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Choosing the Optimal Approach to Define the Methodology of a Tariff System for Thermal Energy Activities

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Research of elements important for defining the methodology of a Tariff system for thermal energy activities is outlined in this paper. The transparent matrix of tariff models is defined. Original equations for regulating the annual revenue and calculating the monthly account for delivered heat by using tariff elements such as provided power, delivered heat energy and monthly fee, are shown in the paper. Special attention is paid to the choice of methods for approving consumption of fuels that are used in heat generation and the criterion for technical losses, i.e. for referential degrees in heat distribution and heat generation where technical losses depend on used fuel type.

Keywords
Methodology
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Tariff system
Thermal energy
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Odabir optimalnog pristupa određivanju metodologije Tarifnog sustava za toplinarske djelatnosti

Izvornoznanstveni članak

U radu je istražen značaj određivanja metodologije Tarifnog sustava za toplinarske djelatnosti. Određena je razvidna matrica tarifnih modela. Izvedene su izvorne formule za regulaciju maksimalno dozvoljenog prihoda i izračun mjesečnog računa preko tarifnih elemenata za isporučenu energiju, snagu i mjesečnu naknadu. Poseban osvrt dan je na izbor metode za priznavanje utrošenog energetskog goriva i postavljanje kriterija za tehničke gubitke, tj. za referentne stupnjeve iskorištenosti kod distribucijske mreže i proizvodnje toplinske energije gdje tehnički gubici ovise o vrsti energetskog goriva.

1 Introduction

Croatian energy legislature [1-3] defines the rules for devising the methodology of a Tariff system for thermal energy activities. The Croatian Energy Regulatory Agency (in further text: the Regulator) passes the methodology, or tariff system without the amounts of tariff elements, after it receives a prior opinion from energy undertakings that perform energy activities for which a tariff system applies and from the Ministry of Economy. In fact, a tariff system consists of a prescribed methodology for defining tariff elements and their amounts. The Government of the Republic of Croatia defines the amount of individual tariff elements in the tariff systems, upon the proposal of the Ministry of the Economy (further in text: the Ministry). An energy undertaking that performs the activities to which a tariff system applies shall submit a proposal to the Ministry, which shall then obtain the opinion of the Regulator.

Choosing the right approach to determine the methodology is an important problem, because the consequences of a wrong concept could be serious. Use of tariff system will determine the business of the thermal energy sector in Croatia in the following years essentially and enable its imperative development. The thermal energy sector is very important for the functioning of society, because thermal energy is used for heating, sanitary water heating, or for technological usage in production. The usage level of thermal energy

Symbols/Oznake

B_{month}	- monthly bill submitted to each customer, HRK - mjesečni račun koji dobije potrošač
$C_{ener.fuel}$	- real energetic fuel price, HRK/kg, HRK/m^3 - stvarna cijena energetskog goriva
$C_{fix(t-1)}$	- amount for covering fixed costs in year t-1, HRK - iznos za pokrivanje fiksnih troškova u godini t-1
$C_{fuel(t)}$	- amount for covering costs of spent energetic fuels in year t, HRK - troškovi potrošenog energetskog goriva u promatranoj regulacijskoj godini t
c_i	- unit price of concrete fuel from this purchase i, HRK/t, HRK/kg, HRK/m^3 - jedinična cijena pojedinog goriva za određenu nabavu i
$C_{var(t)}$	- amount for covering variable costs in year t, HRK - iznos za pokrivanje varijabilnih troškova u godini t
CGA_t	- adjusting factor due to increased number of customers, HRK/customer - podešavajući faktor uslijed porasta broja kupaca
CPI_t	- index of customer prices in year t - indeks potrošačkih cijena u godini t
max C_t	- sales price in year t, HRK - prodajna cijena u godini t
$\Delta Customers$	- difference in number of customers - godišnja razlika broja kupaca
F	- fees amount for stimulating renewable sources and cogeneration usage, regulatory activities and stranded costs, HRK - iznos naknada za poticanje obnovljivih izvora energije i kogeneracije, obavljanje poslova regulacije energetskih djelatnosti i naslijeđene troškove
G	- consumption, t, m^3 - potrošnja
G_i	- unit quantity of each fuel at one purchase i, t, kg, m^3 - jedinična količina pojedinog goriva po jednoj nabavi i
H_d	- lower calorific value of fuel,kJ/kg,kJ/m^3 - donja ogrjevna vrijednost goriva
$H_{d,i}$	- lower calorific value of each fuel i, MWh/kg, MWh/m^3 - donja ogrjevna vrijednost goriva i
I	- index which marks hour in calculated period - indeks koji označava sat u obračunskom razdoblju
I	- inflation index - indeks inflacije
I_t	- index of customer prices - indeks potrošačkih cijena
KC_t	- factor of price correction in year t, HRK - faktor korekcije cijene u godini t
N	- index which marks total hours number of heating in calculated period - indeks koji označava ukupan broj sati grijanja u obračunskom razdoblju
P	- price, HRK/t, HRK/m^3 - cijena
P_t	- price in year t, HRK - cijena u godini t
$f(P_t)$	- Price-cap component, HRK - Price-cap komponenta
$Q_{consum(t)}$	- total thermal energy at disposal for consumption in observed year t, MWh - ukupna toplinska energija raspoloživa za potrošnju u godini t
$Q_{delivered(t)}$	- delivered heat in year t, MWh - godišnja predana toplina
$Q_{delivered,mounth}$	- monthly delivered heat, MWh - mjesečna predana toplina
$Q_{tl-boiler}$	- total technical losses in boiler, MWh - ukupni tehnički gubitci u generatoru pare
Q_{tl-dn}	- total technical losses of heat in distribution network, MWh - ukupni tehnički gubitci toplinske energije u distribucijskoj mreži
Q_{tot}	- total sum of generated and purchased quantities of heat, MWh - sumarna ukupna količina proizvedene i kupljene toplinske energije
R	- revenue in year t, HRK - prihod u godini t
RF_t	- contribution of regulated funds in year t, HRK - prinos od reguliranih sredstava u godini t
R_{month}	- monthly revenue of a regulated company, HRK - mjesečni prihod regulirane tvrtke
$R_{max(t)}$	- maximal annual revenue in year t, HRK - regulirani maksimalni prihod u godini t

