ENERGY AUDIT INFORMATION SYSTEM

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Abstract. *The opportunities provided by energy audits to improve the competitiveness of companies by reducing energy consumption and introducing energy-efficient solutions also allow for achieving the environmental goals set by the European Union and Latvia in relation to climate neutrality. It is important to consider the results of energy audits in the development of both local and regional and national policies, thus setting more precise results to be achieved. At present, there is no unified energy audit development information system in Latvia, in which all audit stages and calculations could be performed; this would reduce clerical and calculation errors and allow data to be predicted and used in policy development, research. As part of the paper, the authors researched the concept of energy audit, its process and the results to be achieved by companies by implementing energy efficient measures, as well as the policy goals of the European Union and Latvia in environmental improvement programmes. The paper summarizes and analyses the programs and methods available in Latvia, which are used to develop energy audits of companies, as well as the practices of other countries and their results.*

The research aim is to develop the specification of the energy audit information system, based on the analysis of the used energy audit information systems. Based on the findings, the authors developed a specification of the program's energy audit information system requirements, which is suitable for the Latvian market.

Keywords: *energy audit, energy audit information system, energy efficiency.*
JEL code: *Q4, O13.*

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Introduction

Every inhabitant of Latvia has encountered topical environmental problems – environmental pollution and waste management problems, air quality problems, extraction and regeneration of natural resources, etc. In 2019, a total of 127.21 million euros were spent on environmental protection in Latvia, which included wastewater management, purchase and use of waste collection and processing equipment, maintenance, protection of the surrounding air and climate, biodiversity, landscape protection and other environmental protection activities ("Vides aizsardzības izdevuma konti…", 2022). Realizing that the economic and environmental sector is facing many

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and varied challenges due to the consequences of the war in Ukraine. Therefore, at the company level and in the development of national policy, it is important to be aware of the opportunities provided by energy audits, which are very relevant now, so that companies can reduce their energy consumption and introduce energy-efficient solutions, thus improving both the competitiveness of companies in the market and achieving the environmental goals set by Europe and the country in relation to climate neutrality.

The availability of a professional energy audit, its development and the investments provided are currently underappreciated in Latvia. Energy audits must be a fast and effective tool to implement national policies and provide companies with support for improving energy efficiency.

The research aim: to develop the specification of the energy audit information system, based on the analysis of the energy audit information systems used.

Research hypothesis: the need and creation of a new energy-efficiency information system is economically beneficial.

The following **tasks** have been set to reach the aim:

1) identify, study, analyse and evaluate sources of information (scientific literature and various types of documents, standards) on the topic;
2) get acquainted with the methodology of energy audits and evaluate the tools used for its performance;
3) develop the energy audit information specification of the system, i.e., see screen sketches;
4) analyse and evaluate the obtained results, formulate conclusions, as well as develop recommendations based on the obtained results.

The following **research methods** were used to achieve the aim and tasks set in the paper: analysis of literature and documents, examining and describing the energy audit system, and its history; the graphical method for displaying statistics and quantitative data; the descriptive method, examining the energy audit systems used in Latvia and the world; the system modelling method in the empirical part, developing the energy audit system specification; the logical construction method in formulating results and conclusions, developing proposals.

As part of the study, the energy audit cycle and its structure in the scientific literature were also examined ("Standard Environmental Management Energy...", 2022; "The energy audit of buildings in 4 steps", 2020), as well as the contributions and results provided by the energy audit in various sectors and countries, for example: Investigating the Thermal Performance of Canadian Houses Using Smart Thermostat Data (Doma et al., 2021), Benchmarking of Industrial Energy Efficiency: Outcomes of an Energy Audit Policy Program (Locmelis et al., 2020), Promoting Sustainable Energy:

Does Institutional Entrepreneurship Help? (Heiskanen et al., 2019), A study of the comparability of energy audit program evaluations (Andersson et al., 2017), Multilevel Governance Energy Planning and Policy: a View on Local Energy Initiatives (Dobravec et al., 2021), Reduction of Energy Consumption and Delay of Control Packets in Software-Defined Networking (Naseri et al., 2021), including practical studies: "Analysis of Energy Use and Energy Savings: a Case Study of a Condiment Industry in India" (Ullah et al., 2021) and "Energy Efficiency – Ecological and Economic Profitability" (Hawrylak, 2020).

Energy efficiency is one of the most important and cost-effective tools available to any facility or organization. Energy efficiency aims to reduce the amount of energy needed to provide products and services or a healthy indoor climate. In the world, an industrial energy audit is already a common practice, while in Latvia it is still something new and applicable to most companies and objects (Grinbergs & Gusta, 2013, 355).

The 2011 study conducted by Ian Shapiro in the United States (USA) analysed more than 300 energy audits, identifying the ten most common errors and problems. As a result, 30% of audits found errors in data, their rewriting and calculations; in 57% of audits, there was an insufficient/erroneous analysis of the calculations of consumed energy bills; 53% of the audits overestimated the savings provided by the improvements to be made (Shapiro, 2011, 26-29). The mentioned mistakes served as the basis – one of the most important reasons for the development of the first computer programs for energy auditors. Their purpose was to reduce errors in data transcription and calculations. Since this study was carried out 11 years ago, there has been a significant leap in development in the energy audit industry, and new and high-quality studies on the compliance and uniformity of energy audits both regionally and internationally would be needed now.

