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MODEL FOR ENERGY ALLOCATION IN HEATING SYSTEMS WITH PARTIAL DISTRIBUTION OF HEAT ALLOCATORS

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ABSTRACT

More than 150 000 households in Croatia have centralized heating system with heated water. Most of heat energy customers are connected to one common heat meter located in the heating substation of the building. These are the buildings built before 2001 in which the piping did not provide for individual metering of heat energy for each apartment. To make cost allocation fairer for customers on a common heat meter, there is a possibility of installing heat cost allocators. For technical functionality of the system, heat cost allocators must be installed on heating fixtures in at least 50 % of the apartments connected to the same metering point. In this paper we will analyze formula for allocation of energy consumption between customers that have cost allocators installed, primarily compared with energy distributed to customers without one. We will propose new method of energy distribution and compare its results and properties with those of formula in use.

KEY WORDS

heating systems, distribution, allocators

CLASSIFICATION

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INTRODUCTION

More than 150 000 households in Croatia have centralized heating system with heated water. Most of heat energy customers are connected to one common heat meter located in the heating substation of the building. These are the buildings built before 2001 in which the piping did not provide for individual metering of heat energy for each apartment. To make cost allocation fairer for customers on a common heat meter, there is a possibility of installing heat cost allocators. For technical functionality of the system, heat cost allocators must be installed on heating fixtures in at least 50 % of the apartments connected to the same metering point. Method for energy distribution was legislated by Ministry of Economy, Labor and Entrepreneurship [1] in year 2008. After first allocators were installed, there was some media reports that customers who installed it were not satisfied with distribution of heat energy consumed; namely they objected that energy (per meter squared) alocated to customers who did not install allocators was lower than those allocated to some customers with allocators. In year 2011, Ministry of Economy, Labor and Entrepreneurship legislated new Regulations for cost allocation of heat energy [2, 3], and this method is currently in use.

First object of this paper is to explain and analyze results of this method. In second chapter, we will introduce alternate method for cost allocation of heat energy, and compare its properties and results with those of current method.

FORMULA FOR ENERGY ALLOCATION

Parameters used for energy allocation are:

- total amount of energy read on a common heat meter, denoted with E_{ZJ} (notification, although little odd, is in correspondence with official notification of Ministry of Economy, Labor and Entrepreneurship regulation),
- area of households connected to a common heat meter, denoted with P_i. Index $i \in \{1, ..., k\}$ ranges over all households connected to a common heat meter. Without loss of generality, we will assume that first m indexed households have installed cost allocators,
- total number of impulses read on all cost allocators in one households, denoted with BI_i, $i \in \{1, ..., m\}$. Energy value of impulses read on allocators is unique for each system. Therefore, those values should be used only relatively one to another.

Those are input data of method used for calculating energy distribution among households connected on a common heat meter. Method uses following calculated values:

- total area of all households connected on a common heat meter, denoted with P_{SSUC},

$$P_{\mathrm{SSUC}} = \sum_{i=1}^{k} P_i ,$$

- total area of all households connected on a common heat meter with installed cost allocators, denoted with P_{SSR},

$$P_{\mathrm{SSR}} = \sum_{i=1}^{m} P_i ,$$

- total area of all households connected on a common heat meter without installed cost allocators, denoted with P_{SSBR},

$$P_{\mathrm{SSBR}} = \sum_{i=m+1}^{k} P_i ,$$

- factor U_{ST} legislated with *Regulations for cost allocation of heat energy* [1-3]. This factor is initially set to 25, and should be changed yearly in dependence of last year heat consumption on common heat meter.

Since heat consumption in households without heat allocators are not measured (weather in actual energy consumption, or number of index points) there is no way to determine part of energy consumed by those households, and part of energy which is lost in transport (within building) or which is used for heating common spaces, such as corridors. Even more, since indexes measured by heat allocators do not have energy value, there is no way to determine even energy consumption of households with heat allocators. That is, if we are determined to use current method of measurement with heat allocators. Therefore, *Regulations for cost allocation of heat energy* set factor U_{ST} as an administrative measure of energy consumption of households without heat allocators in the following way:

$$E_{SSBR} = E_{ZJ} \frac{P_{SSBR}}{P_{SSUC}} \left(1 + \frac{U_{ST}}{100}\right), \tag{1}$$

$$E_{SSR} = E_{ZJ} - E_{SSBR}. \tag{2}$$

In equation (1) E_{SSBR} stands for total energy assigned to all households without heat allocators, and it is calculated as part of total consumed energy (E_{ZJ}) proportional to share of area of all households without heat allocators (P_{SSBR}) in total area (P_{SSUC}), and increased for a factor 1,25 (if U_{ST} is set to 25). This way, formula tries to guess how much households without heat allocators consume more energy (relative to its area) than those with heat allocators. After that, equation (2) allocate remaining energy (up to amount of total energy consumed) to households with heat allocators.

After the totals of energy for all households without heat allocators (1) and for those with heat allocators (2) are determined, further formulas determine amount of energy allocated to each household. For those without heat allocators, it is share of E_{SSBR} proportional to its area:

$$E_i = E_{SSBR} \cdot \frac{P_i}{P_{SSBR}}, \quad i \in \{m+1, ..., k\}. \tag{3}$$

For calculation of energy allocated to households with heat allocators *Regulations for cost allocation of heat energy* introduce one more corrective factor, named U_{POV}. This factor can take value between 0 and 50, and it is used to allocate to households part of consumed energy which is lost in internal transport, or used for heating of common areas. Now we have:

$$E_i = E_{SSR} \cdot \left[\left(1 - \frac{U_{POV}}{100}\right)\frac{BI_i}{BI} + \frac{U_{POV}}{100}\frac{P_i}{P_{SSB}}\right], \quad i \in \{1, ..., m\}. \tag{4}$$

BI in equation (4) stands for sum of all impulses BI_i read on heat allocators. Expression in brackets is convex combination of two values, P_i/P_{SSR} (which is constant) and BI_i/BI (which depends on energy consumption).

