Methods for the electricity supplier selection – case study of the Czech Republic

Martina Kuncova

***Abstract*—**Electricity belongs to the commodities that are more and more important for our lives. The industrialized countries are characterized among other things by the developed technological infrastructure and energetic system. In such a country people do not care much about the electricity distribution system but they think about the costs connected with the electricity consumption. This article describes the situation in the Czech Republic which is divided into three distribution regions and households can choose among many electricity suppliers. The main aim of this contribution is to show the mathematical tools to find the cheapest supplier. As a lot of different tariffs are given according to the electricity consumption and circuit breakers the tariff D25d for the households was chosen for the case study.

***Keywords*—**electricity consumption costs, Monte Carlo simulation, optimization model, tariff rates

I. Introduction

Electricity belongs to the commodities that are essential for our lives and also for the economic development. The expansion of modern technologies and the increase of the electronic equipment usage to ease the work, to relax, to study, etc. causes the higher demand for the sources of energy including electric power consumption. This consumption is higher in the industrialized countries (Fig. 1) but it is also influenced by the natural environment [11].

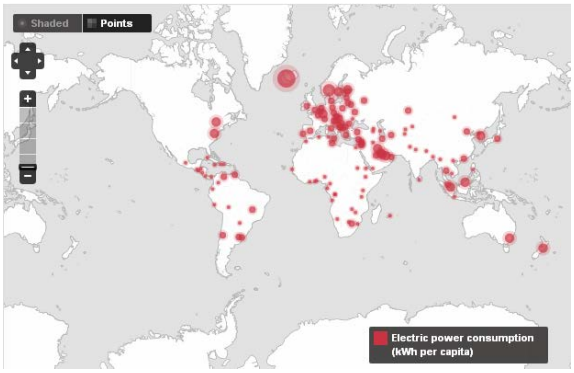

Fig. 1 Electric power consumption (kWh per capita) in all countries

The natural conditions and new electrical equipment projects in the higher energy power consumption per capita in the countries laying farther from the equator (Iceland, Norway) or in the countries with the developed industry, especially oil industry (Bahrain). The situation in the Czech Republic is similar to the neighboring European countries (Fig. 2) [11].

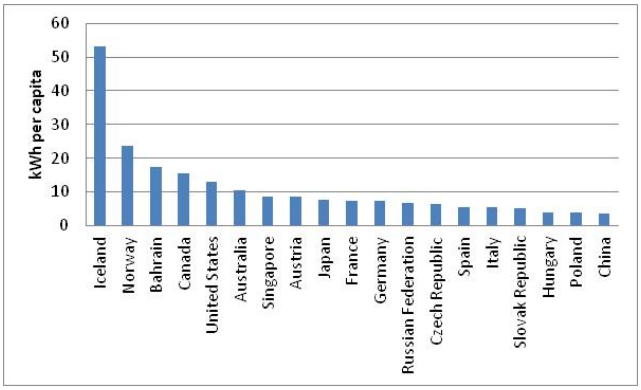

Fig. 2 Electric power consumption (kWh per capita) in selected countries

II. Czech Electricity Market

The electricity market in the Czech Republic is influenced by various subjects. These are not only the consumers and producers but also distributors, suppliers and except of them the Energy Regulatory Office (ERU) and the Operator of the market (OTE) [6]. The transformation of the electricity market in the Czech Republic started in 2002 when the companies could choose its electricity supplier. For the households it started to be possible since 2006. After this process each household and company can choose the supplier of the electricity. This liberalization has led to the increasing number of suppliers entering the electricity market [2].

The Czech Republic is divided into three regions operated by three distributors (PRE, CEZ, E.ON. – Fig. 3) and in each distributor's area a lot of suppliers is working [2]. Each household has its tariff rate according to the supplier's conditions. The complete list of suppliers and their tariffs and prices is changing every year. The selection of the suppliers depends on the contract conditions but mainly on the prices. With respect to all these it is a hard task to find the best supplier. It is influenced by the region where we choose the suppliers and also by the electricity take-off amount.

