the company shows good environmental performance, although an undesirable use of electricity for space heating is detected. It is recommended to switch from electrical heating to a pellet boiler, and also to seek profitable uses of whey, and lowering the consumption of fresh water.**

***Keywords* – energy efficiency, rational use of resources.**

I. Introduction

Cleaner production is important globally, because the growing population is facing a rising demand for all resources, and new climate problems evolve. Locally, at the enterprise level, with rising standards, pollution limits and environmental taxes, cleaner production can increase a business' ability to compete in the market.

This paper discusses a case study of a small scale dairy processing company (DPC) located in the Latvian suburbs. The research is focused on the development of indicators to identify the environmental performance of this company relative to its industry peers. The objectives include suggesting improvements for the manufactory.

II. Process description

The discussed DPC has a growing production output and in the year 2013 it is to receive a Category B pollutants' operation permit. The raw materials that the company uses are milk and numerous additives like starter cultures and spices. A simplified scheme of the process and flows is visible in Fig. 1.

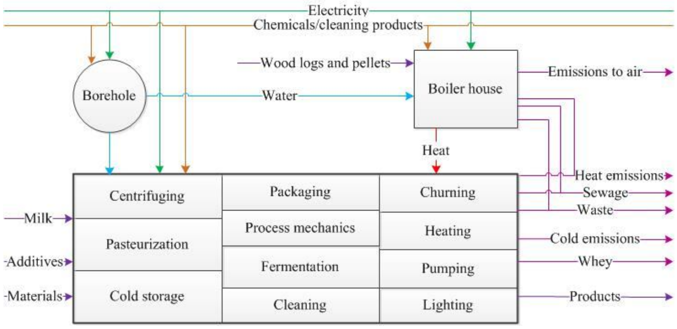

Fig.1. Simplified principal scheme of the process and flows

In the given DPC, around 3.7 thousand tons of raw milk annually are processed into butter, cheese, curd, yogurt, kephir, cream, processed milk and other products. The proportion in which these products are produced varies from one DPC company to another as well as from one year to another. The situation for the year 2012 in the reviewed DPC is visualized in Fig.2.

The varying product types have different energy intensities, but as there is no separate energy metering for each process, it is chosen to create the indicators attributed to the amount of raw milk processed, not the production amounts.

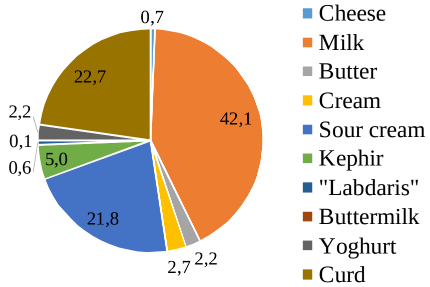

Fig.2. Year 2012. Product type percentage breakdown

III. Resources and materials

A. *Packaging*

The company demonstrates a good practice towards reducing the packaging material consumption by selling loose products as well as reusing plastic packaging containers (Fig.3.).

Fig.3. Plastic container reuse

B. *Water and wastewater*

In the dairy industry, a major burden on the environment is water consumption and wastewater formation. Water is mainly used for cleaning procedures. Usually around 0.5 to 1.5% (in some cases reaching 3 to 4%) of the input raw milk goes to wastewater with cleaning water and leaks. It increases the wastewater chemical oxygen demand, nitrogen and phosphorus levels. [1]

It is thought that using closed tanks instead of open baths can reduce the product loss and the consumption of cleaning water and chemicals. The company has already started a gradual transition to the closed tanks and uses CIP (Cleaning in Place) for these. The open baths are still cleaned manually.

The specific indicator of consumed water for a processed ton of raw milk in this DPC has risen from 1.4 to 1.9 m^3/t in the past three years. With the latest technology and high quality operation, it is possible to achieve 0.8 to 1.0 m^3/t and in existing plants 1.5 m^3/t [1]. Some measures, like using high pressure nozzles with adjustable flow for the manual washing hoses, to lower the water consumption should be considered. This indicator value falls in the range of a well-managed facility according to the Reference Document on Best Available Techniques in Milk Industries [1].

C. *Chemicals*

The chemicals in this DPC are used for the CIP and manual cleaning process. Chemicals used in transport and maintenance are not covered in this work. Manual cleaning uses soda ash and bleaching powder while caustic soda and nitric acid is used for

CIP. Altogether 1.7 kg of cleaning chemicals are used for every ton of raw milk.

D. *Waste*

The DPC produces around 3.6 m^3 unsorted municipal waste per thousand tons processed raw milk; it is handed to a waste management company for disposal. Plastic waste and scrap-iron is collected separately and handed to appropriate service companies for recycling. Paper, cardboard and wood waste is burned on-site in the boiler house or administration wood furnaces.

Apart from the waste, the production process generates a 3rd category material or process by-product -- whey. In this DPC, whey is disposed on agricultural lands as fertilizer. This study recommends assessing the possibility of using whey for the creation of new products because at the moment the whey is disposed with no monetary revenue. About 54% of the purchased input raw milk turns into whey.

A recent study discusses the possibility of using acid whey for production of biogas [2], while sweet whey is being successfully used for production of whey protein concentrate in other Latvian DPCs [3].

The reviewed DPC is a small company, which could pose some problems for successful and continuous whey processing, so it was found that there are two other DPCs in the neighboring regions. Thus there is a possibility for mutually beneficial collaboration or industrial symbiosis with these other companies.

IV. Energy consumption

A. *Thermal energy*

The given DPC produces the thermal energy required for its production on site in a boiler house with a nominal capacity of 0.75 MW. There are two steam boilers in the boiler house, one fueled by wood logs, and the other equipped with a wood pellet burner. The boilers are well aged and their efficiency could be around 65%.

The company is keeping a record of the amount of fuel consumed monthly in absolute units. The amount of consumed thermal energy is calculated using typical fuel moisture and calorific values. Around 1,170.2 MWh of thermal energy are consumed annually.

B. *Electrical energy*

The electrical energy is consumed to sustain the production process, lighting and administrative purposes, but during the winter period electricity is used for space heating of the production facilities. On average, 275.7 MWh electrical energy are consumed in the given DPC annually.

C. *Specific energy consumption*

The specific energy consumption indicators can be compared with other industry peers. For yoghurt and milk producing companies, the electrical energy consumption for one processed ton of raw milk is 0.04 to 0.69 MWh/t, but for cheese producing companies it is 0.02 to 0.81 MWh/t [1]. For the given DPC, electricity consumption for processing one ton of raw milk to produce a mixed range of products is, on average, 0.08 MWh/t. This indicator ranks on the lower end compared to other European companies, but it has to be mentioned that the discussed DPC does not include more energy intense processes like milk and whey powder production.

The specific indicators for fuel-injected heat for yoghurt/milk production vary from 0.05 to 0.42 MWh/t while for cheese production from 0.04 to 1.28 MWh/t [1]. For the given DPC with a mixed product range, the specific heat consumption indicator is 0.29 MWh/t which is again comparatively low.

By analyzing the specific energy consumption, it is noticed that the specific energy consumption depends on the amount of milk processed.

The R^2 value shows a rather good data correlation meaning that with increasing processing capacity, the specific heat consumption decreases.

The data correlation for the use of electricity is not evaluated because the measured electricity consumption includes space heating and would generate an autocorrelation, because the winter period is also associated with the lowest production rates.

V. Suggested improvements

Overall the company shows good practice in gradually approaching cleaner production in its financial capability. At the same time, the use of electricity is considered irrational taking into account its exergical value and costs.

It is proposed to integrate an additional pellet boiler for space heating. As the manufactory already includes a pellet boiler for the production process, it is assumed that the existing infrastructure and personnel is well suited for serving an additional pellet boiler for space heating without significant additional costs.

As a result of a rough economic evaluation, it is discovered that the transition from electric heating to a local central heating system with biomass would pay off already in the third year after the investment. The sensitivity analysis confirms the project viability in different conditions (Fig.4.).

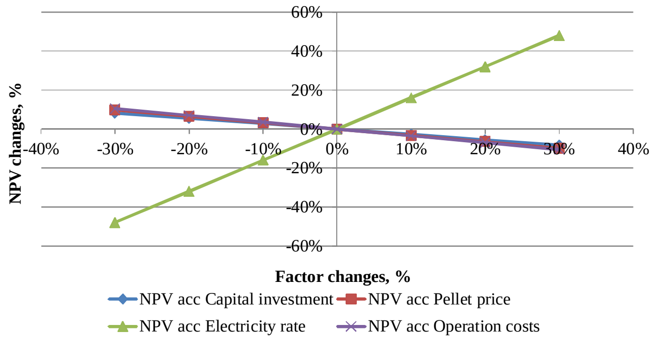

Fig.4. Sensitivity analysis

VI. References

[1] European Commission, Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the Food, Drink and Milk Industries, 2006, pp. 682.

[2] K. Rugele, L. Mezule, B. Dalecka, S. Larsson, J. Vanags, J. Rubulis, Application of fluorescent in situ hybridization for monitoring methanogenic archaea in acid whey anaerobic digestion, Agranomy Research, Põltsamaa: Vali Press, 2013, pp. 372-380.

[3] About the whey protein concentrate: http://www.smiltenespiens.lv/en/produkti/piena-speks, 29.07.2013

Cleaner production for insulation material company and economic calculation

Dace Eihvalde, Dagnija Blumberga, Līga Ozoliņa, *Riga Technical University*

Abstract **–As any other production process, the production of insulation materials involves energy consumption, use of raw materials and generation of waste. Using the correlation and benchmarking method, the data given by the company was analyzed and proposals were made to improve the companies' performance. Based on cleaner production technologies, a solution for reducing the amount of waste is being proposed.**

Keywords **– extruded polystyrene, cleaner production**

I. Introduction

The main production of the company which is the subject of this research is the production of insulation materials. During the last few years, the company has been working on widening the variety of products under production, as well as on increasing the production volumes, thereby creating high quality products capable to compete for the markets in Latvia, Lithuania, Estonia, Spain, Finland, Austria and the CIS countries.

The company has reached many goals regarding cleaner production and reducing its effect on the environment. The company has also set new goals which it is planning to implement. The goals are connected with reducing waste, energy analyzes and efficient use of resources. As the aim of the company is to reduce the amount of waste it produces, a cleaner production technology is suggested by using new, improved technologies to reduce the waste – economic analyzes are made.

II. Production of Insulation Materials

Polystyrene foam panels are produced from foamed polystyrene granules into which pentane (foaming agent) is injected. The process of generating polystyrene foam panels starts with a pre-foaming process, where pentane evaporates and foamed polystyrene granules expand at an increased temperature, creating a closed pore. In the pre-foaming process, pentane and styrene (~ 2%) are released, at which stage conditioning of newly generated granules occurs. After conditioning, granules are inserted into a closed form where, at an increased temperature and pressure, they melt together forming blocks with a volume of 5,4 m^3. New blocks are once more conditioned, cut into plates, and packed.

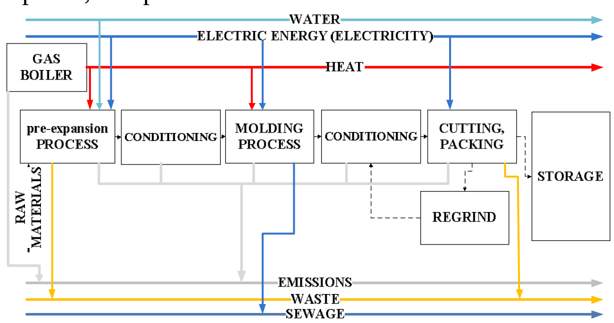

Fig.1. EPS production

Overall, in 2012 the company under discussion generated 124803 m^3 of expanded polystyrene foam products. In the production process 87% heat and 80% electricity is used for expand polystyrene production.

The production of expanded polystyrene (EPS) uses the highest energy intensity. EPS production uses 90% of heat and electrical energy from the total energy consumption.

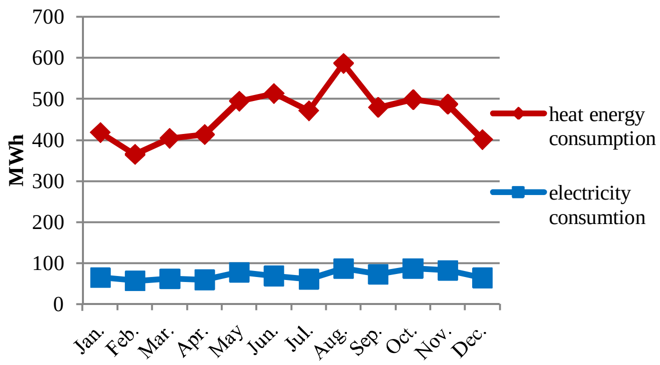

Fig.2. Energy consumption for EPS production (2012)

The consumption of electricity and heat is uneven and has seasonal characteristics. It is also affected by the intensity of production.

The company studied uses water for technological (operation of cooling systems) and administrative purposes. The water is mostly taken from drill holes that are located in the company's territory. In order to fully meet the required water demand of the company's production, additional water is supplied from the city's water system. Almost 90% of the water is used for the production of foam polystyrene.

During the production processes water is reused in the cooling system. Domestic waste water and cooling water of the technological processes enter the sewer system only when the water cannot be reused again.

In the production of EPS, waste is generated from unpacking the materials, as well as after the packaging process of the finished products when polystyrene scraps that cannot be reused again, are generated.

III. Methods of Data Analysis for Insulation Material Production

To determine the company's impact on the environment created from the production of insulation materials and to give proposals for increasing efficiency of the production, data analyses of thermal energy, electrical energy, water consumption, waste water and waste amounts, were conducted.

The company has installed one electricity and one heat meter. The company provides data on its electricity consumption that includes electricity consumed not only by the production process, but also from lightning and administrative needs. Therefore electricity consumption for production processes is expressed as a percentage of the total electricity consumption. Heat readings are taken from one meter. Total consumption includes heat energy consumption for production processes and heating during the winter months. Heat energy consumption is expressed as a percentage of the total heat energy consumption.

The company has installed one water meter both for water required for production processes and household purposes. The amount of water used for production processes is expressed as a percentage of total water consumption. There are no meters for waste water readings within the territory of the company. Waste water is collected and drained in a sewage system together with waste water of neighboring company. Meter readings are recorded once per month and entered into the company's database. Waste is listed separately by dividing municipal waste and industrial waste. Industrial waste (polystyrene) and defected polystyrene products are transferred to other companies that are interested.

Data is used for approbation of benchmark and correlation methods. Obtained data is used for proposing best available technologies for production processes. Selected technologies are economically justified by calculations of economic parameters.

IV. RESULTS

Analyzing obtained data of electric and heat energy as well as water consumption, it can be observed that all the consumption is affected by intensity of production.

With increasing volume of production, the specific electrical energy consumption per unit decreases, but in production of polystyrene blocks, the production during the course of one calendar year is uneven, so with a lower level of production, the consumption of electric power is uneven and specific consumption increases. In a three year period, the specific electrical energy consumption has decreased from 9,6 kWh/m^3 to 7 kWh/m^3.

The analysis of average heat consumption show that specific heat energy consumption per unit has decreased by 10.9 kWh/unit compared to 2010. On average per 1m^3 of product production, around 49.3 kWh are used.

By analyzing available literature, information about the specific energy consumption of foam polystyrene blocks was obtained. Since it is known how much energy consumes EPS production it is possible to compare specific energy consumption of the company with specific energy consumption given in the document, which is used by BAT.

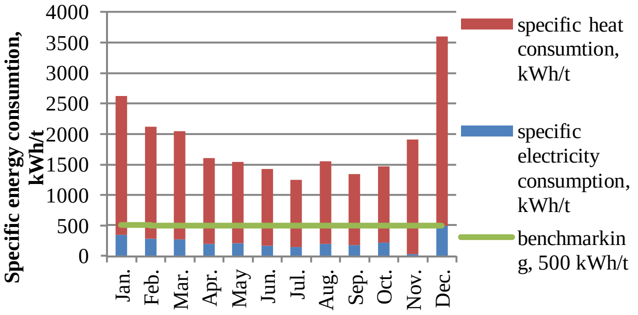

Fig.3. Specific energy consumption for EPS production in 2012

EPS production has very high specific energy consumption, where most of the specific energy consumption is specific heat consumption. The benchmarking value of 500 kWh/t is on the condition that the company used one of the best available techniques, such as reduction of gas level variation, balancing gas line or condenser installation [1].

There is an 8MW gas boiler set, which operates in continuous mode. The company has made calculations in regard to technological improvements, the implementation of which would not provide any benefit for the company.

The goal of the company is to reduce waste amount by 50% or more in comparison to the reference year. The company has an opportunity to reduce waste volume (m3) by more than 50% using EPS thermal processing technology.

EPS waste disposal creates an impact on the environment, since the polystyrene degradation time is very large -- over 1000 years. A new EPS processing technology – thermal recycling – has been developed. After thermal recycling, it is possible to get a new product, which can be used as a building material. With the thermal recycling method, waste volumes can be reduced by 20 times that of the original size. EPS density before recycling is 10kg/m3 and thermal conductivity 0.037 W/mK. After EPS thermal recycling density, thermal conductivity and compressive strength increases to 217 kg/m3, 0,055 W/mK and 8.29 MPa [2]. Installation processing efficiency is 20:1, which means, if 1200 m3 waste per year is generated, then after recycling there will be 60m3 of new products. Waste reduction efficiency is about 95%. After thermal recycling it is possible to get a new product called modified EPS (MEPS), which is used as an admixture of construction materials. Using this material as admixture improves, for example, asphalt absorption of water and slows down the aging process. By using recycled EPS in concrete production, we need fewer technological resources, thus also reducing energy consumption [3].

By installing a thermal recycling system, the company reaches its goals and reduces m3 waste volume by more than 50%. The economic background of the selected technology is determined on the basis of the economic life of the machine, investment, raw materials and operating costs. On the basis of the economic calculation, we conclude that the project is economically justified.

V. CONCLUSIONS

The company has not yet installed individual energy meters, the application of which would make it possible to generate data for electricity and heat consumption for different manufacturing processes. Data analysis of the specific heat and electricity consumption on production is created based on percentage allocations for electricity and heat consumption separately for industry and household use. Expanded polystyrene production is an energy-intensive process. Mostly heat and electrical power is necessary for the pre-expansion and molding processes. Although the company has made the calculations for increasing energy efficiency, they are not implemented and the specific energy consumption exceeds the benchmark value, which is determined by BAT. By installing a thermal recycling system at the company, it is possible to reduce the waste volume by 95% and make a new product – modified EPS (MEPS).

VI. REFERENCES

[1] Reference Document on Best Available Techniques in the Production of Polymers., 2007. – 288 p.

[2] Abdulkadir K., Ramazan D., A new technique of processing for waste-expanded polystyrene foams as aggregates // Journal of materials processing technology.- 2 0 9 (2 0 0 9) 2994–3000 p.

[3] Amianti M., Botaro V.R., Recycling of EPS: A new methodology for production of concrete impregnated with polystyrene (CIP)// Cement & Concrete Composites Vol. 30 (2008) 23–28 p

Applying cleaner production principles in sweet manufacturing

Līva Asere, Līga Ozoliņa, Dagnija Blumberga, *Riga Technical University*

***Abstract* – The research was focused on cleaner production introduction in an exclusive sweet manufacturer to reduce resource consumption such as energy, water, materials and waste. The work was based on benchmarking method to determine amplitude of energy intensity indicator and specific energy consumption rates. Both benchmarks are lower or equal to other sweet product producers because production in this plant is handmade. However, there are still options which can be improved like lighting and ventilation to reduce resource consumption.**

***Keywords* – cleaner production, sweets manufacturing, energy intensity indicator.**

I. Introduction

The aim of the work is to get acquainted with how sweet manufacturing works and to suggest one cleaner production solution using best available technologies to reduce resource consumption. The study is based on an exclusive sweet manufacturer where a lot of work is produced through human resources, not machinery.

II. Technological process

The end products of the sweet manufacturer are truffles, which are made in a timespan of three days. The materials for the production of truffles are kept in storage. At the beginning, all the necessary materials are crushed and the mass of the sweets are made which are kept in storage for one night. On the second day, every small sweet ball is soaked in a specially melted and made chocolate mass. This is the reason why every truffle is glossy. When all the truffles are ready, they are decorated with candied berries, chocolate or nuts.

Before delivering the truffles to the shops, they need to be packed. The packing process is very simple because the company already has specially designed boxes where the exclusive sweets are placed and this is done by some of the company workers.

III. Research methods used and results

The benchmarking method is used to determine the amplitude of energy intensity indicator (EII) and specific energy consumption (SEC). EII is energy consumption per turnover of the company and SEC is energy consumption per one manufactured product kilogram.

Energy intensity indicators in most food manufacturers are larger than 0.2 MWh/kLs. The EEI for an exclusive sweet manufacturer is 0.15 MWh/kLs. The SEC for the best companies in the sector is around 2.0 MWh/t, but the company studied has 4.78 MWh/t. This is much higher than the average, because a lot of the work is done by people, which consumes more energy.

Improvements can be made in the storage space. Conditioning units can be placed there to secure steady temperature during storage, and the materials for production would be fresh longer which would mean smaller costs of transportation. Transportation costs would change by about 5 times if the cost of fuel will increase by 30%.