Formula for energy allocation can be described in following way: first, there is administrative division of total amount of energy into two parts – one allocated to all households without heat allocators installed, and second part, allocated to all households with heat allocators installed. After that, within each part further allocation is made, with regard to area of apartments and number of measured number of impulses.

ANALYSIS OF FORMULA FOR ENERGY ALLOCATION

First thing we need to do, is determine a goal of formula analysis. Since formula for energy allocation can be viewed as a function which assigns *n*-placed vector (values of allocated energy to each of *n* households) to an $(n + k + 3)$-placed vector of arguments (areas of *n* households, number of impulses measured on *k* heat allocators, two administrative factors, and total amount of energy consumed), it is important to determine a way of valuating formula.

From the perspective of consumer, there are two comparisons from which he or she values benefits of installing heat allocators: does reduced consumption after installation of heat allocators results with a lower energy allocation; and how allocation of energy for a household with installed heat allocators compare to energy allocation for a households without one. Regrettably, formula fails in certain situations on both of those accounts – it is possible that higher energy value will be allocated to a household after installation of heat allocators in spite lower energy consumption than before; it is also possible that higher energy value will be allocated to a households with heat allocators than to those without one, even if first one is consuming less energy than latter. Let us see how and why it happens.

Questions from last paragraph actually cannot be answered from real data. Consumption of energy from one month to another is not the same even in one household, let alone in two of them. Even more, there is no (direct) way of determining amount of energy consumed in a household without heat allocators. Real life data simply does not provide enough amount of control over energy consumption.

On the other hand, simulations provide total control over input parameters. In first series of simulations we will set energy consumption level on maximum for all apartments without heat allocators (which is the most common way of behaving), and in household with heat allocators we will set energy consumption level on some percentage of maximal consumption. Each time, we will single out one household, and analyze formula based allocation of energy for that apartment while its energy consumption rises from none to maximal. In those simulations we will have few assumptions which do not hold in real life, but they provide much clearer picture of formula effects. We will assume that all households consume level of energy proportional to its area. This means that all apartments have the same energy efficiency, which is not so in real life, but that assumption will help us understand ramifications of formula alone, without interference of energy efficiency factor.

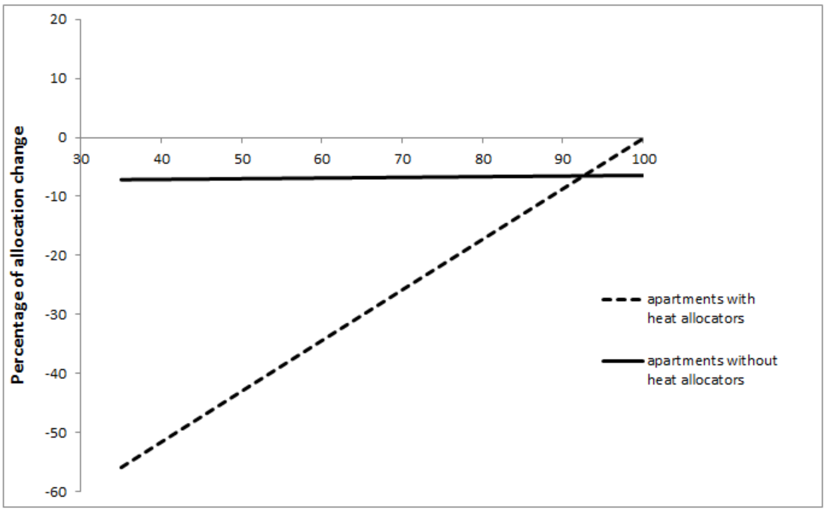


Figure 1. Comparison of energy allocation on 80 % consumption level.

In Figure 1 we can see results of such simulations. Simulations are made on a system with 100 apartments, 80 with heat allocators and 20 without them. Apartments without allocators consumed maximal amount of energy (per square meter), and those with allocators installed consumed 80 % of maximal energy (per square meter). One apartment was singled out, and graph in Figure 2 shows its results. On x-axes is percentage of energy (of maximal energy) consumed in that apartment, while on y-axis we can read percentage difference between its apartment energy allocation if there are no allocators installed and current situation. Red line marks difference in energy allocation for a apartment without allocators installed, and blue one marks difference for an apartment with heat allocators.

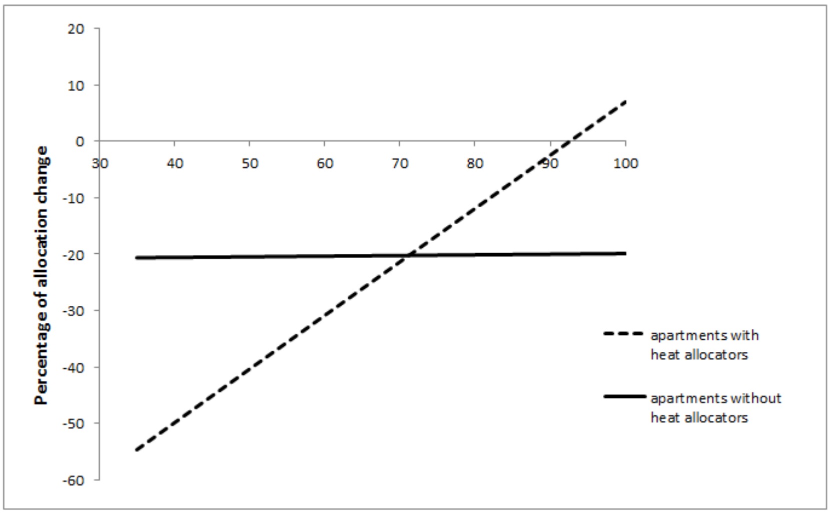


Figure 2. Comparison of energy allocation on 50 % consumption level.

