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REPLACEMENT OF THE REGULATED PRICE OF OIL SHALE-BASED ELECTRICITY WITH OPEN-MARKET PRICE AND REAL-TIME TARIFF SYSTEM OPPORTUNITIES

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Abstract. *The Estonian retail electricity market opened on the 1st of January 2013. The wholesale electricity market has been operating open successfully for some time already. The liberalized electricity market creates new opportunities for consumers. From 1 January 2013, all electricity producers compete on power exchange. This means that the price of the electricity produced from oil shale is no longer regulated by the State and Narva Power Plants, like other power companies, are competing in the open electricity market.*

The liberalized electricity market and new remotely readable meters enable retail dealers to offer consumers more flexible packages. For example, a new pricing system could be developed that takes into account actual costs of electricity production at the exact time these are made.

The aim of this article is to give an overview of possibilities of real-time pricing and compare the existing tariff systems to the hourly variable pricing tariff system.

Keywords: *open retail electricity market, power exchange, tariff systems, electricity price, oil shale, real-time tariff system.*

1. Introduction

Up until 2013, the electricity price was mainly shaped by oil shale-fired power plants and the sales price limit was confirmed by the Estonian Competition Authority. The Estonian Competition Authority confirmed the price limit of electricity sold to the regulated retail market according to the Electricity and oil shale production price regulation principles drawn by the Authority on the basis of the Electricity Market Act [1].

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In Estonia, oil shale-based electricity constitutes the major part of total electricity produced and consumed, therefore it can be stated that until recently the rate of electricity to consumer depended on oil shale-based electricity generation. In 2010, for example, the overall production of electricity was 12 962 GWh and 92.3% of it was produced from oil shale [2]. In the open electricity market, the price of electricity is no longer controlled by the State, instead, it is formed on the market and power exchange. Unfortunately, the opening of the market was also accompanied by the increase of electricity price, since to home user the regulated market price was lower than the current power exchange price.

The open electricity market and remotely readable electricity meters will offer new possibilities for everyone. For decades, there have been talked over real-time tariffs. Although some researches have been made and algorithms developed offering real-time pricing system, until now there have not been appropriate technologies. No meters have been available that could measure the energy consumed at a sufficient interval, i.e. as frequently as its price changes. Technologies that could send real-time pricing information to consumers have been lacking either. But today, such a technology finally exists. Different AMI meters allow the distribution network operator [3]:

a. to measure the consumed energy at the desired interval;
b. to communicate with the consumer through various communication channels (power line carrier PLC, Wi-Fi, GPRS, 3G, WiMax, etc.);
c. to switch consumer on or off the system;
d. to limit consumer consumption;
e. to monitor power quality;
f. to send consumer power outage information.

By today, many developed countries around the world have deregulated their electricity markets. This is aimed at creating conditions for competition among electricity producers to ensure a fair electricity price to consumers, as well as producers. Now that the electricity market is fully open, the oil shale-based electricity is competing with that generated by other modes. In 2012, the Estonian Competition Authority set the average sales price limit of the electricity produced by Narva Power Plants to 29.4 €/MWh [4]. There were 36 power companies in the closed electricity market in Estonia and the average approved price of electricity was 32.9 €/MWh [4]. However, in 2012, the average price of electricity in the Elspot Estonian region was 39.2 €/MWh, i.e. over 19% higher than the Estonian Competition Authority approved average price.

The competitiveness of Estonian oil shale-based electricity in the open market depends on various factors, but largely on CO_2 quotas. If Narva Power Plants would purchase the required CO_2 quotas, it may raise electricity production costs even more. Oil shale-based electricity production releases much more CO_2 compared to the other methods of electricity generation. The production of 1 MWh of electricity from oil shale emits around 1.2 tons of CO_2 (the new Narva Power Plant unit releases

1.07 t/MWh and the old units 1.22–1.40 t/MWh). Whether the oil shale-based electricity is sustainable and also competitive in the open market and secures Estonia's electricity supply depends on the amount and price of the needed CO_2 quotas.

The EU energy policy's objective is to create one single electricity market. At the moment there are 13 power exchanges in the European Economic Area [5], with IPEX of Italy, EEX in Germany and Nord Pool Spot in Norway as the biggest.

In the Estonian closed electricity market conditions, the Estonian Competition Authority confirmed all electricity prices, taking into account the costs of capital, fuel, transmission, etc. In an open market the price of electricity will depend on the point on the consumption curve at which the supply and demand curves intersect. In other words, the price is derived from market equilibrium. At Nord Pool Spot, purchase orders constitute the demand curve and sale offers the supply curve (Fig. 1). The intersection of two curves generates the market price for the next hour [6]. The uniform price is the price level at the intersection of aggregated demand and supply curves and is called market clearing price. It provides a maximum trade volume, also called market-clearing trade volume [7].