R_t	- authorized revenue amount of regulated company in year t, HRK - autorizirani iznos prihoda regulirane tvrtke u godini t
R_t / S_t	- revenue per customer in year t, HRK - prihod po kupcu u godini t
S_{shc}	- standard specific heat consumption, kJ/MWh - standardni specifični utrošak topline po jedinici proizvedene toplinske energije
$SSC_{ener.fuel}$	- standard specific cost of energetic fuel for a certain plant i, HRK/MWh - standardni specifični trošak energetskog goriva za neko postrojenje i
t	- observed (current) year - promatrana (tekuća) godina
$t_{ambient,i}$	- temperature of environment according to informations of Hydrometeorologic institute for each hour in month, °C - temperatura okoline prema podacima Hidrometeorološkog zavoda za svaki sat u mjesecu
$t_{ambient,projected}$	- temperature of environment relevant for planning and amounts -15 °C - temperatura okoline relevantna za projektiranje koja iznosi -15 °C
$t_{room,i}$	- temperature of internal rooms, °C - temperatura unutarnjih prostora
$t_{room,projected}$	- temperature of internal rooms relevant for planning, °C - temperatura unutarnjih prostora relevantna za projektiranje
T_{e1}	- tariff element for energy (delivered heat), HRK/kWh/m², HRK/kWh, HRK/t - tarifni element za isporučenu (preuzetu) toplinsku energiju
T_{e2}	- tariff element for abounded power according to the thermoenergetic permission, HRK/kW, HRK/t/h - tarifni element za zakupljenu snagu prema termoenergetskoj suglasnosti
T_{e3}	- tariff element for fixed monthly fee, HRK - tarifni element za fiksnu mjesečnu naknadu
T_{g1}	- tariff group for industry and business customers - tarifna grupa za industriju i poslovne potrošače
T_{g2}	- tariff group for households at centralized heat system - tarifna grupa za kućanstva na centraliziranom toplinskom sustavu
T_{g3}	- tariff group for households at decentralized boiler houses - tarifna grupa za kućanstva na područnim toplanama
w	- relative ponder to component Price-cap and Revenue-cap, [0,1] - relativni ponder komponenti *Price-cap* i *Revenue-cap*
$W_{abounded}$	- abounded power according to the thermoenergetic permission, MW - snaga zakupljena prema termoenergetskoj suglasnosti
$W_{installed}$	- installed power on side of thermal energy customers, MW - instalirana snaga na strani toplinskih potrošača
X	- efficiency coefficient determined by regulatory body, [0,1) - koeficijent efikasnosti kojeg određuje Regulator
X_t	- efficiency coefficient in year t, [0,1) - koeficijent efikasnosti u godini t
Z	- correction for not planned events - korekcija za nepredviđene događaje
φ	- part of each fuel or heat of total given heat into distribution network during year t - udio pojedinog goriva ili topline u ukupnoj predanoj toplini u distribucijsku mrežu tijekom godine
η_i	- usability degree for combustion of each fuel type i - stupanj iskoristivosti za izgaranje pojedine vrste goriva i

in households and for industrial purposes is one of the development indicators. Greater attention has been paid to that significant power field in Croatia recently. The law on generation, distribution and supply of thermal energy entered into force in April 2005. Up to that time, communal activity of heat supply had been taken from jurisdiction of Law on communal economy, and from April 2005. on, it was finally determined as an energy activity. It is notable that measuring and rationalizing energy usage are initiated by this Law, and it is possible for users to control their own heat consumption. The next important step is to make sub legal acts (of which the tariff system is the most important one) and their consistent realization in practice. However, it is necessary to choose an optimal approach to determine the methodology of a Tariff system for thermal energy activities, because there is insufficient experience with tariff systems making in Croatia in general, and especially methodologies which would be scientifically orientated. That is important, because the thermal energy sector is not a profitable sector of the Croatian economy nowadays, and additional efforts are necessary to advance business technically and technologically, as well as economically, especially concerning existing limitations which are the results of an old distribution network and of long existing treatment of heating price as a social category. Using the methodology of a Tariff system for thermal energy activities has to initiate development and facilitate modernization of the existing energy infrastructure of a thermal energy sector and this will have an influence on increasing energy efficiency and decreasing specific business costs.