As we can see in graph, apartment without heat allocators has approximately 7 % less energy allocation compared to situation prior to installment of allocators in building, almost regardless to its consumption; energy allocation is almost the same, in case of 30 % consumption, just as in case of 100 % consumption. On the other hand, energy allocation for an apartment with heat allocators depends on level of consumption. But, while 60 % saving of energy results with approximately same decrease of energy allocation, consumption of maximal amount of energy brings allocation greater than those of an apartment without heat allocator – at this level of consumption red line in graph gives higher values than the blue one. This feature becomes even more evident in situations with greater overall savings of apartments with heat allocators. In next two figures we can see how energy is allocated in situations when apartments with heat allocators reduce consumption of energy by 50 % and 70 %.

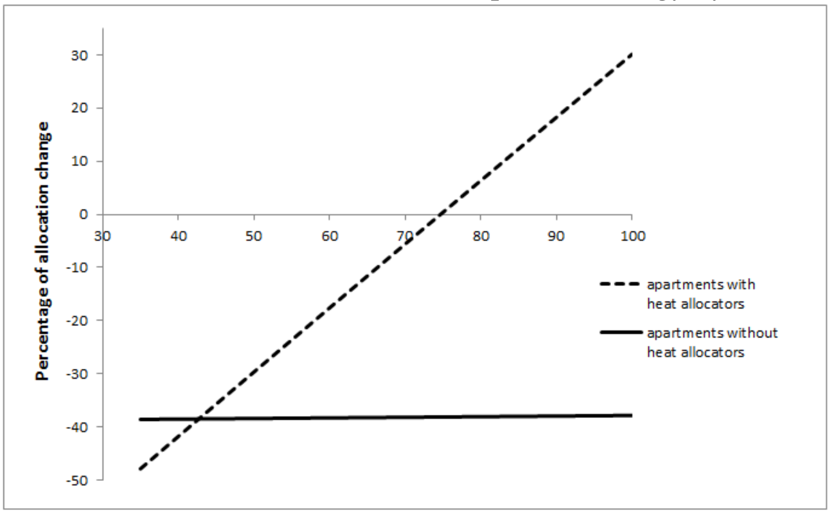


Figure 3. Comparison of energy allocation on 30 % consumption level.

As we can see in Figure 2, when average consumption of energy by households with heat allocators equals 50 % of available energy, when one of those apartments crosses level of consumption of 70 %, it will be allocated more energy than apartments without allocators, even if they are using all available energy. To make things worse, if that apartment uses all available energy, it will be allocated more energy than prior to installation of heat allocators, which in graph can be seen as blue line crosses to positive numbers.

Graph in Figure 3 stresses the problem even more. With average 70 % lesser consumption by households with heat allocators, even consumption of half of available energy brings greater allocation to apartments with heat allocators, than those to apartments without one. If energy savings are less than 20 %, household will be allocated greater amount of energy than prior to installation of heat allocators. In both cases, households without heat allocators, despite maximal consumption of available energy, are allocated with smaller amounts of energy than prior to installation of heat allocators in building.

Described problem is a result of formula construction. Since, formula first determine energy totals allocated to apartments with and without heat allocators, regardless to actual consumption, and then divides those totals between apartments, it is possible for a part allocated to apartment with heat allocators to be greater than any other part. In an extreme case, it can happen that one apartment would be allocated complete energy total reserved for apartments with heat allocators – one apartment can have one impulse spending, while all others have zero. In that case, all energy consumption comes from apartments without allocators, but greatest share of energy allocation goes to an apartment with allocator, in spite its minimal consumption. Simulation of that extreme scenario results with allocation for that apartment 16 times greater than prior to installation of heat allocators.

Next step is an analysis of formula behavior in situation with random consumption. For this purpose energy consumption on households with heat allocators will be randomly generated through uniform distribution of percentage of consumption, rating from 0 % to 100 %. Goal of this simulation is to analyze correlation between energy consumption and energy allocation, so we will set factor U_{POV} to zero. In that case energy allocated by formula should only depend on consumption, since "common energy" factor in equation (4) is set to zero. Result is shown in next figure:

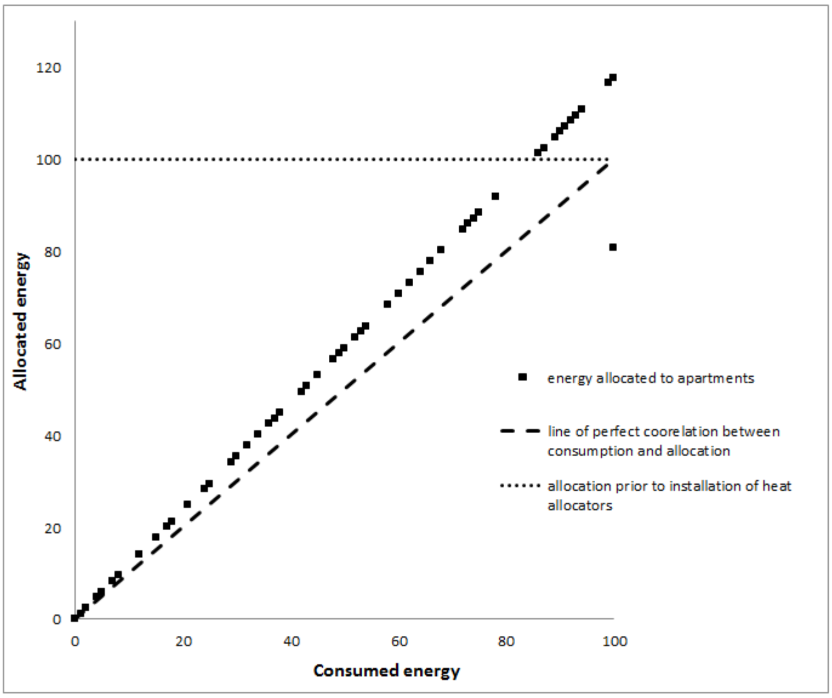


Figure 4. Comparison of energy allocation and energy consumption.

