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ENERGY EFFICIENCY MEASURE COST PREDICTION BY USING REGRESSION ANALYSIS

ENERGOEFEKTIVITĀTES PASĀKUMU IZMAKSU PROGNOZĒŠANA, IZMANTOJOT REGRESIJAS ANALĪZI

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Introduction

The aim of this paper is to review the possibilities of energy efficiency cost prediction. The main part of this paper is dedicated to cost prediction by using regression analysis, which is one of the easiest and widely used data processing methods.

Changes in costs of energy efficiency measures

In order to decrease energy consumption in apartment houses or in public buildings energy efficiency measures need to be applied. There are quite many energy efficiency measures, but the main ones, which give the biggest heat energy savings are:

- insulation of walls;
- insulation of attic;
- insulation of cellar;
- window change.

While the heat energy savings from an energy efficiency measure are the same no matter when it is done, the costs of energy efficiency measures are changing all the time. Recent tendencies of energy efficiency measure market show that these measures are getting more and more expensive each year. For example, Figure 1 shows the change of wall insulation costs over the last four years.

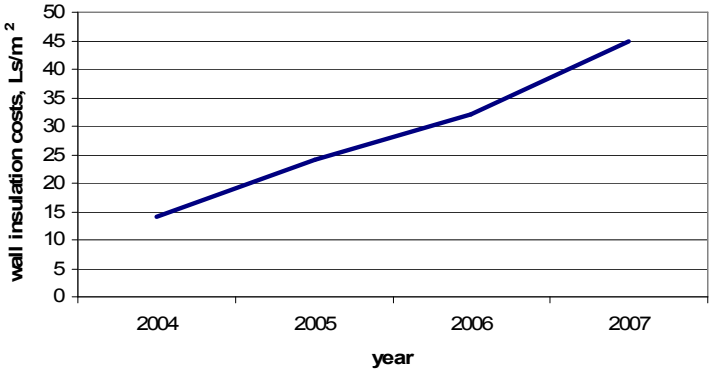

Figure 1. Costs of wall insulation for last four years.

As can be seen in Figure 1, in the ast four years the costs of wall insulation per one square meter of wall have grown more than three times which means that using the same amount of money in year 2007 it was possible to insulate only one third of wall area which could be insulated in year 2004.
This leads to the conclusion that not only the energy savings which are achieved by implementing energy efficiency measures are important, but the costs of energy efficiency measures matter as well.
In order to understand what tendencies in the costs of energy efficiency measures will be seen in the next three or four years, an energy efficiency measure cost prediction was carried out.
Since energy efficiency measures are quite expensive and in order to do them a loan from the bank or other credit institution is usually needed, the costs of energy efficiency measures are taken in such form in which the financing for energy efficiency is granted, i.e., lat per square meter heated or useful area.

Energy efficiency cost prediction methods

Since there is more than one way to predict the costs of energy efficiency measures, it was important to choose a suitable cost prediction method, which could give a proper result. The methods which were taken in consideration are:

- Expert methods and interviews with insulation material providers and manufacturers;
- Time row prediction methods;
- Choice and analysis of indicators;
- Simulation, dynamic modeling;
- Regression analysis.

By interviewing insulation material providers and manufacturers it is possible to predict the costs of these materials. This method can be used if persons who are being interviewed are willing to cooperate and to give the asked information, which often is held as secret and is not revealed. During this study only one of many interviewed insulation material manufacturers responded positively. The main concern about the credibility of data which is given from insulation material

manufacturers and providers is that interviewed persons are interested to give false information which could help to increase the profit of their represented company.
Time row prediction method is a method, which predicts costs by using statistical methods. Since only statistical data is used the credibility of result can be quite poor and unacceptable.
By choosing and analyzing proper energetic end economic indicators it could be possible to reach highly credible results. This method often is used in prediction of energy and economy industries. At present, about 180 energy and eco-efficiency indicators are defined.
Dynamic modeling predicts costs or other needed values basing on analytical or in other way prescribed regulations of a system. If using this method it is possible not to use the statistical data. This means that dynamic modeling is more an economical not mathematical or statistical way of predicting.
Regression analysis makes predictions on factors, which affect costs. In one way, regression analysis is something like dynamic modeling but it has an advantage – regression analysis can include all values, which affect the analyzed factors. Regression analysis is the dominant prediction method in macroeconomic and in company level. Regression analysis has a disadvantage – it fixes values, which are determined in a period of time, but these values can change.