2 Determination of possibility for initiative regulatory acting

Rate-of-return (ROR) and Price-caps regulation (RP-X) are two basic forms of economic regulation nowadays. Both forms are oriented (considering theoretically) to achieving the same aims, but in different ways. The aims presume efforts of a regulatory body to limit the strength of natural monopolies, impede realization of extra-profits by regulated power companies, and prevent unjustified increase of energy prices as well as prices of related services. Rate-of-return regulation is an older form of economic regulation, very often used for regulation of public services, primarily in the USA. It is also called Cost-of-service regulation, because the regulatory body recognizes only costs that are necessary to offer customers good quality service. The principle of this regulation is simple, because costs recognized by a regulatory body are added to the energy basic price. When a certain capital investment level is achieved, a regulatory body determines an acceptable return rate of invested capital on the basis of which a regulated power company realizes adequate profit. Regulated companies are allowed to realize profit to cover business expenses increasing with fixed profit rate on invested funds - which corresponds to capital expense. Consequently, covering business costs increased by a reasonable profit rate determined by a regulatory body should be accepted. It is clear from the preceding explanation why this form of regulation is also called "regulation by return rate". The main objection to regulation by return rate is that it does not give enough initiative for regulated companies to decrease their costs more significantly. Furthermore, another objection is the lack of initiative to improve business efficiency. It is overcome successfully by using the so-called PBR regulation (Performance Based Regulation), which means using different Price-caps/Revenue-caps equations and represents a successful newer form of regulation used by the majority of regulatory authorities worldwide. A lot of papers from this field have been published[1]. The roots of this form of regulation date from the eighties of the twentieth century, when the British Government realized efficient privatization of companies which carried out the most important public services[2]. Soon after establishing Price-caps/Revenue-caps regulation it was determined that regulated power companies accept the advantages of a regulatory realized benchmark which had been used during specific regulatory period over years. It manifested itself in such a way that this approach resulted in decreasing business costs, particularly operational costs. Power companies decreased costs essentially and realized financial savings. That regulation was used mostly by the regulator for regulating the energy activities which were considered as natural monopolies, or which were carried out as public services in Great Britain, the innovator of the previously-mentioned regulation. It related to regulated companies which had been the owners of transmission or distribution networks in electricity power sector as well as electricity supply for tariff customers. A typical Price-cap equation directed at price maximization has the following form:

$$\max C_t = \left(1 + CPI_t - X_t\right) \cdot \max C_{t-1} - KC_t \tag{1}$$

In (1) t is observed (current) year, and $t-1$ is the previous year, in a regulatory period which usually covers a period of three, four or five years. Further, max C_t is sales price in year t, max C_{t-1} is sales price in previous year $t-1$, CPI_t is index of customer prices in year t, X_t is efficiency coefficient in year t, and KC_t is factor of price correction in year t which is added because of calculation of those costs on which regulated power company can not influence.

Revenue-cap equation, with which observed year level is determined R_t - authorized revenue amount of regulated company, starts from realized revenue in previous year R_{t-1} and has a general form as follows:

$$R_t = \left\{\left[R_{t-1} + \left(CGA_t \cdot \Delta Customers\right)\right] \cdot \left(1 + I - X\right)\right\} \pm Z \tag{2}$$

where t is observed (current) year, and $t-1$ is previous year, in a certain regulatory period. CGA_t is the adjusting factor due to increased number of customers (HRK/customer), $\Delta Customers$[3] is difference in number of customers, I is inflation index, X is efficiency coefficient determined by the regulatory body, and Z is correction for non-planned events[4].

[1] Valuable titles to access the field of PBR are [4-6].

[2] Those companies are: British Telecom (1984) in the field of telecommunications; British Gas (1988) in the field of natural gas; National Grid, Regional Electric Companies and Scottish Power & Hydro (1990) in the field of electricity power.

[3] Definition $\Delta Customers$ according source [7].

[4] That could be tax increase, restructuring costs arising from realization of law duties, duties arising from change of legislature concerning environment protection, etc.

It is possible to change Price-cap equation into Revenue-cap equation. The general form of hybrid (combined) Revenue-Price cap equation is as follows:

$$P_{t+1} = (w)\cdot f(P) + (1-w)\cdot\frac{R_t}{S_t} \tag{3}$$

where P_{t+1} is price in year $t+1$, P_t is price in year t, $f(P_t)$ is Price-cap component, w is relative ponder to component Price-cap and Revenue-cap, and $\frac{R_t}{S_t}$ is revenue per customer.

There are mathematical possibilities to create combined Revenue-Price cap equations. Such equations are as follow:

1) For prices, Price-cap equation in form $P = f(P_{t-1})$ and Revenue-cap equation in form $P = \frac{R}{S}$ give the following combined Revenue-Price cap equation;

$$P = (1-w)\cdot f(P_{t-1}) + (w)\frac{R}{S} \tag{4}$$

2) For revenue, Price-cap equation in form $R = P\cdot S$ and Revenue-cap equation in form $R = f(R_{t-1})$ give combined Revenue-Price.cap equation;

$$R = (1-w)\cdot P\cdot S + (w)\cdot f(R_{t-1}) \tag{5}$$

In (4) and (5) P is price in year t, P_{t-1} is price in previous year $t-1$, R is revenue in year t, R_{t-1} is revenue in previous year $t-1$, S is sale in year t, and w is relative ponder to component Price-cap and Revenue-cap. Regulatory authorities determine the values of relative ponder w and its amounts [0,1]. $w = 0$ in case when considered mathematical forms turn into Price-cap equation, or $w = 1$ when they turn into Revenue-cap equation.