As we can see in Figure 4, energy allocation for all apartments (except for one type) are greater than actual consumption of energy, and for a number of them (those apartments with heat allocator that do not consume the least amount of available energy), even greater than value allocated prior to installation of heat allocators. Only type of apartment that benefits form formula is that without heat allocators, marked with square beneath line of perfect correlation.

CONSTRUCTION OF NEW FORMULA FOR ENERGY ALLOCATION

It is a fair question if anomalies described in last section could be avoided. Could we construct better formula which operates under same assumptions as current one, but produces no irregularities? In this section we will show that this construction is possible. New formula will work under same assumptions as current one, but it will always allocate less energy (per square meter) to an apartment with heat allocators installed than to one without allocators. Also, it will assure that energy allocated to an apartment with heat allocators is less than allocation prior to heat allocator installation. Both of those demands are valid; it is reasonable to assume that energy consumption in apartments without heat allocators is maximal, so no apartment with heat allocators, even with maximal consumption should not be allocated greater amount of energy. There is, also question of energy efficiency, but since there is no information of energy efficiency level of apartments in current model, it is only fair to treat apartments without heat allocators at least the same way as an apartment with heat allocator and lowest level of energy efficiency.

Basic idea of new formula for energy allocation is first to determine ratio between energy allocated to households with and without allocators, and after that to make correction toward energy totals, while keeping established ratios. To do that we will need following labels:

- $BI_i^p = BI_i / P_i$, which we will call "weight index", and which gives us measure of number of impulsses relative to area of an apartment, where i ranges from 1 to m,

- $BI^p_{\max} = \max_i \{BI^p_i\}$, or "maximal weight ind", which gives us maximal value of weight index among apartments with heat allocators instaled,
- $U_i = BI^p_i / BI^p_{\max}$, index needed for determening energy allocation for an apartment with heat allocators. It gives us ratio of its apartment weight index compared to maximal weight index among all such apartments.

We start from division of energy into two parts, one for households with allocators, and other for households without one, as follows:

$$\sum_{i=1}^{m} E_i + \sum_{i=m+1}^{k} E_i = \sum_{i=1}^{m}\left\{E_{\mathrm{ZJ}} \cdot \frac{P_i}{P_{\mathrm{SSUC}}}\left[\frac{U_{\mathrm{POV}}}{100} + \left(1 - \frac{U_{POV}}{100}\right)\cdot U_i\right]\right\} + \sum_{i=m+1}^{k} E_{\mathrm{ZJ}} \cdot \frac{P_i}{P_{\mathrm{SSUC}}} \cdot \left(1 + \frac{U_{\mathrm{ST}}}{100}\right). \quad (5)$$

In expression (5) we find basic relations between energy allocated to households. Both allocations have same expression, $E_{\mathrm{ZJ}} \cdot P_i / P_{\mathrm{SSUC}}$, which is a part of energy proportional to apartments area, multiplied by different factor.

In the case of apartments without heat allocators, that factor equals to $1 + U_{\mathrm{SZ}}/100$. Since factor U_{ST} can be changed and proscribed at desired level, it gives us possibility to determine a level for which factor for allocating energy will be greater than 1.

On the other hand, in the case of apartments with heat allocators, basic energy value is multiplied with $U_{\mathrm{POV}}/100 + (1 - U_{\mathrm{POV}}/100) \cdot U_i$, which is convex combination of two values, value 1 and value U_i. Since U_i is ratio of nonnegative values where nominator is surely less or equal to denominator, U_i has value less than 1. Therefore, convex combination of 1 and U_i cannot be greater than 1.

This leads us to conclusion that area proportional value of energy for an apartment with heat allocators will be multiplied by factor less than 1, while the same area proportional value for an apartment without heat allocators will be multiplied by factor greater than 1. So, expression (5) establishes relation between energy allocated to apartments with and without heat allocators in which energy (relative to its area) allocated to an apartment with allocators is less than energy allocated to an apartment without heat allocators (relative to its area). This satisfies elementary sense of justice – a household which saves energy should not pay more than one that does not.

Problem with expression (5) is that while it preserves desired relations between households, there is no guarantee that its value equals to energy E_{ZJ}, so in present form could not be used for allocation of total energy, E_{ZJ}. What expression (5) needs is linear adjustment, which will preserve relations among its components. Therefore, we denote value of the expression (5) with E_1,

$$E_1 = \sum_{i=1}^{m}\left\{E_{\mathrm{ZJ}} \cdot \frac{P_i}{P_{\mathrm{SSUC}}}\left[\frac{U_{\mathrm{POV}}}{100} + \left(1 - \frac{U_{POV}}{100}\right)\cdot U_i\right]\right\} + \sum_{i=m+1}^{k} E_{\mathrm{ZJ}} \cdot \frac{P_i}{P_{\mathrm{SSUC}}} \cdot \left(1 + \frac{U_{\mathrm{ST}}}{100}\right).$$

and calculate factor U_{ZJ} in following way:

$$U_{\mathrm{ZJ}} = \frac{E_{\mathrm{ZJ}}}{E_1}.$$

Now, we have factor, which by multiplying summands in expression (5) gives us allocations with sum E_{ZJ}, but with desired mutual relations. Therefore, for apartments with heat allocators installed, we calculate energy allocation by formula:

$$E_1 = E_{\mathrm{ZJ}} \cdot \frac{P_i}{P_{\mathrm{SSUC}}} \cdot \left(1 + \frac{U_{\mathrm{ST}}}{100}\right) \cdot U_{\mathrm{ZJ}}, \quad i = m + 1, ..., k. \quad (6)$$

For apartments with heat allocators installed, we use following formula:

$$E_1 = E_{ZJ} \cdot \frac{P_i}{P_{SSUC}} \cdot \left[\frac{U_{POV}}{100} + \left(1 - \frac{U_{POV}}{100}\right) \cdot U_i \right] \cdot U_{ZJ}, \quad i = 1, ..., m. \tag{7}$$

If we want to describe formula construction, we would call this construction "bottom-up". Instead of determining totals first, new formula establishes relation between allocations for each apartment, and then extends or shrinks totals so they would fit total consumed energy value. In following figures we can see results of simulations made under same conditions as those in Figures 1, 2 and 3.

