Agronomy Research **12**(2), 645–654, 2014

Analysis of wood fuel use development in Riga

J. Ziemele[1], I. Pakere[1,*], N. Talcis[2], G. Cimdiņa[1], Ģ. Vīgants[1], I. Veidenbergs[1] and D. Bluberga[1]

[1]Institute of Energy Systems and Environment, Riga Technical University, Kronvalda Bulv. 1, LV-1010 Riga, Latvia; [*]Correspondence: ieva.pakere@rtu.lv
[2]JSC 'Rigas Siltums', Cēsu iela 3a, LV-1016 Rīga, Latvia

Abstract. Use of wood fuel is a sustainable solution of district heating system development for the countries which do not have fossil fuel reserves, but have rich forest resources. The study analyses the options for wood fuel use in Latvia's capital, Riga. The STATGRAPHICS Forecasting and regression analysis modelling tools were used to develop two possible forecasting curves showing the trend of wood fuel use until the year 2020. The results show that the share of the amount of heat produced by wood fuel in Riga could reach 25% of total heat demand if the current trend continues.

Key words: wood fuel, forecasting, renewable energy sources, district heating.

INTRODUCTION

The transition to renewable energy source use is a topic of interest for many involved parties: scientists, enterprises, the society and policy makers. Latvia has a target of 42% renewable energy supply by 2020 (Blumberga et al., 2008). One of the leading renewable energy sources in the energy balance is wood fuel, because the Baltic countries have abundant supplies of wood (Dubrovskis, 2011).

In recent years, more and more installed technologies of district heating (DH) systems in Europe are based on renewable energy sources. Sweden and Denmark in their energy strategies aim at switching to renewable energy sources by 2050 (Joelsson & Gustavsson, 2012; Parajuli, 2012). Latvia is slowly following the experience of the Nordic countries. Two renewable energy sources – hydropower and biomass – hold a significant position in Latvia's total energy production. Hydro resources are used mainly for power generation, but biomass is used for production of heat. Nevertheless, most of the boiler houses and co-generation plants in Latvia are still dependent on natural gas resources (Barisa et al., 2013).

Forests cover around 50% of Latvia's territory and the total growing stock is 631 million m^3 (Latvian Central Statistical Bureau, 2013). The average forest processing rate in Latvia reaches 12 million m^3 per year (Barisa et al., 2013). In his research, Dubrovskis (2011) has assumed that the available biomass potential in Latvia is around 25–30 TWh $year^{-1}$. He concludes that, for the time being, the annual logging rate complies with the basic principles of sustainable development.

Latvia is currently not among the countries with the highest biomass share in total fuel consumption even if the price of biomass is around two times lower than the price of natural gas. Madlener (Madlener, 2007) has analysed the framework conditions for successful biomass DH system development. He concludes that sufficient reserves of wood resources are not enough; policy support and grants are also necessary to decrease the share of fossil fuel use. Perednis (2012) emphasises that the problems of collecting, storage and transportation of cutting residues should also be solved by promotion schemes and government support.

Over the past years, the technologies for biomass combustion have been significantly developed. Heat generation efficiency has increased due to the development of wood fuelled cogeneration stations (CHP) (Mathiesen at al., 2012; Troung & Gustavsson, 2013). One of the lately discussed solutions for efficiency increase in CHP is integration of a heat storage system (HSS). Simulations have shown that integration of a HSS can increase the overall energy generation efficiency by around 8% if storage volume is sufficient (Noussan at al., 2013).

The potential of bioenergy development in Latvia has been analysed in several articles (Romagnoli et al, 2012; Barisa et al., 2013). Barisa et al. have analysed different development scenarios of biomass from forestry, energy crops, and agricultural residues. The authors conclude that the largest biomass potential is associated with the use of forest logging residues and timber processing by-products (Barisa et al., 2013). A sustainable biofuels logistics system in Latvia has been investigated by Blumberga et al. (2012). The authors conclude that the use of biomass storage terminals could increase the delivery costs but minimize the moisture content of the fuel. Nevertheless, the most suitable transportation scenario is to chip wood logs in the forest and deliver the wood chips directly to the boiler house.

