

ENERGY AUDITS IN DWELLING BUILDINGS IN LATVIA. DATA ANALYSIS

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SUMMARY

Experience of energy auditing of residential buildings in Latvia discovers problems with discrepancy of data measured and calculated. Analysis of dynamic changes of data presents factors, which influence results of energy audits and proposals for energy efficiency measure. Paper presents analysis of influence of solar radiation and modelling of solar factor for control of heat supply.

Keywords: Energy audits, energy consumption, residential buildings, data analysis, solar energy

1. INTRODUCTION

Implementation of energy audit of buildings in different countries has made valuable contributions into development of political and legislative documentation both for separate countries and for European Union in general. Energy audit becomes more and more popular also in Latvia. The process of audit implementation has especially intensified since the directive of European Union “Energy Performance in Buildings” was published and legislation was adjusted according to the directive. A law for energy efficiency, which would help to introduce the energy efficiency activities implementation system in Latvia, was developed.

Full data analysis is the main precondition for energy consumption reduction in buildings. Energy audit of buildings can be considered as a part of a complicated investigation of a building, which is performed in order to define indexes of energy use in a building and to determine possibilities to reduce the energy consumption volume. Energy audit is necessary for composition of a renovation plan for the building. Currently, there are several barriers for a quick implementation the energy audit system for buildings. They are mainly related to the lack of information and economical issues. That is why for an energy auditor it is important not only to collect data and information and to analyse it. Today there is a unified form for energy audit reports in Latvia. Use of energy audit reports can vary.

- “Quality” of energy use of a building is evaluated in an energy audit report. Energy passport of the building can be annexed to the report, as well as nominated energy marking. These documents are important for evaluation of the market value of a building and an apartment. In case if the building is for sale, a buyer will give priority to a more comfortable building with lower energy consumption level.
- Evaluation of energy efficiency increasing activities is performed as a result of an energy audit. The owner of a building can lower payments related both to energy consumption and to other issues by implementing the suggested promotions.
- Energy audit report is the document on which basis the owner of a building can be positively evaluated for receiving a credit for the building renovation.
- In the future reducing of CO₂ emissions and other activities related to this process will become more and more important. Energy audit is one of the instruments that help to start the way to reduction of greenhouse effect gases in the atmosphere.

An important role plays precision and interpretation of the obtained data of annual (monthly or weekly) energy consumption’s divergence from the nominal value. The data is obtained using benchmarking method in similar buildings. A computer model “Ekomaja” for theoretical heat losses estimation is created. Then the reasons of data discrepancy are searched. On practice appears that the data obtained during energy audit do not concur with ones estimates in calculations for ~ 90%.

2. LEVELS OF ENERGY AUDITS

Energy audit can be done in more or less detailed way. Depending on the object that get audited and on the aims of the audit different audit methods can be used and different components can be added to the audition process. The structure of energy audit is also defined by the available for audit performance resources, documentation, and statistics about energy consumption of the audited building.

In Latvia building energy audits are performed using different approaches: there can be simplified methods or highly detailed analyses. The level of the audit's complicity chooses the client – the owner or the superintendent of the building. Table 1 shows three different levels of audits.

1st level is a basic level of an audit. Basic information about possibilities of water and energy economy is provided. It can be called “walk through” audit.

2nd level. Suggestions about water and energy economy activities are better founded than using the 1st level. Substantiation also includes analysis of specific measurements.

3rd level. Water and energy consumption level is analysed in details. Suggestions about water and energy economy activities and about the necessary investments for their realization are fully prepared for implementation.

Table 1. Levels of energy audit and approaches.

Level of Energy Audit	Approach									
	Specific Energy Consumption	General evaluation of technical systems and poll of the support stuff	Technical documentation	Poll of the building's residents	General measurements	Detailed measurements	Heating balance	Economy possibilities	General investment suggestions	Well-based investment suggestions
1 st level	x ¹	x						x		
2 nd level	x ¹	x	x	x	x		x ¹	x	x	
3 rd level	x ¹	x	x	x		x	x ¹	x		x

¹ Is possible only if water and energy meters are installed.