Concept and history of energy audit

In any industry, the three main types of expenses are energy (electricity, thermal energy), labour and materials. If the amount of work and materials is more difficult to influence, because it determines the quality of the final service or product, then the energy consumption can be gradually improved, reaching the best reading in relation to the performance indicators of the company, for example, the reduction of the consumption of electricity consumed in relation to the amount of production produced, etc.

Energy audit and the need for it arose in connection with energy crises in the world in the second half of the 20th century. Each subsequent crisis in the energy sector forces us to rethink energy consumption and the use of renewable resources in energy production. Eurobarometer 2021-2022, a monitoring tool for EU institutions, revealed that in the winter opinion survey of 2018, environmental changes, and climate change worried 12% of the European Union population, 3% of the population in Latvia ("Standard Eurobarometer 96, Winter", 2022, 2). On June 17, 2011, the standard ISO 50001:2011 "Energy management systems. Requirements with instructions for use" was introduced ("What is the history of the ISO 50001", 2022). This standard is currently used all over the world, and its implementation is equated to an energy audit.

Energy auditing was not popular in the construction industry until 2002 when it was included in the European Directive 2002/91 EC on the energy performance of buildings. Supplementing the document in accordance with climate changes and changes in energy policy, in 2010 it was determined that large companies (and energy consumers) should conduct an energy audit every four years (Egwunatum & Akpokodje, 2019).

The history of an energy audit is not old, its development and demand has increased significantly in recent years and continue to increase. Also in 2022, due to the war in Ukraine, drastic changes affect the economy, which is directly affected by the increase in electricity, natural gas and fuel prices, inflation, the imposed sanctions on certain countries, etc. factors that result in companies looking for ways to save resources. These changes force companies to choose to conduct an energy audit and implement data-based energy efficiency improvement measures outside of the mandatory energy audits stipulated by national legislation.

Looking at the available literature, the concept of energy audit is widely used, and its explanations are various (the concepts of energy audit can be viewed: "Energoefektivitātes likums", 2020; "Енергоаудит", 2010; Mondal, N. d.; "Energy audit", 2022; "Energy Auditing", 2020).

Summarizing the explanations of the energy audit concepts, the authors of the paper formulated a summarizing variant – an energy audit is a comprehensive evaluation of the company's energy, which summarizes various types of energy – electricity, thermal energy, fuel, water, etc. (information for a two-year period) – changes in consumption structures in buildings, processes or equipment, energy flow and provides recommendations for the implementation of economically sound energy efficiency improvement measures. Energy consumption in companies should be viewed more broadly – it is an essential part of company costs, which can be analysed and improved. Energy efficiency means using less energy to do the same amount of work, thereby reducing energy bills and environmental pollution ("What is Energy Efficiency?", 2020). In energy audits, an important part of the analysis is the ratio of energy quantities to the products produced, or the services provided. This indicator makes it possible to assess in the long term whether the introduced energy efficiency measures have been effective because over time the energy consumption in relation to the products produced or the services provided should decrease.

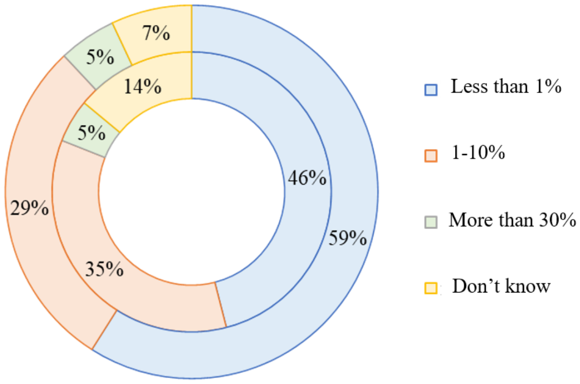

Fig.1 Eurobarometer survey question "How much money, on average, per year has your company invested in improving the efficiency of resource use during the last two years?" collection of answers about Latvia (SMEs, resource efficiency and green markets, 2018)

According to *Eurobarometer 2021* data, among small and medium-sized enterprises (SMEs) in Latvia, 59% of the enterprises invested less than 1% during the year to improve the efficiency of resource use; only 5% of companies invested more than 5% (see Figure 1).