The main aim of this paper is to analyse the use of wood fuel for district heating in Latvia's capital, Riga, and to forecast the future development of the wood fuel share in the overall thermal energy balance of the city. The paper also summarises the different combustion technologies that have been installed in boiler houses in Riga.

The main hypothesis of the research is that 25% of the total thermal energy consumption of Riga can be produced by using wood fuel by the year 2020.

METHODOLOGY

Algorithm of methodology

The modelling algorithm of the research is presented in Fig. 1. The algorithm consists of seven different modules: initial data, data processing, assumptions, target setting, forecasting, climate indicator calculation, and obtaining and discussing of results.

The forecasting process began with data collection from a DH company in Riga. The research is based on the data about the heat produced in the period from 2006 to 2013. The collected data was processed and normalised. In order to set a target for the wood fuel use potential, several assumptions were made. Then, the forecasting was done by using two different methods. The forecast results were used to evaluate the wood fuel use development tendencies from which the possible CO_2 emission reduction was calculated.

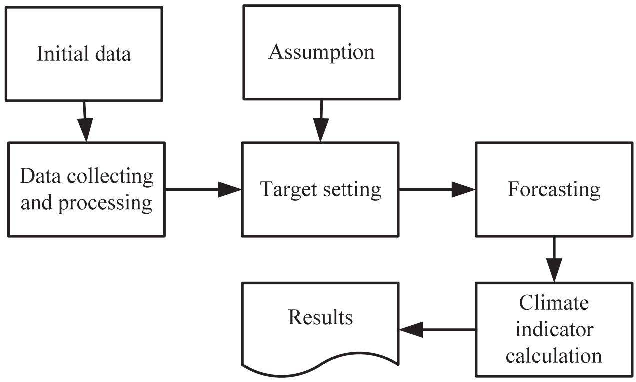

Figure 1. Algorithm of the methodology.

Initial data

A particular DH company of Riga was analysed in this research. The heat for Riga has been produced in 48 boiler houses of the DH company and an additional amount has been bought from other sources (JSC 'Rigas Siltums', 2012). The average amount of heat produced is around 4,000 GWh per year. The proportion of the different heat sources providing heat for the city can be seen in Fig. 2.

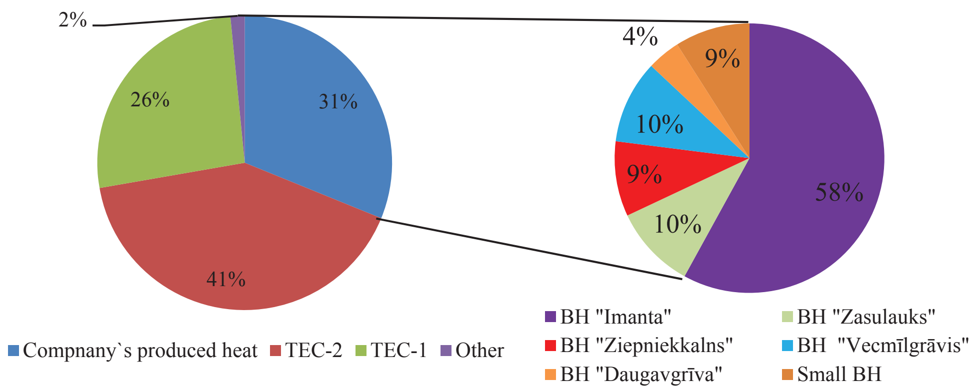

Figure 2. Proportions of heat produced by sources (TEC- thermoelectric power station, BH- boiler house).

Fig. 2 shows that most of the heat has been bought from an electricity producer (see TEC-1 and TEC-2). Around 30% of the total heat demand has been covered by the heat produced in the boiler houses owned by the DH company (its own boiler houses). This research particularly focuses on this part of the heat produced because it can be directly influenced by the DH company. In recent years, the company's largest district heating plants (except the 'Imanta' boiler house) have gradually moved towards the use of wood chips.

In October 2006, the first wood fuelled cogeneration station, 'Daugavgriva', with a steam boiler and turbine generator of 0.6 MW, started operations in Riga.