Since in retail market sellers are competing with each other, the price to households is determined on competitive terms. Although in the open market households may choose between electricity packages offered by many retailers, it is unfortunate that they have to choose only between different fixed electricity price packages whose prices change monthly or even more seldom. Therefore, it is time that consumers should have the possibility

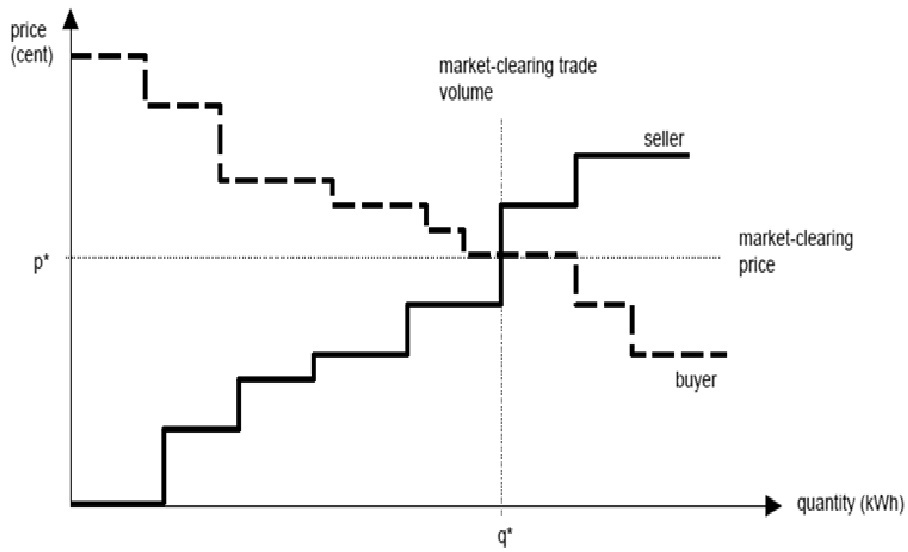

Fig. 1. Aggregated supply and demand curves [7].

to take a real-time price packet, which reflects the current market price and costs of electricity generation.

At the moment, price packages offered to consumers do not mirror actual costs of electricity production. Retailers offer price packages which involve only two rates – daily and nightly. However, this two-tariff system does not motivate consumers enough to plan consumption. Thus, it can be said that the tariffs currently offered are not attractive enough to control consumption. It is important to offer price packages which take into account the network situation and make consumer shift consumption away from peak load. Therefore, to achieve a better demand response it is important to offer more daily rate price packages, or a real-time pricing package.

Eesti Energia AS had in 2012 different price packages – KODU1, KODU2, KODU3, KODU4 and a heating package; it was also possible to choose green energy. Users having the main fuse over 63A had the possibility to select between six different price packages and it was also possible to select green energy. Nevertheless, most consumers are primarily interested in price, followed by origin of electricity, and manufacturer or seller.

In Finland, the Vatenfall energy company offers consumers a price package whose price changes according to the electricity exchange price (Nord Pool Spot, Norway). Unfortunately, the average price for the preceding month is adjusted only once a month. Besides, 3.04 €/month and commission fee of 0.25 € cents/kWh are added. Such an arrangement is actually quite similar to that of the proposed real-time pricing system. The price depends on the exchange price, changing at certain intervals, and the seller takes a fixed commission fee. However, the interval is too long and the price does not entail the production costs at the moment the energy is consumed.

2. Description and objectives of the retail electricity market

Electricity tariffs are not just there, so the seller could benefit from the goods (electricity) sold. Different tariffs could help achieve the desired goals. The main objectives the retail market tariff systems will help achieve are:

a. reducing consumer electricity costs;
b. motivating consumer to regulate consumption;
c. educating consumer;
d. increasing consumer electricity usage efficiency;
e. increasing consumer demand response;
f. approximating load curve;
g. limiting peak load and decreasing load minimum;
h. reducing balancing energy storage costs;
i. increasing integration of wind and solar power.

In Estonia, over 90% of electricity is produced from oil shale. Unfortunately, it is difficult to regulate power production in Narva Power Plants.

Thus, it is vital to adjust the load curve and it is most likely achieved through the price of electricity. For instance, electricity at night should be considerably cheaper to motivate consumers to move consumption on the nighttime.

The wholesale and retail electricity markets have been open for some time and work without problems. Since April 1, 2010, an open consumer has had the right and obligation to choose his own electricity seller. An open consumer was a consumer that used at least 2 GWh of electricity a year at consumption sites through one or more connection points. Until 2013, open consumers formed about 30% of Estonia's electricity consumption [8]. From 1 January 2013, all consumers are open and purchase electricity at the liberalized electricity market, which in turn should boost an open retail market.