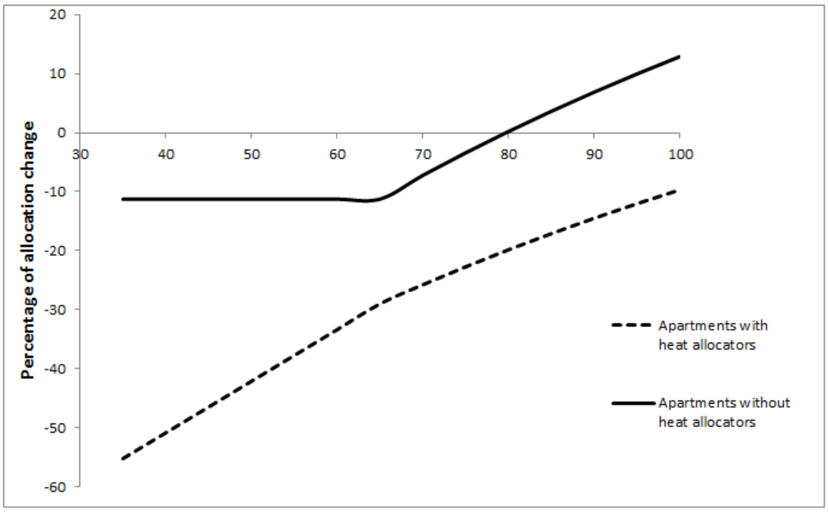


Figure 5. Comparison of energy allocation by proposed formula on 80 % consumption level.

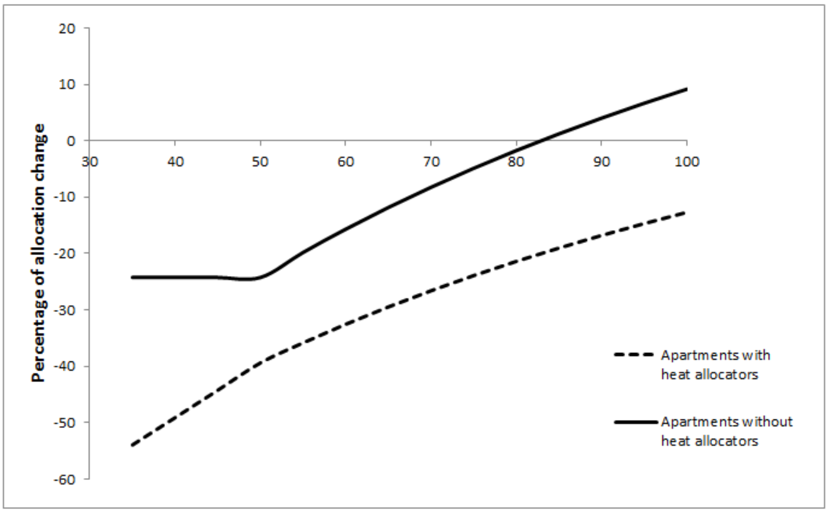


Figure 6. Comparison of energy allocation by proposed formula on 50 % consumption level.

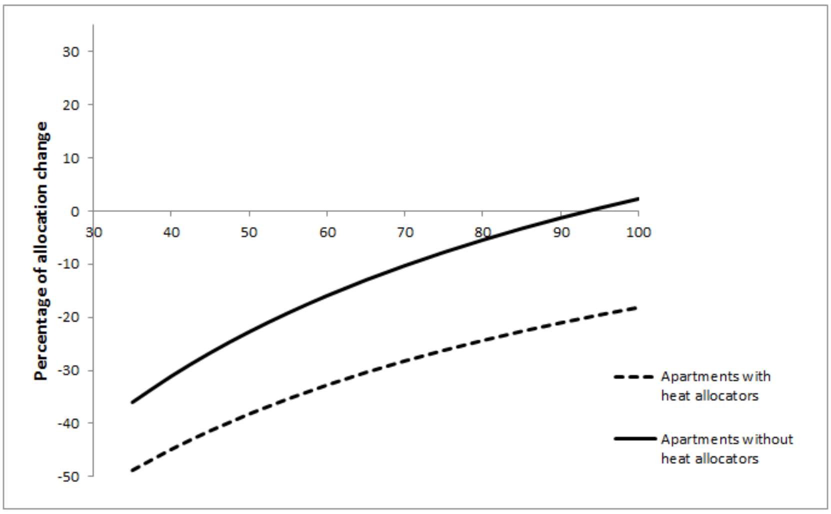


Figure 7. Comparison of energy allocation by proposed formula on 30 % consumption level.

As we can see in Figures 5, 6 and 7, energy allocated to apartment with heat allocators installed is always, as expected, lower than energy allocated to apartments without one. Even more, gap between two values can be moderated by choosing different values for factor U_{ST}. Furthermore, we can see that energy allocated to apartment with heat allocators does not cross x-axis in any simulation, that is, energy allocated to it is smaller than prior to installation of heat allocators. This is consequence of allocating more energy to apartments without allocators than it is proportional to theirs area share. This results with lower amount of energy total which is allocated to apartments with heat allocators. Nevertheless, this property of energy allocation would not hold in real life scenarios, since all energy consumption in simulations are proportional to an apartment's area. There is hidden assumption that all those apartments have same energy efficiency, which is not necessarily so.

When comparing results of simulations with random energy consumption (see Figure 4) of current formula with proposed one, we can also notice improvement.