Using any of energy audit's levels an important condition is to define energy efficiency activities' priorities in every building. The analysis performed during building energy audit shows economic potential of the energy efficiency: technical activities are defined, evaluated in terms of finance, and divided into three priorities. Average anticipated investments are no more than 30 EUR/ m² and payback time is about within 15 years.

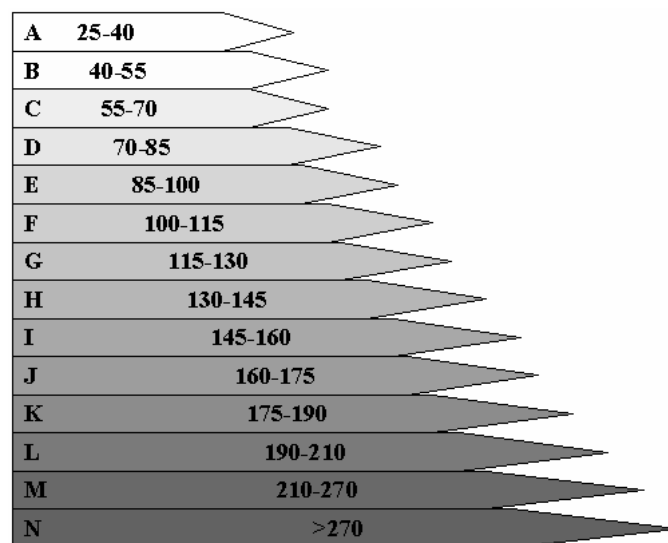


Figure 1. Labeling of buildings according to energy consumption, kWh/m² year.

3. BUILDING ENERGY CONSUMPTION DATA

Screening method is used for labelling of residential buildings in Latvia during last year. Energy labelling of residential buildings in Latvia are implemented for specific energy consumption. Labelling is realised according to data presented in Figure 1.

Energy auditing results in more than 200 buildings in Latvia allow using benchmarking for comparison of data in residential buildings and indicate problems connected with accuracy of data and restrictions in their use.

Data obtained in different energy audits in different regions in Eastern part of Latvia presents problem of discrepancy of data measured and calculated: ~ 90% of residential buildings shows difference. Reasons for that are different: human factors and climatologically conditions (solar and wind energy input), as well as technical reasons (constructions, materials, heating system etc.).

Regression analysis of proved energy consumption data versus heated area are presented in Figure 2. It illustrates bad correlation and therefore other factors have to be involved in analysis of data during energy audits.

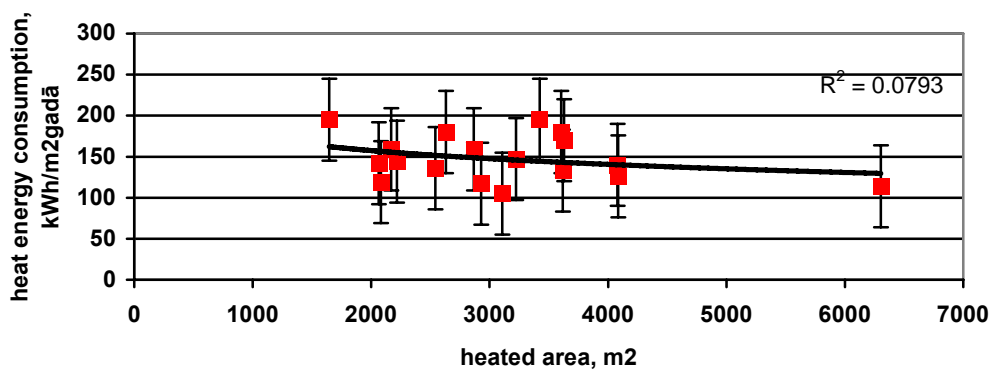


Figure 2. Regression analysis of energy efficiency data of residential buildings.