Estonia was until 2013 undergoing a period of transition from the closed regulated market to the open retail electricity market. So, users that were not open consumers had to buy electricity from their network operator and had no right to change the seller. In the closed retail market, the biggest market share carrier was Eesti Energia AS with 87% in 2009 [9]. In the regulated market, the price was always approved by the Estonian Competition Authority, depending on the costs of oil shale mining, electricity generation, transmission, distribution and sale. In 2010, household consumption accounted for 27% of total consumption and despite increasing energy prices, since 2006 electricity consumption in Estonia has been growing.

The open market consists of many different parties, like end-users, producers, traders, brokers, regulators [6]. Also, there are a transmission system operator (TSO), a distribution system operator (DSO) and a market operator.

There are about 600 000 households in the Estonian retail electricity market, most of them being price sensitive. In addition, there are approximately 100 000 commercial users. Most consumers make no distinction between kW and kWh and they purchase comfort (lighting, heat, etc.). It is important to offer consumers as clear and transparent packages as possible. All consumers should understand which elements contribute to the electricity price. In addition to households, there are bigger consumers (business customers) in the retail market, with consumption >10 MWh. Thus, the sellers should provide electricity to various customers, offering the most suitable and cheapest tariff packages. The sellers should also differentiate between domestic and commercial users. Domestic users include apartments, apartment buildings, detached houses, smart-homes, etc.

Similarly to the closed market electricity price, the price in the open retail market also forms through Formula 1. The only difference is that in the open retail market the price is shaped on competitive terms and is not approved by the Estonian Competition Authority. Grid service (transmission and distribution) is a natural monopoly whose tariffs will be continuously approved by the Estonian Competition Authority.

One of the bases of retail market is remote metering and a well-operating information system. However, a well-working retail market can only be shaped through competition. Thus, many sellers need to find their way to the retail market. Table 1 presents different possible retail-market tariff packages, their description and target groups.

Table 1. Possible tariff systems in open electricity market

Price package	Description	Target group
Fixed-price tariff system	The seller offers consumers a traditional tariff system at a fixed electricity price. It may also include different daily and nightly tariffs, for example, KODU1, KODU2, etc., packages that were offered by Eesti Energia AS in closed electricity market. The agreed rates apply for an agreed period – a year or longer.	Consumers who are accustomed to conventional tariff systems. They are not interested in controlling/planning consumption, or this is not possible. Also consumers who want to plan expenses.
Power exchange price dependent	The seller offers consumers an electricity price that depends on the average power exchange price for the previous day, week or month. It may also include daily and nightly tariffs. Electricity price applies for a calculated period.	Customers who are accustomed to traditional tariff systems. They are not interested in controlling/planning consumption, or this is not possible. At the same time, they are willing to sense the exchange price volatility. It is expected that the price is the lowest in summer and the highest in winter.
Real-time variable electricity price	The seller offers consumers electricity prices according to the power exchange prices and the trading period. Fees are added to the exchange prices.	Customers who are able and who want to regulate consumption. The main target group could be smart-home owners.

The yearly sales-based income of an electricity retailer is calculated by the formula:

$$S_{\Sigma}=\sum_{k=1}^{n} S_{kj}(T), \qquad (1)$$

where S_{Σ} is the retailer income;
S_{kj} is the income from one consumer;
T is the time period;
n is the number of consumers;
j is the number of tariffs.

Renewable energy charge is calculated by Elering AS in accordance with the Electricity Market Act [1] and approved methodology. Elering AS is the Estonian transmission system operator (TSO) and publishes next calendar year's renewable charge every 1st of December. The charge is calculated on the basis of evaluations of the next year's subsidiaries for renewable energy, and consumed network service. Renewable energy charge is meant to support those who generate electricity from renewable energy sources or use efficient cogeneration regime [1].

Electricity excise duty and value added tax (VAT) are decided by the parliament in accordance with the Alcohol, Tobacco and Fuel Excise Act [10].

Electricity bill may be calculated differently according to Table 1:

1. Fixed basic tariff:

$$S_{k1} = S_{E_1} \cdot W, \tag{2}$$

where S_{E_1} is the electricity tariff, €/kWh;
W is the electricity consumption, kWh.

2. Two fixed tariffs (daily and nightly):

$$S_{k_2} = S_{E_{21}} \cdot W_1 + S_{E_{22}} \cdot W_2, \tag{3}$$

where $S_{E_{21}}$ and $S_{E_{22}}$ are electricity tariffs, €/kWh;
W_1 and W_2 are amounts of electricity consumed, kWh.