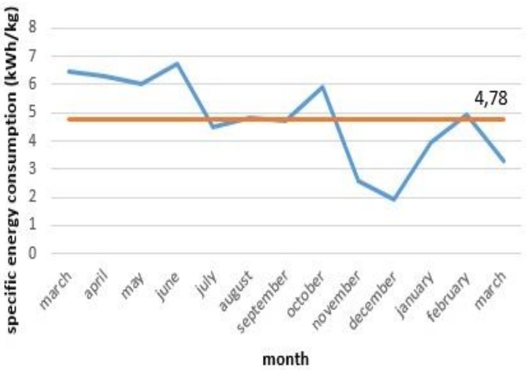

Fig. 1. Specific energy consumption (kWh/kg)

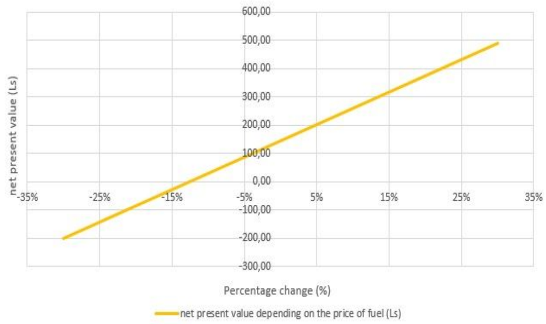

Fig. 2. Changes of present value in the future

IV. Recommendations

1. The company has a water heater and has two options to use less energy – remove it and use heated water from the city water system or warm up the water only for specific periods of time.
2. There is a need for conditioning units in the storage area where the materials are kept to secure steady temperature throughout production.
3. The company needs to give the waste resulting from packaging for recycling. If the recycling company could offer back new printing paper or some other benefits, then both companies would benefit.
4. There is an option to replace lighting installations from luminescent to LED lighting.

V. Conclusions

The company is new, developing successfully, and also introducing new technologies and tools which can help to save energy.

The energy intensity of the company is lower than the average values. However the SEC is two times higher than the benchmark, mainly due to the company's handmade production. Therefore, in order to lower its SEC, the company can invest in lighting and conditioning systems.

Development of methodology for the assessment of changes in household electricity consumption and calculation of CO_2 emissions

Ilze Laicane, Andra Blumberga, Marika Rosa, Dagnija Blumberga, *Riga Technical University*

***Abstract* – Purpose and rationale for this study is based as acase study research within the first smart metering pilot project in Latvia „Promotion of energy efficiency in households, using smart technologies". This study outlines the general principles for the development of the methodology for assessing changes in household electricity consumption and the calculation of CO_2 emissions. The methodology has been established on several successive steps: 1) regression analysis based on variable multi criteria analyses approach to provide overall changes in residential electricity consumption, 2) normalization of electricity consumption data, 3) assessment of changes in electricity consumption, 4) assessment of electricity consumption reduction, and 5) calculation of CO_2 emissions.**

***Keywords* – Smart metering, electricity consumption, household, energy efficiency, CO_2 emissions, data normalization, assessment of changes in household electricity consumption.**

I. INTRODUCTION

In line with the EU total energy consumption reduction targets (Latvia is obliged to reach 9% reduction in end use energy consumption during the period from 2009 to 2016 (Directive 2006/32/EC) [1]), there is still a growing need for improved means of evaluating policy instruments determining the purpose of promoting energy efficiency in the residential sector. Use of smart metering systems in households has been identified as a promising pathway for achieving significant electricity consumption reduction. In this context, the European Union has set an ambitious target for 2020: to equip 80% of households with smart meters (DIRECTIVE 2009/72/EC) [2]. In order to successfully reach this goal, increasing emphasis is being placed on involving every consumer in implementing energy efficiency measures, as well as by providing consumers with qualitative and quantitative information on smart systems and technologies.

II. GENERAL DESCRIPTION OF THE PROPOSED METHODOLOGY

Countless studies related to comparison of household electricity consumption with end-user behavioral characteristics have been reflected recently. The main conclusions from these studies highlight that information has a significant impact on a user's behavior contributing to electricity consumption savings. Some of these estimations show that 10% of energy savings can be achieved due to changing end-user habits and daily routines.

The development of a methodology for the evaluation of electricity consumption savings and CO_2 emission reduction from households has been provided (see Figure 1). Sensitivity analyses is planned to be used for the validation of results. A simple cross-sectional multi criteria analysis is employed to try to explain the differential impacts on electricity consumption across different households.

This analysis considers that the impact on household electricity consumption will include various aspects: resident's personal situation socio-economic and households structural characteristics; household electric appliances and consumption; energy related behavior/attitudes/awareness; information/feedback; technology development etc. factors.

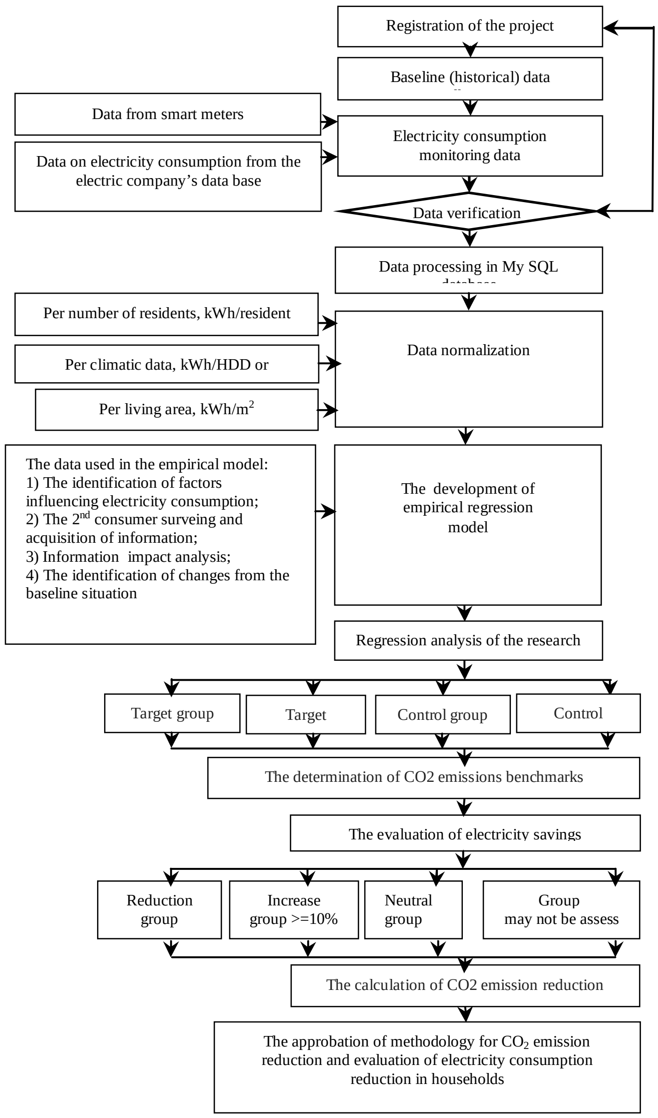

Fig. 1. The algorithm scheme of the proposed methodology.

III. REFERENCES

[1] DIRECTIVE 2006/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC, Official Journal of the European Union, L 114/64, 27.4.2006.

[2] DIRECTIVE 2009/72/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, Official Journal of the European Union, 55/112L, 14.8.2009

Use of biomethane in Latvian transport sector

Sofija Grīnvalde, Ilze Dzene, *Riga Technical University*

***Abstract* – In this research there is methodology to evaluate biogas stations and potential of biomethane from biogas stations in Latvia. There is acquisition from biomethane use in the transport sector in Latvia in case if it is used as CBG (compressed biogas). The experience of other European countries (Germany, Italy, Sweden, Switzerland and others) is used to create the methodology.**

***Keywords* – biomethane (Bio-CH_4), CBG, biogas, biofuel, transport fuel, RES (renewable energy sources)**

I. Introduction

The transport sector in Latvia and throughout Europe is one of the biggest sectors where CO_2 emissions are produced. In the year 2010, from all energy sources in Latvia, 28.2% was used in the transport sector, and in 2011 only 4.1% of energy used in the transport sector was from renewable energy sources – biodiesel and bioethanol [1]. The EU Directive 2009/28/EK from 2009 sets the goal to reach at least 10% renewable energy use in transport sector in 2020. Potential fuel for this goal is selected, which can be produced in 42 existing biogas stations (cogeneration) in Latvia and biomethane can be transported through existing natural gas pipes and transported in cisterns under pressure. Biogas is produced in anaerobic detestation inside bioreactor. The aim of biogas stations in Latvia is to produce electricity from burning biogas in cogeneration and selling it in the electricity market. In the research there is a theoretical evaluation of biogas upgrading to biomethane (CH_4 > 97%) in biogas stations and its use as fuel in the transport sector.

II. Methodology

The location of biogas stations depends on access to raw materials. Thus it is necessary to evaluate location of biogas stations if biogas will be used for upgrading to biomethane.

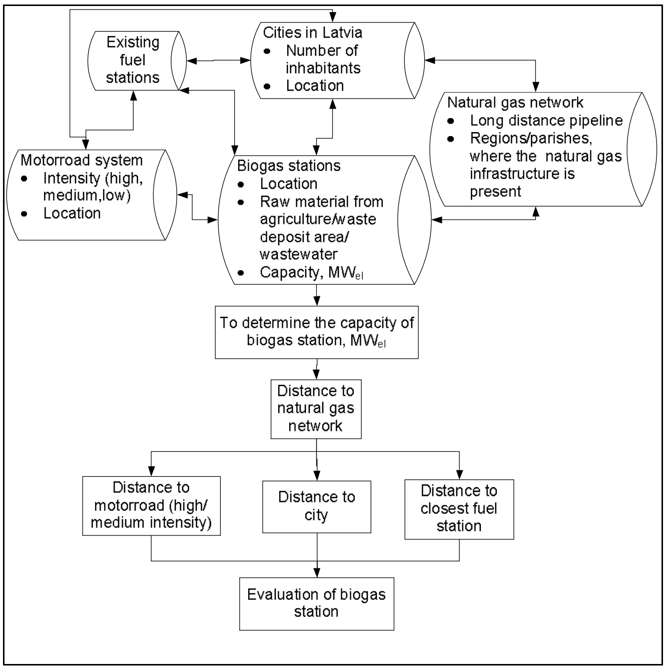

Fig.1. Scheme of methodology – evaluation of biogas station.

The aim of the methodology is to evaluate the use of biomethane as vehicle fuel in Latvia. The methodology takes into account the current situation – location of biogas stations and their production capacity, and existing road and natural gas pipe networks. For evaluation it is necessary to determine the criteria. After criteria there is an assessment of biomethane use as vehicle fuel in the transport sector.

The scheme (fig.) shows five criteria, which were determined as important based upon the research of other countries' experience. The result of the scheme is an assessment to determine their optimal location of selected biogas stations for upgrading and to transport biomethane to consumers. [2, 3,4]

III. Results

After the methodology was applied, all biogas stations are divided in 4 categories:

1st category – capacity of biogas station is more than 1 MW_{el}, distance to natural gas pipes 20 km or less;

2nd category – capacity is more than 1 MW_{el}, distance to natural gas pipes more than 20 km and at least 2 biogas stations (distance max 10 km) with total installed capacity more than 1 MW_{el}, distance to natural gas pipes more than 10 km;

3rd category – capacity 0.6 – 1 MW_{el}, distance to natural gas pipes more than 10 km;

4th category – capacity 1 MW_{el} or less, distance to natural gas pipes are more than 10 km.

As a result, the methodology determined that there are 25 biogas stations (1st and 2nd category) with enough power (total capacity 45.02 MW_{el}) and with an optimal location for biogas upgrading and effective biomethane transportation to consumers in fuel stations. Around these biogas stations there are 280 fuel stations. The distance between fuel and biogas stations is enough, if there is taken into account that for now biomethane injection in natural gas pipes is not yet allowed, so for biomethane transportation there need to use new pipes straight to fuel station or transportation by cisterns.

The potential amount of biomethane from 25 biogas stations (1st and 2nd category) can replace 11.47% of fossil diesel or 28.80% of petrol consumption from the year 2011. This amount of biomethane as a biofuel would take 7.58% in total fuel consumption in the transport sector, but together with 4.1% already used biofuel it would exceed 10% barrier from Directive for year 2020.

IV. References

[1] Ministry of Economics of the Republic of Latvia, statistics „Latvian Energy in Figures", year 2013

[2] T. NSCA 2006. Biogas as a road transport fuel. An assessment of the potential role of biogas as a renewable transport fuel. Research undertaken for the National Society for Clean Air and Environmental Protection. England. November 2008. – 52

[3] Patterson T., Esteves S., Dinsdale R., Guwy A. An evaluation of the policy and techno – economic factors affecting the potential for biogas upgrading for transport fuel use in the UK - Energy Policy 39 , 2011, 1806 – 1816

[4] Martin Frick, K.W. Axhausen, G.Carle, A.Wokaun Optimization of the distribution of compressed natural gas (CNG) refuelling stations: Swiss case studies – Transportation research part D 12, 2007, 10 – 22

Detection of abrupt and incipient faults in solar combisystems with artificial neural networks

Lelde Timma, Dagnija Blumberga, *Riga Technical University*

***Abstract* – The paper presents the application of artificial neural networks for detection of abrupt and incipient fault in solar combisystems. An experimental system, deterministic mathematical model and numerical model were used in the work. The results show that the incorporation of a developed fault detection tool within the solar combisystem raises the performance and reliability of operation.**

***Keywords* – abrupt and incipient faults, artificial neural networks, fault detection tool, solar combisystems.**

I. INTRODUCTION

An interest to incorporate solar collectors within heat supply systems in Latvia is growing. Market expansion of renewable energy sources has been mainly governed by the growing price of non-renewable energy sources (the price for heat energy has grown by 77.3 % in the time period 2006-2011, based on Central Statistical Bureau of Latvia).

Even when solar collectors are considered as a relatively simple engineering solution, failures still occur. The efficiency and reliability of systems can still be increased.

In future, monitoring and controlling equipment should deal with systems under dynamic, interconnected and highly complex algorithms and, at the same time, to have easy and low-priced incorporation, suitability for a variety of alterations and high data handling speed. Additionally, a future goal is the inclusion of a "memory", "learning" and "prediction" skills within the monitoring and control equipment, which could enable to control the system without supervision and to alert an owner about faults in the system before the fault has actually occurred, are future goal.

All the features mentioned above can be achieved within the artificial neural network (ANN). Thus the aim of the work is to develop a fault detection system for solar combisystems based on the principles of the programming of ANN.

II. SCIENTIFIC NOVELTY AND PRACTICAL APPLICATION

The application of ANN for solar combiystems has been conducted within the work. The complexity of the structure of ANN for fault detection in solar combisystems has been investigated. The needed input and output parameters for definition of a parsimonious model are elaborated.

The fault detection tool can be used for both owners of solar combisystems and research facilities. The use of the fault detection tool will escalate the overall efficiency and performance reliability of solar combisystem. The remote real-time monitoring for the variety of solar combisystems is possible with the developed neural network.

III. METHODOLOGY

Within the research, an experimental system, deterministic mathematical model and numerical model were used. Also the definition of the complexity for the ANN model, which satisfies the requirements of the model's parsimoniously, was elaborated. The structure for a numerical model was developed based on the value of R-squared and value of mean square error obtained for various learning algorithms. The developed model of ANN is then used for the determination of developing faults in solar and pellet combisystem.

IV. RESULTS

The highest value of the coefficient of determination and the lowest value of the mean square error was gained for the Levenberg-Marquardt back-propagation training algorithm; therefore the algorithm was used for further development of the artificial neural network. The amount of hidden neurons in the layer was set to 10, since this layout had more stable learning properties. Experimentally, 7 input parameters have been chosen based on the parsimoniously criteria, where R^2 for non-linear autoregressive neural network (NARX) was 96.669 %.

The simplified scheme of the structural assembly for the validated NARX network is given in Fig. 1.

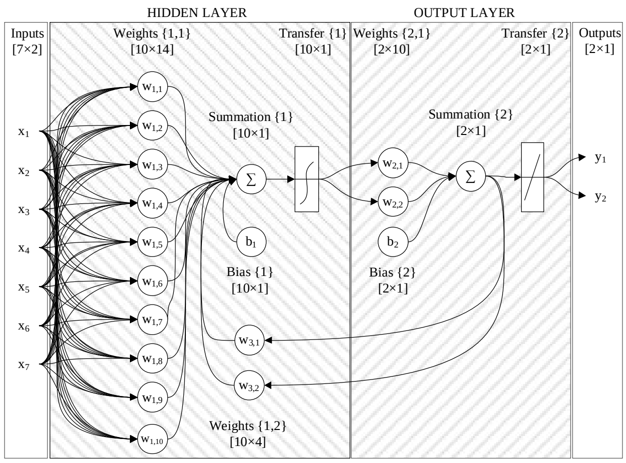

Fig. 1. Structure for the developed and validated NARX network.

Based on the research [1], almost 30 % of solar thermal projects have reported on the damage of a pump in solar collector loop, therefore the first simulation for the fault detection was chosen as solar pump failure. The fault was successfully identified. Other abrupt and incipient faults were also identified and detailed results are given in [2, 3].

V. DISCUSSION AND CONCLUSIONS

The results show that the incorporation of a fault detection tool, which is based on closed loop non-linear autoregressive neural network, within a solar combisystem raises its performance and reliability of operation.

Abrupt (solar pump failure and solar controller failure) and incipient (loose connector) faults for clear sky and cloudy conditions within the solar combisystem have been simulated and detected within the developed artificial neural network.

V. REFERENCES

[1] de Keizer, A. C., Vajen, K. and Jordan, U. Review of long-term fault detection approaches in solar thermal systems, Solar Energy, 85: 1430-1439, 2011.

[2] Timma L., Application of Artificial Neural Networks for Detection of Developing Faults in Solar Combisystems, Master Thesis work, Riga Technical University and Vilnius Gediminas Technical University, 2013

[3] Timma L., Blumberga D. Application of Artificial Neural Networks for Detection of Developing Faults in Solar Combisystems, 8th Conference on Sustainable Development of Energy, Water and Environment Systems, Croatia, Dubrovnik, 22-27 September, 1-11 p, 2013

Introduction to the technology of CO2 capture and geological storage

Ceri J Vincent, *British Geological Survey*

Abstract- **The concept of capture, transport and geological storage of carbon dioxide emitted from power plants and other industrial sources to mitigate greenhouse emissions is presented in this research. Other key aspects including legal requirements, economic and political implications and public engagement are also introduced.**

Keywords **– Carbon dioxide, capture, storage.**

I. Introduction

Carbon dioxide Capture and Storage (CCS) is a key technology in mitigating climate change. It is currently the only technology which offers the opportunity to greatly reduce carbon dioxide (CO_2) emissions from fossil-fueled power plants and industrial processes which generate CO_2 as a by-product.

II. Technology of carbon dioxide capture and storage

Carbon dioxide can be removed from the fuel before it is used (pre-combustion capture) or from the flue gases (post-combustion capture). The most developed capture technology uses an amine scrubbing process but other options such as membranes and cryogenic processes are being researched.

Carbon dioxide transport would likely be by pipeline, though transport by large tankers has been proposed for some offshore storage sites, depending on the amount of CO_2 being transported and the distance between the CO_2 source and the storage site.

A geological storage near the source needs to be identified. Storage sites are selected based on several criteria: storage is undertaken at sufficient depth such that the CO_2 will remain a highly dense fluid, thereby making most efficient use of the storage space, this is usually below around 800 m depth. The CO_2 will be stored in suitable reservoir rock which must be porous and permeable (i.e. the rock must have space between the rock grains and these spaces must be well connected) so that the CO_2 injected via a borehole (or boreholes) can displace the saline fluids found naturally in the pore space in order to allow the CO_2 to be stored. The storage reservoir must be capped by a thick, impermeable rock that will keep the CO_2 trapped. Over geological timescales, at least some of the CO_2 will dissolve into the native pore fluids and eventually, solid carbonate minerals may be deposited. Current estimates for storage capacity for Europe are up to 117 giga tonnes of CO_2 [1]. These assessments are largely based on broad regional studies and need to be refined by detailed investigations for individual storage sites.

The technical feasibility of CCS is demonstrated by large-scale flagship projects operating today including Sleipner (Norway), Snohvit (Norway) and Weyburn (Canada). Each of these projects injects more than 0.7 million tonnes of CO_2 per year into a geological reservoir for secure storage.

III. Other key aspects of CCS

In order to undertake CCS in Europe, the legal and regulatory requirements set out in the EU Directive on geological storage of CO_2 and national regulations must be considered. Across Europe, the state of transposition of the Directive is not uniform, in some countries storage is only permitted on a small scale and in other countries, full scale CCS as a mitigation option is encouraged.

Economic implications of CCS arise both from the cost of the technology and the regulatory framework. Currently the main scheme offering commercial credit for reducing emissions in Europe is the EU Emissions Trading Scheme (ETS) whereby companies are granted or purchase a number of credits for their CO_2 emissions.

Public engagement is key to the success of CCS. This requires clear and timely communication with relevant stakeholders. This aspect of CCS is increasingly important as the technology moves forward towards large-scale implementation. Networking and knowledge-sharing activities at national, European and international levels, such as those achieved through the CO_2GeoNet Network of Excellence and the FP7 coordination action CGS Europe, play a significant role in this process.