Collecting of data, correlation of data

In order to make prediction of energy efficiency costs it is needed to collect historical data about the costs energy efficiency measures. The needed data were gathered from energy audits, which have been conducted all over Latvia in the time period from the year 2002 to year 2007.
Since energy efficiency costs were predicted not for the area of surfaces which have to be insulated (or changed – in case of windows) but for heated or useful areas of a building, the costs which in energy audits are given for the area which is to be insulated, were recalculated to costs which are based on heated or useful areas. This means that regression analysis can be done only for those surfaces of building envelope which have a good correlation to heated area, i.e., if you know the heated area, you can tell the area of an element of building element.
Figure 2 shows that correlation between the heated area of a building and the surface of walls in the same building is high, which means that it is possible to use regression analysis to predict costs of wall insulation. There are about 115 buildings represented in figure 2.

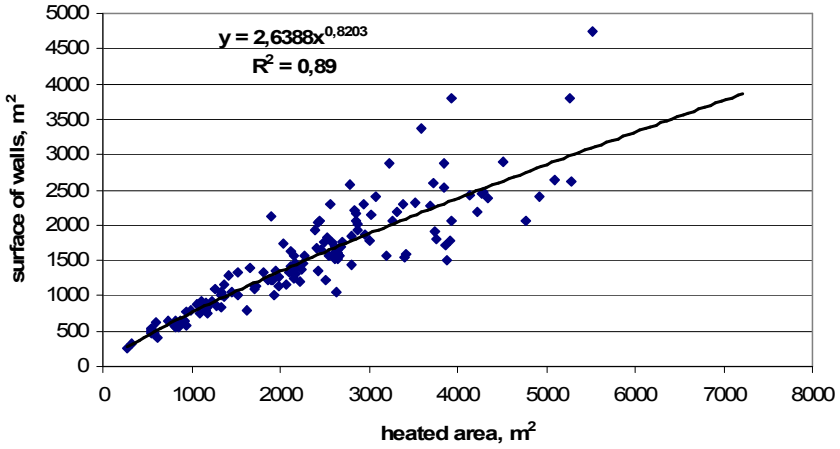

Figure 2. Correlation between heated area and wall surface in a building

In figure 3 the same method as in figure 2 is used to determine whether there is any correlation between the heated area and surface of cellar. As analysis shows there is a correlation but in this case it is not so good as in the case with surface of walls and heated area. The correlation still is quite high but in this study it was considered to be too low for further cost prediction. The same method was used to determine which elements of building envelope have high enough correlation to heated area. Upon completion of this analysis only 2 elements of building envelope were accepted for further cost prediction. These elements are:

- Walls (correlation between wall surface area and heated area R^2=0,89);
- Windows (correlation between window surface area and heated area R^2=0,91).

The correlation for attic and cellar surface areas was lower. Data with such correlation could be used if the total cost of all needed energy efficiency measures for a building would be predicted.

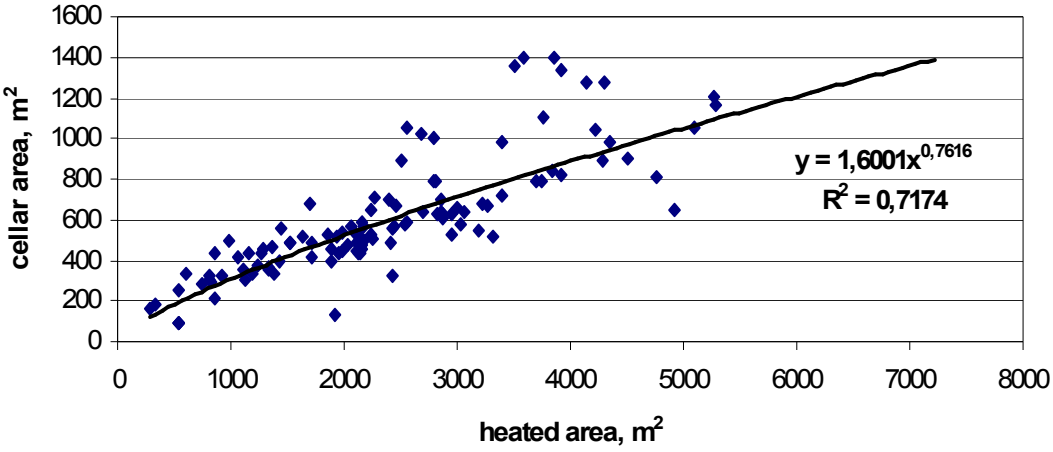

Figure 3. Correlation between heated area and cellar area in a building

Short term cost prediction for wall insulation and change of windows

By using regression analysis the costs of energy efficiency measures are predicted and the result is an equation, which can be solved by choosing the year for which to predict the costs of an energy efficiency measure.
The equation (1) shown below is a midresult of cost prediction for wall insulation.