3. Tariff based on the average power exchange price for the previous period:

$$S_{k3} = S_{E_{t-1}} \cdot W_t, \tag{4}$$

where $S_{E_{t-1}}$ is the average exchange price for the previous period (day, week, month, year, etc.), €/kWh;
W_t is the electricity consumption during the period, kWh.

4. Real-time pricing system:

$$S_{k4} = S_{E_{t+1}} \cdot W_t, \tag{5}$$

where $S_{consumer,t+1}$ is the price for the next period (15, 30, 60 minutes), notified at the beginning of the next period and which applies during the next period, €/kWh;
W_t is the electricity consumption during the period, kWh.

3. Real-time pricing system

The proposed real-time pricing system is a system that calculates the electricity price to consumer and sends him the respective information at the beginning of each time period. The interval may be 15 minutes, one hour or any of the currently suitable electricity market trading periods. The consumer price changes in real time and applies during the agreed interval. The price of electricity should reflect the network situation, i.e. availability of wind power, system load, generating capacity, temperature, etc.

For end-user the volatility of electricity price will remain a concern. Most consumers are accustomed to fixed prices and know how to plan expenditures. But when electricity price fluctuates within a large range a day, expenditure planning will be much more complicated. The real-time tariff system could effectively help achieve objectives considered in the chapter Description and objectives of the retail electricity market.

According to the current order in the energy market the seller has to make the most accurate prognosis of consumption one day ahead and purchase the desired amount of electric power from the day-ahead market (Elspot). Then, during the day the seller has to make consumption prognosis one hour ahead and buy the necessary amount of electric power on the intraday market (Elbas) if needed. This means that one hour before delivery (real-time), the seller has to perform the last transaction.

Elspot is a day-ahead market. 12:00 central European time (CET) is the time of market closure for bids with the delivery for the next day. Simply put, the price is set at the point on the consumption curve at which the selling and buying price curves intersect. The price is typically announced to the market between 12:30 and 12:45 CET with a 3-minute warning, after that trades are settled. From 00:00 CET the next day, contracts are physically delivered hour by hour according to the contracts entered into. Elbas is a continuous intraday market and trading takes place every day around the clock until one hour before delivery [11].

At the moment in Estonia, the balancing energy prices and amounts are calculated on the second business day by Elering. Elering provides transmission services for producers, distribution networks and corporate consumers in Estonia. In addition, Elering provides the balancing service for balance responsible parties. Therefore the seller who wants to offer consumers the tariff system whose electricity price changes in real time has to predict balancing energy prices to calculate the price to households. The prediction of balancing energy prices clearly bears a risk for the seller and is therefore included in the seller fee.

Thus, the energy price calculated by the retailer consists of three components:

$$S_{E_{t+1}} = S_{t,elspot} + S_{t,elbas} + S_{comission}, \tag{6}$$

where $S_{t,elspot}$ is Elspot's electricity price;
$S_{t,elbas}$ is Elbas' electricity price;
$S_{comission}$ is the seller fee, which includes the seller's expenses, profits and risk of balancing energy.

So, theoretically, the retailer needs 25 different models for load forecasting, considering the present organization of the electricity market. Therefore, if the trading period is one hour, then one day needs 24 models. If the trading period is shorter than one hour, even more models would be needed.

A seller for Elspot prognosticates consumer consumption in his portfolio by Formula 7 and, based on these predictions, makes necessary transactions in Elspot:

$$P_{t,cons,elspot} = f(x_1;x_2...x_n), \tag{7}$$

where $P_{t,cons,elspot}$ is the predicted consumer consumption for each next day trading period;
t is the trading period (24 periods in Elspot);
$x_1;x_2...x_n$ are factors that influence consumption (time, temperature, electricity price, etc.).

Thus, the price based on Elspot will be calculated by the formula:

$$S_{t,elspot} = f(P_{dem};P_{sup}), \tag{8}$$

where P_{dem} is the power demand;
P_{sup} is the power supply.

In addition, there is another model to predict the intraday load to be employed for trading in Elbas:

$$P_{t,cons,elbas} = f(x_1;x_2...x_n) - P_{t,cons,elspot}, \tag{9}$$

where $P_{t,cons,elbas}$ is the required power from Elbas;
$x_1;x_2...x_n$ are factors that influence consumption (time, temperature, electricity price, etc.); here the factors are adjusted during the forecast;
$f(x_1;x_2...x_n)$ is the predicted load for the next hour.

When $f(x_1;x_2...x_n) = P_{t,cons,elspot}$, the prognosis is the same as the predicted load for the next hour. Therefore, an additional transaction will not be necessary.