By means of different Revenue-cap equations the regulatory authorities can determine maximal allowed revenue of regulated companies in the energy sector. This method regulates maximal revenue which could be realized by a regulated company in certain year of regulatory period. It should be pointed out that Revenue-cap is simpler to determinate and control than Price-cap form. Revenue-cap is compatible with accounting standards which are usually used and follows demands of regulatory authorities well. Therefore, it would be efficient for considered methodology to use the method of maximal allowed revenue of thermal power company. This method determines suitably the revenue amount in observed year t for which regulatory authorities allow according to realization of each thermal energy activity. Respecting justified business costs, each company is

Table 1 Matrix of tariff models

Tablica 1. Matrica tarifnih modela

Tariff groups (consumption category) Kategorija potrošnje T_g	Tarrif models / Tarifni modeli TM		Tariff elements / Tarifni elementi T_e		
			Energy / Energija T_{e1}	Power /Snaga T_{e2}	Fee /Naknada T_{e3}
T_{g1} - Industry and business customers Industrija i poslovni potrošači	TM_1 separate heat meter zasebno mjerilo	heating water vrela/topla voda	T_{e11} HRK/kWh	T_{e12} HRK/kW	T_{e13} HRK
	TM_2 separate heat meter zasebno mjerilo	technologic steam tehnološka para	T_{e21} HRK/t	T_{e22} HRK/t/h	T_{23} HRK
	TM_3 shared heat meter zajedničko mjerilo	heating water vrela/topla voda	T_{e31} HRK/kWh/m^2	T_{e32} HRK/kW	T_{e33} HRK
	TM_4 shared heat meter zajedničko mjerilo	technologic steam tehnološka para	T_{e41} HRK/t	T_{e42} HRK/t/h	T_{e43} HRK
T_{g2} - Households at centralized heat system Kućanstva na centraliziranom toplinskom sustavu	TM_5 separate heat meter zasebno mjerilo		T_{e51} HRK/kWh	T_{e52} HRK/kW	T_{e53} HRK
	TM_6 shared heat meter zajedničko mjerilo		T_{e61} HRK/kWh/m^2	T_{e62} HRK/kW	T_{e63} HRK
T_{g3} - Households at decentralized boiler houses / Kućanstva na područnim toplanama, zasebnim kotlovnicama	TM_7 separate heat meter zasebno mjerilo		T_{e71} HRK/kWh	T_{e72} HRK/kW	T_{e73} HRK
	TM_8 shared heat meter zajedničko mjerilo		T_{e81} HRK/kWh/m^2	T_{e82} HRK/kW	T_{e83} HRK

allowed reasonable and socially acceptable funds return invested in business.

3 Matrix of tariff models

Elaboration of methodology for generation, distribution and supply of heat should be started with creating a matrix of tariff models (further in text: matrix). One of the matrices appropriate for use in the Croatian thermal energy sector is presented in table 1. Tariff elements in this matrix are financial amounts given in HRK for energy, power unit and fixed monthly fee, and are determined according to the categories of consumption. The categories of consumption are the following tariff groups: T_{g1} for industry and business customers, T_{g2} for households at centralized heat system and T_{g3} for households at decentralized boiler houses. Tariff elements in the matrix are: T_{e1} for energy (delivered heat), T_{e2} for abounded power according to the permission for thermal energy production and T_{e3} for fixed monthly fee[5]. In fact, tariff elements in the matrix are financial amounts given in HRK for delivered energy, power and fixed monthly fee, which along with the methodology form a Tariff system for thermal energy activities.

By using the tariff elements given in the matrix, it is possible to make the following equation:

$$B_{month} = Q_{delivered,month} \cdot T_{e1} + W_{abounded} \cdot T_{e2} + T_{e3} \tag{6}$$

where B_{month} is monthly bill submitted to each customer, $Q_{delivered,month}$ is monthly delivered heat, $W_{abounded}$ is abounded power according to the permission for thermal energy production, and T_{ei} are tariff elements. Furthermore, it is possible to express monthly revenue R_{month} of a regulated company as the sum of amounts of all the bills issued in one month:

$$R_{month} = \sum_{j=1}^{k} B_{month(j)} \tag{7}$$

where k is number of customers.

Finally, equation for R – annual revenue (concerning each year of regulatory period) has form as follows:

$$R = \sum_{m=1}^{12} \sum_{i=1}^{n} Q_{delivered,month(m)} \cdot T_{e1(m)} + \sum_{m=1}^{12} \sum_{i=1}^{n} W_{abounded} \cdot T_{e2(m)} + \sum_{m=1}^{12} k_m \cdot T_{e3(m)} \tag{8}$$

There is a rule that the Regulator has to determine $R_{max(t)}$ – maximal annual revenue of company which carries out generation, distribution or supply of heat for tariff customers. Hence, the condition $R \leq R_{max(t)}$ has to be fulfilled.