Benchmarking method, which was used for evaluation of various energy efficiency indicators, presents levels of values of specific energy consumption per unit (kWh/m²; kWh/m³, etc.). The value of energy efficiency indicators both provides numerical signs and gives the opportunity to compare different end users. For example, the specific energy consumption shows the size of energy consumer and their behaviour. Figure 3 shows the specific energy consumption of residential energy consumers by scoring levels.

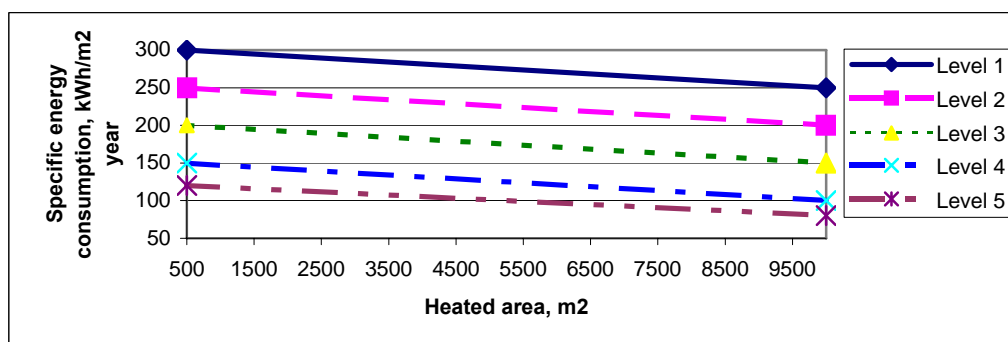


Figure 3. Assessment of residential energy consumption for space heating.

Analysis of data is continued for one of the large consumers by evaluation of hourly and daily energy consumption with control of heat consumption by outdoor temperature. Regression analysis of heat energy consumption versus outdoor temperature shows dissatisfactory correlation of data (see Figure 4).

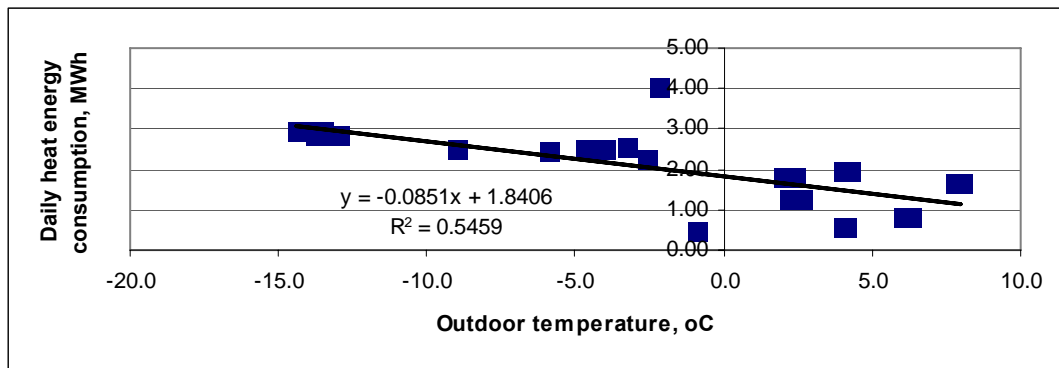


Figure 4. Regression analysis of daily energy consumption versus outdoor temperature in residential building. Case study.

Therefore one of the next steps is to find and start evaluation of influence of factor with dynamic changes. First of all such factor is solar radiation.

4. SOLAR ENERGY INPUT IN HEAT ENERGY BALANCE OF RESIDENTIAL BUILDING

One of the most important heat sources in a building is radiation of the solar. It depends on the location of the building according to the sky. Characteristics of the intensity of the radiation provided by Latvian Environmental, Geological and Meteorological Agency are shown in the Figure 5.