The price based on Elbas will be calculated by the formula:

$$S_{t,elbas} = f(P_{dem};P_{sup}). \tag{10}$$

Electricity price calculation and consumer notification should therefore be in accordance with the algorithm shown in Figure 2. The algorithm starts with checking the time, i.e checking the next trading period. On the previous day, the seller has carried out deals in the Elspot market. So, the seller knows how much power he has bought from Elspot for the next trading period and at which price. Then the seller determines the current consumption and forecasts consumer consumption in his portfolio for the next trading period. Next, the seller examines whether the amount of power purchased from Elspot is sufficient. If there is enough power, then time is checked and if needed, the seller re-forecasts and performs an additional control. If the amount of power is not sufficient, the seller will make an additional transaction in the Elbas market, check the time again and if needed, re-forecast and perform an additional control. If t = i–1, Elbas is closed for the next hour trading period. The seller checks consumption until t = i. If t = i, the next trading period has begun and the seller must notify consumers of the ongoing period`s electricity price. After the consumers have been notified, the seller can start calculating the price for the next period.

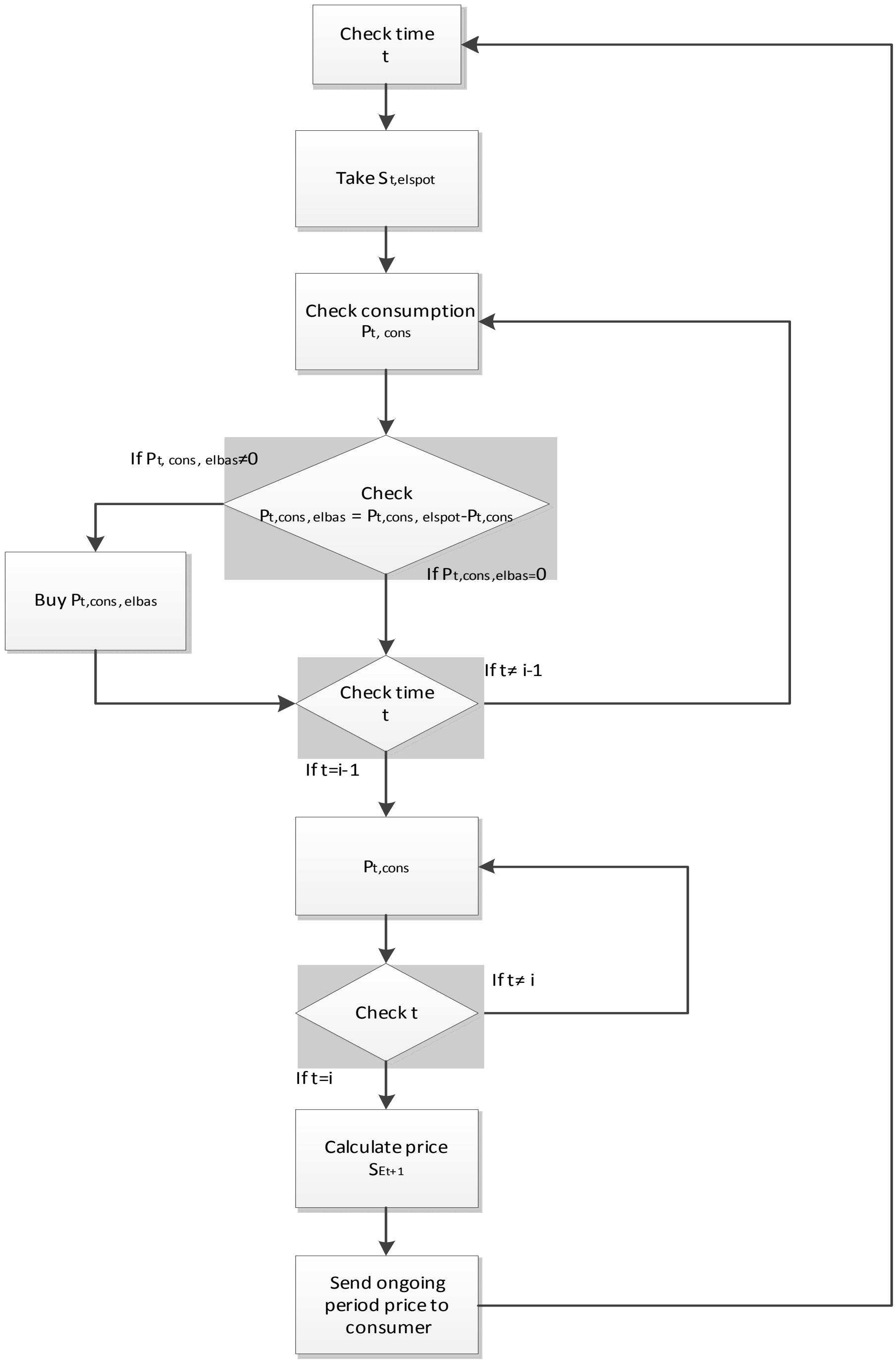

Fig. 2. Algorithm for calculating the electricity price and notifying the consumer.