4 Possibilities for calculating cost of fuel

Cost of fuel is absolutely dominant in the category of business costs of thermal power companies. It amounts to about 50 % of business costs in the developed countries in Europe. It reaches 60-70 % in Croatia because of price increase of fuels over the last two years and prices of delivered heat have not changed during this time. Therefore, an equation for regulating maximal allowed revenue should comprise this cost as a separate factor. Cost of fuel is a function of generated heat, used fuel types and technical as well as technological characteristics of plants. SSCener.fuel is standard specific cost of fuel for a certain plant i, given in HRK/MWh. It is calculated as:

$$SSC_{ener.fuel} = C_{ener.fuel} \cdot \left(\frac{S_{shc}}{H_d} \right) \tag{9}$$

where S_{sch} is standard specific heat consumption onto unit of generated heat energy for plant type i (kJ/MWh), $C_{ener.fuel}$ is real fuel price (HRK/kg, HRK/m^3), and Hd is lower calorific value of fuel (kJ/kg, kJ/m^3).

Regarding that fuel cost appears in generation of heat, regulated maximal revenue $R_{max(t)}$ will be just considered, which can be realized in HRK by a company that generates heat energy for tariff customers in each year of regulatory period. This revenue can be defined as follows:

$$R_{max(t)} = C_{fix(t-1)} \cdot (1 + I_t) \cdot (1 - X) + C_{var(t)} + C_{fuel} + RF_t + F \tag{10}$$

where $C_{fix(t-1)}$ is the amount for covering fixed costs in year $t-1$ (HRK), I_t is index of customer prices, X is efficiency coefficient [0,1), $C_{var(t)}$ is amount for covering variable costs[6] in year t (HRK), RF_t is contribution of regulated funds in year t (HRK), and F is fees amount for: stimulating renewable sources and cogeneration usage, regulatory activities and stranded costs (HRK). From the regulatory point of view, it is necessary to choose a correct approach for approving costs for used fuels, because this is the biggest category of business costs during observed regulatory year.

Two basic regulatory approaches are possible for covering costs for used fuels during observed regulatory year t. The first one is orientated according to the costs - it means that really emerged costs will be approved regardless of efficiency of thermal power company.

[5] Fixed monthly fee refers to capability of heat generation system, maintenance and inmeasuring of heat meters in heat distribution and costs of calculating service in heat supply.

[6] Variable costs include costs of material, energy, spare parts, small inventory

The second one is technically orientated and stimulates introduction of criterion of efficiency for these costs.

4.1 Cost approach towards covering costs of spent fuels

When $C_{fuel\,(t)}$ i.e. amount for covering costs of spent fuels in year t is calculated, it is necessary to take into consideration as follows:

1. Total installed power; it means power registered and being in evidence, from contracts concluded between suppliers and customers.
2. Fuel quality, certified by attests for lower calorific value H_d and quality of chemical composition of fuel.
3. Outer project temperature for certain locality.
4. Technical losses in heat generation and heat distribution (distribution network), defined by regulatory authorities.

Costs of fuel purchase are defined on the basis of:

a) fuel quantity spent for generation of heat, measured and given to heat meter of distribution network, taking into considaration lower calorific value for used fuel as well as for approved technical losses in generation, depending on type of used fuel according to following criteria: up to 15% for natural gas, up to 20% for masut, up to 20% for coal, up to 35% for biomass, biofuel, biogas or waste,

b) enclosured documentation of realized fuel purchases (sales contracts, invoices, warehouse receipts, quality attests with defined lower calorific value).

In case that regulatory body chooses the described method of approving costs of fuel, higher purchase price of fuel than that which was valid on the market during the observed period should not be approved. It means that regulatory authorities have to monitor all business activities of thermal power companies and state in market of oil and oil derivatives too, according to regulatory monitoring rules described in [8]. $C_{fuel\,(t)}$ – amount of costs for total purchased quantity of different fuels in year t is calculated as the sum of amounts of purchases of each fuel type (sum of individual purchases, or product of quantities and unit prices for each fuel type) following the equation:

$$C_{fuel(t)} = \sum_{i=1}^{n} G_{i(gas)} \cdot c_{i(gas)} + \sum_{i=1}^{n} G_{i(oil)} \cdot c_{i(oil)} + \sum_{i=1}^{n} G_{i(coal)} \cdot c_{i(coal)} + \sum_{i=1}^{n} G_{i(bio)} \cdot c_{i(bio)} \quad (11)$$

where G_i is unit quantity of each fuel at one purchase (t, kg or m^3), and c_i is unit price of concrete fuel from this purchase (HRK/t, HRK/kg or HRK/m^3).

In the event that one part of fuel quantity was purchased at foreign currency clause, foreign currency should be converted into HRK according to the exchange rate which was valid when relevant fuel quantity was paid.

4.2 Technical approach towards covering costs of spent fuels

Fuel costs $C_{fuel(t)}$ should be calculated on the basis of heat quantities (which are measured) delivered in distribution network, and not on the basis of purchased fuel quantities. In that case, a thermal energy producer would be interested in increasing usability of plant based on approved losses, and to realize fuel savings as well. Equation for calculating costs for fuels and purchased heat in year t (HRK/year) has the following form:

$$C_{fuel(t)} = \left(\frac{\varphi_{gas}}{\eta_{gas} \cdot H_{d,gas}} \cdot c_{gas,t} + \frac{\varphi_{oil}}{\eta_{oil} \cdot H_{d,oil}} \cdot c_{oil,t} + \frac{\varphi_{coal}}{\eta_{coal} \cdot H_{d,coal}} \cdot c_{coal,t} + \frac{\varphi_{bio}}{\eta_{bio} \cdot H_{d,bio}} \cdot c_{bio,t} + \varphi_{heat} \cdot c_{heat,t} \right) \cdot Q_{delivered(t)} \quad (12)$$