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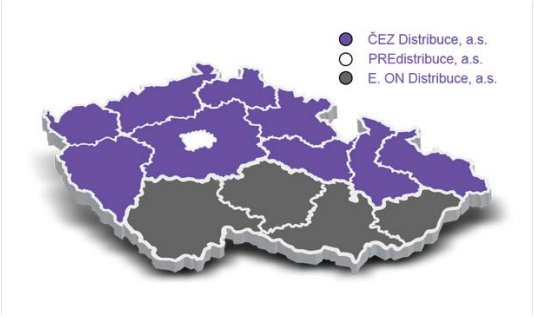

Fig. 3 Distribution regions of the Czech Republic

The formula for the final annual electricity cost calculation is not easy as it includes more factors such as consumption, fixed fees or taxes. The prices also differ for the tariff rates given by the distributor according to the consumption type (if the electricity is used for general purposes or also for heating, accumulation etc.). Generally the price for the electricity consumption (for all tariff rates) can be divided into two components. The first one is the controlled charge for services related to electricity transport from the generator to the final customer. This charge is annually given by Energy Regulatory Office (ERU) [5]. It covers:

- monthly lease for the circuit breaker,
- price per megawatt hour (MWh) in high tariff (HT),
- price per megawatt hour in low tariff (LT),
- price per system services,
- price for the support of the renewable energy purchase,
- charges for the electricity market operator,
- electricity ecological tax (28.30 CZK per 1 MWh).

The second part of the total price is given by the electricity supplier. It covers:

- fixed monthly fee for the selected product,
- price per megawatt hour (MWh) in high tariff (HT),
- price per megawatt hour in low tariff (LT),

The final price is increased by VAT that was 20% till 2012 and 21% since 2013.

III. METHODS FOR THE SUPPLIER SELECTION

Various techniques and methods can be used to model the situation on the market and the problem can be solved by several different approaches [11]. The first one is the mono-criteria model minimizing the total costs when we suppose the electricity consumption is non-stochastic and its amount is known and so we can calculate the total costs. The results can be found via various web calculators (for example [5]). However electricity consumption is not given in real practice. We know average consumption and maybe standard deviation or some minimal and maximal limits and so the better approach is the usage of the stochastic models, such as Monte Carlo simulation model. The third possibility is the usage of the optimization model with unknown consumption when the aim is to look for the consumption ranges for each suppliers' product to minimize the annual costs. The last approach is the application of multi-criteria (non-stochastic) model and comparing of alternatives with respect to several prices (criteria).

A. Mono-criteria model with cost minimization

The formula for the annual cost calculation for each supplier's product is following:

$$COST_{ij} = (1+VAT)\begin{bmatrix} 12\left(mf_{ij} + mf_j\right)+ \\ + p_{HT}c\left(ph_{ij} + ph_j\right)+ \\ + p_{LT}c\left(pl_{ij} + pl_j\right)+ \\ + c\left(os + t\right) \end{bmatrix} \quad (1)$$

where

i … product, i =1, …, m,
j … distributor, j = 1, …, 3,
VAT … value added tax (VAT = 0.21 in 2015),
mf … fix monthly fee,
c … annual consumption in MWh,
p_h … price in high tariff per 1 MWh,
p_l … price in low tariff per 1 MWh,
p_{HT} … percentage of the consumption in high tariff
p_{LT} … percentage of the consumption in low tariff
o_s … price for other services per 1 MWh,
t … electricity tax per 1 MWh (t = 28.3 CZK).

According to the prices valid for the given year and according to the set consumption and percentages of the consumption in high/low tariff it is possible to calculate the annual cost a select the minimum that indicates the best product.

B. Monte Carlo simulation

Simulation is a technique for the real world situations imitation usually via a computer model [3]. The model can be used to study the system and see how it works, to find where the problems come from, to compare more model variants and select the most suitable one, to show the eventual real effects of alternative conditions and courses of action, etc. As simulation models use principles taken from mathematics and statistics, they are sometimes added to the problematic of the operational research or management science [10] where different models are constructed to find the optimal solution or the optimal choice. Simulation itself usually has not the main aim to find the best alternative but it might help in this process.

Monte Carlo simulation is associated with the systems affected by randomness when several different scenarios are randomly generated to obtain the probability description of the selected results [4]. It can be applied in any situation where some uncertainty appears. This is typical situation for various decision-making processes in economics as in finance [4] or banking [7], [11]. Monte Carlo simulation in connection with the electricity market is usually applied for the random generation of the whole demand for the distributed units [6] but it is possible to use it to find out the cheapest supplier according to the tariffs rates and random annual electricity consumption c in (1) generated from the normal distribution [7] or other suitable distributions. Also the percentage of the

consumption in high and low tariff can be taken as a random variable generated from the uniform distribution with ranges 0 and 1.