$$y = 6{,}4862 * e^{0{,}1962x} \quad (1)$$

where

y	-	dependent variable value;
x	-	independent value;
6,4862 and 0,1962	-	regression coefficients.

By using mathematical transformations a regression equation (2) that represents the cost prediction for wall insulation is obtained. Using this equation it is possible to predict the costs of wall insulation for period from year 2008. to year 2010.

$$C_{wall\_ins} = 6{,}4862 * e^{0{,}1962*(n-2000)} \quad (2)$$

where

C_{wall_ins} - average costs, LVL/m^2(heated area);
n - year of prediction;
2000 – reference year, which is used in calculation process.
Figure 4. shows the result of costs prediction for wall insulation in a chart.

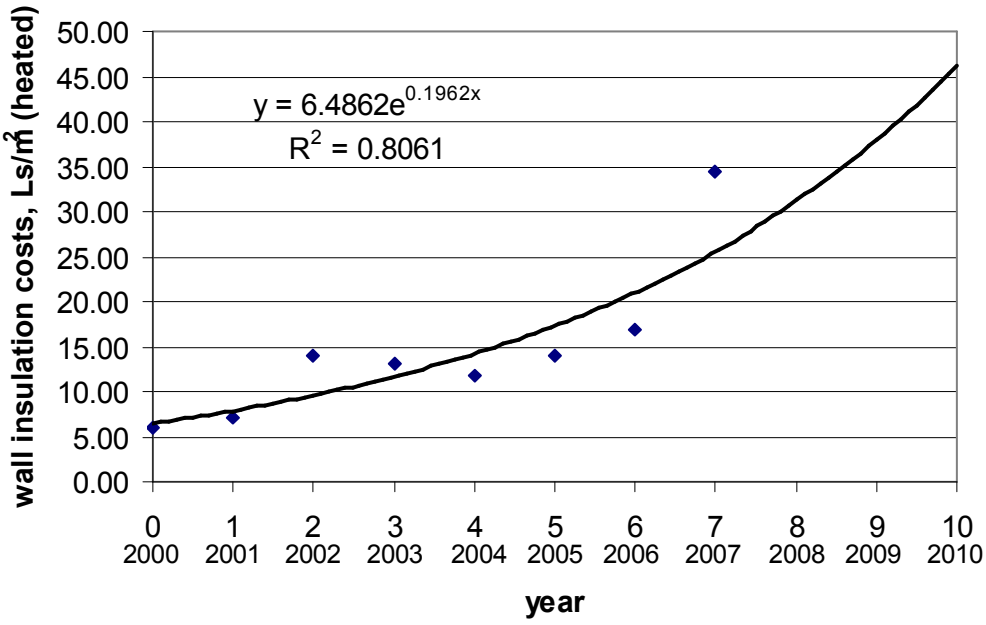

Figure 4. Wall insulation cost prediction in a chart.

As mentioned above the same analysis was done for such energy efficiency measures as the changing of old windows and wall insulation using different insulation materials. Results of cost prediction analysis can be seen in table 1.

Table 1.

Results of cost prediction analysis

Energy efficiency measure	Equation describing cost prediction	Type of equation	Correlation coefficient
Wall insulation using polystyrene (0,1m)	$C_{wall\_ins} = 6{,}4862e^{0{,}1962(n-2000)}$	Exponential	0,81
Wall insulation using rock wool (0,1m)	$C_{wall\_ins} = 8{,}4902e^{0{,}1678(n-2000)}$	Exponential	0,8
Change of old windows	$C_{window} = 0{,}6699(n-2002) + 8{,}8189$	Linear	0,89

Results, which can be seen in table 1, can be used for short term time period, i.e, approximately three years.

