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Uncertainty of Energy-saving Measures

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Abstract

Increasingly, there is talk of energy savings in buildings. Several programs have been outlined to help reduce energy consumption. Most energy measures are done based **on** energy savings achieved. That is, reducing energy expenditure on heating compared to the original state. The second aspect emphasizes the cost of the measures being implemented.

Since energy-saving measures are being made based **on** a simplified model of the building, the result of the measure's effectiveness is the most inalienable. This uncertainty can greatly affect the return on investment in the measure and should influence the adoption of the proposal.

The main objective of the thesis is to evaluate the impacts of uncertainty on the calculation of energy savings. Show areas of uncertainty, primarily to identify input data that is burned by uncertainty. Another task is to identify the main causes of the uncertainty of the result. And to suggest possible measures that would lead to a better description of the situation, a description of the model needed and the compilation of the necessary input data.

Part of the text is to propose and evaluate uncertainty assessment approaches in the calculation of energy measures. View benefits and disadvantages of these approaches and choose the optimal approach. Using this text, it is possible to choose the appropriate method of the procedure for determining the uncertainty of the result of the proposed energy-saving measures.

Keywords

Building energy economy; energy efficiency of buildings; energy poverty, household expenses.

Introduction

The European Union and its Member States have committed themselves to implementing the EPBD II into their legislation. Part of the directive are procedures for assessing the energy performance of buildings. These procedures are used as an essential approach to designing energy-saving measures. Based on the results of the calculation, the measures are compared and evaluated. It is therefore necessary to know as precisely as possible the exact result of the measures [1].

However, it is necessary to consider the values of the values given in the given equations. If inaccurate data is inserted into the specified procedure, it is not possible to achieve the exact result. The inaccurate result distorts the reality of the proposed measures and cannot be decided correctly. The possible variants of the solution will be compared in the text and their advantages and disadvantages will be shown [2, 3].

Another aspect that determines the best option is the price and especially the return on investment. Therefore, not only the achieved energy savings are evaluated, but also the price of the given measure, which is compared with the financial return in the form of savings of energy costs.

When choosing the right austerity, it may seem that the costlier the value is, the greater savings will be made. This view considers the final energy consumption. A more important factor than final energy consumption is the consumption of non-renewable primary energy.

Calculation model

Several factors influence the calculation of energy measures, which affect the final evaluation of the proposal. If we evaluate the proposal only from an energy point of view, it is always necessary to count the data that most accurately describes the given condition of the object and then the proposed modifications. Any deviation from reality leads to a misstatement of the result, which then loses its usefulness [5, 6].

Existing buildings, especially older construction times, are made from a variety of materials. Physical values of these materials are often diverse and not standardized. Because there may be a deviation of the model from the actual state that influences the evaluation of the design result.

Actuality of input data

Costs of work carried out and the prices of materials used for the proposed measure give rise to deviations during construction. For every return proposal, you need to know the most accurate price. Since there are many materials in the market and many building materials manufacturers and resellers can be selected, they must be individually tailored for each calculation.

Prices vary considerably from one store to another. The impact on this award has many aspects. For very small stores, low prices cannot be expected, because in small quantities the store is unable to get low prices from suppliers for quantity and other benefits. Suppliers of the same type of material are many, and are therefore overtaken in various discounts, promotions,

For building materials, the notion that shopping in the internet store is often cheaper is often not the case. Also, the so-called list prices on websites or in printed catalogs are often informative only and the final price is decided by the quantity of consumption, the distance of imports and the region or even the district of collection. For retailers, prices are also affected by many aspects. Construction materials with a large turnover of material receive rebates for taking a large amount. Another influence on the price of individual types of materials also has a location, because the use of building materials varies considerably between regions and districts and this is also affected by the price [7].

As the Inventory of Cost Optimum Buildings Inputs Study shows, the prices of materials purchased in the building often differ from those listed in the pricelist. When designing an energy measure and calculating its return, uncertainty is induced into the calculation. The up-to-date price lists should be kept up to date.

Methodology

Firstly, important aspects of the energy measure are identified. The most frequent variants of austerity measures will be compared and the uncertainties of the input data will be evaluated. The input data of the calculation will be compared in terms of availability of the data, measurement and adaptation to the given object and the proposed measure.

Uncertainties of the calculation are divided into three categories. The first important category is the uncertainty of creating a model of the current state where the model is drawn from reality. The second category is austerity measures. Here the uncertainty is caused by the difference between the proposal and the actual implementation of the proposed measures. This category is related to the third one, which is influenced by the behavior of the user. In the last category, there are values that add uncertainty to the last part of the calculation, including the return calculation.

**Uncertainty of the current status of the object**

A comparative methodology framework from Member States requires that:

* identify reference buildings characterized by their functionality and geographic location, including external and internal climatic conditions,
* identify the energy efficiency measures to be assessed for reference buildings,
* Evaluate the need for final and primary energy of reference buildings and reference buildings for which energy efficiency measures are being implemented,
* Calculate the cost of energy efficiency measures during the assumed economic life cycle, using the principles of the comparative methodological framework.