C. Optimization model

The situation when the aim is the cost minimization evokes usual optimization model or linear programming problem. In each optimization model it is necessary to define the decision variables, the objective function and the constraints. In contrast with the previous situation the annual consumption c is not random or stochastic but it forms the only decision variable and also the objective function. The aim is to find the ranges (minimal and maximal) for the annual consumption for each product (if possible) that guarantee the cost lower than for other products. First it is necessary to compare all the products pairwise to find the dominated ones. For non-dominated product we are able (based on (1)) to calculate the values of energy consumption c that ensure winning of the given supplier/product. The mathematical model of this problem for each product $i,k = 1, \ldots, m$ and distributor $j = 1, 2, 3$ can be written as following [8]:

$$\min(\max)\ z = c$$

subject to:

$$COST_{ij} \leq COST_{kj} \qquad (2)$$

When there exists no optimal solution for the product i then choosing this product the minimal annual costs can never be achieved for any consumption level.

D. Multi-criteria decision-making model

Multi-criteria evaluation of alternatives belongs to the category of discrete multi-criteria decision making models where all the alternatives ($a_1, a_2, \ldots, a_p$) and criteria ($f_1, f_2, \ldots, f_n$) are known. To solve this kind of model it is necessary to know the preferences of the decision maker. These preferences can be described by aspiration levels (or requirements), criteria order or by the weights of the criteria. We may find a lot of different methods [6], [8], [15] depending on the type of information about the criteria and alternatives we have and also depending on the aim of the decision-making process. The main aims are: to find the best (compromise) alternative, to order the alternatives from the best to the worst or to separate the alternatives into good and bad ones. As in the situation of the product selection we have quantitative data and we need to obtain the order of the alternatives, the suitable methods that use different computational principles are WSA and TOPSIS.

WSA (Weighted Sum Approach or WSM-Weighted Sum Model) sorts the alternatives based on the values of their utility functions which in this case are assumed to be linear. It requires the information about the weights of the criteria. Higher value of utility means better alternative [15].

The basic concept of the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is that the best alternative should have the shortest distance from the ideal alternative and the farthest from the basal alternative [12]. The method is also able to rank the alternatives using the relative index of distance of the alternatives from the basal alternative. Higher relative index of distance means better alternative. The user must add only the information about the weights of criteria.

One possibility is to compare all products (alternatives) according to the prices (9 criteria) regardless of the distribution area or we can analyse the distribution regions separately. In that case we suppose three decision criteria for each product j (ph, pl, mf as in (1)) for each distributor with the weight vector $\boldsymbol{v} = (v_1, v_2, v_3)$ and m products as alternatives.

IV. Case Study for the Tariff Rate D25d

According to the previous analysis [10] the case study is aimed at the products offered in the Czech Republic by different suppliers for the year 2015 for the tariff rate D25d. This tariff rate is given to household when the electricity is used also for the accumulative heating and hot water heating for lower and middle yearly offtake with operative management of the validity period of the low tariff for 8 hours. It is so-called dual tariff rate as it covers 2 periods (high tariff, low tariff) during the day. The ranges for the electricity consumption were taken from the real data with the electricity consumption about 10 MWh annually with the circuit breaker from 3x20A to 3x25A, if necessary the percentages of consumption in high/low tariff are 45% and 55%. According to the ERU calculator [5] the 60 products (offered by 32 suppliers – Tab.2) in each distribution area are compared.

When we compare the average prices (taken from all 60 products in 2015 and from 57 products in 2014) in 3 distribution areas (Tab. 1) we see that the highest avg. monthly fee is in PRE region, the fixed fee for the circuit breaker is highest in the CEZ region and nearly all ph_i and pl_i prices are lower in 2015 than in 2014 (except pl_i for CEZ).

Tab. 1 Average prices in CZK for all 3 distribution areas for 2014 and 2015

year	distr. region	*mf* avg.	ph_i avg.	pl_i avg.	cb_i	ph_i	pl_i	*os*
2014	**E.ON**	43.6	1508.3	893.2	90	1592.0	30.6	621.8
	PRE	50.5	1462.3	896.6	98	1563.7	24.5	
	CEZ	44.7	1484.3	886.7	105	1731.9	36.4	
2015	**E.ON**	43.1	1396.7	862.5	95	1518.4	30.0	607.2
	PRE	46.7	1376.0	859.1	102	1508.5	24.4	
	CEZ	43.9	1382.6	856.5	110	1727.6	36.9	

mf avg. … average monthly fee for the given distributor *i*,

p_{hj} avg. … average prices for all *j* products in high tariff per 1 MWh,

pj_l avg. … average prices for all *j* products in low tariff per 1 MWh,

ph_i … prices of the distributor *i* in hight tariff per 1 MWh

pl_i … prices of the distributor *i* in low tariff per 1 MWh

o_s … price for other services per 1 MWh

Tab. 2 List of the products for the tariff D25d [5]