Long term cost prediction

In order to predict costs in the long term it is very important to understand how the energy efficiency market works. When long term predictions are done the credibility of prediction is significantly worse than in case of short term prediction. In this study long term cost prediction was made by using regression analysis. The aim of long term cost prediction was to conclude what type of equations should be used in this kind of cost prediction (in case of short term cost prediction equation with highest correlation coefficient is used). As an example for long term cost prediction in figure 5 different equations are used for one energy efficiency measure.

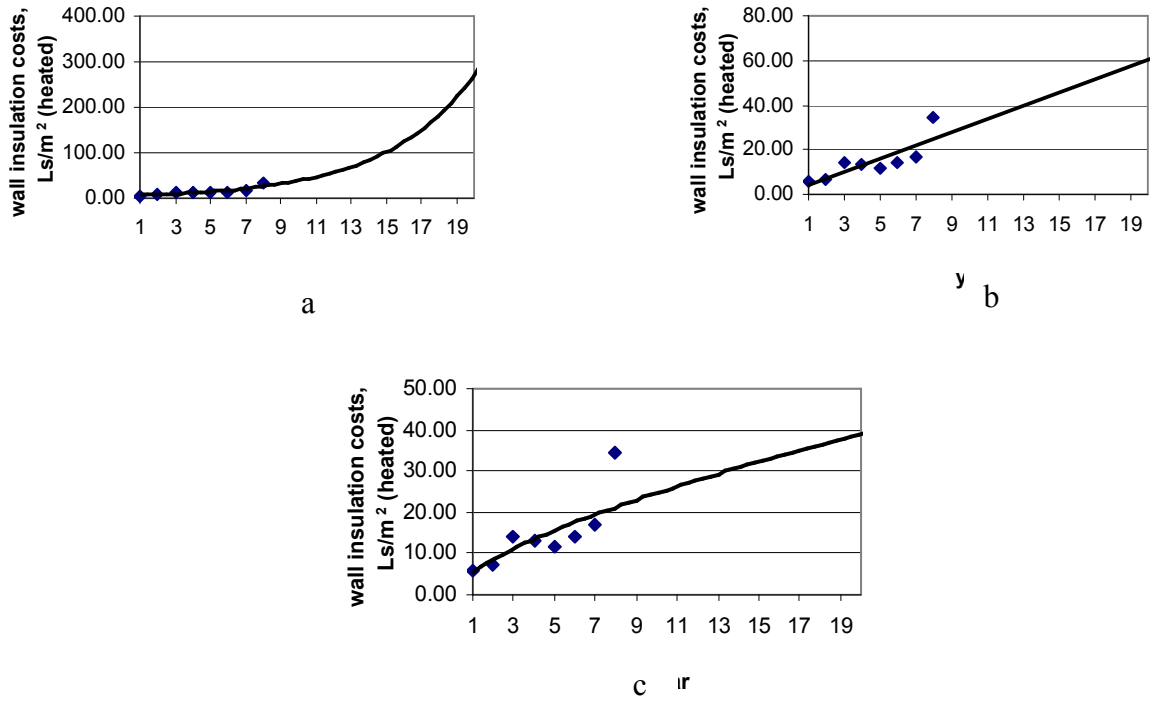

Figure 5. Long term cost prediction using different equations:
a – exponential; b – linear; c – power

In figure 5 "*x* axis" represents years in such way that number 1 is year 2000, number 2 is year 2001 and so on. As can be seen from figure 5, if for long term prediction we would use exponential equation which was used for short term prediction then by year 2019 the predicted wall insulation price would have grown to approximately 270 Ls/m^2 (heated) which is about 7,8 times more than in year 2007. Knowing the way how energy efficiency measure market is growing and knowing other economical tendencies this study suggests for predicting energy efficiency costs in long term to use linear or power equations instead exponential equations which usually are used for short term predictions.

Žogla G., Kameders A., Blumberga D. Energoefektivitātes pasākumu izmaksu prognozēšana, izmantojot regresijas analīzi.