Another heating plant using wood chips was launched in 2010. The 'Vecmilgravis' heating plant has an installed capacity of 2 x 7 MW, because two AK-7000P1 water boilers with a sloping moving grate in front were constructed. Both heating plants are equipped with a flue gas condenser.

In 2012 two more modern heating plants 'Ziepniekalns' and 'Zasulauks' were starting the heat production from the wood chips. The heating plant 'Ziepniekalns' has installed co-generation technology with power capacity 4 MW. The boiler with a modern combustion area and the capacity of 20 MW is installed in.

The main reason for the use of wood fuel is the ability to reduce the heat production costs. This was caused by two main aspects:

1. The rapid increase of fossil fuel prices (see Fig. 3). The price of natural gas increased around 2.5 times during an eight year period (compared with the year 2000);

2. Latvia has undertaken to fulfil its international commitments on countering climate change (UN FCCC, 1992). In 2005, Latvia joined the GHG emissions trading system.

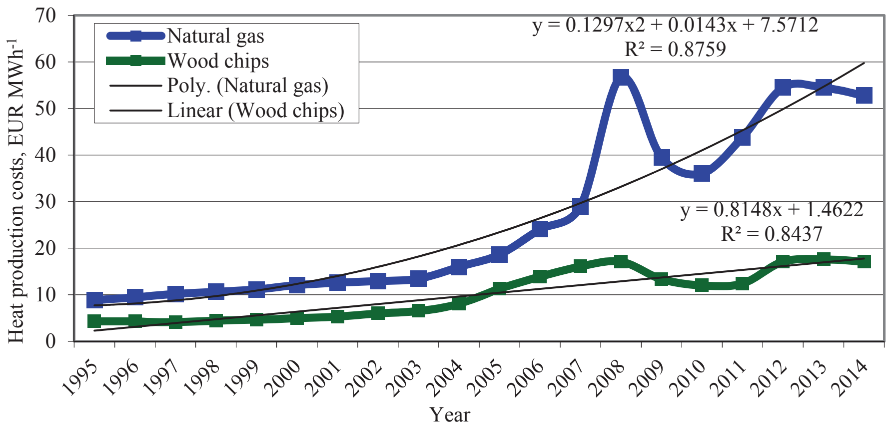

Figure 3. Price dynamics of different fuels.

The use of cheaper fuel reduces the heat tariff by around 1 Euro MWh^{-1} at the end of the year 2013.

Data collection and processing

Historical data about wood fuel consumption and the amount of heat produced in particular heating plants were collected in order to model the existing situation. Additionally, data about the total amount of heat produced by the DH company were obtained.

Processing of the data allowed researchers to evaluate whether all of the collected data could be used for modelling. The technological process of heat production was continuous but with short stops due to repair work. Consequently, all of the collected data can be considered reliable.

The initial data were normalised so the heat consumption corresponds to a standard year with a heating period of 203 days and the average heating season temperature of 0°C.

Assumption

One of the fundamental assumptions within this research is that the climatic conditions in Latvia will remain the same. The second assumption concerns the fuel price dynamics. The authors assume that the price levels will continue to change according to the previous trends (see Fig. 3.) and the price of natural gas in 2020 will be three times higher than the price of wood chips.

One of the most important criteria to model the forecast is the selected forecast period. The authors have chosen to develop the forecast until the year 2020, because the European Union targets for the increase of the renewable energy resources share has been set for 2020 (European Commission, 2012).

Target setting

Three different wood fuel use scenarios have been developed for the particular company:

- Pessimistic (wood chips share of 40% of the heat produced in company-owned boiler houses);
- Ordinary (wood chips share of 60% of the heat produced in company-owned boiler houses);
- Optimistic (wood chips share of 80% of the heat produced in company-owned boiler houses).

In the pessimistic scenario, it was assumed that financial capital will not be freely available for the company and fossil fuel prices will remain at the existing level or will decrease. Thus, significant new capacities of wood fuel will not be installed. In the ordinary scenario, the main assumption was that financial support related to 'green energy' will be available for the company and the use of wood will develop gradually. In the optimistic scenario, investment will be available and the price of fossil fuels will increase. Consequently, the company will almost completely switch to renewable energy sources, leaving a small share of fossil fuels covering the peak loads.