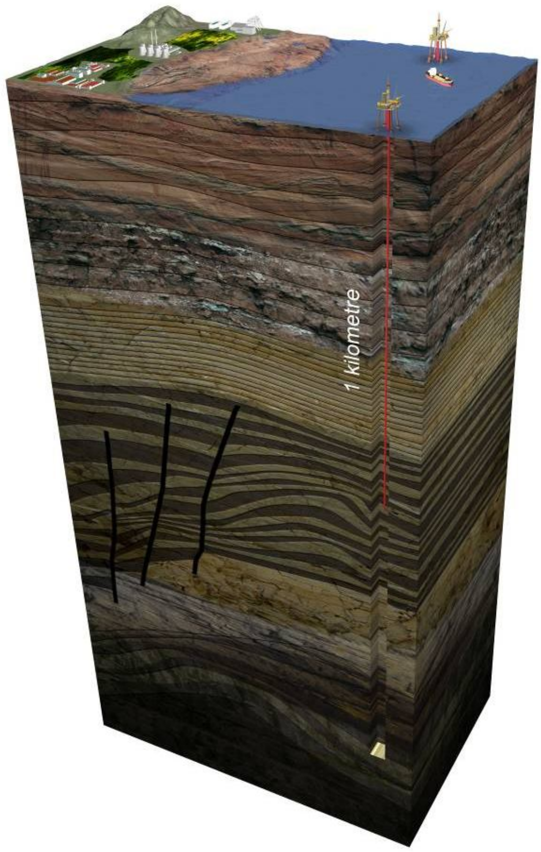

Fig.1. Simplified image of geological storage site for CO_2 (copyright BGS and Nottingham Centre for CCS)

IV. References

[1] EU GeoCapacity D16 Storage capacity. Available from http://www.geology.cz/geocapacity/publications

Influence of biomass pretreatment process time on furfural extraction from birch wood

Prans Brazdausks, *Latvian State Institute of Wood Chemistry; Institute of Energy Systems and Environment*,
Maris Puke, Irena Kruma, Nikolajs Vedernikovs, *Latvian State Institute of Wood Chemistry*

Abstract – **Furfural is a biomass-derived chemical that can be used to replace petrochemicals. In this study, dilute sulphuric acid hydrolysis was used for hemicelluloses extraction from birch wood. The reaction was investigated at different biomass treatment times (10-90 min, increasing it by 10 min). It has been found that the greatest amount of furfural, i.e. 10.3%, which is 70.0% from the theoretical yield, can be obtained after 90 min. Given that furfural yield generally does not exceed 50% from the theoretical amount, the result can be considered as very good.**

Keywords **– birch wood, cellulose, hemicelluloses, bioethanol, furfural.**

I. Introduction

However rich our planet`s nature and however varied its resources, these reserves are not inexhaustible. Increasing consumption some of the resources will be depleted faster than can be reproduced or faster than science and production industry will be able to offer solutions for replacing them with other resources or raw materials. For example, with a decline in the availability of fossil fuels, humans are forced to search for an alternative to ensure their existence and welfare development. One of the alternatives is to start using biomass as a raw material for production of various chemical products.

Biomass is one of the world`s biggest and sustainable renewable resources, which contain carbon. Its good management and efficient utilization to the organic chemical products with a high added value are a great challenge for both scientists and the entire green chemistry industry.

Bioethanol production of lignocellulose containing raw materials (for example, wheat, barley and rice straw, sugarcane bagasse, wood residues, etc.) is one of the areas of biomass application. It is well known that biomass consists mainly of cellulose, hemicelluloses and lignin, but the available parts of biomass for bioethanol extraction are cellulose and hemicelluloses, which must be disposed of by the pretreatment process. This process is one of the most important stages of bioethanol production, in which the mechanical and chemical structure of biomass cell wall is changed, as well as makes it easier to convert to bioethanol in further proceedings.

During the lignocellulosic biomass pretreatment process, degradation products with an inhibitory effect on the fermentation process may be formed.

One of the greatest inhibitors in the pretreatment process is 2-furaldehyde or furfural, which is generally derived from C_5 polysaccharides - pentosans, mainly xylose and arabinose, that are contained in the hemicelluloses of lignocellulosic materials [1]. However, own furfural has been identified as one of the top 30 high-value, bio-based chemicals. Besides, furfural and its derivatives are the future key chemicals that find wide applications in oil refining, plastics, food, pharmaceutical and agrochemical industries [2] and also have been used to make jet and diesel fuel range alkanes, to serve as a gasoline blendstock [3].

So, it is very important to combine the production of furfural and bioethanol in the same process, but so far it had not been possible even in theory, because, in all known furfural extraction technologies, 40-50% of cellulose is destroyed during furfural formation, when biomass with high pentosan content is used [2]. Therefore, to resolve this problem and at the same time improve the ecology and economy of the pretreatment process, kinetic parameters of furfural formation need to be changed.

The main objective of this study was to determine the influence of time on the formation of furfural dynamics and its yield from lignocellulosic biomass with high pentosan content in the biomass pretreatment process. As a biomass pretreatment method, we used acid-catalytic dehydration, which is the only route for production of furfural in today`s chemical industry [1], [2].

II. Experimental

Birch wood was used as the raw material, because it is one of the most widespread tree species in Latvia and has high content of cellulose (44.9%, calculated on oven-dried wood) and hemicelluloses (26.3%, calculated on oven-dried wood).

At first birch wood logs were chipped to a technological woodchips scale and air-dried to room moisture, then sieved to a size between 10 and 20 mm and stored in sealed plastic barrels for further use.

Before starting the furfural extraction from birch wood, the prepared woodchips were mixed with a catalyst solution in a specially constructed blade shape mixer. As a catalyst, dilute sulphuric acid solution was used, which is commonly used in industrial practice for obtaining furfural from different plant raw materials [2].

The birch wood chips, mixed with a dilute sulphuric acid solution, were treated with a continuous steam flow in an original pilot plant, which enables modelling the industrial process.

The time of biomass pretreatment was changed from 10 to 90 min, increasing it by 10 min, but constant parameters of the hydrolysis process were catalyst concentration, catalyst amount and process temperature. After each 10-min period, condensate samples, which contain furfural, were taken.

Those condensate samples were analysed by the "Potassium bromide-bromate" method, which gives results about the influence of time on the formation of furfural dynamics and its yield. This method is based on the disruption of furfural double bonds by the action of bromine.

The amount of furfural in hydrolysate was calculated by equation (1):

$$\text{Furfural, \%} = \frac{(a-b)\cdot V \cdot 0{,}0024}{n \cdot G_o} \cdot 100 \qquad (1)$$

where:

a – thiosulphate volume in the blank test, mL
b – thiosulphate volume in the condensate test, mL

V – volume of the condensate, what was obtained in the hydrolysis process, mL
N – volume of the condensate, what was taken for analysis, mL
G_o – oven-dray mass of the sample, what was taken for analysis, g
0.0024 – mass of furfural, which corresponds to 1 mL of sodium thiosulphate solution.

III. Results and discussion

The time of biomass treatment is one of the main technological parameters. To study the influence of biomass pretreatment time on the formation of furfural dynamics and its yield, we selected nine different residence times, i.e. 10, 20, 30, 40, 50, 60, 70, 80 and 90 min. In order to compare the results of the study with theoretical results, all obtained results were calculated to oven-dried wood.

A. *Influence of time on the formation of furfural dynamics*

As demonstrated by the results of the study on the dynamics of furfural formation, its greatest amount of 2.34-2.62%, which is 15.95-17.86% from the theoretically possible amount, was formed in the first 10-min period from the beginning of birch wood pentoses monosaccharide dehydration process.

A similar amount of furfural, i.e. 2.09-2.33%, which is 14.25-15.88% from the theoretically possible amount, was also obtained in the next 10-min period from the beginning of the process. In the next 10-min period, the amount of furfural was from 1.42% to 1.67%, which is from 9.68% to 11.38% from theoretically possible amount, respectively.

Continuing the birch wood hydrolysis, the amount of furfural formation gradually decreased. In the 5th 10-min period, the amount of furfural was only from 0.79% to 0.87%, but in the 9th 10min period, the amount of furfural was 0.32% on the average.

B. *Influence of time on furfural yield*

The results of the study on the yield of furfural from birch wood have shown (Table I) that the greatest yield of furfural, i.e. 10.27%, which is 70.00% from the theoretical yield, can be obtained after 90 min. Since the furfural yield generally does not exceed 50% from the theoretical amount [1], [2], the result can be considered as very good. Wherewith it is possible to obtain a high added value product and create a cleaner production technology using the dilute acid hydrolysis pretreatment method for preparing biomass for bioethanol production.

IV. Conclusions

1. The greatest amount of furfural was formed in 10 min to 30 min from the beginning of birch wood pentoses monosaccharide dehydration.
2. Increasing the time of biomass treatment in the range from 10 to 90 min, the amount of furfural increased from 2.6% to 10.3%, which is 17.6-70.0% from the theoretical yield. Since the furfural yield generally does not exceed 50% from the theoretical amount, the result can be considered as very good.
3. Due to the fact that lignocellulose, which has become more accessible for bacteria or enzymes, remains after extraction of furfural, the results of this study will be the basis for further research on the acquisition of second-generation biofuel from birch wood.

V. Acknowledgements

This study was supported by the European Regional Development Fund (ERDF) project No. 2010/0288/2DP/ 2.1.1.1.0/10/APIA/VIAA/038.

VI. References

[1] Zeitsch K. *The chemistry and technology of furfural and its many by-products*, 1st Edition, Elsevier, 2000.
[2] Hoydonckx H.E., Van Rhijn W.M., van Rhijn W., de Vos D.E., Jacobs P.A. Furfural and Derivatives. In *Ullmann's Encyclopedia of Industrial Chemistry*, 7th Edition, Wiley-VCH, 2007.
[3] Xing R., Qi W., Huber G.W. Production of furfural and carboxylic acids from waste aqueous hemicellulose solutions from the pulp and paper and cellulosic ethanol industries. *Energy & Environmental Science*, 2011, vol. 4, N 6, p. 2193–2205.

TABLE I

Influence of biomass pretreatment time on the furfural yield from birch wood, % from oven-dried wood

Experiment		10 min exp.	20 min exp.	30 min exp.	40 min exp.	50 min exp.	60 min exp.	70 min exp.	80 min exp.	90 min exp.
Time, min	10	2.58	2.56	2.57	2.46	2.34	2.59	2.62	2.50	2.40
	20		4.65	4.72	4.79	4.49	4.68	4.76	4.65	4.67
	30			6.26	6.43	6.11	6.10	6.19	6.08	6.34
	40				7.62	7.32	7.15	7.28	7.17	7.50
	50					8.15	7.94	8.08	8.01	8.37
	60						8.55	8.71	8.63	9.04
	70							9.22	9.11	9.55
	80								9.49	9.96
	90									10.27

Design of a support program for energy efficiency improvement in Latvian industry

Kristīne Dobrāja, Līga Ozoliņa, Marika Rošā, *Riga Technical University*

Abstract - **The aim of this paper is to assess the voluntary agreement for increasing energy efficiency in industry of Latvia and provide recommendations for more effective implementation in the future. Energy efficiency in Latvian industry and data monitoring of the CCFI (Climate Change Financial Instrument) subprogram "Complex solutions to reduce greenhouse gas emissions in production facilities" is analyzed. An evaluation of the voluntary agreement is given and outlines suggestions for more effective implementation of the Latvian program to achieve the defined energy reduction targets for industry.**

Keywords – **voluntary agreement, energy efficiency, Latvian industrial sector**

I. Introduction

Industrial sector is the third largest energy end-consumer in Latvia. It is possible to reduce energy consumption in the industrial sector by introducing energy efficiency measures. Energy efficiency has an important role to improve environmental sustainability, energy security and economic indicators in the industrial sector. This paper presents an evaluation of energy efficiency in the Latvian industrial sector and an evaluation of the CCFI sub-program "Complex solutions to reduce greenhouse gas emissions in industrial buildings" and voluntary agreement program. The aim of the evaluation is to develop a voluntary agreement program and make proposals for its effective implementation in Latvia.

II. Assessment of Energy Efficiency in Latvian Industrial Sector

The energy consumption of the industrial sector on average is 32 PJ/year over the last 5 years. Therefore it is essential to look at the breakdown of the sector as well as the number and size of enterprises and their energy efficiency performance. The Latvian industrial sector ranks third in final energy consumption after households and the transport sector. The industrial sector is divided into three sub-sectors: construction, mining and quarrying, and manufacturing. Each of the sub-sectors includes a variety of industries that are classified taking into account the NACE Rev. 2 classification [1].

So far, there are few studies carried out on energy efficiency in the Latvian industrial sector. The first official document which was attributed to the improvement of energy efficiency in the Latvian industrial sector was the First Latvian Energy Efficiency Action Plan 2008 – 2010 followed by the Second Latvian Energy Efficiency Action Plan (NEAP) 2011 - 2013. Developing the First and Second NEAP the target was set as 159 GWh energy savings in the industrial sector by 2016. The target 159 GWh is around 2% of the final energy consumption in the industrial sector [1].

III. The Evaluation of the Sub-Program of the Climate Change Financial Instrument

The sub-program "Complex solutions to reduce greenhouse gas emissions in industrial buildings" is within the framework of the project CCFI. The sub-program was granted financial support for energy efficiency measures. By introducing the subprogram it was planned to achieve the target of NEAP - 159 GWh until 2016 [1, 2].

A. *Energy savings for the year 2012*

The enterprises which had submitted their monitoring reports for the full year have achieved energy and CO_2 emission savings. Average difference between planned and achieved results of CO_2 emission savings is ~55% greater than expected between 7 companies. The average energy savings between 7 enterprises is around 50% more than planned. It would be necessary to analyze energy audit data and monitoring reports again in cases where the difference between the achieved energy consumption and the planned is 3-5 times more. Data with wide variations is not appropriate for further use because it does not present objective results of effectiveness in a particular case.

B. *The current energy savings by implementing projects*

The initial estimated energy savings were 34 GWh if 48 enterprises implement all that was planned. Consequently, in 2012, 43 enterprises were involved in the subprogram. The energy savings of 43 enterprises could amount to 29 GWh. At the moment, the project is implemented and completed/almost completed in 39 enterprises and the planned energy savings has reached only 28.1 GWh. There is still necessary 130.9 GWh energy savings which is 82% of the NEAP target. This shows that it is necessary to introduce the second measure - voluntary agreement [1, 2, 3].

IV. Voluntary Agreement as an Energy Efficiency Support Policy Instrument for Industry Sector

Voluntary agreement is an instrument for potential detection and long-term policy planning instrument for industry. The instrument is widely and successfully implemented throughout Europe. Scandinavian countries - Sweden, Finland, Norway – have extensive experience in the development of voluntary agreements. Developing Latvian agreement program there should be taken an example from the Scandinavian countries [4].

A. *Voluntary agreement in Latvia*

Voluntary agreement as a measure to reduce energy consumption in industry was included in the Second NEAP. The Cabinet of Ministers Regulation No. 555 "Agreements on Energy efficiency, promoting energy audits and energy management systems in industrial enterprises" entered into force on 15 July, 2011. Successful agreement program is based on a clear and specific target. Neither the base year nor the future target which is to be achieved through the implementation of this regulation is defined. The responsible institutions and participants of the agreement program are also not defined – administrator, programs agent, the auditor, the client. The creator of the program is the administrator. The Ministry of Economy is the administrator. There is not paid much attention to marketing activities in the Latvian agreement program. Public awareness - seminars, discussions, contacting with the media and enterprises, is very important for the successful implementation of the program. There is no state financial support - subsidies - mentioned in the Cabinet of Ministers' regulation. Evaluating the experience of other countries, it can be concluded that the Latvian program is not fully developed and thus, the energy savings' target for the industrial sector will not be achieved [1, 5].

An agreement program should be made like a system with components. The components move towards the system to the certain direction and stimulate to achieve the target of the program. The components are subordinate activities/instruments that contribute the achievement of the results (Fig. 1.).

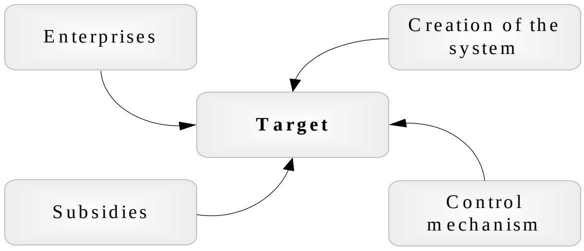

Fig. 1. The components of voluntary agreement

There should be created a system that will manage the program and defined the responsible institutions for the successful introduction, implementation and achievement of the results. There should be evaluated which will be the clients. Stable and specific control mechanism promotes to achieve the program's objectives. The introduction of subsidies is economically stimulating tool that will increase the number of program participants and the successful introduction of the program and its implementation.

The target of the program should be specific, measurable, appropriate, realistic, and timed (*SMART*) [6]. If the *SMART* concept is used to define the target then it could be:

- Achieve 10% of energy savings in 20% of the industrial enterprises during the period 2015 – 2020

According to the requirements of the Directive 2012/27/EU, the implementation of the Directive must be started by 15 June, 2014. To begin implementation, a focus group needs to be established, data collected, a database must be established, a target set and the agent of the program must be defined. The marketing activities should be launched from the beginning of the program. Training and certification of the energy auditors should be conducted in the first implementation years of the program. There is active program promotion in the beginning to attract enterprises. When carrying out energy audits, the control and implementation of energy efficiency measures occurs throughout the process. The first energy savings would be witnessed in those enterprises that were involved from the beginning of the program. The submission of the monitoring reports continues until the program is fully closed. The controls of the monitoring reports also continue until the program is fully closed. Program evaluation and implementation of improvements should be performed after the first year of implementation of the program. All the activities that were described before are linked together and are making a scheme how the voluntary agreement is working (see Figure 2).

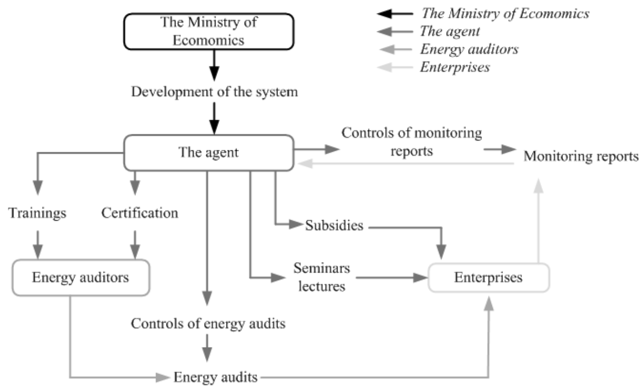

Fig. 2. A set of activities of voluntary agreement

Voluntary agreement can be a successful program and could achieve the necessary energy savings for the industrial sector in Latvia.

V. Conclusions

The energy saving target of the Latvian industrial sector will not be achieved by introducing only one energy efficiency measure. There is a need to introduce other measures to improve energy efficiency. One of the priorities is voluntary agreement. Ministry of Economic has determined that with this program should reach 130.9 GWh or ~ 82% of the energy savings target. The introduced regulations of the Cabinet of Ministers No.555 are incomplete and should be improved. The set target will not be achieved by 2016 because voluntary agreement is a long-term policy planning tool. Experience of Scandinavian countries would be appropriate to Latvian support policy programs. Within the Latvian agreement program, it is needed to clarify the target, to establish a system that is responsible for overseeing the program, to define the control mechanism, to set a specific client of the program, to set the type and size of subsidies and to create a marketing program. To achieve the target of the Second NEAP for the industrial sector, 20% of manufacturing and mining and quarrying enterprises should be involved in the program and each enterprise must achieve 10% energy savings. By covering a great number of enterprises, it would be possible to promote energy efficiency in the industrial sector and corporate awareness of the possible measures would increase.

VI. References

[1] Ministry of Economics, Second Latvian Energy Efficiency Action Plan (2011-2013), Riga, 2011, Latvijas Vēstnesis, 2011, Nr. 148. / 4546.

[2] Climate Change Financial Instrument, [Accessed] 22.04.2013.] Available: http://kpfi.lv/modules/Konkurs/projekti.php?id=8&lang=lv

[3] Paturska A. Atbalsta politikas instrumentu izvērtējums energoefektivitātes paaugstināšanai rūpniecības sektorā Latvijā. Bachelor thesis., Riga. 2012. – 64 p.

[4] Thollander P., Dotzauer E. An energy efficiency program for Swedish industrial small- and medium-sized enterprises, Journal of Cleaner Production. – Nr. 18, 1339. – 1346 p, 2010

[5] The Cabinet of Ministers regulations No. 555 “Agreements on Energy Efficiency, promoting energy audits and energy management systems in industrial enterprises”, Latvijas Vēstnesis. – Nr. 109./4507. 201

[6] M. G. Rietbergen, K. Blok Setting SMART targets for industrial energy use and industrial energy efficiency, Energy Policy, Volume 38, Issue 8, 4339.-4354 p. 2010

Production of electric devices

Anna Paturska, Līga Ozoliņa, Dagnija Blumberga, *Riga Technical University*

***Abstract* – In this paper, one of the biggest companies in Baltics providing products such as microelectronic components and electric devices is studied. The aim of the study was to explore the company and the main processes using data analyses of production and energy consumption. At the end of the study, one suggestion is given for cleaner production based on electricity consumption in one of the company's facilities – mounting facility.**

***Keywords* – production of electric devices, cleaner production, electric digest production, manufacturing processes, mounting facility.**

I. Introduction

The company was established in 1959 and, until today, its production, space and production facilities have decreased more than ten times, however it is still one of the leading companies in the Baltic region providing products such as microelectronic components and electric devices.