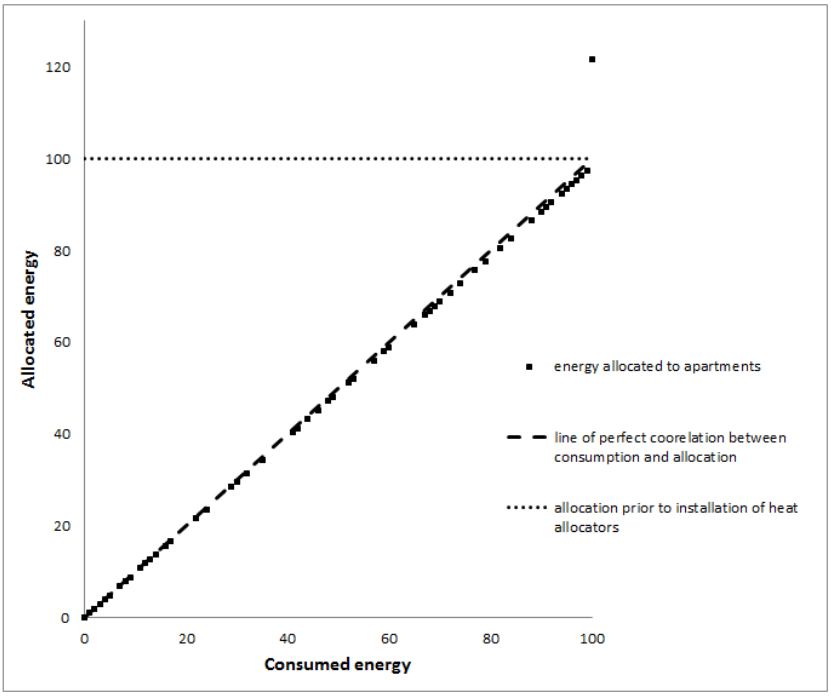


Figure 8. Comparison of energy allocation and energy consumption according to proposed formula.

Correlation between energy consumption and energy allocation is this time almost perfect. This is consequence of setting maximal impulse consumption BI^{p}_{max} as a basis for energy allocation. Apartments with heat allocators are allocated energy proportional to its relation to BI^{p}_{max}, while apartments without one are allocated greater amount (for a factor U_{ST}) of energy than apartment with maximal impulse consumption. Since, there is fair chance that one of the apartments with heat allocators uses (almost) all available energy, correlation in simulations becomes almost perfect. Isolated point above line that represents allocation prior to installation of heat allocators represents energy allocated to apartments without allocators. Again, gap between those two values can be moderated with value of U_{ST}.

Understanding why proposed formula works well in a given situation can lead us to conclusion when and why its results are not same level. As said, existence of at least one apartment with consumption remarkably higher than average consumption of apartments with heat allocators, enables formula to establish desired relations between apartments with heat allocators and apartments without one, since apartment with highest relative impulse consumption is set as one with consumption of all available energy (for that apartment). If apartments with heat allocators were all consuming exactly the same amount of energy (relative to its area), formula would lose its important benchmark. In that case, proposed formula would be unable to distinguish different levels of average consumption – it would treat them as same (since impulses are not normalized to some energy level); only difference would come from indirect influence of different energy totals. Let us see how proposed formula is working under those conditions. In following simulations all apartments with heat allocators were set to equal (relative) energy consumption, and "solidarity" factor U_{POV} was set to zero, so we would emphasize influence of consumption part of formula.

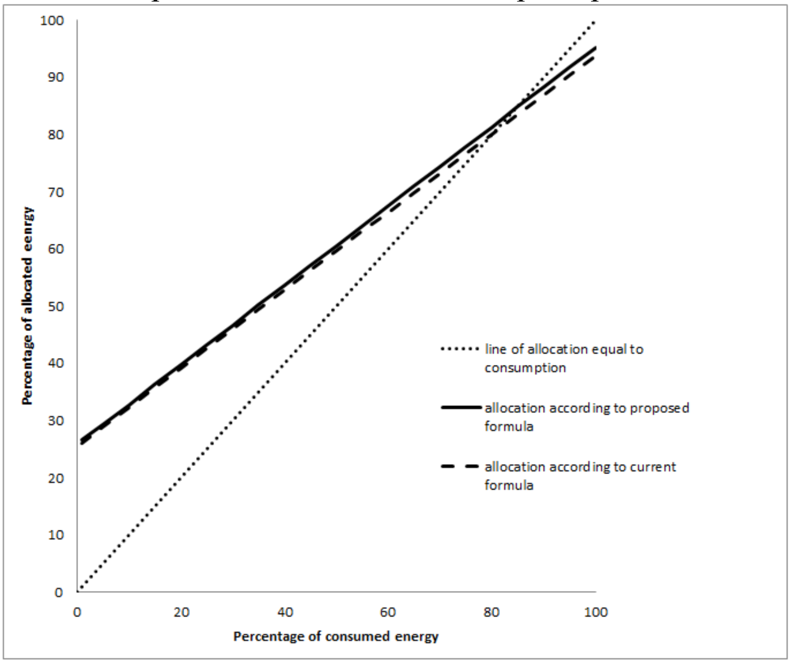


Figure 9. Comparison of current and proposed formula effects in "worst case scenario".

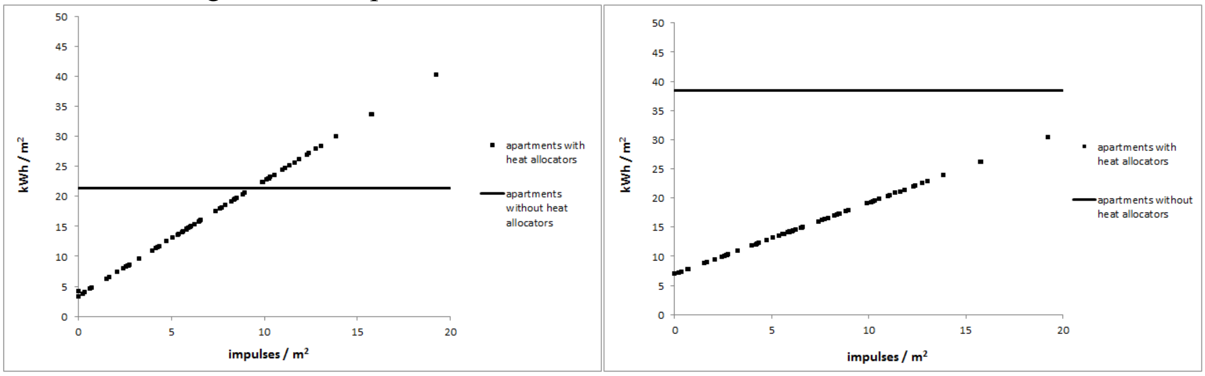
As we can see in Figure 9, if we take into account highly unlikely consumption distribution, in which all apartments with heat allocators consume exactly same percentage of available energy, proposed formula gives results significantly worse than those presented in Figure 8. Again, we stress unlikelihood of that scenario, since neither all apartments can have same energy efficiency, even if all its residents decide to use same percentage of available energy.