Equation to determine the monthly energy requirement

$Q\_{H,nd}=Q\_{H,ht}-ɳQ\_{H,gn}$ (1)

$Q\_{H,nd}$ monthly energy demand

$Q\_{ht}$ monthly heat losses

$Q\_{gn}$ monthly heat gains

$ɳ$ factor of usability

The previous equation shows the basic equation for calculating the monthly energy requirement of the object state. The equation is given in ČSN EN ISO 13790. If the savings of the proposed measure are to be calculated, it is necessary to compare the monthly balances of the two variants.

$Q\_{Save}=Q\_{H,nd, actual}-ɳQ\_{H,nd, variant}$ (2)

$Q\_{Save}$ monthly energy savings of the proposed variant compared to the current state

$Q\_{H,nd, actual}$ monthly energy demand of the current state

$Q\_{H,nd, variant}$ monthly energy demand of the proposed variant

Uncertainty of proposed variants

The uncertainty of the proposed variants depends on the precision of the choice and description of the materials, products and construction methods used. The uncertainty of the design values can be caused by a construction site where deviations from the design may occur.

The second category is the uncertainty of the properties of individual materials. These can be caused by laboratory tests, where the properties of materials are determined, or can result in poor work and failure to comply with technological procedures.

The temperature that is entered into the calculation is the uncertainty caused by measuring the temperatures of the current state, which can lead to the design of temperatures for the proposed measure. Uncertainty in outdoor temperatures is due to the averaging of monthly temperatures applied to the current year, the difference in these temperatures can cause great uncertainty over the total heat demand. The uncertainty of the internal temperature is due to the inaccuracy of the thermostat measurement and also to a certain delay of the heating system.

Values of price indicators

After the calculation of the annual energy balance of the current state and condition with the proposed austerity measures determines the energy savings, it is possible to determine the return of the given proposal. Discounted payback time for a given proposal is calculated as:

$DPP\gg 0=-I+ \sum\_{n}^{DPP}\frac{Q\_{save}\*C\_{Q}}{\left(1+i\right)^{n}}$ (3)

$I$ investment of the measure

$C\_{Q}$ energy price (based on saved energy and given time period)

Attributes that bring uncertainty to the return on the project:

* Uncertainty of the amount of the investment,
* The uncertainty of the energy savings of the proposed measure
* Uncertainty of energy prices

**Aspects of user behavior**

One of the categories of calculation that has a significant impact on energy saving measures are aspects of the behavior of the household that uses the object. In particular, the heating method, the heating cycle length, the internal temperature and the intensity and the way of ventilation are affected.

Mechanization of ventilation will reduce the magnitude of the uncertainty of the input data, but especially in older buildings where ventilation mechanics is not and is not even standardized is one of the largest areas of uncertainty.

User behavior increases the uncertainty of the following input data for the energy savings of the object:

• Indoor temperature,

• Intensity and length of ventilation,

• Heating mode

Possible methods for determining uncertainty

The following text summarizes the possible methods of calculating uncertainty about energy savings and returns. After comparing methods, it should be possible to determine the appropriate method for use on the model.

A suitable model should instead indicate the uncertainty of its result, which be:

* Average value + deviation

$$X\pm δ\_{X}$$

* The range in which the result will move

$$X\_{minimal}\leq X\leq X\_{maximal}$$

Use of statistical data and their deviations

One way to determine the uncertainty of a given result is to use statistical data. Measures already taken will be evaluated and a comparison made with the proposals under which the measures were implemented. The difference in the values is determined by the deviation. A database of measures and their proposals will be created.

For new proposals, the database always chooses measures that fall into the same category as the new design. Based on the similarity of the measure and the package for which the measure is proposed, a likely variation of the result is determined.

The disadvantage of this solution is the need for a large amount of data and its manipulation so that it can be used to determine uncertainty. At the same time, the next model would be the most absent, which would be caused by mere comparison of cases, and the uncertainty would not have to correspond directly to the case, only to the statistical average.

Use of the methods specified directly for the calculation of the measure

The first statistical method did not work directly with the calculations, but only based on the similarity based on the previously stored statistical data. Its advantage was that it worked with the real results achieved by austerity measures. The following methods, on the other hand, are based directly on the calculation of the energy balance and the calculation of the return on investment. They are adapted to copy the calculation, and based on the deviations of the input data, they count the uncertainty of the result. Unlike the previous method, they depend on determining the uncertainty of the input data, which must be determined by the developer of the calculation.

The disadvantage of these methods is also the fact that they are fully dependent on the accuracy of the given equations, according to which the resulting value is calculated. If the calculated computational model is inaccurate and does not correspond exactly to reality for simplicity, another uncertainty is recorded in the result. The statistical method eliminates this uncertainty.

The Monte Carlo method

The Monte Carlo method uses statistical data that is created for each input parameter of the calculation. This creates a sufficient database of data that matches the input values. Based on the determined scatter of the input values, a set amount of data is created. These data are then processed according to the specified calculation procedure.