No. of the product	Company and name of the product
1	E.ON elektřina aku
2	E.ON elektřina trendAku duben
3	E.ON Jistota
4	RIGHT POWER ENERGY s.r.o.-eDomov
5	PRE komfort aku 8
6	ČEZ D-aku basic
7	ČEZ D-aku comfort
8	ČEZ D-aku garant
9	ČEZ D-aku Fix
10	ČEZ D-aku etarif
11	ČEZ D-akumulace etarif fix
12	Erste Energy Services - Standard
13	Erste Energy Services - AKLIENT
14	Stabil Energy E Tarif
15	Stabil Energy VIP
16	Corasta comfort Aku 8
17	Corasta Taurus Aku
18	Optimum Energy Standard
19	Centropol Energy Premium 2016 aku
20	Centropol Energy eOptimum aku 8
21	Centropol Energy aktiv
22	Bohemia Energy Home Aku Garance 2015
23	EP Energy Trading Klasik Jistota 2014
24	Nano Energies Trade
25	Nano Green s.r.o.
26	VEMEX Energie Standard
27	VEMEX Energie FIX 2015
28	ELIMON svěží domácnost
29	ELIMON svěží energie 12
30	ELIMON svěží energie 24
31	ELIMON svěží energie 36
32	ELIMON eProdukt
33	Global Energy G aku
34	Global Energy fix 2015 G aku
35	Global Energy fix24
36	Europe Easy Energy Easy aku
37	Europe Easy Energy Company aku
38	Europe Easy Energy junior/seniorúZTP
39	Europe Easy Energy duo
40	ST Energy standard
41	X Energie
42	Amper Market
43	Fosfa
44	ARMEX Energy Akumuluace
45	ARMEX Energy Elektřina Fix
46	Comfort Energy prim plus domácnost
47	Fonergy Standard
48	Fonergy Premium
49	Energie2
50	eYELLOW single
51	eYELLOW Double
52	LAMA energy Standard
53	LAMA energy Premium
54	Eneka Standard
55	Eneka Jednička
56	Central Energy
57	Pražská plynárenská Aku D
58	Pražská plynárenská Aku D Flexi
59	AKCENTA ENERGIE
60	CARBOUNION KOMODITY

A. Results of mono-criteria model

For the model (1) it is necessary to know all prices and to suppose that the annual consumption is fixed. When the consumption is 10 MWh per year with the division of 45% and 55% for hight/low tariff is set the best product is influenced by the distribution region. While in PRE and CEZ the winner is ST Energy Standard, for the E.ON it is the product of the company CARBOUNION COMMODITY. The final annual cost are minimal in PRE region and we can see (Tab. 3) that the best product in CEZ region has higher value than the 5th product in PRE region. The difference between lowest and highest annual cost is about 20 %.

Tab. 3 Best and worse products and the annual cost in CZK

order / distr.	E.ON Prod.	E.ON cost	PRE Prod.	PRE cost	CEZ Prod.	CEZ cost
1	60	29685.5	40	29608.2	40	31000.9
2	40	29791.4	60	29695.9	60	31124.9
3	24	29816.2	24	29826.8	24	31219.3
4	37	30146.5	48	29955.4	48	31348.1
5	48	30235.5	37	29999.6	37	31392.3
…	…	…	…	…	…	…
58	1	33772.3	1	33782.7	1	35175.4
59	34	34100.2	34	33942.4	34	35344.8
60	33	35459.6	33	35240.1	33	36514.9

B. Results of Monte-Carlo simulation

Monte Carlo simulation model must contain at least one random variable. In the case of the supplier selection there are two possibilities for the simulation. The first one is to take the annual consumption in (1) as the random variable, the second one is to extend the model by adding also the percentage of the consumption in high and low tariff as a random number.

For the first case the ranges for the electricity consumption in each month were set at about 900 kWh per month on average (Tab.4), the high tariff is used in 45% from the whole consumption. The simulated consumption was generated for each month from the normal distribution with 20% of the average taken as the standard deviation. In all Monte Carlo simulations 1000 experiments have been tried to randomly select consumption for each month and afterwards the annual costs are calculated. For the simulation, the MS Excel and its add-in application Crystal Ball were used.