Even then, as shown in Figure 9, results of proposed formula equal to those of formula in current use, so even then usage of proposed formula would not give worse results, but the same as now. But in vast majority in situations, in which at least one apartment have higher consumption than average, proposed formula gives better result.

TESTING THE FORMULA ON REAL DATA

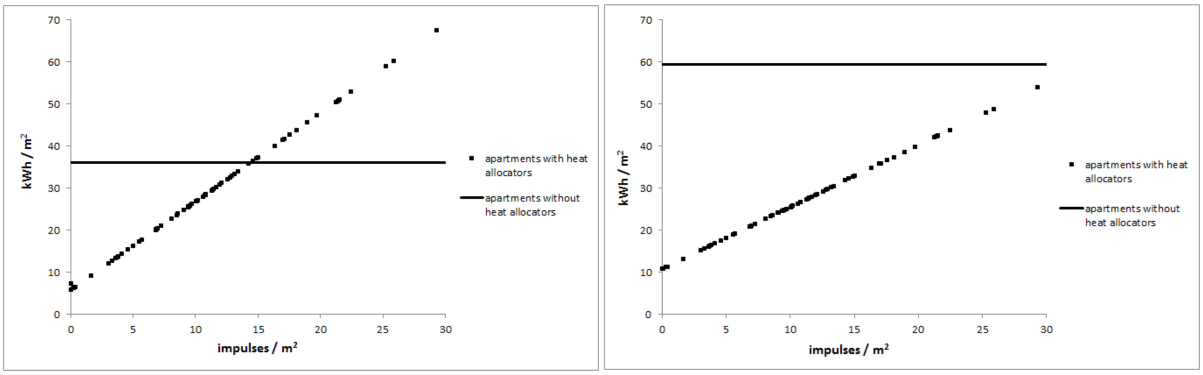
Through the article we were dealing with simulations, which cannot give us complete picture of how formula works. For instance, one of underlying assumption in all simulations was that all apartments consume energy proportional to its area; that is, all apartments have same energy efficiency. That, of course, does not have to be so. That is why it is useful to test formula, both current one and proposed one, on real data, to see how they behave. First we will present data obtained in city of Rijeka, Croatia, in apartment building located on Ivana Lenca 28, during January, February and March of 2012.

As we can see on left side of Figures 10, 11 and 12, significant number of apartments (to be precise, 21 in January, 18 in February and 22 in March out of 73 apartments) is allocated greater amount of energy than one allocated to apartments without heat allocators. One of them (dot in a upper right corner) is allocated four times as much energy per square meter in March! Current formula also gives one more surprising result; there are apartments with highest relative energy consumption, which are allocated approximately 70 kWh/m^2 in February and March of 2012. But in February we find that apartment to consume 30 impulses per meter squared, while consumption in March equals to 10 impulses per meter squared. On the other hand, proposed formula marks difference between those consumptions, with higher allocation for higher consumption.



Current formula Proposed formula

Figure 10. Comparison of allocated energies for an apartment building in city of Rijeka, based on measuring taken in January of 2012.



current formula proposed formula

Figure 11. Comparison of allocated energies for an apartment building in city of Rijeka, based on measuring taken in February of 2012.

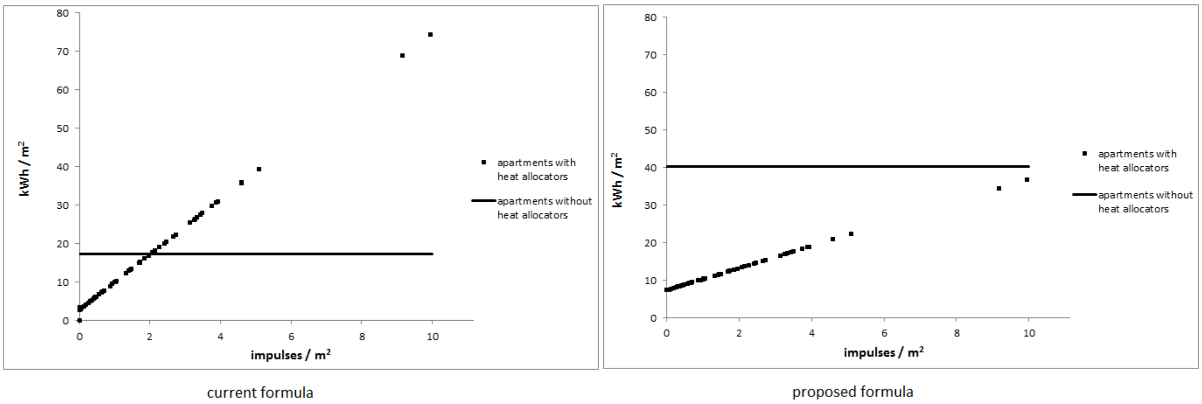


Figure 12. Comparison of allocated energies for an apartment building in city of Rijeka, based on measuring taken in March of 2012.

If we use proposed formula for same data, we find all apartments with heat allocators have less energy allocated than apartments without one. Furthermore, since greater number of apartments is allocated maximum energy (all apartments without allocators, as opposed to an apartment singled out in first distribution), spread of allocation is narrower. In this case, apartments with area of 94 % of total area have heat allocators installed. For both calculations $U_{POV} = 20$ is used, while U_{ST} is set to 25 in current formula, and to 10 in proposed formula.