The company is located around 8 km from the centre of the city of Riga.

II. Scheme of Existing Production Facilities and Summary of Collected Data

The production of products is organized in three different facilities:

- Facility of semiconductor structures;
- Mounting facility;
- Facility of electro technical devices.

In the facility of semiconductor structures, crystals or „microchip hearts" are being produced by means of which microchip works. This facility fulfills crystals functions. The prepared crystals are then forwarded to the mounting facility where micro schemes are being produced - frames, covers and other details are being attached to crystals.

The facility of electro technical devices is not connected with any other facility, but works independently, producing electric plates.

As the cleaner production advice is being provided only for the mounting facility, only information regarding this specific facility will be provided in the remainder of the paper.

A. *Mounting facility*

In mounting facility crystals that are produced in semiconductor structures facility are being used. In this facility crystals are being processed in different devices and micro schemes. (see Fig.1.)

Crystal plates are being forwarded from the semiconductor structure facility to the first section, where the crystals are separated one by one. First crystal plates are cut by using a plate slicer, afterward the separated plates are being stretched and crystals separated one from other. This device also separates broken crystals. After separating the crystals, it is essential to examine the appearance of the crystals as well as to check that there are no broken crystals left. This operation is done manually by a few employees using a colored microscope.

After separation of the crystals, there are three different options for further processing – crystals can be attached to frame, attached to body or not attaching to anything. According to these three options, the crystals are being forwarded to separate sections.

Attachment of the crystal to a frame or body is done by the same principle as in the previous production step – on the chosen part, a drop of glue is placed, and a crystal is attached and soldered with a soldering device. The crystals can be attached with aluminum or golden „legs".

After attaching the outputs, there is a quality check, during which the connection of frames, bodies and crystals are examined. If it is not good, the product is considered broken.

The third option to attach the outputs is the non-body option where the crystal is not attached to anything – outputs are being attached directly to the crystal. This process is done manually with a high quality microscope, using tweezers.

After attaching the outputs, the crystals are covered with a layer of varnish to protect them from the effects of the external environment. When the protection coat is applied, the products are forwarded to the thermal cycler in the corresponding section, where the protection coat is dried at a temperature of 150°C – the possible fluctuation of temperature is +/- 10°C. The drying process takes 7 hours.

Further, the products are forwarded to a confinement room where they are kept at least half an hour at a specific temperature of 120°C with a permissible fluctuation of temperature +/- 10°C in the presence of nitrogen. After the process of confinement, an imposition of a protective cap is done. A plastic pill is put on the product – it melts and covers the product with a kind of protecting cap. Later a metal cap, which is previously cleaned in a specific vacuum device, is put on products. This step is essential because of high requirements regarding tidiness and the environment. After attaching the cap, the micro scheme goes through a thermal examination, after which it is finally finished.

Before delivering micro schemes and transistors to costumers they have to be tested. Both thermal reliability as well as hermetic seclusion is being tested along with other tests.

After the tests, all schemes are tested for quality manually, divided by properties and labeled. After labeling, another test is conducted for final examination, after which the products are sent to the warehouse.

B. *Finished products*

The finished product in the mounting facility is divided into two groups – micro schemes and transistors. Overall, ten different products are produced:

- Operational amplifiers;
- Voltage comparators;
- Analog-to-digital converters;
- Digital-to-analog converters;
- Accurate voltage to frequency and frequency to voltage converters;
- Timers;
- Voltage regulators;
- Transistors and transistor pairs;
- RF transistors;
- Digital signal processors (DSP);

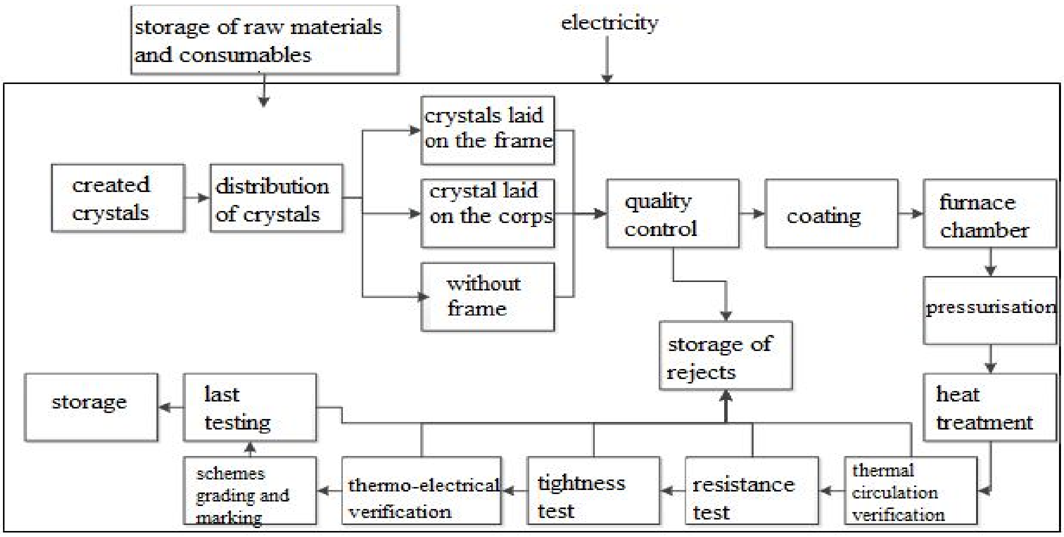

Fig. 1. Scheme of Mounting corps. Each of the given types contains different products with different properties and functions, for example, different voltage range. The company produces more than 200 different types of micro schemes and transistors.

C. *Data analysis*

All processes are being powered by electricity. Thermal energy is used only for heating.

The consumption of electricity, both by months and years, is explained with uneven production – products are produced irregularly on special order from clients (see Fig.2).

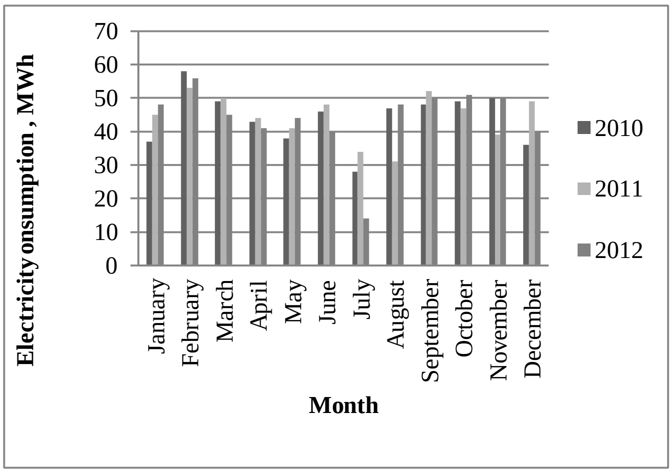

Fig. 2. Energy consumption of Mounting facility

III. Proposal for Cleaner Production

It is proposed to replace all ventilators from old ventilation system to new ventilation equipment (see Table I).

The results in Table 1 shows that using these devices a 10.5% energy savings can be achieved in the mounting facility every year. In addition, changing devices in all facilities would give a significantly higher savings.

Around 84% of the savings in a year are obtained from electricity consumption in the ventilation system and 10.5% savings from the total electricity consumption.

For the implementation of these recommendations, investment is assumed to be 8000 Ls, which, taking into consideration the given information, should pay off in less than three years. Assuming that the economic life of the equipment is 10 years, income generated from the proposed actions could be up to 59875.56 Ls. This project is economically feasible, knowing that the net present value of money for the 10 year long economical life period is 15111.48 Ls and the value of net profit margin is 53 %.

TABLE I

EXPECTED SITUATION AFTER IMPLEMENTATION OF THE PROPOSED IMPROVEMENTS

	Nr. of ventilators	Operating time	Energy consumption by ventilation devices	Total energy consumption in mounting facility
Present situation	6	5 ventilators operates 2688 h per year, 1 operates 8784 h per year	66.7 MWh	~530 MWh/year
Expected situation	6	5 ventilators operates 2688 h per year, 1 operates 8784 h per year	10.4 MWh	~474 MWh/year

IV. Conclusions

In this research, an electricity consumption reduction event is proposed for the company studied – the replacement of the ventilation system in the mounting facility – replacement of central ventilators. This recommendation is both technologically and economically justified, providing reduction of energy and expenses for the company.

The energy saving green campus program and environmental effect

Iryna Rubezhniak, Olena Shelimanova, Evgeny Antipov, Olena Varava, Nadezhda Yosypenko, *National University of Life and Environmental Sciences of Ukraine*

Abstract -**The simplified energy audit and detailed energy audit of buildings of the NUBiP of Ukraine were carried out. The saving measures, such as insulation of the outer wall by foam polystyrene, modernization of the commercial center of calculation and regulation of heat energy consumption were proposed.**

Key words **energy-saving measures, energy audit, polystyrene insulation layer, commercial block of heat consumption and regulation accounting, greenhouse gases**

The power saving green campus program in National University of Life and Environmental Sciences of Ukraine (NUBiP of Ukraine) was based on an assessment of gas volume [2] that was used for heat of hostels, university buildings and technical structures, quantity and composition of harmful air emissions. For this purpose, a simplified energy audit was carried out in 2012 of separate educational buildings and students hostels of the university with the aim of proposing measures to reduce energy use, as well as the related emissions and the economic cost of the energy used.

The analyse of data indicated that the heat consumption of university buildings increased from 25918,6 (in 2008) to 28629,0 Gkal (in 2010), i.e. every year the gas consumption for purpose of building heating and hot-water supply increased [3].

It is well known that air pollutants such as nitrogen dioxide, carbon monoxide, sulfur dioxide and particulates are produced as a result of gas combustion for space heating. During the study period, the quantity of carbon dioxide increased by 2-7% due to natural gas combustion [1]. According to the Intergovernmental Panel on Climate Change, carbon dioxide is the most important of the greenhouse gases which increases as a result of human activity.

The student hostel №7 and university building №8 were selected for the detailed energy audit [2]. Once the heat consumptions were calculated, the following saving measures were applied with the same simulation tool:

A. Insulation of the outer walls by a heat-insulation layer of foam polystyrene. The heat balance was calculated for three thicknesses of insulation layer (50; 100 and 150 mm). The calculating application program "KAN OZC" (Producer Company „KAN-Therm" (Poland) was used to calculate heat losses after thermal modernization. This program is certified in Ukraine and can be used for calculation of the heat losses of both separate premises and buildings. The algorithms and calculations of "KAN OZC" correspond to Ukrainian effective standards and building norms. The comparative analysis of heat losses before and after modernization of buildings shows that the optimal thickness of the insulation layer of polystyrene is 100 mm. After polystyrene application, the thermal resistance increased 4.2 times (3.3 m^2 K/W) and the total amount of heat loss decreased 1.4 times (215443 W).

B. Modernization of commercial center of calculation and regulation of heat energy consumption.

Energy consumption in hostel №7 and university building №8 were reduced by raising the thermal characteristics is 265,2 Gcal and 112,4 Gcal, respectively due to proposed energy-saving measures. Table 1 shows the economic effect of the proposed saving measures.

TABLE 1

ECONOMIC EFFECT OF ENERGY SAVING MEASURES

Measures	Objects	Reduction of heat energy, Gcal/y	Economic effect, UAH	Payback period, years
Heat insulation of outer walls	building №8	90,2	69084	4,5
	Hostel №7	199,8	153026.82	3,2
Modernization of commercial center of calculation and regulation heat consumption	Building №8	22,2	17003	4,7
	Hostel №7	65,4	50089.86	1,2

The payback period of saving measures is from 1, 2 to 4,7 years.

The total amount of harmful air pollutants decreased by 40% for university building №8 and by 69% - for hostel №7 due to the reducing gas consumption and proposed measures.

Thus, energy-saving measures reduce the amount of the greenhouse gases and disastrous effects of the global warming.

REFERENCES

[1] Safiulina, K.R.,. Kolienko, A.G, Tormosov, R.Yu. *Energy Saving on college campuses: A guide for the students*. Moscow: Higher Saves list. Education,"Polygraph plus", 2010.328p.

[2] Kozirsky, V.V., Berek, O.M., Shelimanova, O.V., Antipov, E. A.. Result of simplified energy audit of objects of NUBiP of Ukraine. *Energy and Utilities and automatic*, 2012, № 1 (12), p. 55-63.

[3] Varava . O.I, Yosypenko, N.V, Rubezhniak. I.G. Environmental effect of energy-saving technology of "green campus *The Urgent Ecological and Environmental Management Problems:* Coll. Res. Articles. – Issue 15. – M.: PFUR, 2013. –p.494-498

Principal concepts of CO_2 geological storage: from rock sampling to coupled time-lapse petrophysical and seismic numerical modelling. Case study of prospective onshore and offshore structures in Latvia

Kazbulat Shogenov, Alla Shogenova, *Institute of Geology, Tallinn University of Technology*
Olga-Vizika Kavaddias, *IFP Energies nouvelles*
Davide Gei and Edy Forlin, *OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale*

Abstract – **In this study we (1) selected and sampled two onshore and two offshore geological structures within the Cambrian saline aquifer suitable for CO_2 geological storage in the Latvian area of the Baltic Region, (2) determined reservoir quality of the Cambrian sandstones prospective for CO_2 storage in four structures, (3) estimated storage capacity, (4) studied geochemical, mineralogical and petrophysical alterations of the host reservoir and cap rocks, induced by CO_2 storage and (5) provided coupled perophysical and seismic numerical modelling of CO_2 plume within one offshore storage site.**

Our study clearly shows effectiveness of applied time-lapse rock physics and seismic numerical modelling methodology to detect presence of injected CO_2 and monitor its evolution in the E6 Baltic Sea offshore structure.

Keywords– **CO_2 geological storage, time-lapse rock physics and seismic numerical modelling, petrophysical alteration, geophysical monitoring**

I. Introduction

This manuscript briefly describes the main findings of the author PhD study – "Petrophysical models of CO_2 plume at the prospective storage sites in the Baltic Region". The goals of the study are to (1) select and sample geological structures within the Cambrian saline aquifer suitable for CO_2 geological storage (CGS) in the Latvian area of the Baltic Region, (2) determine reservoir quality of the Cambrian sandstones prospective for CGS in the structures, (3) estimate storage capacity, (4) study geochemical, mineralogical and petrophysical alterations of the host reservoir and cap rocks induced by CGS, and (5) provide coupled petrophysical and seismic numerical modelling of CO_2 plume within E6 offshore oil-bearing storage site to monitor CGS. The study aimed on these targets [1, 2, 3] is briefly described below.

II. Data and methods

Six onshore wells from the South Kandava and Dobele structures, as well as the E6-1/84 and E7-1/82 wells from two offshore structures E6 and E7, respectively were selected for detailed study. 24 samples of Deimena Formation of Middle Cambrian sandstone reservoir and Lower Ordovician cap rock were taken from five drill cores stored in the Latvian Environmental, Geological and Meteorological Centre (LEGMC). 15 of these samples represent the reservoir across all four structures, while nine samples from the onshore wells are taken from the cap rock [1]. Three-dimensional (3D) structural models were constructed [2]. Four unpublished exploration reports (1970-1984, in Russian) stored in LEGMC were used. A more detailed 3D geological static model of the E6 structure, supporting fluid flow simulation of CO_2 storage, was built.

CO_2 injection "alteration experiment" supporting acidification effect of aquifer brine was conducted at IFP Energies nouvelles (IFPEN).

A full range of (1) petrophysical and petro-acoustical, (2) geochemical and (3) mineralogical research were conducted in previous studies before [1, 2] and after the alteration experiment:

(1) Grain and bulk densities, porosity, permeability, P- and S-wave velocities (measured at IFPEN petrophysical laboratory)

(2) X-Ray Fluorescence analyses (XRF), X-Ray Diffraction (XRD) and chemical analysis using gravimetric and titration methods (measured at Acme Analytical Laboratories Ltd., Vancouver and at Tallinn University of Technology - TUT)

(3) Transmission electron microscope (TEM) and scanning electron microscope (SEM) studies (at TUT)

Experimentally measured properties were compared with reported data and the average properties of rocks were estimated. This data were applied in a theoretical CGS capacity (M_{CO2t}) estimation. We developed "optimistic" and "conservative" approaches for M_{CO2t} estimation in the studied structures according to different storage efficiency factors applied. In turn, optimistic and conservative M_{CO2t} were calculated with minimum, maximum and average values (min-max/mean) of porosity estimated using measured and reported data.

Finally, we applied time-lapse rock physics and seismic numerical modelling methodology to compute synthetic seismograms before and after injection of CO_2 and analyzed seismic response while injecting CO_2 into the E6 offshore geological structure. We applied White's mesoscopic rock physics theory to compute the P-wave velocity (V_P), attenuation and quality factors of a partially saturated medium. We estimated properties of reservoir rocks with different CO_2 saturations, specifically 5%, 10%, 15%, 50% and 90%, without and with petrophysical alteration effect. We performed plane-wave simulations and NRMS difference technique to compare seismic datasets before and after CO_2 injection simulating seismic acquisitions at different times over the same studied area [3].

We implemented petrophysical alteration effect of the CO_2 hosting rocks that expected to be reflected in the seismic response. Seismic numerical model of stored underground CO_2 plume was coupled for the first time in this study with petrophysical alteration model. We applied the alteration approach in two different scenarios: (i) CO_2 homogeneous reservoir saturation approach (**uniform model**) and (ii) CO_2 plume accumulation approach (**plume model**). Thereby, we developed four scenarios: *(1) Uniform model without alteration effect, (2) Uniform model with alteration effect, (3) Plume model without alteration effect and (4) Plume model with alteration effect*. Synthetic seismic sections were produced, analyzed and compared with baseline dataset (before injection of CO_2). The first two scenarios were conducted to explore visualisation ability of the seismic technique in the studied geological structure. The third and fourth scenarios present more realistic approaches in case of CO_2 injection and involved more complex study (plume shape and CO_2 concentration model).

III. Conclusions

- Geological structures in Latvia were estimated as prospective reservoirs for CO_2 storage. The structures lead to a structural high within the Cambrian saline aquifer and impermeable seal, which are suitable for both CO_2 and natural gas storage.
- Good reservoir properties of the Cambrian sandstones were confirmed by new laboratory experiments in three studied boreholes (E6-1/84, E7-1/82 and Db92). Measured petrophysical properties confirm those reported in earlier data.
- The best reservoir properties (porosity and gas permeability) were found in sandstones from the Latvian E6 offshore structure. This structure was estimated as the most prospective for CGS in the Baltic Region. Its estimated optimistic CO_2 storage capacity was in the range of 251-602 Mt in total (average 377 Mt). However, the risk of CO_2 leakage due to uncertainties of fault system should be considered and further fault integrity risk assessment work is required.
- Estimated optimistic CO_2 storage capacity was 14-66 Mt in the E7 offshore structure, 5-122 Mt in the South Kandava and 56-145 Mt in the Dobele onshore structures. The conservative CO_2 storage capacity was 101-243 Mt in total in the E6, 3-13 Mt in the E7 offshore and 1-32 Mt in the South Kandava and 11-29 Mt in the Dobele onshore structures. Total capacity of the four structures in the study estimated by optimistic approach was 326-935 Mt and average 612 Mt. Using the conservative approach it was 116-317 Mt and average 205 Mt.
- The total optimistic maximum (602 Mt) and average (377 Mt) storage potential of the E6 structure is higher and nearly the same respectively as previously reported total potential of all 16 onshore Latvian structures (400 Mt). Even its average conservative capacity (152 Mt) is the largest among all the onshore and offshore structures studied until now in Latvia.
- Two split by faults compartments of the E6 structure were considered as separate substructures defined as E6-A and E6-B. Estimated theoretical CO_2 storage capacity of the E6-A was 243-582 Mt (mean 365 Mt) and E6-B part 8–20 Mt (mean 12 Mt) according to optimistic approach. Estimated conservative capacity of the E6-A was 97-233 Mt (mean 146 Mt) and of E6-B part 4–10 Mt (mean 6 Mt). Estimated area and conservative average capacity of E6-B part were in the same range as the area and conservative capacity of E7 structure (47 km^2 and 6 Mt in E6-B, respectively and 43 km^2 and 7 Mt in E-7, respectively).
- The synthetic plane-wave, difference and NRMS sections clearly indicate the presence of CO_2 in the reservoir formation in the E6 offshore structure for various saturation levels.
- P-wave velocity drops quickly from 0 to 15% CO_2 saturation, with slight decrease at higher saturations.
- Difference between 1% and 15% of CO_2 saturation is clearly detectible on seismic sections, while after 15% it is difficult to monitor CO_2 saturation change.
- Our study shows effectiveness of time-lapse seismic surveys to monitor the presence of CO_2 in the E6 Baltic Sea offshore structure already from the first stages of the injection (1% of reservoir fluid saturation). This study plays a crucial role in developing an optimal seismic monitoring plan in the studied area.