Forecasting

Two different tools were used for forecasting the amount of heat produced of wood fuel: STATGRAPHICS Centurion 16.1.15 software and a regression analysis model developed with Excel.

For the model in STATGRAPHICS, the period of 1 month and a seasonality of 12 months were used. An ARIMA (p,d,q)x(P,D,Q) model was chosen for the forecasting, because it has been widely used for modelling in different scientific fields. The general form of the model can be expressed in terms of the backwards operator B, which operates on the time index of a data value. Using this operator, the model takes the form (Zhu & Wei, 2013):

$$\begin{aligned}(1-B-B^2-\ldots-B^p)(1-B^s-B^{2s}-\ldots-B^{Ps})(1-B)^d(1-B^s)^D\,(Y_t-\mu) = \\ = (1-B-B^2-\ldots-B^q)\,(1-B^s-B^{2s}-\ldots-B^{Qs})a_t\end{aligned} \quad (1)$$

where a_t is a random error or shock to the system at time t, and μ represents the process mean for the stationary series.

A residual autocorrelation function with a confidence level of 95% was used to test the forecast model. The residual autocorrelation at lag k measures the strength of the correlation between residuals *k* time period apart. The residual lag *k* autocorrelation is calculated from:

$$r_k = \frac{\sum_{t=1}^{n-k}(e_t - \bar{e})(e_{t+k} - \bar{e})}{\sum_{i=1}^{n}(e_t - \bar{e})^2} \quad (2)$$

where: *t* is the time period; e_t is one period ahead of forecasting; *n* is the sample size (number of observations used to fit the model); $t + k$ is the forecasting time. The developed STATGRAPHICS Centurion forecasting model was compared with the regression model developed from the yearly data.

Climate indicator calculation

Installation of new technologies using renewable energy sources means that no burning of other fossil fuels is necessary. This reduces the amount of emissions emitted in the atmosphere due to the change of fuel and development of advanced combustion technologies with increased boiler efficiency. The avoided GHG emissions E (t CO_2 per year) are calculated in this research.

RESULTS

Data about heat production in Riga were collected in order to evaluate the wood fuel use potential. When comparing the yearly amount of heat produced from wood fuel and the total heat produced in the company-owned boiler houses (see Fig. 4.), high further potential can be seen. The share of wood fuel use has increased from 3% in 2006 to 21% in 2013.

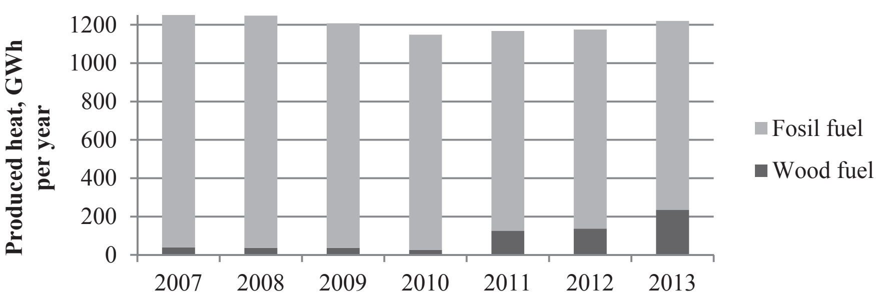

Figure 4. Produced heat by energy source per year.

Fig. 5 shows the heat produced from wood chips per month in four different boiler houses in the period from 2006 to 2013. It can be seen that during the last 3 years there has been a significant increase in wood chips use as three new boiler houses were adjusted for biomass use. Two of them were reconstructed in 2013, so it is not yet possible to evaluate their operation.

Since 2006, the heat produced from wood fuel has increased from around 3 GWh per month to 33 GWh in November 2013. This rapid increase is due to two newly reconstructed boiler houses, 'Ziepniekkalns' and 'Zasulauks'.