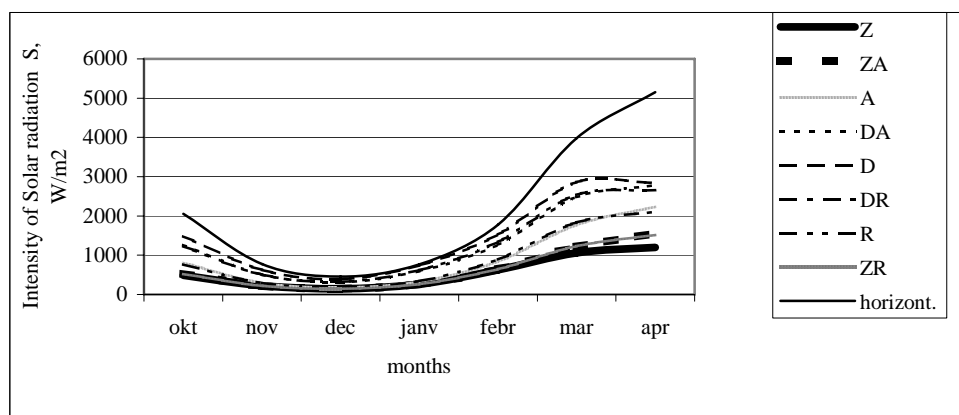


Figure 5. Average monthly solar radiation intensity on horizontal and variously oriented vertical surfaces.

The data about average monthly solar radiation intensity is obtained by adding total twenty-four hour values of solar radiation for one month in the conditions of average cloudiness. For investigation of the solar influence on building energy consumption average heating season values were used. Influence of the solar radiation on the heat balance of a building depends on two important values.

- Window glass cover solar factor. Influence of solar radiation on the heat balance of a building is influenced by window glass cover solar factor S , which is a part of total solar radiation volume that gets inside the building.
- Shading of the building. Solar radiation influence on the heat balance of a building is also dependant on this second essential factor – shading of the building factor. It describes how much of the building surface is covered by the obstacles disturbing access of the solar radiation.

Influence of the both factors on the heat balance of a building depends on the location of the building according to the sky; on the window glass cover density of the constructions, and on shading of the building. Interconnection of these values described in the following equation:

$$q_s = S_n \times (S_Z \times (F_{IZ1} \times S_{s1} + F_{IZ2} \times S_{s2} + F_{IZ3} \times S_{s3} + F_{IZ4} \times S_{s4}) + S_{ZR} \times (F_{IZR1} \times S_{s1} + F_{IZR2} \times S_{s2} + F_{IZR3} \times S_{s3} + F_{IZR4} \times S_{s4}) + S_R \times (F_{IR1} \times S_{s1} + F_{IR2} \times S_{s2} + F_{IR3} \times S_{s3} + F_{IR4} \times S_{s4}) + S_{DR} \times (F_{IDR1} \times S_{s1} + F_{IDR2} \times S_{s2} + F_{IDR3} \times S_{s3} + F_{IDR4} \times S_{s4}) + S_D \times (F_{ID1} \times S_{s1} + F_{ID2} \times S_{s2} + F_{ID3} \times S_{s3} + F_{ID4} \times S_{s4}) + S_{DA} \times (F_{IDA1} \times S_{s1} + F_{IDA2} \times S_{s2} + F_{IDA3} \times S_{s3} + F_{IDA4} \times S_{s4}) + S_A \times (F_{IA1} \times S_{s1} + F_{IA2} \times S_{s2} + F_{IA3} \times S_{s3} + F_{IA4} \times S_{s4}) + S_{ZA} \times (F_{IZA1} \times S_{s1} + F_{IZA2} \times S_{s2} + F_{IZA3} \times S_{s3} + F_{IZA4} \times S_{s4}) + S_h \times (F_{lh1} \times S_{s1} + F_{lh2} \times S_{s2} + F_{lh3} \times S_{s3} + F_{lhj4} \times S_{s4})), W, \quad (1)$$