IV. References

[1] Shogenov, K., Shogenova, A., Vizika-Kavvadias, O. Petrophysical properties and capacity of prospective structures for geological storage of CO_2 onshore and offshore Baltic. Elsevier, Energy Procedia, in press, 2013, pp. 1-8.

[2] Shogenov, K., Shogenova, A., Vizika-Kavvadias, O. Potential structures for CO2 geological storage in the Baltic Sea: case study offshore Latvia. Bulletin of The Geological Society of Finland, . Bulletin of the Geological Society of Finland, 85(1), ISSN: 0367-5211, 2013, pp. 65-81.

[3] Shogenov, K., Gei, D. Seismic numerical modeling to monitor CO2 storage in the Baltic Sea offshore structure. 10-13 June 2013, London, UK, Extended Abstract. EAGE, ID 16848, Tu-P08-13, 2013, pp. 1-4..

Implementation of perspectives of CCS technologies in Ukraine

Maryna Bezkrovna, *Donetsk National University, Ukraine*, Vladislav Osetrov, *DonetskGeology, Ukraine*, Mykola Shestavin, *Donetsk National University, Ukraine*

***Abstract* – Performed analysis of Ukrainian stationary sources of CO_2 emissions into the atmosphere and the geology of eastern regions leads to a number of preliminary recommendations for further scientific and technological research to be carried out to provide process of implementation of CCS in Ukraine.**

***Keywords* – CO_2 emissions, carbon capture, geological storage, geographic information system, Eastern Ukraine.**

I. Introduction

Performed analysis of Ukrainian stationary sources of carbon dioxide emissions (CO_2) into the atmosphere and the geology of eastern regions leads to a number of preliminary recommendations for further scientific and technological research to be carried out to provide process of implementation of CCS technologies in Ukraine.

The study was carried out in the framework of the Grant No. DCI/ENV 2010/243-865 "Low-Carbon Opportunities for Industrial Regions of Ukraine (LCOIR-UA)", which is implemented by the Donetsk National University (Ukraine) and funded by the European Union – http://www.lcoir-ua.eu

II. The Potential of Sources of CO_2 Emissions

Using the information of the 5 open databases: IEA, BELLONA, CARMA, DTEK and BIOMASS, - as well as new further data obtained directly from the thermal power plants, iron and steel, coke, cement, chemical plants and oil refineries, geographic information system (GIS) sources of CO_2 were established. The study covers five eastern regions of Ukraine (previously mentioned).

This GIS in the test mode is available on the LCOIR-UA project website and businesses can read this data about their emissions of CO_2, which are listed in network connections, and correct the data in accordance with the actual volumes of emissions of the enterprise.

Using this GIS, one can estimate the amount of CO_2 emissions from a particular company, as well as obtain data about its geographic location and other useful information about the company (5 variants of icon size of enterprises conform to the following gradation of enterprises in terms of emissions of CO_2: 1 Mt/year or less, 1 - 4 Mt/year, 4 - 7 Mt/year, 7 - 10 Mt/year, 10 Mt/year or more).

GIS makes it possible to simultaneously analyze all the enterprises of chosen industries of the Ukrainian economy (Fig. 1), or consider only companies in selected industries: coal-fired power stations (as of 2011, the share of coal in the fuel thermal power plants is more than 97.5% vs 52.3% as shown in the CARMA) is currently represented in the GIS; 12 gas-fired plants - 1; steel mills - 13; coking plants - 14; cement plants - 8; various chemical plants (including oil) - 3.

It is planned to extend this database with data on CO_2 emissions from all enterprises which are the major air pollutants in these regions -- the enterprises of housing and communal services of the city, houses in the private sector, as well as from road transport.

Fig. 1. GIS of stationary sources of CO_2 emissions in the Eastern Ukraine

As this GIS is based on informal sources of information, the real value of the volume of CO_2 emissions from a particular company may differ from the values presented in the GIS. In such cases, an enterprise may apply to the LCOIR-UA project website with a proposal to update the information on the volume of CO_2 emissions, to be in line with the official statistical reporting of the enterprise. Such regular updates on the amount of CO_2 emissions would indicate a commitment to a responsible attitude towards the problems of global climate change and an awareness of the role of a "carbon footprint" in the occurrence of these problems.

III. The Potential of CO_2 Storage Reservoirs

Pumping of CO_2 in geological formations has more than thirty years of experience working to improve oil and gas recovery beds. In addition, in recent times numerous studies on the geological storage of CO_2 are held in various countries. As a long-term storage of CO_2, porous or fractured sedimentary rocks (collectors) are mainly considered, limited by the surrounding mountain environment and the earth's surface with low permeable or substantially impermeable rocks (confining or tires).

It should be noted that natural gas storage (including combustible ones) of natural genesis are reliable over hundreds of thousands or millions of years, leakage of these gases are negligible. There are three main types of formations where geological storage of CO_2 is possible: oil and gas basins which are depleted or are in the stage of depletion, deep-lying saline formations and unmineable coal seams. Among other possible geological formations, basalt formations and organic rich shales are also considered, but their potential remains insufficiently studied.

The success of the method of the geological storage of CO_2 is confirmed by the results of experiments carried out at different times by the companies MRCSP, MGSC, SECARB, SWP, WESTCARB, Big Sky, PCOR (USA), as well as in projects Weyburn, Fenn Big Valley (Canada), Sleipner (Norway) , Yubari (Japan), Qinshui Basin (China), etc.

Search and selection of geological structures and horizons that can serve as long-term storage of CO2 in oil and gas basins is based, as a rule, on the results of the previous searching and exploration works, and the determination of potential areas for CO_2 storage requires additional research.

In Ukraine, there are large oil and gas provinces with large amounts of productive horizons. One of the largest oil and gas regions - the Dnieper-Donets Basin is located within the boundaries of two large structures - the Dnieper-Donets Valley (DDV) and the Donets Coal Basin (Donbass). Gas presence of Dnieper-Donets basin is closely related to the clastic sedimentary rocks of the Middle and Upper Carboniferous and Lower Permian. The Methane gas content of Donbass is also associated with the coal-bearing Carboniferous strata.

The results of previous exploration works have shown that one of the most promising areas in terms of gas-bearing potential in the geological conditions of DDV and Donbass region are the areas with the stored hydrochemical sediments of Permian age. The important role of hydro-chemical deposits is their good insulating properties (alternating-tight oil and gas layers of rock salt, gypsum and anhydrite dense).

The location of hydrochemical sediments in the upper part of a large cycle of sedimentation where litho-facies composition is dominated by rocks with good reservoir properties is also important.

These factors, combined with high power gas permeable sedimentary rocks, have created favorable conditions for the free migration of hydrocarbons and their concentration under an impenetrable veil of hydro-chemical sediments. In the Donbas Lower Permian hydrochemical formations are developed in the north-western part within Bakhmutskaya and Kalmius Toretskoy-basins. The structure and Bakhmutskaya Kalmius-Toretskoy basins contains three floors: the Paleozoic, Mesozoic and Cenozoic. Mesozoic and Cenozoic structural floors are unpromising in terms of the geological storage of CO_2.

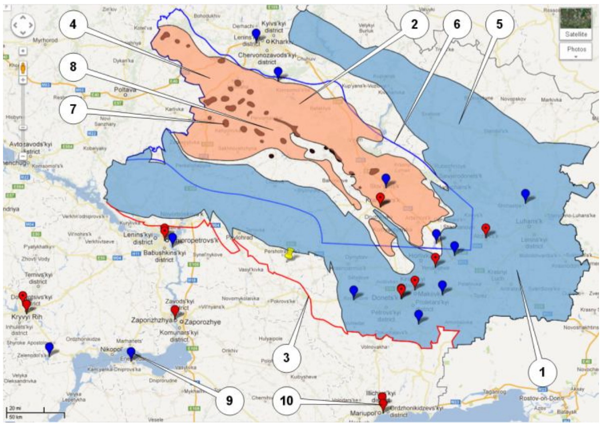

Fig. 2. GIS of possible sites of geological storage of CO_2 in Eastern Ukraine:
1. Donets coal Basin;
2. Dnieper-Donets gas-oil basin;
3. Southern border of diffusion of paleozoic sedimentary deposits;
4. Permian salt-bearing section;
5. Carboniferous coal-bearing sediments;
6. Devonian saline aquifers;
7. Devonian salt rods;
8. Biliaivka, Kharkiv obl., where the samples were taken for the study of porosity;
9. Power Plants;
10. Iron & Steel Works.

The results of analysis on the possible areas of geological storage of CO_2 have been merged into a single GIS of storage of CO_2 (Fig. 2), which is available on the project website and shows the following: Devonian salt stocks, Permian salt-bearing sediments, Carboniferous coal-bearing deposits; Devonian boundary saline aquifers horizons, the border of the Paleozoic sediments, the Dnieper-Donets gas-and oil-bearing basin and the Donetsk coal basin, as well as the location of the main sources of CO_2 - energy enterprises and steel sectors.

IV. Recommendations on the Allocation of Plots of CO_2 Storage

The procedure for the allocation of promising areas of long-term distribution of geological CO2 storage sites on the territory of eastern Ukraine is suggested. One of its stages includes analytical studies of reservoir properties of each layer at different depths, mineralogical and petrographic analyzes of rocks that form the horizon, the study of hydrodynamic, hydro-geological and structural-tectonic features of the entire thickness to the depth of the proposed store. Based on these data reservoir storage capacity can be calculated.

Only when the full complex of studies will be carried out, the conclusions about the suitability of the selected horizons for long-term storage of CO_2 will be made, and most importantly – the conclusion of the environmental services of process safety injection and storage of CO_2 to the environment and people, it will be possible to proceed to the stage of preparation of experimental studies. Based on the results of foreign geological storage of CO_2 and features of the geological structure of the Donets Basin, some Districts (namely, Novomoskovskiy, Petrikovskii, Lozovskaya, Starobelsky and North-western outskirts of the Donbass) are proposed for further study of their potential geological storage of CO_2.

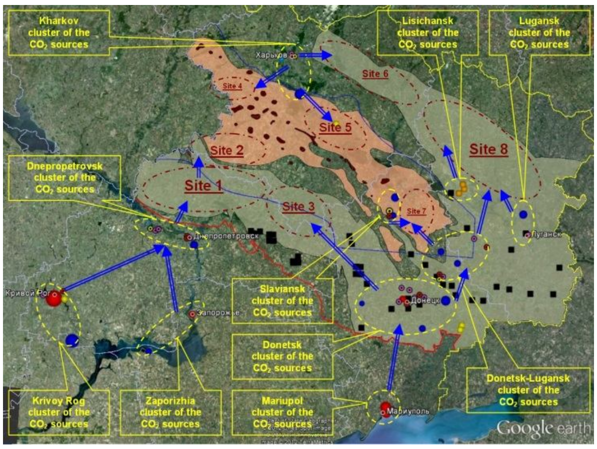

Fig. 3. Geographic location scheme of clusters of sources of CO_2 emissions, possible sites for the geological storage of CO_2 and the approximate direction of transport of CO_2 from emission sources to the geological storage tanks

Summarizing the results of these preliminary studies, which are based on open source information, the geographical location scheme of clusters of sources of CO_2 emissions, possible sites for the geological storage of CO_2 and the approximate direction of transport of CO_2 from emission sources to storage tanks (Fig. 3) was built, where conventional sources of CO_2 clusters are marked with yellow hatched ovals, from which the blue arrows indicate the approximate direction of transport of CO_2 to the alleged sites of storage - brown dash-dotted ovals. Furthermore, black squares show the location of existing coal mines near which reservoirs for CO_2 storage fundamentally cannot be placed.

Production of foliage extracts

Laura Pastare, Līga Ozoliņa, Dagnija Blumberga, *Riga Technical University*

***Abstract* – The paper focuses on technical and economical analysis on a foliage extract manufacturing plant that produces natural food enriches, fodder additives, raw materials for other industries, essential oils, wax, sodium chlorophylline, chlorophyll-carotene paste and more. The aim of paper is to determine a environmental "weak points" of whole plant and give a cleaner production suggestion (with economical analysis) how to overcame it in order to achieve higher environmental standards than legally necessary. A detailed analysis of production processes and their data was made, it was concluded that manufacturing itself is up to Best Available Techniques as far as suggestions goes. As the production itself is quite unique it wasn't possible to use benchmarking to determine its performance. The "weak point" is steam generation for manufacturing needs. Now a diesel steam generator is used, the suggestions is to replace it with biomass gasification steam boiler. Economical analysis of this suggestion shows that it is effective and economically reasonable if specific production capacity can be retained.**

***Keywords* – foliage extract, steam generation, economical analysis,**

I. Technological Processes of Manufacturing and Output Data

A. Technological process description

Since year 1999 the production plant has been processing coniferous trees foliage into extractive groups and is doing so residue free. Manufactured products can be used for forage or in food, cosmetic, pharmaceutical or plant protection product industries or as an end-product. The main raw material used is coniferous foliage (pine or spruce). In order to ensure good quality end product the acquisition and usage of it is seasonal. Because of this and changing product demand the factories nature of activity is irregular. The manufacturing process starts with shredding the foliage to ensure higher extraction and smoother production. After shredding hot solvent Nefras C2 (petrol; further Nefras) is added and the extraction process goes on for few hours. After extraction the liquid product flow is separated into fractions – water-soluble, Nefras-soluble, wax and used foliage. As the foliage still contains traces of hazardous solvent, steam is blown through it, in order to separate it from mass. Steam and solvent mix then is distilled, to separate and re-use Nefras. Distillation process is used throughout the manufacturing process to recover hazardous and pricey solvent. The two flows after extraction process are already an end-product – wax and water soluble preparation – plant growth stimulator. Next part of manufacturing differs for different types of confers. Different types produce different end-products, but usages of them are tantamount. Nefras-soluble extract from spruce is saponificated, distilled, washed and split into fractions repeatedly, but pine is heated, distilled and split into fractions in different combinations. The end products include wax, essential oils, sodium chlorophylline paste, chlorophyll-carotene paste, food enriches, fodder additives, different extracts and preparations and used foliage (is sold as part of compost). Analyzing and judging manufacturing process altogether (see Figure 1), one should keep in mind that the processes are linked very closely and it is not possible to manufacture only one type of product without defining other product as waste (in this case the productions stops being non-residue), this affects not only the waste management of company but also merchandising. Depending on raw materials the proportions of manufactured end-product can vary, but in a small range. Most of the production phases demand heat and steam (especially distillation) which is produced in situ with diesel steam

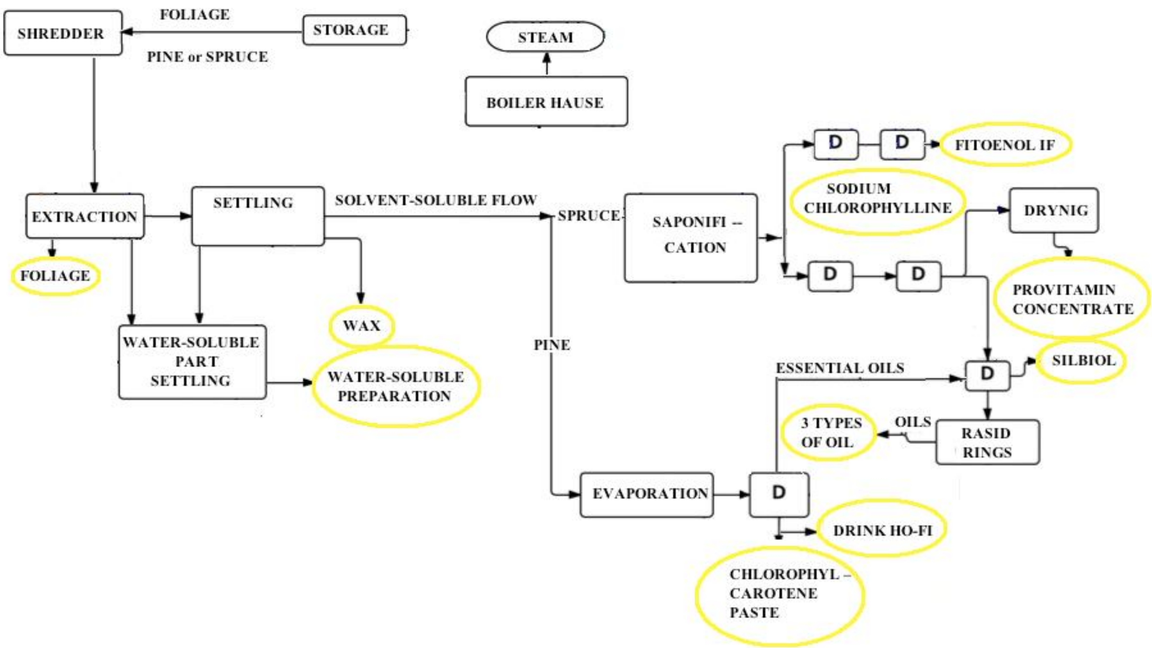

Fig. 1. Production process flow chart

generator. This could be the environmental "weak-point" of the company as the hazardous solvent is recovered and re-used.

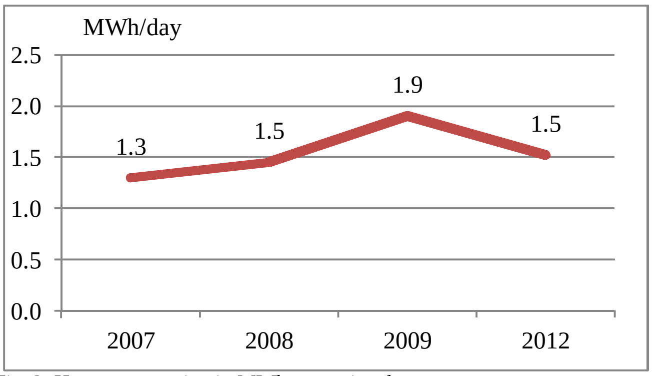

Fig. 2. Heat consumption in MWh per active day

B. Data collection

As the factory works irregularly, its performance is analyzed by years not months (active days are in range from 40 to 150, max 260 per year). As the production processes are so linked, its not possible to distribute used raw-materials, energy, water or heat per specific product unit, only absolute numbers or data per amount of foliage or data per active day can be used in analysis. Heat consumption in previous years (see Figure 2) has grown, as

Although in year 2009 factory worked for only 40 days, it worked full speed, probably more active days at a time, so less materials or energy is wasted. Also the manufactured amount of end-product per day shows that year 2009 has been the most effective one (see Figure 3).

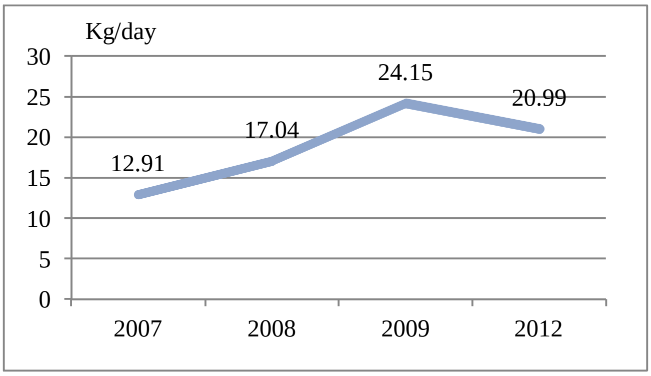

Fig. 3. Produced amount of end-product per active day in kg

C. Data analysis methodology

As the usage and analysis of output data is limited due to the specific type of manufacturing process, it is not possible to compare it to other factories. Only other plants with similar end-products are linked to scientific work with emphasis on the product itself, not the process of production. The emphasis in analysis is on heat production as those arethe highest expenses for the company.

II. Result Analysis

A. Proposed energy efficiency measure

As the manufacturing already is residue free and it has successfully adopted the main BAT suggestion for organic chemistry industries (recover solvents after extraction), the next main step would be to change the existing diesel steam generator to biomass-fueled steam generator. The main reasoning behind this suggestion is growing fuel prices (the price drop the start of the company has grown from 0.06 Ls per liter to 0.80 Ls per liter) and the fact that the generator anyway would need replacing in near future. Most of the biomass generators take more time to generate certain amount of steam (compared to liquid-fueled generators), the suggestion is to implement biomass gasification steam boiler. Although investments in such boiler are higher than regular biomass steam generator, its properties fit better in the situation and won't slow down the manufacturing processes and their efficiency is higher.

B. Economical analysis of proposed measure

Output data used in analysis – investments 120 000 Ls, O&M (including extra worked salary) 1324 Ls/year, biomass price – 10.29 Ls/MWh, diesel price – 79.58 Ls/MWh, boilers efficiency – 85 %, diesel steam generator efficiency – 92.7 %, project life duration – 15 years, banks interest rate – 10 %.

Calculated weighted average cost of capital (with self-investment 20 %, bank – 80 %) is 10.4 % (in further calculations this value is used as discount rate). When calculating the net present value cash flow for project length, its visible that it becomes positive in year 13, but after year 15 its value is 13 320 Ls. Internal rate of return is 12.18 % which means that project is economically reasonable. Profability index is 1.1 meaning that project is cost effective. But before implement project, one must take into account that investments are quite high and the duration of project is long, in this time the output data values can change and influence the outcome. The most sensitive inputs are diesel prices (it describes the amount of money saved every year due to change in fuel), investment amount and the needed amount of heat (production capacity). Fall in diesel prices is unlikely; amount of investment won't change, so the only danger is production capacity which is dependent on product demand. In case of implementing this project, manufacturer must be sure of its ability to maintain the needed capacity to get the positive outcome.