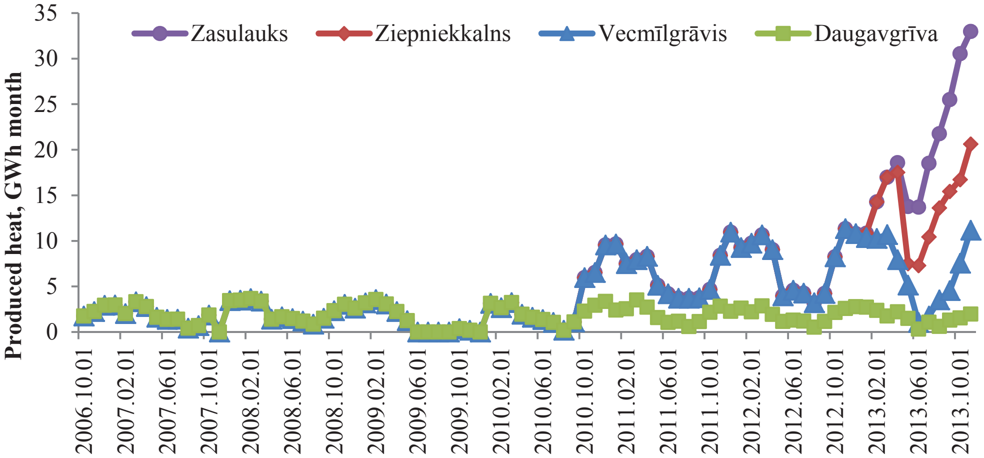

Figure 5. Changes in heat produced from wood chips in different boiler houses.

Historical data about heat production from wood chips was used to develop two different forecasting models. The first model was developed by using the regression analysis method. Fig. 6 shows the trend line for the increase in wood chip use in the period from 2007 to 2013, which was further adjusted for evaluation of wood chip potential.

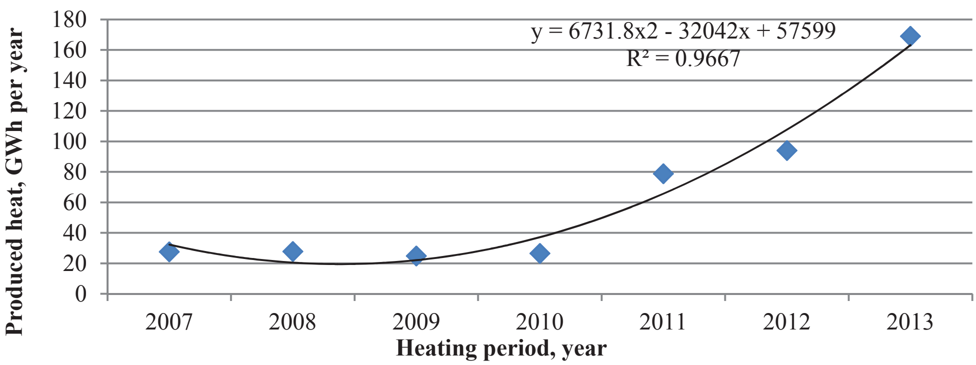

Figure 6. Regression analysis of heat production from wood chips.

The second forecasting model was developed by using monthly data about heat produced from wood fuel. The results of the ARIMA time series model can be seen in Fig. 7. The 'Ziepniekkalns' and 'Zasulauks' boiler houses were not included in this model due to the lack of data about their operations. The ARIMA model requires data from at least 24 months of operations.

The seasonality of heat production can be seen in Fig. 7. Nevertheless, the overall tendency towards heat produced from wood chips is increasing by covering more of the city's heat consumption. The model shows that it would be possible to produce around 600 GWh during the coldest months by 2020. In order to compare both of the models, the monthly data from the ARIMA model were summed to obtain yearly data.

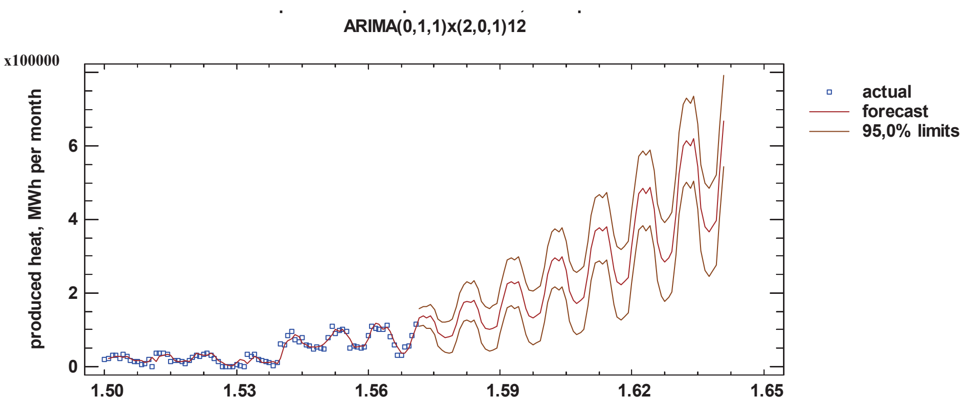

Figure 7. ARIMA forecast model (2006–2020) (1.50–1.53 three-year period).