With that kind of system, the price will depend on the seller`s skills, i.e. his ability to forecast consumer load and carry out transactions on the power exchange. The seller's goal is to provide as low-cost electricity to consumers as possible since concurrently consumers are interested in sellers who provide the cheapest electricity. If in a consumer's opinion the seller does not offer the lowest real-time electricity price, he can choose another seller on the retail market.

4. Apartment building consumption analysis

During the period December 13–19, 2011, electricity consumption by an apartment building with 15 apartments was measured (Fig. 3). The purpose was to compare tariffs valid for the analyzed period to the tariffs of the pricing system which change on the basis of the power exchange price. Readings were taken every hour, using remotely accessed single-phase electricity meters NP 515.23D – 1E1ALNI (ADD GRUP, Moldova). This particular apartment building was a stone house with central heating, the apartments also had a furnace or fireplace, and an oven. The main fuse of one apartment was 25 A.

The aim was to create consumer load curves and determine whether the tariff system based on the market price would be more consumer friendly than the KODU1 and KODU2 tariff systems that were offered, and the price packages KINDEL and MUUTUV currently offered by Eesti Energia AS.

As expected, apartment consumption varied and was quite random. Therefore, exact load curve schedules for workdays or weekends could not be generalized. However, it may be pointed out that on workdays, consumption rose from 1 pm to 3 pm, reaching maximum, and fell from 7 pm to 9 pm. On weekends, consumption increased between 7 am and 9 am and dropped between 6 pm and 7 pm. Since the period of measurements was relatively short, it would be necessary to monitor consumers during a longer period of time to determine their consumption habits and obtain a more detailed load curve. Figure 3 gives a good overview of how random household consumption was during the day. Figure 4 shows power consumption and power exchange prices during the period December 13–19, 2011.

The load curve for the apartment building monitored was quite similar to the Estonian load curve, consumption peaks fell on higher price rate periods. Also, it became obvious that due to the timing of the main electricity consumption, the electricity bills of individual consumers tend not to decrease if the electricity price is based on the market price.

For all apartments, the KODU1 tariff system proved to be the cheapest. It was on average 3.5% cheaper than Elspot's Estonian area price based real-time pricing system and 4.4% cheaper than the Finnish area price based real-time pricing system. The KODU2 tariff system was more expensive than KODU1 for all apartments. However, prices of the Estonian and Finnish area price-based real-time systems were lower than the KODU2 tariff system