III. Conclusion

The change of existing diesel steam generator to biomass gasification steam boiler is economically justified and can lower the costs for fuel more than five times. Also the environmental gain for such a project would be lower emission by 74 tons CO_2 per year.

Improvement of efficiency of solar PV. Potential materials for organic photovoltaic cells

Janis Latvels, Raitis Grzibovskis, Aivars Vembris, *Institute of Solid State Physics, University of Latvia*,
Dagnija Blumberga, *Institute of Energy Systems and Environment, Riga Technical University*

***Abstract* – Organic photovoltaic (OPV) cells are considered as perspective alternative to present energy sources. In this work three derivatives of original N,N'-dimetilaminobenziliden-1,3-indandione (DMABI) material are presented as potential materials for OPV. The absorption spectra of investigated derivatives are blue shifted compared to original DMABI. Use of these derivatives in multilayer solar cells with original DMABI allows broadening the spectral response range of OPV.**

***Keywords* – organic photovoltaic cells, thin films, indandione**

I. Introduction

Organic materials are increasingly applied materials for various electronics and OPV sector is one of the most perspective fields. Selection of materials is one of the options for OPV improvement as wide range of organic materials can be used to broaden the spectral response range of OPV.

In this work N,N'-dimetilaminobenziliden-1,3-indandione (DMABI) derivatives with various functional groups were investigated. Functional groups were selected with aim to improve the energetic parameters and photoelectrical properties. The selection was also made with an emphasis on broadening the spectral response range of OPV. The absorption maximums of chosen derivatives are blue shifted compared to the DMABI and some other DMABI derivatives.

II. Description of Experimental Research

The typical sandwich-type structure for the samples was used where single layer of organic material is sandwiched between two semi-transparent metal electrodes on the glass substrate. There were made nine identical active areas during evaporation – each at the point of intersection of Au and Al electrode. The active area of the samples was obtained 4 mm^2 (see Fig. 1).

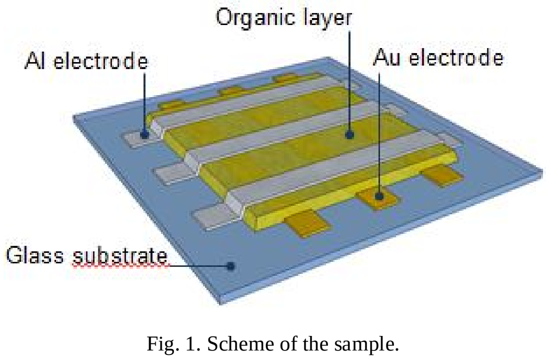

Fig. 1. Scheme of the sample.

Two different metals were used for electrodes. Gold (Au) was used as a bottom electrode but in case of top electrode Au diffusion into organic layer was observed – after evaporation of Au as top electrode there was short circuit in the sample. Therefore aluminium (Al) was chosen as a top electrode – its evaporation temperature is much lower than Au and thereby protection of organic layer is more possible.

The samples were fabricated by thermal evaporation in vacuum $1{\cdot}10^{-6}$ mbar.

As a layer surface roughness of the organic materials was too high to put the top electrode successfully, the substrate was cooled to the temperature -100°C. Thus it was possible considerably reduce the roughness of the organic layer and facilitate formation of smooth aluminium layer on it. All layers were made without breaking vacuum between evaporation steps. The samples where organic molecules are mixed with poly(methyl methacrylate) (PMMA) were made to obtain absorption spectra for determination of optical band gap as it was not possible to do for evaporated thin films due to high roughness of surface that cause high light scattering in the layer.

III. Results and Discussion

A number of methods may be applied to characterize energy gap of organic molecules in solid state. Charge carriers are not quasi-free electrons and holes in case of organic crystals. They form a polaron type quasi-particle enveloped in electronic and vibronic polarization clouds. Energy difference between electronically relaxed hole and electron is attributed to optical band gap E_G^{Opt} [1]. Low energy threshold of organic thin film absorption spectra may be used to obtain E_G^{Opt}. The electronically and vibrationally relaxed state difference of holes and electrons corresponds to adiabatic energy gap E_G^{Ad}. The value of adiabatic energy gap E_G^{Ad} correlates with the value of threshold energy of photoconductivity E_{Th}, $E_G^{Ad} = E_{Th}+\Delta E$, where ΔE is effective relaxation energy of ion pair state [1].

The quantum efficiency of photoconductivity $\beta(h\upsilon)$ allows to estimate the threshold energy of photoconductivity E_{th}.

In figure 2 the comparison of investigated compounds absorption spectra is given. The blue line corresponds to absorption maximum for original DMABI [2]. It gives possibility to use them in tandem solar cells as these compounds would absorb ultraviolet light and let through the red light absorbed by, for example, silicon. Thus, combining several materials with different absorption it is possible to use greater part of sun light.

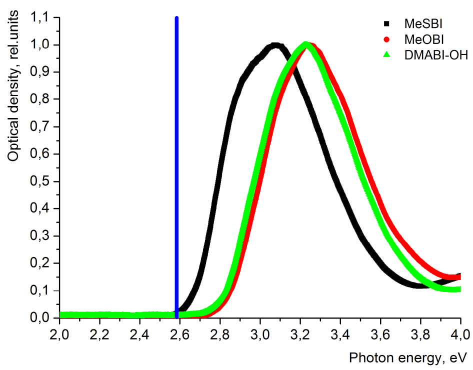

Fig. 2. Comparison of absorbtion spectra of investigated compounds with DMABI (spin-coated samples). The blue line corresponds to the absorption maximum of DMABI

The benefit of substitution of functional groups is summarized in Table 1.

TABLE I

THE INCREASE OF THRESHOLD ENERGY OF PHOTOCONDUCTIVITY E_{TH} AND OPTICAL ENERGY GAP E_G^{OPT} VALUES OF DMABI-OH, MEOBI AND MESBI.

Compound	E_{th} (eV)	E_G^{Opt} (eV)
DMABI-OH	0.10±0.03	0.65±0.03
MeOBI	0.49±0.03	0.70±0.03
MeSBI	0.28±0.03	0.53±0.03

Increase of energy gap means that these compounds will absorb light close to ultraviolet region but width of absorption spectrum for them will be narrower. This allows using the compounds for tandem solar cells in combination with other compounds.

Increase of energy gap is related also to efficiency of solar cell. One of the characters that influence efficiency is open circuit voltage. The energy gap of material is the difference of highest occupied molecular orbital level (HOMO) and lowest unoccupied molecular level (LUMO). In two material system open circuit voltage is mainly determined by the difference of HOMO level of donor material and LUMO level of acceptor material [25, 26]. Use of the investigated materials in combination with materials with similar HOMO and LUMO levels and wide energy gap would give increase of open circuit voltage.

IV. CONCLUSIONS

Investigation of new materials gives the possibility to find materials with better properties and in combination with several materials increase efficiency of solar cells.

In comparison to DMABI, studied compounds have wider energy gap - higher energetic threshold where absorption starts. This property could be used by making tandem solar cells. The shifting of absorption spectra of investigated compounds gives possibility to broaden the spectral response range of OPV cells in combination with materials with different absorption. These compounds could absorb light in blue-ultraviolet region while passing through, for example, red light absorbed by other layer. Wider energy gap also influences efficiency of solar cell by increasing open circuit voltage.

The experiments showed that acquisition of absorption spectra of compounds that tend to make polycrystalline thin films could be difficult because of polycrystalline structure. To avoid that it was necessary to mix these compounds in PMMA matrix.

High roughness of surface of films points that the investigated compounds could be used in polymer OPV cells. Films in mixture of polymer are smooth and this eases the production and reduces the costs of OPV cells as the substrate has not to be cooled. Investigated compounds could be used also for evaporated OPV cells as lower layer covered by some other organic material which makes smooth surface of film. In that case the compounds could increase the efficiency of OPV cells not only by broadening the spectral response range of OPV cells, but also by increasing the interface area of two materials. The surface roughness of lower layer also stimulates light scattering. This allows absorbing more light and increasing the efficiency of solar cell.

ACKNOWLEDGMENTS

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REFERENCES

[1] E.A. Silinsh, M. Bouvet and J. Simon, Determination of Energy Gap Values in Molecular Crystals, *Molecular Materials* 5 1, 1995, p. 1 – 24.

[2] M. Rutkis, A. Vembris, V. Zauls, A. Tokmakovs, E. Fonavs, A. Jurgis, V. Kampars, Novel second-order nonlinear optical polymer materials containing indandione derivatives as cromophores, *SPIE Proceedings, Organic optoelectronics and photonics*, Eds. P.L.Heremans, M.Muccini, A.Meulenkamp, Vol, 6192, 61922Q, 2006

[3] B. Qi, J. Wang, Open-circuit voltage in organic solar cells, *Journal of Materials Chemistry*, vol. 22, no. 46, 2012, p. 24315.

Analysis of operation mode for complex DHS

Girts Vigants, Ivars Veidenbergs, Gundars Galindoms, Edgars Vigants, Dagnija Blumberga, *Riga Technical University*

***Abstract* – The overall effectiveness of DHS operation depends on the effectiveness of each element of the system separately, as well as on the interaction of all elements which can be evaluated by definite parameters on the operation of the system. The results, which comprise some most essential parameters, reveal that the impact of the temperature of supply and return water does not impact on the total efficiency of the system. Special attention is paid to losses in the heating network in cases with or without a flue gas condenser.**

***Keywords* – Gas condenser; energy efficiency improvement; heat supply system; heating network; climate technology**

I. INTRODUCTION

In Latvia, the district heating systems (DHS) play a significant role, supplying about 80% of users with heat energy. This is economically cost effective from many points of view, as it is possible to achieve a higher efficiency of energy production, at the same time taking into account heat losses in DHS. Another advantage of compact DHS is the possibility to use the wholesale trade principle, since all the expenses forming the tariff per MWh produced in a large system are comparatively low [1,2]. DHS are very similar; they are composed of three elements: a heat source, heat networks and heat consumers, but the Latvian experience shows that the overall efficiency of the DHS is very different, and it reflects on heat consumer tariffs. Heat rates of Latvia's DHS companies differ by more than two times. It is important to assess the inputs - fuel, such as Latvia's cheapest heat is produced from wood chips. The correct way is to think long-term - maximum optimization of DHS so that heat networks and individual customers would have as low heat losses as possible, and maximum efficiency of heat source. In Latvia the most economical DHS is a complex system which encompasses an essentially ramified chain of heat consumers and a boiler house, at which it is possible to deeply cool flue gases at a flue gas condenser.

II. METHODOLOGY FOR DHS OPERATION ANALYSIS

Experience shows that, generally, the operational effectiveness of a heating system depends on the effectiveness of each separate element:

- efficiency of the energy source;
- heat losses in the heating network;
- energy effectiveness of the heat consumer(s).

The effectiveness of a DHS is also significantly influenced by the correlation among all three said components, which can be evaluated by introducing particular parameters on the operation of the system:

$$\eta_{DHS} = f\,(t_{supply}\,;\, t_{return};\; G_{DHS}\,;\, t_{fg};\, \alpha;\, CO;\, q_{loss}\,;\, q_{cons}\,;\, t_{const}\,;\, t_{ot}\,;\, W;\, A), \qquad (1)$$

where:
η_{DHS}-efficiency of heating system;
T_{supply}-temperature of supply water in heating network;
T_{return}-temperature of return water in heating network;
G_{DHS}-flow rate in the heat supply system;
T_{fg}-temperature of flue gases at the chimney opening;
α-air consumption ratio at the chimney opening;
CO-concentration of carbon monoxide in flue gases;
q_{loss}-heat losses in the surrounding environment;
q_{cons}-specific energy consumption of heat consumers;
t_{cons}-consumer temperature at heat substation;
W-wood moisture contents;
A-wood ash contents;
T_{out}-outdoor temperature.

The methodology for DHS operation analysis, the algorithm of which is described in this article, includes using the described equation system in modeling the effectiveness of a complex DHS.

III. RESULTS OF THE EXPERIMENTS

The methodology has been approbated at the DHS of Ludza, where a condenser for deep cooling of gases is installed in the boiler house which condenses steam from the gases which are formed as a result of burning wet woodchips. The flue gas condenser set up in the boiler house of the Ludza heating system has been operating for two years. The condenser has increased the total energy efficiency of the whole heating system. It is important to reach the maximum efficiency that the system can provide and to sustain this for the longest period possible [3].

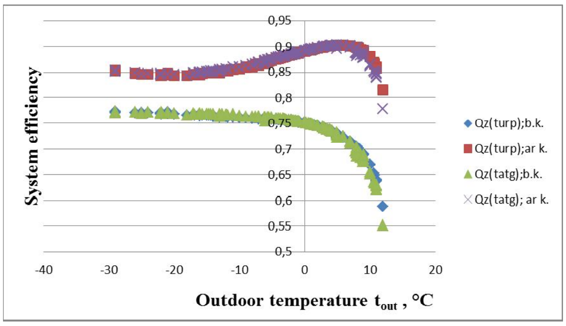

Fig. 1. Changes in system efficiency depending on the outdoor temperature, if $Q_{loss\ (supply)}$ and $Q_{loss\ (return)}$ system with and without a condenser

The initial results, which include some most essential parameters of the ones listed above, reveal that the impact of the temperature of supply and return water on the total efficiency of the system does not differ (see the curves in the Fig. 1). Special attention is paid to losses in the heating network in cases with or without the flue gas condenser.

The character of curves reveal that, at the current temperature graphic of the Ludza DHS, the effectiveness of the heating system increases in case the fuel gas condenser is used when the outdoor temperature is above 0 ^{0}C. This is contrary to what happens with effectiveness in case the deep flue gas cooling does not take place.

IV. CONCLUSION

The operational effectiveness of a complex DHS depends on outdoor temperature. Moreover, in case a flue gas condenser is used, the efficiency increases if outdoor temperatures are above 0^0C.

Green roof water retention modeling by SWMM

Rihards Rušenieks, Agris Kamenders, *Riga Technical University*

Abstract **– Green roof rainwater runoff retention capability is studied and modeled in this paper. Modeling is done in Stormwater Management Model 5.0 (SWMM) software. The model is based on an existing warehouse-type building located in Riga and on hourly Riga climatic data of 2012. Evaluation of the model is carried out and future fields of study of green roof ecological benefits are discussed.**

Keywords **– extensive green roof, rainwater retention, green urban building, urban planning, energy efficiency.**

I. Introduction

Green roof technology is becoming more and more widespread in the world. Apart from esthetical value, green roofs have many ecological benefits as well. Green roofs are basically vegetation layers which are put on the roof of a building (either when building new buildings or refurbishing existing ones) with supportive layers. Two types of green roofs exist – extensive and intensive systems. An extensive green roof is lightweight (60 - 150 kg/m2) and non-inhabitable by people. The vegetation consists of grass, moss, succulents, stonecrops, and irrigation and maintenance is not required. Intensive green roof systems are roof gardens, which are heavyweight (180 - 500 kg/m2), fulfill a recreational function with the possibility of urban gardening. The vegetation may be shrubs and trees, and irrigation and regular maintenance is required. Intensive green roofs are more suitable for areas with high population density, but in case of Latvia (and the other Baltic countries), extensive systems are more appropriate.

II. Green roof capacity for rainwater retention

Green roof as an option for water retention was first mentioned in German researches in 1985 [1]. Since then many additional studies have been carried out. German Green roof FLL Guidelines (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau) provide the following figures:

TABLE I

Rainwater runoff reduction according to FLL guidelines [2]

Thickness of green roof [mm]	Vegetation	Water retention, annual [%]
20-40	Moss/stonecrops	40
40-60	Stonecrops/moss	45
60-100	Stonecrops/moss/herbs	50
100-150	Stonecrops/herbs/grass	55
150-200	Grass/herbs	60

III. Green roof rainwater retention modeling

The USA Environmental Protection Agency (EPA) software Storm Water Management Model 5 (SWMM), which is widely used by other authors, is chosen for modeling. The software is based on a system first developed in 1971, currently its fifth version is used. The latest updates were made by USA EPA Nation risk management research laboratory`s Water supply and water resource section in cooperation with the private sector. SWMM performs dynamic perception and precipitation runoff simulation both for single and long term events.

Modeling was done on a comparative basis implemented by a LID controller, simulating rainfall runoff on an equal area of the buildings, in one case -- with an ordinary roof, in the other case with a green roof. As warehouse-type, flat roof building with a total space of 2425 m^2 was chosen for the model. After refurbishment, the building serves for entertainment purposes and is located in Riga.

In one case, the roof was ordinary and in the other case, the roof was an extensive green roof. Both buildings were connected to the city`s sewage system. Rainfall source was added. The simulation was carried out for a one year period (365 days) and for one year period (2012). The simulation time step was set as one hour due to precipitation data, which is available as hourly. Precipitation and other climatic data were obtained from the Latvian Environment, Geology and Meteorology Centre.

IV. Results and discussion

Results about rainwater runoff from the warehouse-type building in Riga are shown in the table below:

TABLE II

Results of SWMM model

Subcatchment	Green roof	Ordinary roof
Total precip	717,50	717,50
Total runon	0,00	0,00
Total evap	25,57	7,11
Total infil	356,52	0,00
Total runoff	319,55	715,96
Runoff coeff	0,445	0,998

Interpretation of results indicate that the total precipitation amount in 2012 was 717,5 mm (average is 700 mm). The green roof has vegetation, soil and water storage layers, and, for that reason, runoff from the green roof was only 319,55 mm (45%). More than half – 356,52 mm (55%) – infiltrated in the soil and was absorbed by plants. This water was transported back in the atmosphere by transpiration. This process significantly relieved pressure on the sewage system. Small amounts of water (25,57 mm) evaporated immediately,. In case of the ordinary roof,almost all rainwater was discharged in the city’s sewage system.

V. References

[1] Ernst W., Weigerding **I**. Oberflächenentwässerung, Gewässerentlastung durch ökologische/ökonomische Planung, Bundesblatt, 34 (11) (1985), pp 722–732

[2] Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e. V. – fll Guideline for the Planning, Execution and Upkeep of Green-Roof Sites. Roof-Greening Guideline. January 2002

Assessment of roadside particulate emission mitigation possibilities

Dzintra Slišāne, Dagnija Blumberga, *Riga Technical University*

***Abstract – This research* introduces a system dynamics model for road transportation PM10 emission analysis. The developed model is used to compare PM10 emissions in 4 cases, one of which is the baseline, the other 3 envisagedifferent road transport emission reduction methods. Simulation results showed that the highest daily PM10 reductions can be achieved by combining technological and administrative methods.**

***Keywords* –Air pollution, road transportation, particulate matter, system dynamics**

I. Introduction

In Europe the number of cars is increasing each year and cargo operations are dominated by road transportation. In the Baltic States (Lithuania, Estonia and Latvia) long-distance transport is well developed –in these countries accordingly 70%, 73% and 85%, respectively, of freight is delivered by road. It is one of the most influential sectors in many aspects; one of them is environmental impact. The main environmental impacts of transportation are GHG emissions, increased noise levels and air quality deterioration. In the EU, transportation is the main source of PM10 and PM2.5 emissions. Particulate matter (PM) is fine dust particles that are usually marked with the letters PMxx , the index indicates the size of dust particles. Due to its diminutive dimensions particulate matter is capable of penetrating deep into the respiratory system, causing serious harm to human health. According to the World Health Organization, living in the most polluted cities and regions can reduce a person's life expectancy by about two years. To protect human health, the European Union has set air quality standards for PM10 and finer particle PM 2.5 fractions, but in many countries, including Latvia, pollution concentration exceeds the standards.[1]

II. Transportation PM10 Emission System Dynamic Model

PM_{10} concentration in the immediate vicinity of the road depends on a number of factors; it is a complex system that is also constantly re-suspending dust particles deposited on the road surface.System dynamics models have been used for various complex system analyses for over 50 years.

During the work, the system dynamic methodology was used in order to simulate PM_{10} emission production and re-suspension processes in a section of Brivibas street, wich is the central street in Riga. Developed transport PM_{10} emission model consists ofonestock(PM10_emissions_in_air) with theoutgoing andincomingflow. Stockaccumulates the amount of airborne PM_{10}in grams per1kmof the street. Input flow shows thePMformationrate (g/ h),it is influenced byfour main factors:

- vehicle exhaustemissions
- tireand brakewear,
- pavementimpact factor
- re-suspension.

Negative flowisPM_{10} settling. Basic elements of System dynamic models are illustrated in Fig. 1.PM_{10}concentrationis calculated by dividingthe quantityof PM_{10}in the air(g) bystreetnotionalvolume. The notionalvolume of the street is calculatedby multiplying theaverage height of buildings on the streetwithstreetwidth andlength(in this case1000 m). The developed model can be used only for canyon type streets and roads. The transport PM_{10} emission model structure is illustrated in Figure 1.