where φ is part of each fuel or heat of total given heat into distribution network during year t, C_i is usability degree for combustion of each fuel type, $H_{d,i}$ is lower calorific value of each fuel (MWh/kg or MWh/m^3), and $C_{i,t}$ is fuel price for gas, fluid fuel, coal, biomass, biogas, biofuel, waste or purchased heat (HRK/kg, HRK/m^3 or HRK/MWh). Furthermore, following relation is valid:

$$\varphi_{gas} + \varphi_{oil} + \varphi_{coal} + \varphi_{bio} + \varphi_{geo} + \varphi_{sol} + \varphi_{heat} = 1 \quad (13)$$

In (12) presented $Q_{delivered\,(t)}$ refers to heat given in calculated year t into distribution network (MWh/year) and can be calculated from the following equation:

$$Q_{delivered\,(t)} = \eta_{gas} \cdot H_{d,gas} \cdot G_{gas} + \eta_{oil} \cdot H_{d,oil} \cdot G_{oil} + \eta_{coal} \cdot H_{d,coal} \cdot G_{coal} + \eta_{bio} \cdot H_{d,bio} \cdot G_{bio} + Q_{geo} + Q_{sol} + Q_{heat} \quad (14)$$

For gas, fluid fuels, coal, biomass, biofuel, biogas and waste is valid:

$$\varphi_i = \frac{\eta_i \cdot H_{d,i} \cdot G_i}{Q_{delivered(t)}} \quad (15)$$

where Gi is the quantity of each fuel spent during year (t, kg or m[3]).

For geothermal and solar energy as well as for purchased energy

$$\phi_i = \frac{Q_i}{Q_{delivered(t)}} \quad (16)$$

Is valid total given thermal energy on input of distribution network $Q_{delivered\ (t)}$ except over (14) can be expressed too as:

$$Q_{delivered(t)} = Q_{tl-dn} + Q_{consum(t)} \quad (17)$$

Following relation is valid also:

$$Q_{delivered(t)} = Q_{tot} - Q_{tl-boiler} \quad (18)$$

$Q_{tl\text{-}dn}$ presents total technical losses of heat in distribution network, $Q_{consum\ (t)}$ total thermal energy at disposal for consumption in observed year, Qtot total sum of generated and purchased quantities of heat, $Q_{tl\text{-}boiler}$ total technical losses in boiler during transformation of fuel calorific value into thermal energy, all expressed in MWh in observed year t.

$Q_{consum\ (t)}$ which would refer to observed year t can be expressed by equation:

$$Q_{consum(t)} = \frac{W_{installed}}{t_{room,projected} - t_{ambient,projected}} \cdot \sum_{i=1}^{n} (t_{room,i} - t_{ambient,i}) \quad (19)$$

where $Q_{consum\ (t)}$ is consumption heat (MWh/year), $W_{installed}$ is installed power on side of thermal energy customers (MW), $t_{room,\ projected}$ is temperature of internal rooms relevant for planning[7], $t_{ambient,\ projected}$ is temperature of environment relevant for planning and amounts -15 °C, $t_{room,i}$ is temperature of internal rooms[8], $t_{ambient,\ projected}$ is temperature of environment according to information of Hydrometeorological Institute for each hour in the month. Further, i is the index which the marks hour in calculated period, and n is the index which marks total number of hours of heating in calculated period.

4.3 Calculation of approved costs for fuel

The calculation of approved costs for fuel is shown in table 2. using a mix of heating oil and natural gas according to cost principle expressed by equation (11). Quantities of spent fuel approximately correspond to fuel consumption in power plant - heating plant (EL-TO) Zagreb during the year 2004 and that is the only similarity to the presented case. Except for approved costs for fuel, by using presumed "real" usability degrees, quantities of given heat and parts of each fuel in fuel mix, are calculated.

A technical approach to covering of fuel costs is shown in table 3. Fuel quantities and total approved cost are calculated by taking parts of each fuel in fuel mix and total given heat as known (from table 2.) as well as by approved usability degrees.

If heat generation company assures better usability degrees of its equipment than values approved by regulatory body, then it can realize additional revenue which amounts to 2.39 % in shown case. This should be enough stimulation for investment in equipment to realize improvment of operation. From the regulatory point of view, it is the most difficult to calculate part of each fuel in fuel mix.

Table 2 Cost approach to fuel expenses valuation
Tablica 2. Troškovni pristup pokrivanju troškova za gorivo

Fuel Gorivo	Consumption Potrošnja G		Price Cijena P		η	H_d		Delivered heat Predana toplina $Q_{delivered(t)}$ MWh	φ	Fuel cost Trošak goriva $C_{fuel(t)}$ HRK
Heating oil Lož ulje	20,000	t	1 200	HRK/t	0.82	40,000	kJ/kg	182,222	0.201	24 000 000, 00
Gas Plin	90,000	10^3 m^3	0, 80	HRK/m^3	0.87	33,338	kJ/m^3	725,101	0.799	72 000 000, 00
Total Ukupno								907,323		96 000 000, 00

[7] As adequate temperature it can be used 19 °C.