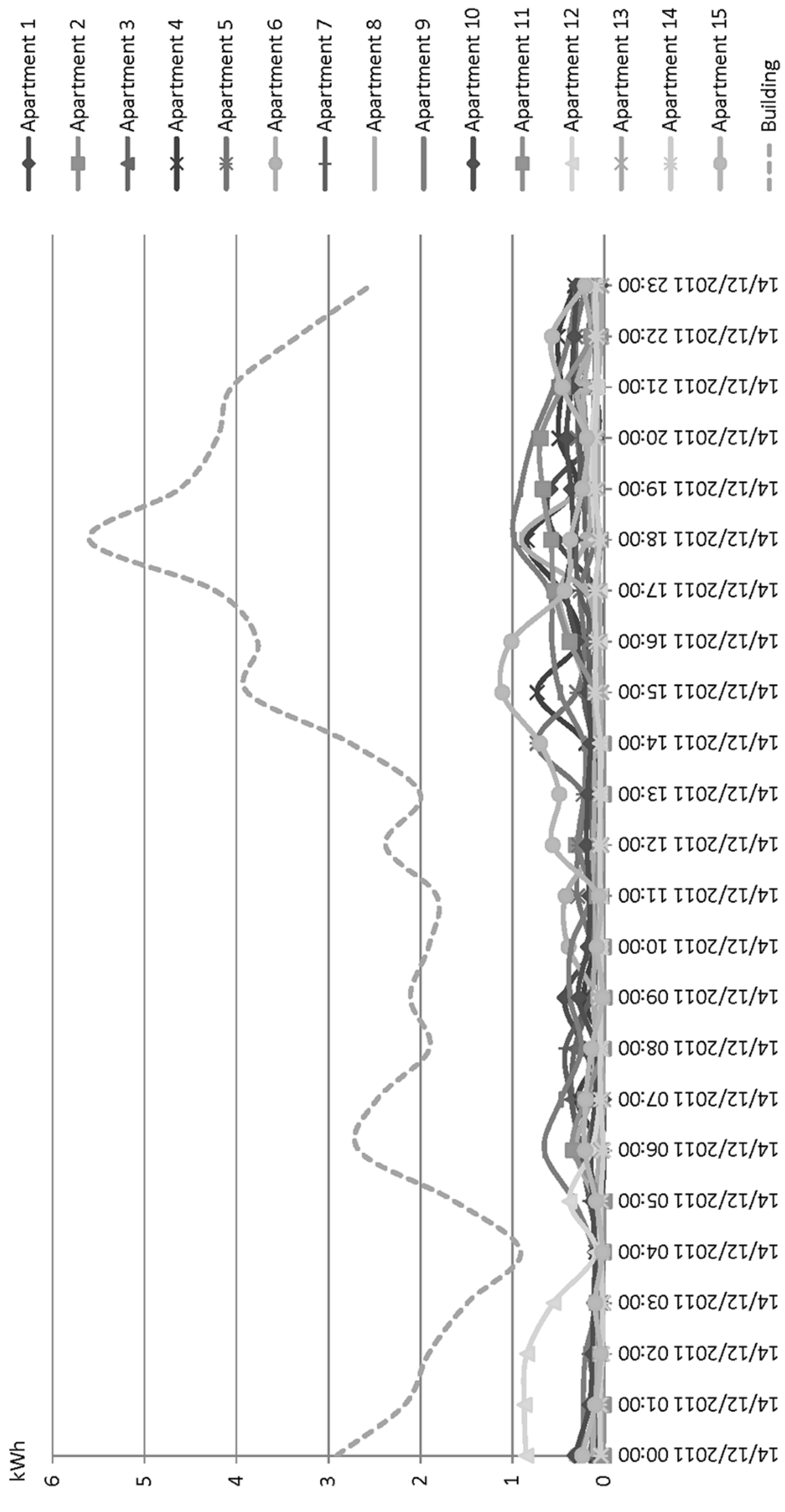

Fig. 3. Consumption by apartment building and individual apartments during one day.