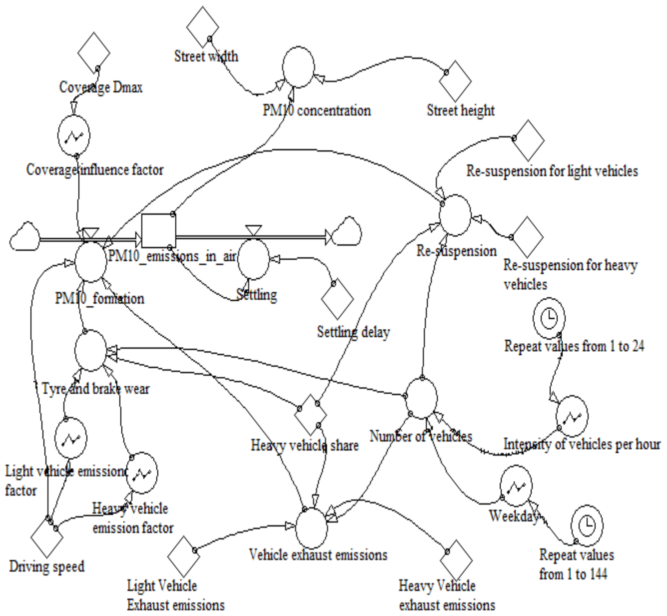

Fig.1. Transportation PM_{10} emission models structure

Vehicle exhaustemissions from tireand brakewear, pavementinfluence factor and re-suspension are dynamic values that vary depending on vehicle driving speed, traffic intensity and share of heavy vehicles. PM_{10} emissions are also influenced by wind speed, air humidity and other factors which are not dependent on human action and therefore are not included in the model.

III. Parameters and Assumptions

The brake and tire wear emission values used in the developed model, were taken from a project report “Guideline development for preparation of vehicle-related PM_{10} and$PM_{2,5}$ modelling in Latvian conditions” and European Monitoring and Evaluation Programme „EMEP/CORINAIR Emission Inventory Guidebook – 2007” .In order to include the option of different road surfaces, which could prove to be useful in further research, tire wear emissions in the developed model are multiplied by surface impact factor. Abrasion factor for new asphalt is 0.024 mg/km per passenger vehicle. This figure includes both tire and road surface wear. Particle size distribution shows that the surface wear is negligible(<10%).The model operates under the assumption that PM_{10} settling is only influenced by gravity force.[2][3]

IV. PM10 Reduction Methods

Based on the parameter sensitivity analysis, three main points of force application were chosen: PM10 settling speed, re-suspension and the number of vehicles. PM10 concentration reduction tools can be divided into two groups:

1. Technological tools (road cleaning, wetting, use of chemical suppressants);

2. Administrative tools (traffic restrictions, air quality taxes).

Four different action policies were developed aimed at reducing the PM10concentration levels:

Baseline scenario - baseline scenario reflects a situation where no measures to reduce the concentration of particulate matter are taken and transport intensity corresponds to the data from the Riga City Council Traffic Department about Brivibas - Tallinn street intersections on the fourth November 2009.

Scenario A. The use of technological tools.Streetsurfaces are sprayed with CMA solution (25% CMA and 75% water). Additionally road surfaces are cleaned mechanically once a month.

Scenario B.The use of Administrative tools.Introduction of a rush hour fare.

B1. Additionally to scenario B, heavy traffic flows are diverted to the roundabouts of Riga (the proportion of heavy vehicles - 0,02).

Scenario C. The combination of both technological and administrative tools from scenarios A and B.

V. Results

Pollution mitigation policies that are described in the previous section were simulated using the developed transport PM10 emission model. The simulation time is 24 h.

VI. Conclusions

Developed transport PM10 emission model can be used to assess PM10 concentration for streets with different characteristics.It was determined that the most effective is scenario C,which uses both administrative and technological PM10 pollution mitigation tools. Scenario B1 (only administrative PM10 mitigation methods – rush hour fare and heavy vehicle traffic restrictions) was the second most effective. Peak PM10 concentration in scenarios C and B1 differs only by 5 μg/m3, therefore it would be useful to carry out the cost-benefit analysis of these policies to decide which one is more appropriate for Riga.In order to get more realistic results, the model should be supplemented with data about the effects of braking, acceleration and driver's driving style on brake and tire wear. By supplementing the model with economic parameters and weather data, it can be used for the cost-benefit analysis of PM_{10} mitigation policies or to determine under which weather conditions or at what time pollution mitigation methods should be implemented.

Simulation results – PM10 concentration changes during one day (24h) – are shown in Fig.2.

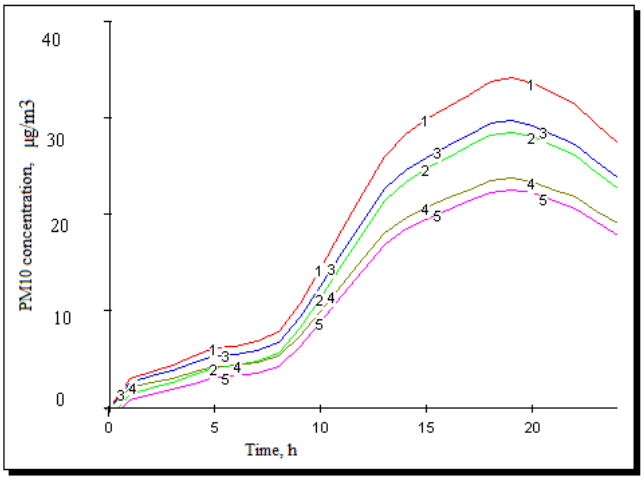

Fig.2. Simulation results: 1 – the baseline scenario; 2 - scenario A, 3 - Scenario B, 4 - Scenario B1, 5 – Scenario C

VII. References

[1] Overview of the air quality in Latvia 2011. LVĢMC// http://www.meteo.lv/fs/CKFinderJava/userfiles/files/Vide/Gaiss/Gaisa_kvalitate/Parskati/parskats_par_gaisa_kvalitati_Latvija%20_2011_gada.pdf [25.04.2013.]

[2] Vadlīnijusagatavošanatransportlīdzekļuradītā PM10 un PM2,5piesārņojumamodelēšanaiLatvijasapstākļos. Projektaatskaite.-Rīga, 2008. novembris.- 21.

[3] EuropeanMonitoringand EvaluationProgramme „EMEP/CORINAIR Emission Inventory Guidebook – 2007”

Development of green energy systems in Latvia and Lithuania

Agnese Skujevska, Francesco Romagnoli, *Riga Technical University*

Abstract **– The aim of work is to evaluate the existing power systems in Latvia and Lithuania and work out policy instruments which allow increasing the role of renewable energy resources in electricity generation. Tasks of the work are: study of literature, analysis of produced electricity, selection of suitable calculation model, development of the power system simulation, choice of policy instruments.**

Keywords **– electricity generation, renewable energy sources, system dynamics.**

I. Introduction

Electricity is an important part of everyday life, the existence of which is self-evident. 38% of all Latvian households consumed an average of 2,000 kWh and more per year in 2010. Although there is no problem in today's economically developed countries on any deficit of electricity, recent public attention turns more to the amount of energy produced, and how electricity is generated. There are several reasons for this sitution, the most important include global climate change, international conflicts on energy sector and others. In Latvia and Lithuania both renewable energy and imported natural gas are used for electricity generation. In order to be more independent in the energy sector, as well as produce electricity in a more environmentally friendly manner, it is necessary to increase the share of renewables in electricity generation.

II. Electricity generation system description in Latvia and Lithuania

Latvia and Lithuania are located in similar climatic conditions, but each of them has its own electricity supply system characteristics. In Latvia, a large part of electricity is produced from hydropower plants and from natural gas while in Lithuania, much of the electricity is imported.

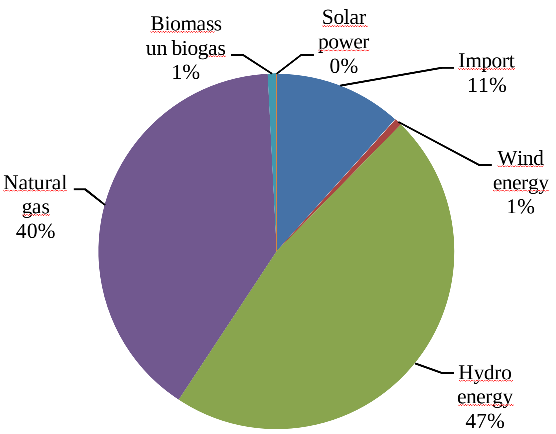

Fig.1.Energy sources distribution of electricity production in Latvia (2010) [1]

The figure shows that renewable electricity generation accounts for almost half (49%) of the total electricity generation in Latvia. This relatively high figure is due to the operation of hydropower stations on the Daugava River, but it can be increased by reducing the use of natural gas for electricity generation and replacing it with other sources, such as wind power.

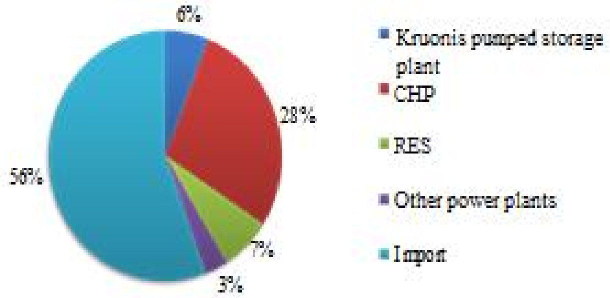

Fig. 2. Produced electricity in Lithuania (2010) [2]

In 2010 Lithuania was the biggest importing country of electricity in the EU. The average rate of imported electricity between the European countries is 10%. The current situation is well illustrated by Figure 2, with more than half of the consumed electricity in Lithuania imported from other countries. CHP plant generates 28% of used electricity.[2,3]

III. Modeling of electricity production system development

Power system model creation takes place after the above five processes: problem formulation, the creation of dynamic hypotheses, model formulation and simulation, model testing and development of policy.

A. *Problem formulation*

The model is designed to increase RES in electricity generation. As in any process, including an increase of RES in the electricity sector is mainly driven by economic aspects.

B. *Creation of dynamic hypotheses*

The author puts forward a dynamic hypothesis that capacious economic policy tools are most effective in increasing the use of RES. To display it in visual form, a causal loop diagram is made. Increase or decrease of installed capacity affect the flow of investment, which, in turn, is affected by equipment depreciation. To decide which equipment depreciation will rise and which will fall, the two affecting models are made: the subsidy and willingness to use wind energy.

C. *Model formulation and simulation*

To display the current status of electricity production, the model was constructed on program Powersim Constructor. The main stocks of the model are installed wind capacity and the amount of electricity produced from natural gas. Each stock has one incoming and one outgoing flow. Input describes each stock investment (GW/year), while the outgoing flow of equipment depreciation (GW/year) in each given year.

IV. Potential scenarios for power system development

The base year for development of electricity production system scenario is assumed 2010. Simulation is carried out for 40 years, i.e. until 2050. To be able to compare the effectiveness of policy instruments, in the base scenario no policy instrument is used. The rest of the developed scenario titles and used policy instruments are summarized in Table I.

TABLE I

USED POLICY SCENARIOS AND THEIR MAIN FEATURES

Scenario title	Designation	Risk red. instr.	Eff. incr. instr.	Subsidies instr.	Feed-in tariff instr.
Base sc.	BSc	-	-	-	-
Scenario 1	RSc	✓	-	-	-
Scenario 2	EfSc	-	✓	-	-
Scenario 3	Sub10Sc	-	-	✓	-
Scenario 4	Sub20Sc	-	-	✓	-
Scenario 5	Sub20-0Sc	-	-	✓	-
Scenario 6	Sub50Sc	-	-	✓	-
Scenario 7	FeedInSc	-	-	-	✓
Scenario 8	AllSc	✓	✓	✓	✓

A. Scenarios for Latvian power system

In 2010, electrical energy was produced mainly in three large hydropower plants and natural gas cogeneration plants. The wind power sector took up only 1% of the total production, which was 50 GWh.

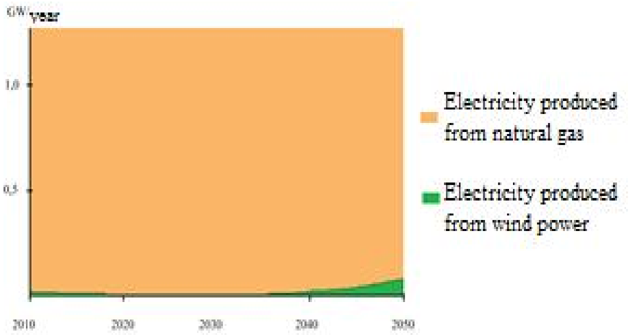

Fig. 3. Base scenario for electricity generation in Latvia

If we assume that the action is not taken to increase wind energy, then, as shown in Figure 3, the installed capacity of wind energy in the first 20 years is even decreasing and then slowly increasing.

Figure 4 shows that, if we use all policy instruments for 40 years then almost 100% in cogeneration with natural gas generated electricity will be replaced by electricity produced using wind energy. However, all of these instruments require a significant financial investment, and activities implemented to raise society awareness and training.

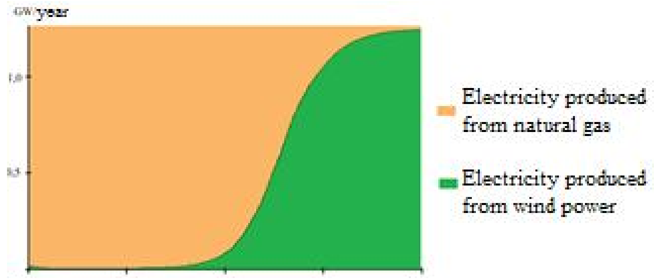

Fig. 4. 8th scenario for electricity generation in Latvia

B. Scenarios for Lithuanian power system

Now, as well as in 2010, most of the electricity in Lithuania was imported. In 2010 it was 56% of the total required amount of electricity. Natural gas installed capacity is slightly lower than in Latvia but wind power plant capacity is more than three times higher. In 2010, the installed wind capacity was 185 MW. [3]

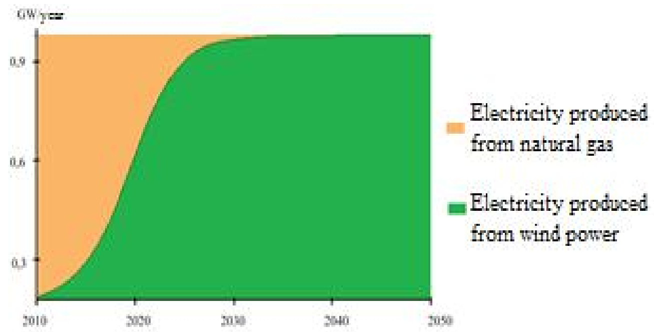

Fig. 5. 8th scenario for electricity generation in Lithuania

As shown in Figure 5, equipment of natural gas replacement to wind power plants by 2050 is achieved by applying the risk reduction instrument, increase of the effectiveness instrument and subsidies of 20%. This scenario is without feed-in tariff impact, due to the fact that Lithuanian legislation is different from the situation in Latvia which developed feed-in tariff model was applied. Lithuania's positive features are a higher share of installed wind energy capacity than natural gas equipment installed capacity as well as higher natural gas prices, which affect the simulation results.

V. REFERENCES

[1] About the amount of produced electricity in Latvia: http://data.csb.gov.lv/DATABASE/vide/Ikgad%C4%93jie%20statistikas%20dati/Ener%C4%A3%C4%93tika/Ener%C4%A3%C4%93tika.asp

[2] Ministry of Energy of the Republic of Lithuania. National Energy Independence Strategy of the Republic of Lithuania. – Vilnius, 2012.

[3] National Control Commission for Prices and Energy. Annual Report on Electricity and Natural Gas Markets of the Republic of Lithuania to the European Commission. – Vilnius, 2012

Efficiency determination of Latvian district heating plants

Jeļena Ziemele, Dagnija Blumberga, *Riga Technical University*

Abstract **– This paper is dedicated to Latvian town and rural district heating system heat rate analysis. The developed methodology allows the identification of indicators that influence heat tariff values and sets benchmark values, depending on the share of different fuels in tariff, capacity utilization rate and quantity of heat produced. The methodology is verified, in practice, on 26 direct heating systems in Latvia that are operated by equipment using energy wood, natural gas and diesel fuel.**

Keywords **– District heating, benchmarking, energy efficiency.**

I. Introduction

Improving energy efficiency is one of the priorities in European Union countries. To ensure efficient use of energy, the Directive (2012/27/ES) [1] requires Member States to carry out analysis of district heating potential use effectiveness. Energy regulators should pay attention to this issue when making decisions related to heat supply, because there are more than 60 currently operating district heating companies in Latvia that vary in size, production, technical condition and fuel type. Difference in the tariffs of different district heating companies gives reason to study their components and talk about the need to implement energy efficiency measures on-site in energy production plants [2], as well as the need to replace expensive fossil fuels with relatively cheaper domestic wood [3,4]. This paper summarizes operating data of 26 large (installed capacity of 14MW to 560MW), and 40 medium-sized and small (from 14 MW to 0.1 MW) heating companies for the last three years.

II. Methodology of heat tariff analysis

Considering that heat tariff determination requires pooling of a number of indicative values and, based on both the heat source operating indicators (installed capacity, heat production, efficiency, fuel type, heat technological solution) and the tariff calculation methodology, was established the algorithm. The modeling algorithm contains the benchmark method that characterizes company performance. A variety of data characterizing companies' operation and coefficients obtained by calculations, are used to form district heating benchmarks. For example, the benchmark for heat loss in networks is the maximal possible losses. This means that the owner of the heating network needs to address energy efficiency issues, if losses exceed benchmarks value.

Capacity utilization rate A_N is used for cross-referencing of the heating companies' operation:

$$A_N = \frac{N_N}{Nuz} \qquad (1)$$

where
N_N – power requirement during heating season, MW
Nuz – installed capacity of the company, MW.

Another district heating energy parameter is fuel part in tariff A_F, which includes heat production costs:

$$A_F = \frac{VC_F}{IE_Q} \qquad (2)$$

where
VC_F- fuel cost, LVL/year,
IE_Q- proceeds from the sale, LVL/year.

These and other indicators with benchmarks are incorporated into the heat tariff setting methodology.
Data statistical processing is carried out using the software STATGRAPHICS Centurion.

III. Results

The proposed methodology was tested with Latvian heat supply companies' performance data. In Figure 1 illustrates heat sales tariff dependence on fuel share in tariff. Data were grouped according to the type of fuel – wood or natural gas. The regression equation was created and its statistical evaluation was made for each group.

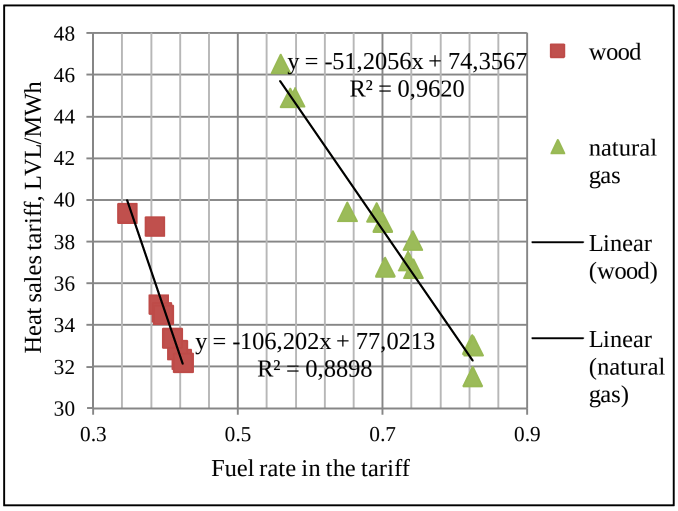

Fig.1 Heat sales tariff depending on fuel rate in tariff

The regression equation for natural gas fuels boiler houses is:

$$T = 74.3567 – 51.2056A_F \qquad (3)$$

where
T – heating tariff, LVL/MWh.

The processed data set m=13. t criteria are calculated with the program STATGRAPHICS Centurion. As shown in Table 1, $|t| >$ ttab can be observed in all cases. This means that all the parameters are significant and maintained in the equation.

The regression equation obtained for wood fuels boiler houses is:

$$T = 77.0213 – 106.202 AF \qquad (4)$$

The results of statistical evaluation are summarized in Table I.

The analysis shows that the value of R^2 is 0.8898 and the correlation coefficient is 0.94.The value of the correlation coefficient shows close correlation between the heat sales tariff and fuel component in the tariff. The created model explains 88.98% of the analysed cases.

TABLE I

RESULT OF STATISTICAL EVALUATION

Parameters	Value	t criterion	P value
Constant b0 (2.1)	74.3567	35.367	0.0000
Constant b1 (2.1)	-51.2056	-17.431	0.0000
Constant b0 (2.2)	77.0213	13.688	0.0000
Constant b1 (2.2)	-106.2020	-7.519	0.0001

IV. CONCLUSIONS

The calculation methodology is developed with an algorithm which includes detection of heating tariffdependence on the indicators that are independent variables: capacity utilization factor, fuel component of tariff, equipment efficiency ratio, heat losses in tracks and production of heat release.

[4]

The results show that the current situation, where the natural gas fuel boiler houses tariffs range is from 32 to 46 LVL/MWh and wood fuels boiler houses - from 32 to 39 LVL/MWh (Figure 1.), could be avoided in the future. With the help of the benchmark is limited tariffs range, within which the values of tariffs are determined, and the heat sources are encouraged to switch to renewable energy.