The results obtained from both forecast models can be seen in Fig. 8. There is a small difference between the forecasting models. According to the regression analysis, it would be possible to produce 40% of the total heat with wood chips by 2016. The STATGRAPHICS model shows that the same amount of heat from wood fuel can be produced by 2015. Both models show that the company could almost completely exclude fossil fuel use by 2020, if it sets even more ambitious targets.

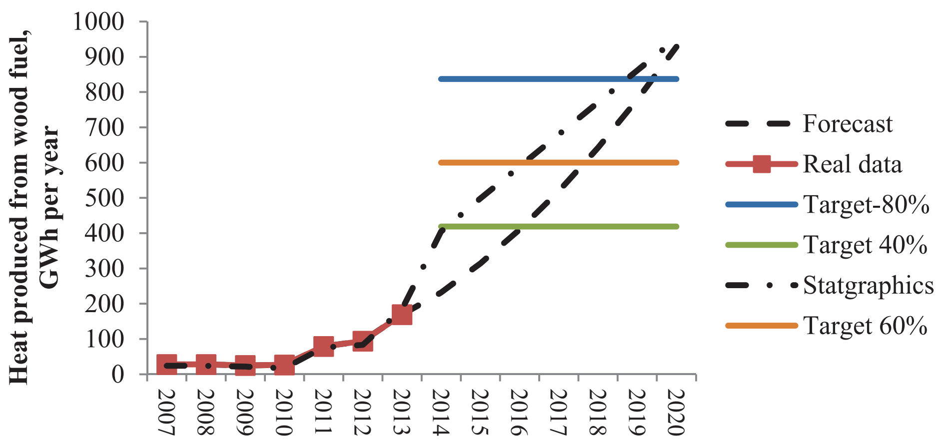

Figure 8. Results of the forecast models by using regression analysis and STATGRAPHICS Forecasting.

To reach such a target, it would be necessary to ensure continuous wood chip supply. As mentioned before, the availability potential of wood chips in Latvia is around 25–30 TWh. In order to reach the optimistic scenario, it would be necessary to use around 3% of the available wood chips in Latvia.

Use of wood fuel results in a significant CO_2 emission reduction. The avoided CO_2 emissions in the 13-year period (from 2007 to 2020) were calculated assuming that the industry will substitute the use of natural gas. The total CO_2 emission reduction for different scenarios can be seen in Table 1.

Table 1. The sum of avoided CO_2 emissions for different scenarios

Scenario	Avoided CO_2 emission, thous. t	Produced heat, GWh
From 2007 to 2013	99	439
Target 40% (2007–2020)	576	2,568
Target 60% (2007–2020)	782	3,484
Target 80% (2007–2020)	959	4,275

Table 1 shows that, until now, around 100 thousand tons of CO_2 emissions were avoided from 2007 to 2013 by introducing wood fuelled boiler houses instead of using natural gas. An almost tenfold reduction in emissions will be achieved if the target of 80% of heat from wood fuel is reached by 2020. The amount of avoided emissions in the analysed period would be around 1 million tons CO_2 if 80% of the heat would be produced from wood chips.

CONCLUSION

The study analyses the options of wood chip use in Latvia's capital, Riga. The STATGRAPHICS Forecasting and regression analysis modelling tools were used to develop two possible forecasting curves showing the trend of wood chip use until the year 2020.

The results show that the lowest target, with a wood fuel share of 40% of the company-produced heat, can be reached by the year 2014–2016. A level of 60% of the heat produced with wood fuel could be reached by 2015–2017. By 2020, the company would produce around 850 GWh by using wood fuel if ambitious targets are set. The availability of wood chips in Latvia is high; the wood fuel increase potential is two times higher than the use in 2013.