As the consumption is taken from the symmetrical probability distribution the order of the products is similar to the results from the previous model (Tab. 3). The order of the suppliers and their products in 2015 according to the average annual prices is nearly the same in all regions. On the first place there are 2 suppliers (that offer only one product each): CARBOUNION KOMODITY or ST Energy Standard. The advantage of the simulation is the possibility to compare not only the average annual cost but also the histograms and probabilities. The differences of the annual costs of the supplier CARBOUNION KOMODITY in all regions can be seen in Fig. 4. It is clear we cannot say that the CEZ region is

always the most expensive but the probability is higher as the average annual cost are higher than in other regions. On the other hand we can say that some of the products are always worse – see Fig. 5.

Tab. 4 Data for electricity consumption generation

month	average consumption (kWh)
January	933
February	973
March	900
April	819
May	771
June	730
July	689
August	665
September	730
October	795
November	835
December	892
Total	9732

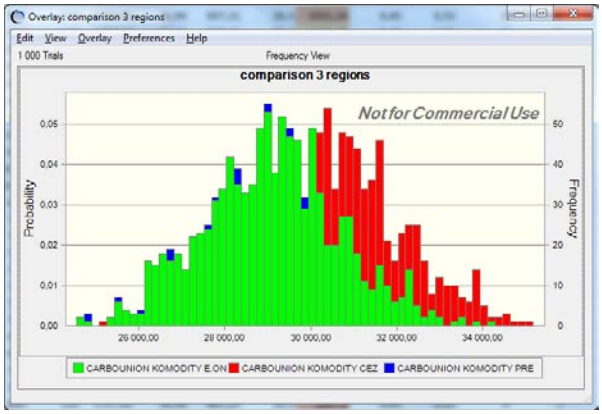

Fig. 4 Histograms for the annual costs for the supplier CARBOUNION KOMODITY

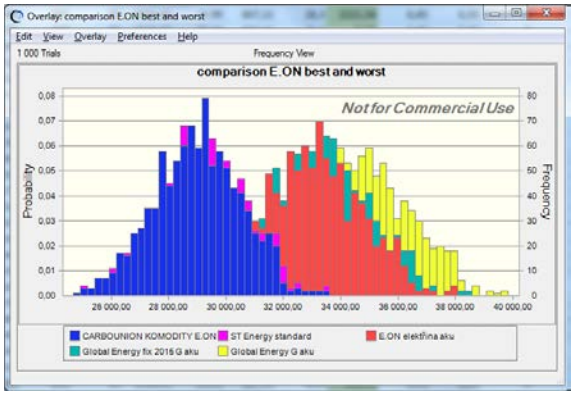

Fig. 5 Comparison of the best and worst products – region E.ON

For the best products the probability that the annual costs are lower than 30000 CZK is around 74-76% for the best products (region PRE, ST Energy; region E.ON CARBOUNION KOMODITY), but only around 44% in CEZ region. The worst products have this probability close to zero so there is very small chance to have the household annual electricity consumption costs lower than 30000 CZK.

In the second model the percentage of the consumption in high tariff is not equal to 45% but it is generated from the uniform distribution with minimum 40% and maximum 100% as the high tariff is used more during the day (the low tariff can be used only for 8 hours daily). The results differ from the previous order especially in the cheapest product – now it is no.24-Nano Energies Trade but the annual costs are of about 4000 CZK higher, the probability of being under 30000 CZK is now only around 15 % for the best products. The products offered in the CEZ region are still the most expensive ones and the difference between the cheapest product in E.ON region and CEZ is more than 5%.

Tab. 5 Best and worst products in the second simul.model

order / distr.	E.ON Prod.	Avg. ann.cost	PRE Prod.	Avg. ann.cost	CEZ Prod.	Avg. ann.cost
1	24	33720	24	33721	24	35708
2	60	34312	60	34311	60	36325
3	40	34602	40	34413	40	36420
4	48	35050	48	34795	48	36862
5	47	35931	58	35420	14	37617
…	…	…	…	…	…	…
58	1	39175	34	38983	34	41089
59	34	39278	1	39174	1	41196
60	33	41123	33	40677	33	42503

C. *Results of Optimization model*

Using model (2) with the percentage of the consumption in high tariff set to 45% the 60 products for all three distributors were analysed. Only 4 products can be selected as the best ones (Tab. 6) but this is the mathematical result. In reality only 3 products are the cheapest as the product no. 43 (Fosfa) had the minimal annual cost only in case of zero consumption.