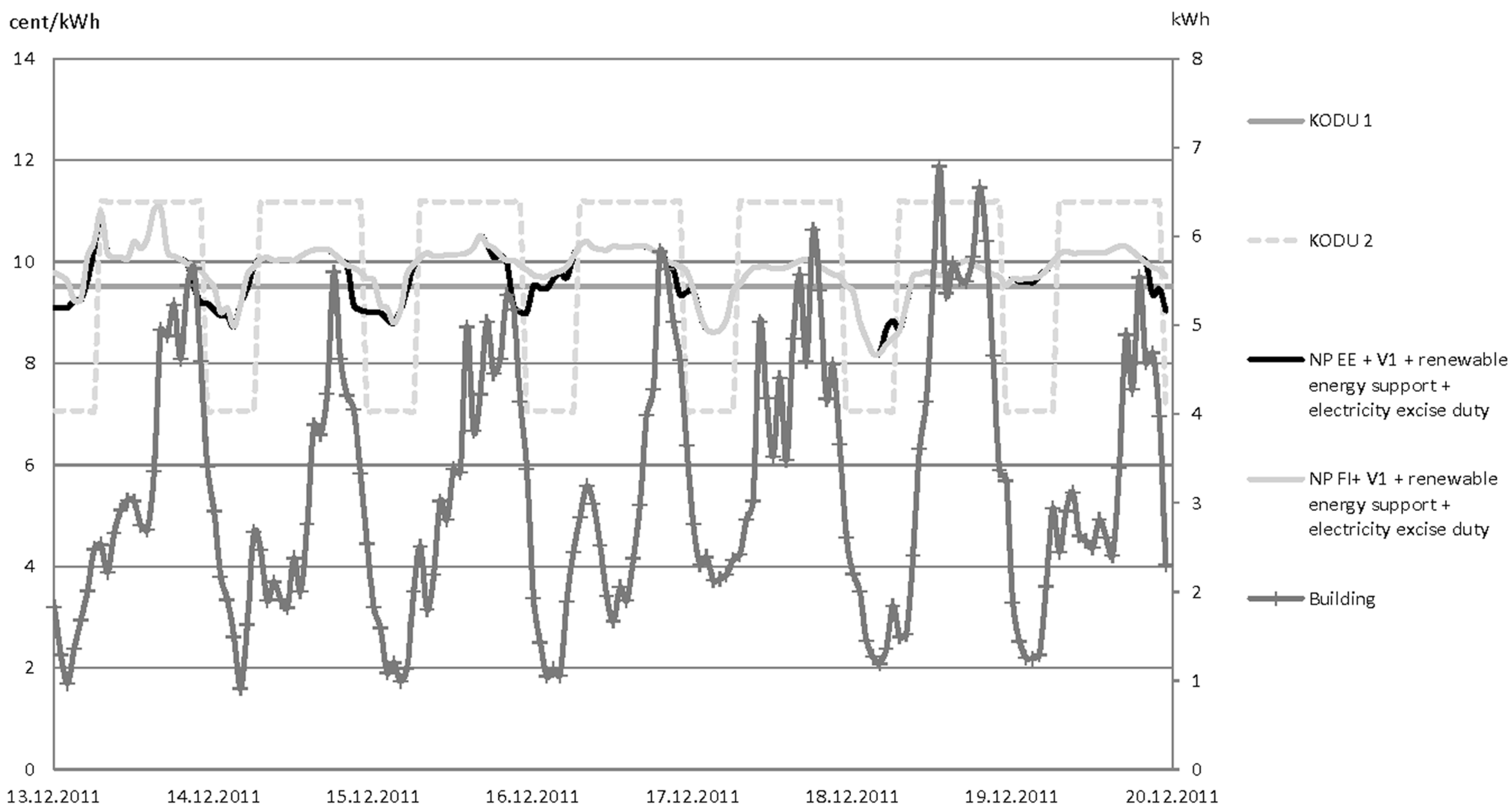

Fig. 4. Apartment consumption and electricity price, December 13–19, 2011.

price, by 4.7 and 3.9%, respectively. It should be noted that the analysis of the electricity market based tariff system did not include vendor's commission. Considering the vendor's commission, the market based pricing system would be even more expensive than KODU1 and may even surpass KODU2. It also turned out that during the observed period of time Nord Pool's Estonian area price was 21.6% and Finnish area price 29.4% lower than their average prices in 2011.

Comparison of the price packages KINDEL and MUUTUV offered by Eesti Energia in 2013 to regulated market tariff systems KODU1 and KODU2 shows that KINDEL is 28% more expensive than KODU1 and 18% more expensive than KODU2. When comparing MUUTUV to regulated tariff systems, then MUUTUV is 13.6% more expensive than KODU1 and only 4.6% more expensive than KODU2. The comparison for the MUUTUV package was made on the basis of NordPool`s Estonian area prices during the period December 13–19, 2011.

When moving the measured load curves to March 1–7, 2011 (during this period Nord Pool's Estonian and Finnish area prices were higher than the average electricity price in these regions, by 22.4 and 25.9%, respectively), KODU1 expectedly turns out to be the cheapest; Nord Pool's Estonian area price-based real-time pricing system is 24.2% and Finnish area price based real-time pricing system 32.5% more expensive. Also, compared to the KODU2 package the Nord Pool Estonian area price based real-time pricing system is 14.3% and the Finnish area price-based real-time pricing system 22.1% more expensive. However, once again it should be noted that the price based on the power exchange price does not take into account the seller's fees.

5. Conclusions

1. Currently the price packages offered to consumers do not reflect actual electricity production costs. It is important to offer price packages which take into account the network situation and make consumer move consumption away from peak load and fulfill minimum load. Therefore, to achieve a better demand response it is important to offer more daily rate price packages, or a real-time pricing package. The opening of the electricity market and application of remotely readable meters allow sellers to offer tariff systems whose electricity price will change hourly according to the power exchange price.
2. The apartment building consumption analysis showed that the electricity price based on the power exchange's hourly changing price may at times be lower than the price of regulated market's electricity price packages. For example, during the period December 13–19, 2011 NordPool's Estonian area price was 21.6% and Finnish area price 29.4% cheaper than their average prices in 2011. During the period in question, for all

apartments the KODU1 tariff system proved to be the cheapest, and the KODU2 tariff system was more expensive than KODU1 for all of them. However, the prices of Estonian and Finnish area price-based real-time systems were lower than that of the KODU2 tariff system. It should be noted that by analyzing the electricity market based tariff system vendor's commission was not included. However, considering vendor's commission, the market based pricing system would be even more expensive than KODU1 and may even surpass KODU2. It should be taken into account that KODU1 and KODU2 packages were based on the regulated electricity price. However, when comparing the currently offered price packages KINDEL and MUUTUV to the previous tariff systems of Eesti Energia AS, it appears that current price packages are up to 28% more expensive than price packages based on the regulated electricity price. Considering the appreciation of electricity in the open market, the energy price based on the hourly changing power exchange price will at times be lower than the price of fixed-price packages in the open retail market.

3. The electricity price on the power exchange is volatile and it is impossible to forecast the next year`s electricity price since it depends on many different factors. It is clear that the intraday exchange market price fluctuates and during some periods of time the prices may be lower than regulated market tariffs and in other periods, higher. This means that the real-time tariff system will enable customers to regulate consumption in order to keep their electricity costs as low as possible.

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