The disadvantage of this method is the need to create a large database of input data. All data is then combined with other generated input data, and a large number of results are calculated that are statistically processed. The method allows input of various model input data distributions. There is a need for a special generator and algorithms that would include all the data in the calculation.

Analytical uncertainty analysis method - Error Analysis

The uncertainty propagation analysis method is based on the fact that, for values having independent uncertainties, the second power of the total uncertainty is the sum of the second powers of uncertainty. Independent uncertainty can be understood as a value that is independent of uncertainty. It is based on the theory that there is little probability that both values will have an extreme variation and therefore the overall uncertainty is reduced.

According to the basic formula for calculating the uncertainty, the result can be determined as the square root of the sum of the second powers of the sum of the uncertainties of the individual variables and the derivation of the function according to the same variable.

The advantage of this method is work directly with defined calculation formulas. Unlike the Monte Carlo method, it is not necessary to generate enough input data and there is no need to generate algorithms to process these data. The disadvantage of the method is to consider only the normal distribution of uncertainty in the input data. The input data are thus determined by the mean value and the deviation.

The calculation equation should be supplemented by additional equations that calculate the partial uncertainties for each partial calculation result.

Results

One of the basic ideas of the thesis was the reflection on the accuracy problem of the calculation, which is predetermined by the national and European standards. Distorted data that we cannot be certain about, and for this reason the effect of this uncertainty of input variables on the uncertainty of the result has to be determined.

The uncertainty of the result can be calculated at each input. Some inputs are more likely to occur. Because return on investment in austerity measures works with several models, it is necessary to consider the uncertainty of each of them.

The model that will process the uncertainty calculation must have such parameters to be able to account for uncertainty inputs at the following points:

* Existing condition
* Measures proposed
* Return on investment

Evaluation of calculation methods:

Statistical method

* Works with real realizations
* It is necessary to have a sufficient data base
* The uncertainty of the new proposal is only

The Monte-Carlo method

* Works directly with computational equations
* You must create a database of input values
* Algorithms that process data are required to calculate the uncertainty of the result

An uncertainty spreading analysis method

* Works directly with computational equations
* Only the mean and deviation are counted
* It is necessary to change the calculation equations

Knowledge of sufficient decay is necessary in every design of the energy measure. However, greater emphasis on the transfer is necessary when energy savings after energy measures are used as a source of finance for repayment of the loan. This method is possible in addressing energy poverty. In these cases, the calculation must be accurate and the household cost should not be increased. It is necessary to calculate the resulting savings so precisely that they can be used to repay the investment.

Conclusion

The basic data obtained in the work are the values of calculations of energy-saving measures, which we cannot determine with certainty and with uncertainty. By using a legislative calculation of the energy balance of the object and the selected input data, it is possible to determine equations that need to be adjusted to allow for an expanded calculation. It is important not only to calculate the mean value of the estimate, but with the adjusted equations, it is possible to calculate the deviation of the result.

Using predefined limits, it will be possible to decide on the suitability of the calculation process and to indicate its suitability for further decision making. If the resulting uncertainty value exceeds a predefined threshold, it will be possible to determine the input data to be specified and obtained, so a more accurate calculation and decision-making bases.

This study should be followed by further studies to determine the suitability of individual methods of calculating the uncertainty of the result. It is necessary to evaluate the pros and cons of methods and to determine the method that is most suitable for the calculation mode. This model should determine the uncertainty of the result based on the uncertainty of the input data.

The proposed tool should allow to calculate the total heat consumption balance based on total internal gains and total heat losses. The most ideal method, which would be sufficiently detailed, would be monthly calculation of the heat demand and calculation of the discounted return time. Thus, the user of the calculation model would determine not only the mean value of the input values, but also determine the uncertainty of the given value. Uncertainties should be determined either on the basis of an individual approach or it would be more appropriate to provide an ancillary table to determine the uncertainty threshold.

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References

1. Official Journal of the European Union (2012). DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL: on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.
2. Taylor, John R.. An introduction to Error Analysis. Sausalito, California: University Science Books, 1997, ISBN 978-0935702750
3. Ronald W. Shonkwiler, Explorations in Monte Carlo Methods, ISBN 978-0387878362
4. Rademaekers, K. at al. (2016). Selecting Indicators to Measure Energy Poverty: Final Report, Rotterdam: European Commission, DG Energy. Available at: <https://ec.europa.eu/energy/sites/ener/files/documents/Selecting%20Indicators%20to%20Measure%20Energy%20Poverty.pdf>
5. ČSN EN 15 459 Energy performance of buildings - Procedures for the economic evaluation of energy systems in buildings, 2010
6. ČSN EN ISO 13790 Energy performance of buildings - Calculation of energy consumption for heating and cooling, 2009
7. MPO, 2016, Updating cost optimal building inputs, <http://www.mpo-efekt.cz/upload/7799f3fd595eeee1fa66875530f33e8a/aktualizace-nakladoveho-optima-v10.pdf>
8. Error Propagation. Lectureonline. [online]. [vid. 11. 10. 2014].: <http://lectureonline.cl.msu.edu/~mmp/labs/error/e2.htm>