[8] These temperature can account 20 ± 1 °C by day, or 15 ± 1 °C at nights.

Table 3 Technical approach to fuel expenses valuation

Tablica 3. Tehnički pristup pokrivanju troškova za gorivo

Fuel Gorivo	Consumption Potrošnja G		Price Cijena P		η	H_d		Delivered heat Predana toplina $Q_{delivered(f)}$ MWh	φ	Fuel cost Trošak goriva $C_{fuel(f)}$ HRK
Heating oil Lož ulje	20,500	t	1 200	HRK/t	0.8	40,000	kJ/kg	182,222	0.201	24 600 000,00
Gas Plin	92,117	10^3 m³	0, 80	HRK/m³	0.85	33,338	kJ/m³	725,101	0.799	73 694 118,00
Total Ukupno								907,323		98 294 118, 00

In order to evaluate error influence in this evaluation on revenue, realized by producera, sensitivity analysis has been done which is shown in Figure 1. From Figure 1 it could be calculated that an error in evaluation of heating oil part in fuel mix of 1% influences revenue in amount of 0.315 %, which can be acceptable.

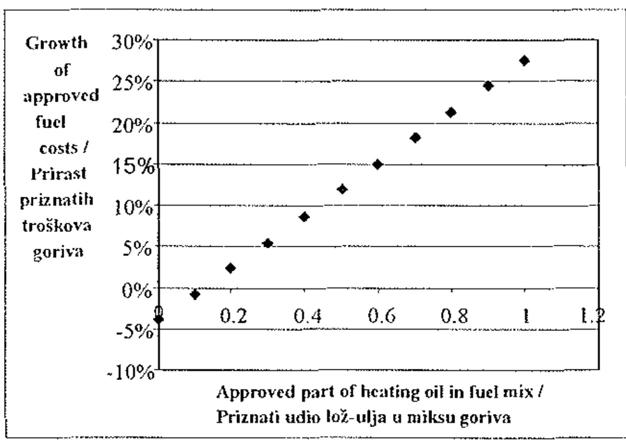

Figure 1 Approved fuel cost increase as a function of approved heavy oil share in fuel mix

Slika 1. Prirast priznatih troškova za gorivo u zavisnosti od priznatog udjela lož ulja u miksu goriva

5 Losses in heat generation and heat distribution

For defining criteria of losses in systems for heat generation and heat distribution (which is needed to be defined by the methodology) it should start with data presented in table 4. From the table, it is obvious that these losses[9] are several times bigger in transient countries than in countries of West Europe. It refers to heat consumption (kWh/m³), distribution losses (% of delivered heat), number of water refillings, and losses of heat generation (% of fuel energy). So the number of water refillings[10] is 6.7 times bigger, 1.7 times more heat is used, and losses are 2.8 times bigger in heat generation and 2.7 times in heat distribution. Information for Croatian thermal energy sector corresponds with the above-mentioned. Causes of such bad condition are: old equipment, bad maintenance, bad regulation, insufficient insulation of pipeline and over-dimensioned system. Hence, big investments are necesarry for modernization of thermal energy systems. But this is not possible to realize with existing sales prices of heat.

Usability degree of old boiler plants in heat generation is assessed in a range from 60 to 80 %, which is very low. It can be increased by modernization up to 85 %. It is possible by using modern systems automatization, with burner replacement and with systematic cleaning of burning surfaces. Losses in distribution networks caused by pipeline leaking and bad insulation are different among heat distribution companies, but they are not smaller than 10 % anywhere in Croatia. For instance, losses in heat distribution are about 12 % in heating water network of centralized thermal energy system in Zagreb, and the number of water exchanges is 25, while the number of water exchanges is 12 during heating period in Osijek, and heat loss amount is about 18 %. Such situation demands revitalization of distribution networks by replacement of pipes with new pre-insulated pipes[11].

[9] All losses are calculated as an average of adequate ranges shown in table 4.

[10] Annual volume of water refillings/water volume in network.

[11] Steel pipes are used today which are coated with polyurethane foam, with protective wrapper from high density polyethylene

Table 4 Losses in heat generation and heat distribution

Tablica 4. Gubici u proizvodnji i distribuciji toplinske energije

CHARACTERISTICS: Unit consumption of heat and typs of losses ZNAČAJKE: Jedinična potrošnja topline i vrste gubitka	Unit Jedinica (1)	Middle and East Europe and ex USSR Srednja i Istočna Europa te bivši SSSR (2)	West Europe Zapadna Europa (3)	Proportion Omjer (2/3)*100
Heat consumption (annual energy consumption/ heated space) Potrošnja topline (godišnja potrošnja energije/ grijani prostor)	kWh/m^3	70 – 90 $\overline{x}$ = 80	45 – 50 $\overline{x}$ =47,5	168 %
Distribution losses Gubici distribucije	% of delivered heat % isporučene topline	15 – 25 $\overline{x}$ = 20	5 – 10 $\overline{x}$ = 7,5	267 %
Number of water refillings (annual number of water refillings/water volume in network) Broj izmjena vode (godišnji volumen nadopuna/ volumen vode u mreži)	Fillings in year Punjenja godišnje	10 – 30 $\overline{x}$ =20	1 – 5 $\overline{x}$ = 3	667 %
Generation losses Gubici proizvodnje	% of fuel energy % energije goriva	15 – 40 $\overline{x}$ = 27,5	5 – 15 $\overline{x}$ = 10	275 %