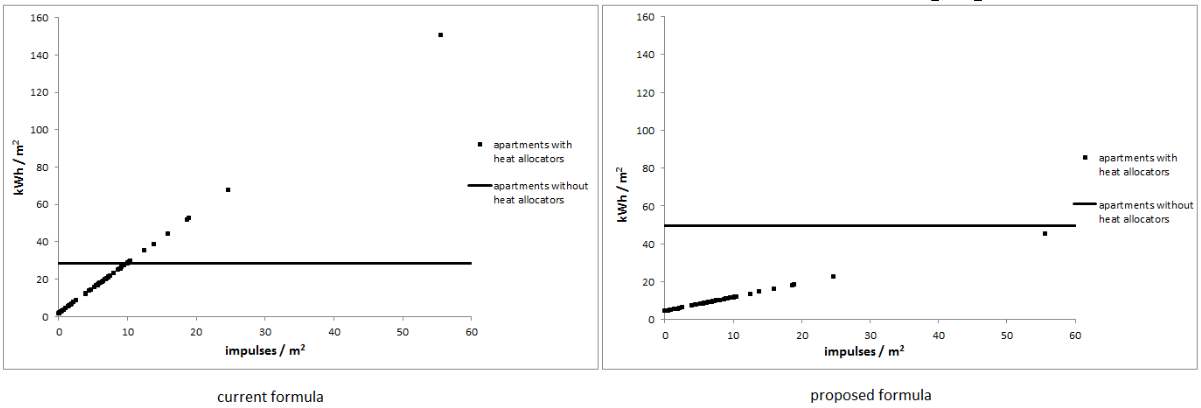


Figure 13. Comparison of allocated energies for an apartment building in city of Slavonski brod, based on measuring taken in December of 2012.

Same behavior we find in results of formulas calculated over data collected on measure position “Centar 4” in city of Slavonski brod in December of 2012. Parameters used in calculation are the same as those in calculations for Rijeka example. In this case, apartments with heat allocators account to 67 % of total area. Once again we can see that energy allocation for a number of apartments with heat allocators is higher than allocation to apartments without one. One of them is allocated four times more energy. Proposed formula, once again tone down extremes, with allocation to all apartments with heat allocators lower than those without one. It is noticeable that highest energy allocation according to current formula equals to 150 kWh/m^2, while with proposed formula it is 50 kWh/m^2.

CONCLUSIONS

One of the main goals of energy allocation model in multiple-occupancy residential buildings is developing “the formulas for conversion from measurement to allocation which would adjust the allocation for unmeasured parameters in accordance with the concept of equal payment for equal thermal comfort amenity” as stated in Guidelines of American Society of Heating, Refrigerating and Air-conditioning Engineers Inc [4; p.8]. Guidelines propose several methods of evaluation for share of energy consumed by non-monitored apartments. Guiding principle should be allocation of energy as close as possible to actual consumption. Unfortunately, results of simulations and data testing in this article shows that formula currently in use in Croatia does not seem to do this very well.

Both simulations and data testing showed that current formula through allocation favors non-monitored apartments, at the expense of part of monitored apartments with higher relative consumption. Proposed formula, on the other hand, sets different method of calculation; by starting with relation between allocation for monitored and non-monitored apartment, it builds "bottom-up" energy totals, which is in the end corrected to an actual energy total consumption. This method is recognized in ASHRAE Guideline, which states: "The estimates of monitored energy use, losses, auxiliary energy, and non-HVAC loads described in the preceding two paragraphs are unlikely to add exactly to the estimated total primary HVAC energy use. The two estimates should be adjusted to sum to total primary HVAC energy use, using for guidance such objective criteria as expected seasonal trends in monitored use, losses, and non-HVAC loads."

It is our belief that proposed formula is giving dynamic way of estimation of energy consumed by monitored and non-monitored apartments, which are then adjusted (by factor E_1) with total consumption. Result of such dynamic formula, which does not uses prescribed factors for consumed energy fractions, are allocations that work well in different types of consumption – with ones with low level of consumption, just as well as with ones with high level of consumption; something that proscribed energy allocation cannot deal with. We hope that this model will eventually help in construction of better models for energy allocation in complex systems with partial distribution of monitoring energy consumption.

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MODEL ALOCIRANJA ENERGIJE U SUSTAVIMA GRIJANJA S PARCIJALNOM DISTRIBUCIJOM RAZDJELNIKA TOPLINE

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SAŽETAK

Više od 150 000 kućanstava u Republici Hrvatskoj se grije putem centralnih sustava opskrbe toplinskom energijom. Većina tih potrošača priključena je na zajedničko brojilo utrošene energije, koje je locirano u toplinskoj stanici u zgradi. Najvećim dijelom radi se o zgradama građenima prije 2001. godine, tako da toplinske instalacije nisu predvidjele ugrađivanje kalorimetra kojim bi se mjerio utrošak toplinske energije u svakom stanu zasebno. Kako bi se uvela pravednija raspodjela troškova grijanja, koja bi bila u proporciji sa konzumiranim dijelom toplinske energije, uvedena je mogućnost ugradnje toplinskih razdjelnika, koji se prema zakonskim odredbama moraju ugraditi stanovima čija ukupna površina premašuje 50% ukupnih grijanih površina priključenih na zajedničko mjerilo. U ovom se radu analizira formula koja alocira dijelove energije stanovima sa ugrađenim toplinskim razdjelnicima, prvenstveno u usporedbi sa energijom alociranom stanovima bez ugrađenih razdjelnika. Također, u radu je izložena konstrukcija nov formule za alokaciju energije u opisanim sustavima, te su njezini rezultati uspoređeni sa rezultatima formule u upotrebi.

KLJUČNE RIJEČI

sustavi grijanja, distribucija energije, alokacija energije