where

- S_n – Solar shading factor
- $S_Z, S_{ZR}, S_R, S_{DR}, S_D, S_{DA}, S_A, S_{ZA}$ – flow density of the solar radiation accordingly to northern, north-western, western, south-western, southern, southeastern, eastern, north-eastern facade and horizontal surfaces, W/m^2
- $F_{IZ1}, F_{IZ2}, F_{IZ3}, F_{IZ4}, F_{IZR1}, F_{IZR2}, F_{IZR3}, F_{IZR4}, F_{IR1}, F_{IR2}, F_{IR3}, F_{IR4}, F_{IDR1}, F_{IDR2}, F_{IDR3}, F_{IDR4}, F_{ID1}, F_{ID2}, F_{ID3}, F_{ID4}, F_{IDA1}, F_{IDA2}, F_{IDA3}, F_{IDA4}, F_{IA1}, F_{IA2}, F_{IA3}, F_{IA4}, F_{IZA1}, F_{IZA2}, F_{IZA3}, F_{IZA4}, F_{lh1}, F_{lh2}, F_{lh3}, F_{lhj4}$ – Area of window glass cover accordingly to northern, north-western, western, south-western, southern, southeastern, eastern, north-eastern facade and horizontal surfaces, m^2
- $S_{s1}, S_{s2}, S_{s3}, S_{s4}$ – Window glass cover solar factor

Value of the window glass cover solar factor S_s depends on the type of the window glass and varies from 0,12 (outer glass covered with solar radiation reflective material) till 0,87 (normally one-layer glass). Shading factor describes S_n how much of the constructions of the building are covered with obstacles disturbing access of the solar radiation. Value of the shading factor varies from 0,4 (very high shading (>80%)) till 1,3 (insignificant shading (<20%)).

To forecast a parameter, also a parameter of the solar radiation intensity influence on the energy balance of a building, the authors worked out a model that can also be used in dwelling buildings in Latvia.

To develop the model several buildings were inspected. As a result was obtained data about constructions, their geometric parameters, thermal physical characteristics of the building structures, glass cover density in the constructions of the buildings, ventilation systems, door systems, types and condition of the windows, orientation of the building against the sky, number of blank walls, characteristics and isolation condition of the water supply system, number of the inhabitants, heat energy consumption, and location of the building according too the neighboring buildings.

Very important and complicated is the quality of measurement data. The data must be:

- comparable;
- detailed;
- proved.

If the data is comparable, there is confidence that the main influencing factors were taken into consideration and the precision of the data is satisfactory. That also proves that a better result in the comparison of the calculations and measurement data by improving the measurement results. The data must be detailed because only that the reason can be found in case of difference between the calculations and measurement results.

This all means that in addition to the information about total energy consumption of the building, there has to be also possibly fullest information about its influencing factors. Double prove of the data ensures the fact that the data will not contain any odd or incorrect data. The data get proved by comparison of measurement data for three seasons. In the further analysis only data for one season will be used.

As a describing indicator of the energy consumption is used the ratio between heat energy amount, consumed for heating purposes during the heating season, and heated area unit and degree-day, $kWh/m^2.d.d$. Relating energy consumption to the degree-day of the heating season, outdoor temperature differences are excluded. Because of this the indicator becomes more informative and resumptive. These indicators describe more detailed the consumption changes obtained during the process of increasing the energy efficiency.

One of the most essential questions of data statistical analysis is about the used data set – how big it has to be in order to be representative enough and to let define a suitable empiric model. The practice shows that the number of measurements has to be 10...20 times bigger than number of independent variables [3] of

the regression equation. Bigger number of data let develop a more accurate model, but the process becomes more labor- time-, and mean- consuming. That is why the right choice of the data set volume is a compromise decision between the time necessary for data collection, payments, and the necessary precision of the model. The volume of $m = 27$ for data set analysis is considered to be the representative in case of one variable.