The system of indicators established in the study makes it possible to achieve higher(improved?) energy-efficient operation of heat supply companies in the long-term.

V. REFERENCES

[1] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, Official Journal of the European Union, L315, Volume 55., 14.11.2012

[2] Difs, K., Trygg, L., Pricing district heating by marginal cost, *Energy Policy*, pp. 606 – 616, 37, 2009

[3] Okkonen, L., Suhonen, N., Business models of heat entrepreneurship in Finland, *Energy Policy* 38, pp.3443 – 3452, 2010

Perspectives of the plywood product manufacturer to apply cleaner production principles

Ilze Podniece, Liga Ozolina, Dagnija Blumberga, *Riga Technical University*

***Abstract* - The paper identifies opportunities for a specific plywood production enterprise to implement cleaner production principles through the optimization of energy, water, materials and waste streams. A variety of specially adapted offers are proposed for the implementation of cleaner technologies. By calculation, it is shown that replacement of the electric boiler with a solar collector system is feasible (payback period - 3 years).**

***Keywords:* cleaner production; production of plywood products; solar collector system**

I. Introduction

Cleaner production techniques or practices mean good housekeeping, input material change, better process control, equipment modification, on-site recovery/reuse and production of useful by-products. Practicing cleaner production principles have ecological benefits and are economically feasible. [1]

II. Current situation and technological production scheme of resource flows

The plant studied receives key raw materials - birch plywood from the concern Ltd. “Latvijas Finieris” and then a variety of mechanical and chemical treatments are applied - cutting, sawing, painting, bending, gluing, staining, varnishing, milling and grinding edges, depending on the specificity of the expected product (sawn plywood, processed plywood, complete sets of plywood, plywood cuttings, traffic signs, furniture and sports equipment). Plywood (98%), peel chippings and adjuvant (glues, varnishes, putty, resin, stain, paint, solvents and hardeners) are used as raw materials (see Fig.1).

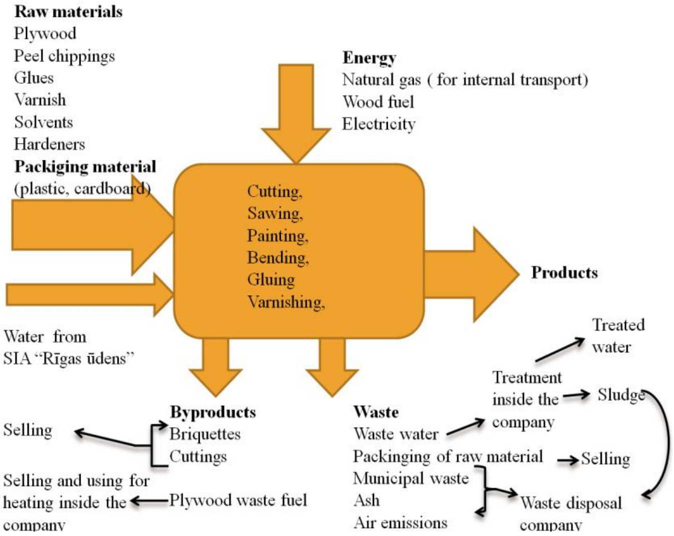

Fig.1. Flow diagram of production resources

Total energy consumption was calculated as a sum of electric energy consumption and consumed energy from other energy sources such as plywood chips (used for heating) and propane (used for fuel trucks), taking into account the specific energy density of each source.

Practically the only energy form which is used in direct production processes is electricity. Water is not used in direct productions processes.

The biggest amount of waste consists of wood waste and sawdust (67%). Municipal sewage sludge (coming from the company’s organic wastewater treatment installation) and furnace ash (from the incineration of waste plywood in the boiler house) also constitute a noteworthy amount of the waste. Hazardous waste accounts for only a small portion of all the transferred waste. The total weight of produced waste is 140,8 tons. The main atmospheric emissions are dispersed in solid particles, VOCs, phenol and formaldehyde. [2]

The main principles of cleaner production already implemented by the company are production of the useful by-products - briquettes, energy recovery from plywood waste in a special furnace, usage of environmentally friendly materials, e.g., water-based glue, the use of certified (FSC Mixed Credit, 100% PEFC Certified, FSC Controlled Wood) plywood (at customer request). The “end of the pipe” technologies used in the company are flue gas filters and wastewater treatment. [2]

III. Methodology for data analysis

The specific energy consumption (SEC) was calculated by the 1st equation, knowing the typical product output m^3/year and the total annual electricity consumption. The products’ were not differentiated by types in spite of different energy demand due to the fact that 90% of the output is sawn plywood and processed plywood, while all other types of products collectively account for the remaining percentage.

$$SEC = \text{total energy consumption} / \text{amount of production } (MWh/m^3) \quad (1)$$

The calculated specific energy consumption value is 45.9 MWh/m^3 of produced outputs.

$$NPV_n = -K + \sum \frac{CF_n}{(1+WACC)^n} \quad (2)$$

where

NPV – net present value, Ls;
CF – cash flow (the difference between income and costs);
n - calculated consecutive year;
K – capital expenditure, Ls;
WACC – weighted average cost of capital, %.

The value of the weighted average cost of capital in calculation was adopted to be the same as the discount rate, which shows the value of money or profitability of the proposed changes.

$$PI = \frac{\sum \frac{CF}{(1+WACC)^n}}{K} \quad (3)$$

where

PI - profit index, dimensionless

For an economic feasibility calculation of the solar collector installation, the common economic tools, such as net present value (2) and profit index (3), which indicate feasibility as well as payback period, were used.

IV. Analysis of Results

Currently the required heating load is only about one-third of the nominal output of the boiler, in order to optimize the boiler operating mode 10 m^3 heat storage tank is set, in the future it could be increased or connected in series or in parallel with the other tank because there are no other heat consumers in close proximity to the company.

Waste stream optimization solutions are: sorting municipal waste or burning it at high temperatures, or reproducing furnace bottom ash and wastewater into useful by-products.

For reducing the electrical energy consumption, it is proposed to replace the fluorescent bulbs with light-emitting diodes (LEDs) and replace electric boilers with domestic hot water preparation to a solar system. In the winter, hot water is prepared for employees by a central heating boiler while, when the central heating is not required, two 2,2-liter 200 kW electric boilers are used for domestic hot water.

The transformation of electricity into heat due to its higher exergy is wasteful and expensive, so feasibility study of solar collector system's project was done. It was determined that the optimal solar panel angle of inclination in Riga, where the company is located, during the non-heating season is 30 °. [3]

A real offer in the market for a flat solar collector with a sufficient absorption area (2 × 5,53 m^3) was found in order to fully ensure that the required amount of hot water preparation in non-heating season will be provided. The replacement of electric boilers with domestic hot water to solar collectors constitutes a capital cost of 4150 Latvian lats (Ls).

In order to make an economic calculation, the following assumptions were made: assumptions about the funding scheme (equity capital and borrowed capital ratio, profit margin and interest rate), inflation and energy price increases, as well as the operating time and maintenance cost. Estimated operating costs are low and include change of heat transfer fluid every six years, as well as maintenance of the collector's surface. The economic calculation was made for the first 10 years of operation, which is the normal warranty period of such systems.

By calculations it is shown that the project is economically feasible because the values of economic tools indicating the profitability of the project meet minimum requirements, i.e., the net profit value (NPV) is greater than zero, the internal rate of return greater than the discount rate and the profit index (PI) value is greater than one. Already in the third year of operation (at baseline), the NPV is greater than zero, so the investment pays off within 3 years.

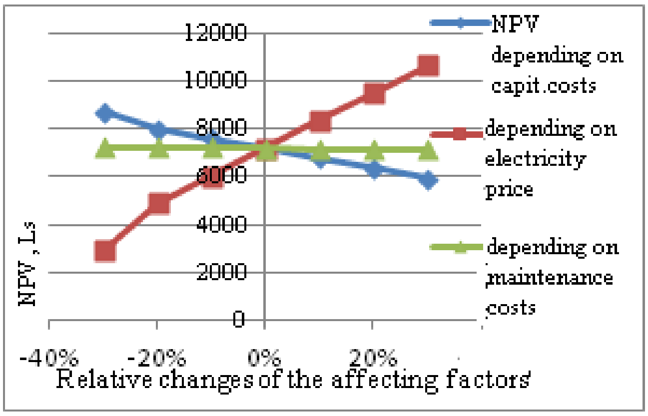

Fig.2. NPV relative change depending on changes in the amount of capital investment, operating costs and electricity prices

With a sensitivity analysis, the relative and absolute NPV changes are detected by changes of key output size – capital costs, operating costs and electricity price. According to the obtained results, NPV is more sensitive to electricity price changes, the curve is "steeper" (see Fig. 2), which means that small changes of this factor causes relatively significant changes in NPV values, while the operation costs change leave almost no impact on the NPV value in the wide (±30% changes from base scenario) range.

IV. Conclusions

The company has already implemented eco-friendly and sustainable production processes and is also planning to continue to do so in the future.

Since the company is a plant inside a big wood processing concern, the companies within the group have a mutually symbiotic relationship that positively affect one another because collaboration with others is one of the cleaner production principles.

The wood origin waste utilization usually presents no environmental concerns because of the useful characteristics of the material.

The company was not ready for large investment that pays off only in the long term, so a simple as well as economically and environmentally justified solution was proposed.

V. References

[1] United Nations industrial development organization. Cleaner production // http://www.unido.org/what-we-do/environment/resource-efficient-and-low-carbon-industrial-production/cp/cleaner-production.html - [30.04.13.]

[2] SIA „Troja" categories B permit of pollution 10.01.2009. – 09.01.14.

[3] Incident global irradiation for the chosen location// http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php# - [21.05.13.]

Use of activated carbon generated from biomass source (poplar sawdust) for the removal of dye

Umran Tezcan Un, *Funda ATES, Anadolu University*

***Abstract*- The removal of dyes from wastewater has been studied with using cheap, efficient and ecofriendly adsorbent as an alternative source of activated carbon. This study investigates the use of activated carbons prepared from poplar sawdust for the removal of reactive orange 13 (RO13) dye from aqueous solution. A series of experiments were conducted in a batch system to assess the effect of the some parameters, i.e. initial pH, initial dye concentration and adsorbent dosage. The results showed that the maximum dye adsorption was obtained at pH 2, as the amount of adsorbent increased, the percentage of dye removal increased, accordingly but it decreased with the increase in initial dye concentration. The 100% removal of Reactive Orange 13 was obtained using 0.06 g activated carbon at pH of 2. It can be concluded from this study that activated carbon generated from the poplar sawdust has high performance for the removing reactive dye from wastewater.**

***Keywords*-Reactive orange 13, poplar sawdust, adsorption, activated carbon**

I. Introduction

Dyes used in the textile industries cause environmental concern because of generated colored wastewaters. Color is the most obvious indicator of water pollution and affects the aesthetic nature and reduces photosynthetic activity. Some dyes are toxic, non-biodegradable due to their strong resistance toward light and harmful to aquatic living creatures, even highly carcinogenic to human health. In order to solve this environmental problem, several processes have been investigated, such as coagulation-flocculation[1], electrocoagulation [2], biological treatment [3], ultrafiltration [4] and adsorption [5].

Several adsorbent such as pomegranate peel[6], sugarcane bagasse pith [7], pistachio hull waste [8] were used for the production of the activated carbon. The use of poplar sawdust as a source of adsorbent has been limited studied.[9,10] The objective of the present study was to assess the ability of activated carbon generated from the poplar sawdust to remove reactive orange 13 from aqueous effluent. The effects of operational parameters such as pH, adsorbent dose and initial dye concentration were determined in the batch experiments.

II. Experimental Studies

In the experimental study, activated carbon was produced from the poplar sawdust in a fixed-bed reactor. The bio-mass sample was activated using chemical activation technique. Chemical activation was done using KOH with the impregnation ratios of 1/1 and impregnation time of 48 h. The impregnated sample was heated with a rate of 10 ºC/min to the final pyrolysis temperature of 800 ºC in the inert (N_2) atmosphere. To remove residual chemicals the carbonized samples were washed several times until the pH became neutral and then dried. The obtained activated carbon was used in the further experiments for the removal of dye from the wastewater.

In the adsorption experiments Reactive Orange 13 (RO13) obtained from the local textile industry in Eskisehir, Turkey was used. The chemical structure of RO13 which has a chemical formula of $C_{24}H_{15}ClN_7Na_3O_{10}S_3$ and a molecular weight of 762.04 g/mol is presented in Fig.1. It belongs to non-metal azo group of cyanuric based reactive dyes and is used for cotton viscose fabric or the dyeing and printing. A model wastewater with a required initial concentration was prepared from the stock solution of RO13 (1000 mg/L). The pH of the solutions were adjusted using 1N H_2SO_4 or 1N NaOH. All chemicals were of analytical reagent grade.

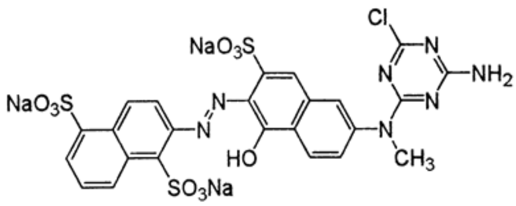

Fig. 1: Chemical structure of reactive orange 13

In the experimental studies 30 mL of dye solution was treated using activated carbon at a constant agitation speed rate. Dye absorbance after equilibrium was determined by centrifuging and analyzing the supernatant spectrophotometrically using a double beam UV spectrophotometer (Shimadzu Model: UV 1700) at the wavelength that correspond to the maximum absorbance of the sample (λ_{max}=488 nm). Dye concentration was calculated from the calibration curve of absorbance vs. concentration.

Dye removal efficiency was calculated as (1)

$$\% = \frac{C_o - C_e}{C_0} x100 \qquad (1)$$

Where C_0 and C_e are the initial and final concentrations of dye in mg/L, respectively.

III. Results and Discussion

A. Effect of pH

The pH is an important factor in the adsorption process of dye in aqueous solutions. The effect of solution pH on dye removal was studied using pH of 2 to 7 for the adding 0.045g activated carbon and 50 mg/L of initial dye concentration and 2 h of contact time. Results are shown from the Fig.2. It can be seen that dye removal efficiency was higher at lower pH. Dye removal efficiencies of 97.5%, 94%, 75%, 74%, 66% and 66% were obtained for the pH of 2, 3, 4, 5, 6 and 7 respectively. This results show us that the dissociation of functional groups on the active sites of adsorbent surface and aqueous chemistry is affected by pH change.

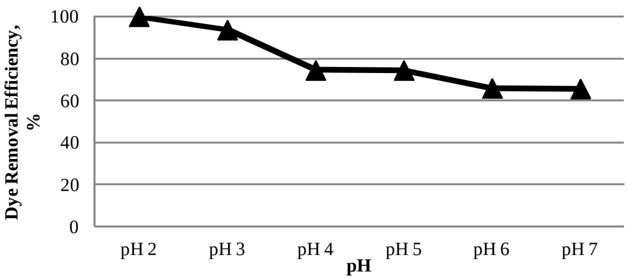

Fig.2. Effect of pH on dye removal efficiency

B. Effect of Adsorbent Dose

Adsorbent dosage determines the capacity of an adsorbent for a given initial concentration of the adsorbate. The effect of the adsorbent dose on the percentage of dye removal was studied at pH 2. As seen from the Fig. 3 as the adsorbent concentration increases, percentage adsorption increases. The percentage of dye removal was increase from 23% to 100% with the increasing of sorbent dosage from 0.0015 to 0.06 g. With the increasing the adsorbent dose, the number of sorption sites at the adsorbent surface also increases, thus dye removal increase. Similar increase in dye removal with the increasing adsorbent amount was also observed by other researchers in literature [11,12].

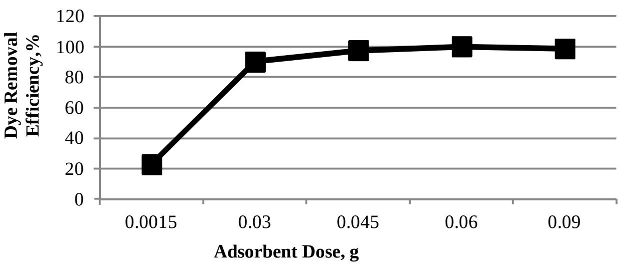

Fig. 3: Effect of adsorbent dose on dye removal efficiency

C. Effect of initial dye concentration

Initial dye concentration influences the percentage removal of dye. At constant adsorbent dose of 0.06 g and pH of 2 the effect of dye concentration on the percentage removal is shown in Fig. 4. While increasing the initial dye concentration from 50 to 250 mg/L, the dye removal efficiencies decreased from 100% to 81.5%, respectively. It is evident that dye adsorption is highly dependent on initial concentration. Because active sites of surface is saturated and active sites is not available for the further adsorption of the high initial concentrations. Similar results have been reported in the literature [13,7]

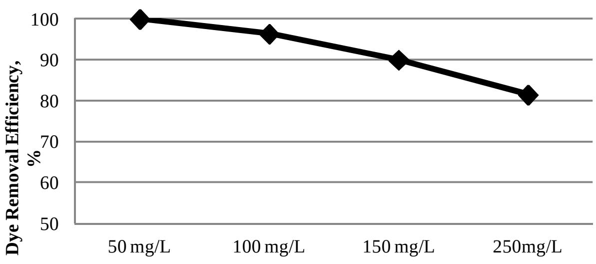

Fig. 4: Effect of adsorbent dose on dye removal efficiency.

IV. Conclusion

In this work, activated carbons prepared from poplar sawdust have been used successfully as an adsorbing agent for the removal of reactive orange13 (RO13) dye from aqueous solutions.

The adsorption is highly dependent on the pH of the solution, adsorbate dosage and dye concentration. The maximum adsorption of dye was obtained at an initial pH of 2. The removal efficiency increased with the increasing amount of adsorbent and decreased with the increasing dye concentration. The 100% removal of Reactive Orange 13 was obtained using 0.06 g activated carbon at pH of 2.

As a result of the present study it can be shown that activated carbon generated from the poplar sawdust is efficient for the removing reactive dye from wastewater.

V. References

[1] Szyguła, A., Guibal, E., Palacín, M. A., Ruiz, M., Sastre, A. M., Removal of an anionic dye (Acid Blue 92) by coagulation–flocculation using chitosan. Journal of Environmental Management, 2009, vol. 90, Issue 10, p. 2979-2986

[2] Tezcan Un, U., Aytac, E., Electrocoagulation in a packed bed reactor-complete treatment of color and cod from real textile wastewater . Journal of Environmental Management, 2013, vol. 123, p. 113-119

[3] Shahid Chatha, S. A., Asgher, M., Ali, S., Hussain, A. I., Biological color stripping: A novel technology for removal of dye from cellulose fibers. Carbohydrate Polymers, 2012, vol. 87, Issue 2, p, 1476-1481

[4] Alventosa-deLara, E., Barredo-Damas, S., Alcaina-Miranda, M.I., Iborra-Clar, M.I., Ultrafiltration technology with a ceramic membrane for reactive dye removal: Journal of Hazardous Materials, 2012, vol. 209–210, p. 492-500

[5] Kannan, C., Muthuraja. K., Devi, M. R., Hazardous dye removal from aqueous solution over mesoporous aluminophosphate with textural porosity by adsorption Journal of Hazardous Materials, 2013, vol. 244–245, p. 10-20

[6] Amin, N.K., Removal of direct blue-106 dye from aqueous solution using new activated carbons developed from pomegranate peel: Adsorption equilibrium and kinetics. Journal of Hazardous Materials, 2009, vol. 165, Issues 1–3, p. 52-62

[7] Amin, N.K., Removal of reactive dye from aqueous solutions by adsorption onto activated carbons prepared from sugarcane bagasse pith. Desalination, 2008,vol. 223, Issues 1–3, p. 152-161

[8] Moussavi, G., Khosravi, R., The removal of cationic dyes from aqueous solutions by adsorption onto pistachio hull waste. Chemical Engineering Research and Design, 2011, vol. 89, Issue 10, p. 2182-2189

[9] Pekkuz, H., Uzun, I., Güzel, F., Kinetics and thermodynamics of the adsorption of some dyestuffs from aqueous solution by poplar sawdust. Bioresource Technology, 2008, vol. 99, Issue 6, p. 2009-2017

[10] Acar, F. N., Eren, Z., Removal of Cu(II) ions by activated poplar sawdust (Samsun Clone) from aqueous solutions. Journal of Hazardous Materials, 2006, vol. 137, Issue 2, p. 909-914

[11] Anbia, M., Salehi S., Removal of acid dyes from aqueous media by adsorption onto amino-functionalized nanoporous silica SBA-3. Dyes and Pigments, 2012, vol. 94, Issue 1, p. 1-9

[12] Hameed, B.H., Removal of cationic dye from aqueous solution using jackfruit peel as non-conventional low-cost adsorbent. Journal of Hazardous Materials, vol. 162, Issue 1, 2009, p. 344-350

[13] Ates F., Tezcan Un, U., Production of char from hornbeam sawdust and its performance evaluation in the dye removal. Journal of Analytical and Applied Pyrolysis, 2013,, In Press, Corrected Proof, http://dx.doi.org/10.1016/j.jaap.2013.01.021