Tab. 6 Best products for all distributors and the consumption and price ranges

	product no.	consumption in MWh		costs in CZK	
		from	till	from	till
E.ON.	43	0.000	0.000	1379.40	1379.40
	48	0.000	4.397	1379.40	14067.3
	40	4.397	7.423	14067.3	22558.5
	60	7.423	*unbounded*	22558.5	*unbounded*
PRE	43	0.000	0.000	1481.04	1481.04
	48	0.000	5.009	1481.04	15743.0
	40	5.009	14.039	15743.0	40828.0
	60	14.039	*unbounded*	40828.0	*unbounded*
CEZ	43	0.000	0.000	1597.20	1597.20
	48	0.000	5.009	1597.20	16498.5
	40	5.009	16.856	16498.5	50921.7
	60	16.856	*unbounded*	50921.7	*unbounded*

The results confirm previous findings that for the consumption about 10 MWh per year the choice of the best

product is dependent on the distribution region. In E.ON region the best product is no. 60 (CARBOUNION KOMODITY) for the annual consumption higher than 7.423 MWh whereas in other regions this product starts to be the cheapest for nearly two times higher consumption and for the 10 MWh the winner is no. 40 (ST Energy Standard). For the household with energy consumption less than 4.4 MWh per year the product number 48 (Fonergy Premium) is the best tariff regardless of distributor.

D. Results of Multi-criteria Decision-making Model

As it was mentioned in chapter 2 there are 10 different prices that influence the final cost paid by consumer. However price per system services, price for the support of the renewable energy purchase, changes for the electricity market operator and electricity ecological tax are fixed for all tariffs, all suppliers and all distributor on condition that the total consumption is identical. Therefore it is possible to use only six variables (six criteria): monthly lease for the circuit breaker, 2 prices of distributor and suppliers per MWh in high tariff, 2 prices of distributor and suppliers per MWh in low tariff and fixed monthly fee for the selected product. To be able to compare the results with previous models each region was analysed separately and so only 3 criteria were necessary: fixed monthly fee, price of suppliers per MWh in high and in low tariff. As both selected methods need cardinal information for criteria the weight vector $\boldsymbol{v}$ = (0.5, 0.225, 0.275) for the three criteria (due to consistency with previous analyses where the percentage of the consumption in high tariff was a little bit lower than in low tariff).

It is obvious a tariff that is dominated cannot be chosen as a winner and so for selection of the best tariff it is sufficient to analyze only non-dominated products. As the second best alternative can be placed on the second rank in the case of final rank all alternatives have to be analyzed. Therefore the analyses were done for each region and for all 60 products to be able to obtain the order of the products. There are only 8 products that are non-dominated in each region – these are no. 13, 24, 37, 39, 40, 45, 48, 60. The order of the products is nearly the same for all regions (with slightly different utilities in WSA and scores in TOPSIS), so only E.ON is described in Tab.7. The order is nearly the same with the 6 criteria. The best product corresponds with the situation of small consumption in optimization model but the rest is different.

Tab. 7 – Results of the WSA and TOPSIS methods for the E.ON region

product no.	WSA		TOPSIS	
	order	utility	order	score
48	1	0.872	1	0.886
39	2	0.829	2	0.823
43	3	0.784	3	0.815
40	5	0.772	7	0.725
24	10	0.718	12	0.706
60	14	0.646	15	0.525

V. CONCLUSION

The situation on the electricity retail market in the Czech Republic is not clear because of the number of suppliers and its products. The formula of the annual cost calculation of the electricity consumption contains a lot of factors and so it is hard for the household to compare the cost and to choose the cheapest product. In this article four mathematical principles how to cope with this problem were presented on the case study of the tariff D25d where 60 products are offered in 3 distribution regions. Each method needs different information but the results are not so different. For all products the cheapest distributor is PRE in 2015, the most expensive is CEZ distributor. That is why the selection of the cheapest supplier for the selected household is influenced by the distribution area. Regardless this fact the lowest costs of the electricity consumption for the year 2015 can the household achieve using the product offered by the CARBOUNION COMMODITY company, the ST Energy company or by the Fonergy company. The selection of the cheapest product can save about 20% of the annual electricity consumption costs on average. As for the methods the best and complete results gave the optimization model but when we consider that the randomness of the consumption should be included then the Monte Carlo simulation is a good tool. The multi-criteria evaluation of alternatives in this situation does not offer the same results as other models (regardless the change of the criteria weights) so it should be used in situations when other criteria than prices are important.

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