The statistic data proceeding of the energy consumption for heating for the described 27 buildings was made using linear one factor model, the dependant variable value of which is energy consumption indicator kWh/m² d.d., and independent indicator is particular intensity of the solar radiation.

$$y = b_0 + b_1 \cdot s \quad (2)$$

where

- y - values of the measured energy consumption indicator, kWh/m².d.d.;
- b₀ - free term of regression;
- b₁ - regression equation factor;
- s - particular intensity of the solar radiation , W/m²a.p.

The numerically expressed of the factors and equations obtained as a result of the analysis (2) can be expressed as

$$q_s = 59,85 - 3,58 \cdot s. \quad (3)$$

The analyzed data set and graphical expression of the regression equation are shown on the Figure 6.

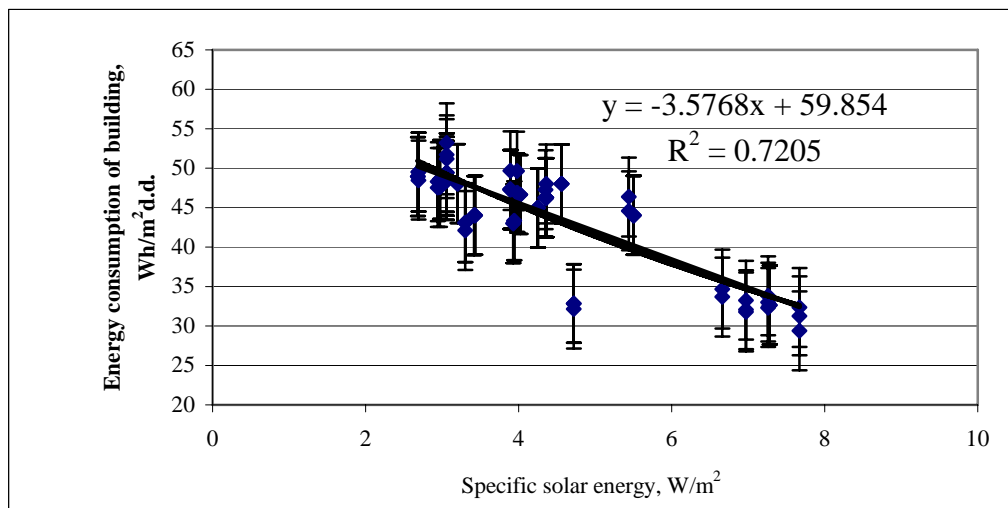


Figure 6. Energy consumption of buildings versus specific solar energy.

As can be seen, when the indicator of intensity of the solar radiation increases, particular energy consumption for heating decreases. The defined value of correlation coefficient R^2 is 0.71, which means that the empirical equation (3) describes 71 % of the measurement results' changes. Correlation coefficient $R = 0.85$ shows that correlation between energy consumption for heating of a building and specific intensity of the solar is rather good. The observed data dispersion indicated another factor of influence, which has not been described here. Other regression models were considered during the data analysis process, but they showed lower values of correlation coefficients.

5. CONCLUSIONS

1. Energy auditing of residential buildings in Latvia discovers problems with discrepancy of data measured and calculated. Regression analysis of energy consumption data versus heated area shows bad correlation. Energy labelling of residential buildings in Latvia are implemented for specific energy consumption today. Energy labelling prioritisation (5 levels of energy consumption versus heated area) gives added value for energy auditors.

2. Analysis of dynamic changes of data of heat energy consumption creates need for additional analysis of provide creates factors, which influence results of energy audits and proposals for energy efficiency measure.
3. Analysis of influence of solar radiation allows finding empirical equation for calculation of heat energy added by solar energy to residential building versus orientation of building in area. Energy auditors have additional tool for proposal of modelling of solar factor for control of heat supply in Latvia.

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