Maksājumi par siltumenerģiju turpina augt, un viena no šo maksājumu samazināšanas iespējām ir energoefektivitātes pasākumu veikšana. Lai saprastu, kā attīstīsies energoefektivitātes pasākumu tirgus, ir svarīgi prognozēt šī tirgus attīstību. Cenu prognozēšanai ir iespējams izmantot vairākas metodes. Šajā pētījumā cenu prognozēšana tika veikta, izmantojot regresijas analīzi. Regresijas analīze ir vienkāršs cenu prognozēšanas veids. Šī metode pasaulē tiek izmantota ļoti plaši un bieži. Šajā pētījumā energoefektivitātes pasākumu izmaksas tika aprēķinātas, izmantojot mērvienību Ls/m^2, kur platība ir attiecināta nevis uz norobežojošo siltināmo konstrukciju laukumu, bet gan uz ēkas apkurināmo platību. Šāda mērvienība tika izmantota tāpēc, ka bankas, kuras parasti tiek

izvēlētas kā energoefektivitātes pasākumu veikšanai nepieciešamā finansējuma avots, kredītu izsniedz, balstoties uz ēkas apkurināmo platību.
Izmaksu prognozēšanas rezultātā tika noteikta sienu siltināšanas un logu nomaiņas izmaksu prognoze. Tika izstrādātas gan īstermiņa, gan ilgtermiņa izmaksu prognozes. Izmaksu prognozēšanas rezultātā var secināt, ka energoefektivitātes pasākumu izmaksas turpinās augt, kas nozīmē to, ka, jo agrāk šie pasākumi tiks ieviesti, jo mazākas būs to izmaksas, līdz ar to tiks panākts lielāks energoefektivitātes pasākumu veikšanas ekonomiskais izdevīgums.
Noslēgumā iespējams secināt, ka regresijas analīze ir noderīga metode dažādu energoefektivitātes pasākumu izmaksu prognozēšanai.

Zogla G., Kamederes A., Blumberga D., Energy efficiency measure cost prediction by using regression analysis.
Costs for heat energy keep growing and one of possibilities to minimize costs for heating is to do some energy efficiency measures. In order to understand how the energy efficiency measure market is going to develop in near future it is important to make cost predictions. There are many methods how to predict costs. In this study on cost prediction regression analysis was chosen. Regression analysis is an easy way how to predict costs and this method is widely used all over the world. In this study costs of energy efficiency measures were calculated in Ls/m^2 where the area represents not the surface area of building envelope elements that need to be insulated but it represents the heated or useful area of building. Such unit of measure was used therefore that banks give loan (for implementing energy efficiency measures), which is based on the heated area of a building.
As the result of study costs were predicted for wall insulation and window change. Both short and long term predictions were made. Results of cost prediction show that costs of energy efficiency measures will continue to grow, which means that the faster energy efficiency measures will be implemented the cheaper and gainfully they will be.
As a conclusion it can be said that regression analysis is a good method how to predict costs of different energy efficiency measures.

Жогла Г., Камедерс А., Блумберга Д., Прогнозирование затрат на мероприятия по энергоэффективности, применяя регрессионный анализ.
Расходы на теплоэнергию продолжают расти, и одна из возможностей уменьшения этих расходов это реализация энергоэффективных мероприятий. Чтобы понять, как будет развиваться рынок мероприятий по энергоэффективности, важно заниматься прогнозирование развитие этого рынка. Прогнозирование цены возможно применяя различные методы. .В данном исследовании прогнозирование было реализовано посредством регрессионного анализа. Регрессионный анализ это простой способ, для прогнозирования цены. Этот метод в мире используется достаточно широко и часто. В данном исследовании затраты на мероприятия по энергоэффективоности были рассчитаны используя единицы измерения Ls/м^2, где площадь относится не к площади ограждающих конструкций, которые надо утеплять, а к отапливаемой площади здания. Подобная единица измерения используется потому что, банки, которые обычно выбираются как необходимый источник для финансирования проведения мероприятий по энергоэффективности., выдают кредит, основываясь на отапливаемую площадь здания.
В результате прогнозирования затрат был проведён прогноз затрат на утепление стен и смену окон. Были разработаны как краткосрочный, так и долгосрочный прогноз затрат. В результате прогнозирования затрат можно сделать вывод, что затраты на проведение мероприятий по энергоэффективности продолжают расти, что означает то, что чем раньше эти мероприятия, тем меньше будут затраты, и в связи с этим будет достигнута большая экономическая выгода проведения мероприятий по энергоэффективности.
В заключение можно сделать вывод, что регрессионный анализ это хороший метод для прогнозирования различных энергоэффективных мероприятий.