Table 5 Referential usability degrees for separated heat generation

Tablica 5. Referentni stupnjevi iskoristivosti odvojene proizvodnje toplinske energije

Fuel Energetsko gorivo	Industrial steam Industrijska para %		Regional heating Područno grijanje %	Separate heating plants Posebne toplane %
Pit-coal Kameni ugljen	88	83*	86	84
Natural gas Prirodni plin	91	85*	90	88
Lignite Lignit	88	83*	86	84
Heating oil Lož ulje	89	84*	88	86
Biomass Biomasa	82		80	79
Industrial gas (refineries, coke plants) Industrijski plin (rafinerije, koksare)	88	82*	87	85

* The referential usability degrees of industry steam generation are shown according to suggestion of CEFIC interest groupation.

* Referentni stupnjevi iskoristivosti proizvodnje industrijske pare prema prijedlogu CEFIC interesne grupacije.

In an analysis made with the purpose of an defining acceptable level for approved losses (which should be regulated by the methodology) information about referential usability degrees of separate heat generation in European countries are used. It is foreseen that referential values will be stipulated as an addition to Directive 2004/8/EC [9] on the promotion of cogeneration. Actual suggestion of working group is shown in table 5.

As opposed to plants for separate generation of electricity power, the age of plants for separate generation of heat, was not considered in the suggestion of referential values because technical development in this field was not significant over the last decade. Referential values suggested for generation of industrial steam are rated as too high in the report [10] of groups CEFIC and IFIEC[12], and reduction of values was suggested, as shown in table 5. Suggested smaller value of industrial steam generation of 85 %, in boilers heated by natural gas, is based on statistic data from the Netherlands. Usability of 82 % for

[12] CEFIC and IFIEC are important interest groupation because they represent companies in which over 60 % of European industry co-generation capacities are installed.

boilers which use fuels produced in industry process[13] is explained with in appropriate composition of "waste fuels". Suggested referential values of usability degrees for boilers heated by coal and heating oil are based on the fact that combustion of hard and fluid fuels is less efficient than combustion of natural gas.

In practice, real usability degrees can vary from values declared by equipment producers significantly, which depends mostly upon number of operation hours, management of operational plant, starting and return temperatures, quantity of return condensated substance, frequency of loading changes, as well as upon length of operation lasting at loadings which are lower than nominal. Lower values than those declared by equipment producers are used for defining savings index for primary energy in analysis of Austrian cogeneration potentionals too, which is presented in table 6. Different categories of plants for separate heat generation are shown in the table. Values in table 6 indicate that production of dry-saturated steam is less efficient than production of heating water. Efficiency of small heating systems is lower as well as plants heated by biomass or waste.

Table 6 Referential efficiency for separated heat generation (Austria)

Tablica 6. Referentne efikasnosti odvojene proizvodnje topline (Austrija)

SEPERATED HEAT GENERATIONS ODVOJENE PROIZVODNJE TOPLINE	Referential degrees Referentni stupnjevi
Hard fuel, high temperature boilers > 1 MW Kruta goriva, visoko temperaturni kotlovi > 1 MW	0.85
Fluid fuels, high temperature boilers > 1 MW Tekuća goriva, visoko temperaturni kotlovi > 1 MW	0.90
Gas fuels, high temperature boilers > 1 MW Plinska goriva, visoko temperaturni kotlovi > 1 MW	0.90
Boilers for generation of dry saturated steam (all fuels) Kotlovi za proizvodnju suhozasićene pare (sva goriva)	0.80
Small heating systems Mali sustavi grijanja	0.75
Industrial gases Industrijski plinovi	0.80
Biomass and waste Biomasa i otpad	0.75

[13] Those boilers use refinery gases, cracking gases.

In connection with "approved technical losses" which should be defined by the methodology, for referential usability degree of distribution network η_{dn}=85 % can be used. That means that the Regulator should approve technical losses in a distribution network up to 15 % of total thermal energy measured on entrance of the network. These losses would be smaller gradually, so values of approved losses will be adjusted to actual EU values after 2010. Technical losses in heat generation depends on type of used fuel and could be approved up to 15 % for natural gas, up to 20 % for masut, up to 20 % for coal and up to 35 % for biomass, biofuel, biogas or waste.

6 Conclusion

Methodology of a Tariff system for thermal energy activities is necessary after analysis of conditiona in the Croatian thermal energy sector has been made by the Regulator. This paper has shown the way how to connect a matrix of tariff models consequently with maximal approved revenue in observed year *t* of regulatory period placed in relation to the total revenue calculated by using tariff elements from the matrix. Two possible approaches for approving the costs of used fuel are elaborated for heat generation as the most cost-intensive thermal energy activity, i.e. costs approach and technical approach. As shown, it would be optimal to choose a technical approach, because it stimulates energy efficiency, taking into consideration usability degree for combustion of each fuel type.

Based on the analysis that is made in the paper, and starting from actual condition in the Croatian thermal energy sector, it follows that it is necessary to define an adequate transitional period, during which higher "approved losses"[14] of heat generation and heat distribution will adjust by time to the EU referential values. Thus, the energy undertakings that carry out thermal energy activities should have explicit obligation to invest in system modernization over the next years.

[14] The level of losses is defined in the paper.

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