Wood fuel use for heat production has a positive impact on the environment due to the decrease of CO_2 emissions. In the case of the optimistic wood usage scenario, it would be possible to reduce CO_2 emissions by around one million tons in a thirteen-year period. In order to accurately determine the impact on the environment, the life cycle of wood fuel harvesting should also be analysed, and the particulate matter from wood combustion needs to be taken into account.

In order to further increase the use of wood fuel for district heating, additional financial support for installation of new technologies is required. Other forecasting trends would be observed if a sharp change in fuel price levels would occur.

REFERENCES

Blumberga, D., Romagnoli, F. & Žandeckis, A. 2008. Analysis of Wood Fuel Flow in Latvia.: *9th Baltic Economic Forum: Energy Efficiency and Renewables Conference: Forum Documentation*, Latvia, Riga, 3.–4. November, pp 189–196.

Dubrovskis, D. 2011. Forest resources in Latvia. Materials from the 5th Latvian Green Energy Forum. September 7, Riga, Latvia (in Latvian).

Parajuli, R. 2012. Looking into the Danish energy system: Lesson to be learned by other communities. *Renewable and Sustainable Energy Reviews* **16**, 2191–2199.

Joelsson, J. & Gustavsson, L. 2012 Swedish biomass strategies to reduce CO2 emission and oil use in an EU context. *Energy* **43**, 448–468

Barisa, A., Cimdina, G., Romagnoli, F. & Blumberga, D. 2013 Potential for bioenergy development in Latvia: Future trend analysis. *Agronomy Research* **11**(2), 275–282.

Latvian Central Statistical Bureau 2013. Central Statistic Bureau database. [Online] Available at: www.csb.gov.lv[Accessed 16 January 2014]

Perednis, E., Katinas, V. & Markevičius, A. 2012. Assessment of wood fuel use for energy generation in Lithuania. *Renewable and Sustainable Energy Reviews* **16**(7), 5391–5398.

Madlener, R. 2007. Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria. *Energy Policy* **35**(3), 1992–2008.

Chinese, D., & Meneghetti, A. 2005. Optimisation models for decision support in the development of biomass-based industrial district-heating networks in Italy. *Applied Energy* **82**(3), 228–254.

Mathiesen, B.V., Lund, H. & Connolly, D. 2012. Limiting biomass consumption for heating in 100% renewable energy systems. *Energy* **48**(1), 160–168.

Romagnoli, F., Blumberga, A., Blumberga, D., Barisa, A., Dzene, I., Rošā, M. & Rochas, C. 2012. Policy Strategy Effects for a Sustainable Improve of a Wood-Based Energy Structure in Latvia: an Integrated Dynamic Model of the District Heating System. *Biomass Policies, Markets and Sustainability: 20th European Biomass Conference and Exhibition*, Italy, Milan, 17.-22. June, pp. 2147–2161.

Blumberga D., Lipsane L., Laicane I., Gusca J.& Kalnins S.N. 2012. Analyses of Wood Fuel Chain in Latvia. *Agronomy Research* **10**, 25–38.

Truong, N.L., & Gustavsson, L. 2013. Integrated biomass-based production of district heat, electricity, motor fuels and pellets of different scales. *Applied Energy* **104**, 623–632.

Noussan, M., Cerino Abdin, G., Poggio, A., & Roberto, R. 2013. Biomass-fired CHP and heat storage system simulations in existing district heating systems. *Applied Thermal Engineering* **1**, 1–7.

JSC 'Rigas Siltums' 2012. Annual report. [Online] Available at: http://www.rs.lv/index.php?aid=1&id=13 [Accessed: 16 January 2014]

The United Nations Framework Convention on Climate Change (UN FCCC) 1992. Convention text, Rio de Janeiro, June [Online] Available at: http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf [Accessed: 16 January 2014]

European Commission 2012. 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/ 55

Bangzhu, Zhu & Yiming, Wei. 2013. Carbon price forecasting with a novel hybrid ARIMA and least squares support vector machines methodology. *Omega* **41**(3), pp. 517–524.