Energy audit information systems in the world

The first energy audit programs were created after 2010 and were initially created by private companies to optimize their operations and improve the work process in order to be able to perform energy audits faster and more conveniently. Convinced of the effectiveness of the programs, they were developed, and the licenses of the programs were offered to other companies as well. Various energy audit programs are more developed and available in the United States (US) and Canada. In 2020, a compilation of the ten most popular energy audit software programs was published (based on data on the most frequently used energy audit programs in 2019; the names are given in the original language): EMAT ("Audit services", 2022; "About EMAT", 2022); TREAT ("TREAT Energy Audit Software", 2022); Energy Analysis Software ("Rebecca Energy Management", 2021); OptimiMiser ("OptiMiser is a collaborative...", 2022); Weatherization Assistant ("Software description", N d.); Green Training ("Energy Audit Software", N. d.); HomeSelfe ("HomeSelfe RE's innovative technology", 2016); FirstFuel ("Behavioral Energy Efficiency", N. d.); Buildee ("Uncover Energy Efficiency", N. d.); SnapCount (The lighting retrofit software that changed everything, 2022).The Simuwatt Energy Auditor program is also widely used, with the help of which the costs of auditing and modelling existing commercial buildings can be reduced by 25%. The program was developed with the technical assistance of the National Renewable Energy Laboratory. Simuwatt uses DOE's open-source modelling tools EnergyPlus and OpenStudio (Roth, 2017). It should be mentioned that this company also owns the energy audit platform Buildee.

Current energy audit methods are generally expensive, time-consuming and require a high level of expertise, especially when maintaining a large and diverse portfolio of equipment/tools, as stated by the authors of the 2020 study "Changing how energy audits are done" M. Goss and T. King (2020). The authors also offer their own solution – an alternative approach to the usual energy audit, a software application and calculation tool called REM (*Rapid Energy Modelling Tool*).

Energy audit information system – specification of requirements

In the part of the research, the authors developed the offer of the energy audit information system program, which is suitable for the Latvian market and the peculiarities of nature and resources. The name of the energy audit program is EAS, which is an abbreviation of the Energy Audit System. The specification of energy audit information system requirements is made from the point of view of an energy auditor, assuming that the software is created and maintained by the private sector, the main client is auditor companies. Mutual energy auditors and large companies/large electricity consumers work in a B2B (Business to Business) model.

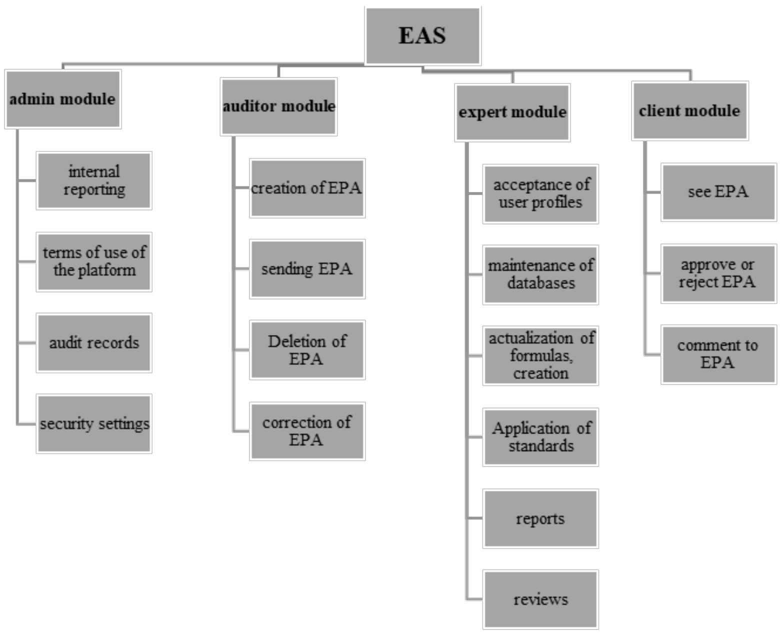

Figure 2. Functional decomposition of the EAS program (created by the authors)

The basic functional requirements for the EAS program are to perform energy audit calculations in accordance with the requirements of the regulatory standards for energy efficiency calculations, their national annexes and the regulatory acts and recommendations binding on Latvia:

- ensure correct calculations and adapt the form of the energy audit to the specifics of the company; provide the user with the opportunity to enter input data necessary for the calculation,
- provide control of parameters and input data values (control of measurement units, mutual dependencies of input data values, maximum and minimum values, comparison with similar data, etc.),
- ensure energy efficiency standards, their national annexes and the calculation of the results specified in the current regulatory acts,
- provide the user with the opportunity to see with which formulas and with which value the specific calculation value was obtained,
- provide structured calculation data export from the system,
- ensure the storage of information on energy efficiency calculations, for example, so that the competent authority can verify the professional activity of independent experts or independent experts use the performed calculations or their data for future calculations (for example, for re-evaluation of the energy efficiency of the building),
- maintain centralized (can be corrected by an expert) and decentralized (can be corrected and used by users in their calculations) databases, such as building material catalogues, the essential consumer database, in which to enter various characteristics that can be automatically used for calculations,
- create calculation templates for faster start of calculations in the case of similar objects – both templates maintained by the administrator and individual templates created by users,
- maintain a centralized standard catalogue of energy efficiency improvement measures, to be used when preparing an overview of economically justified energy efficiency improvement measures, the implementation costs of which are profitable in the expected (planned) lifetime and allowing the user to manually enter forecasted energy prices, time periods, planned costs and benefits in percentage, kilowatts, and kilowatt hours.

Future development opportunities of the program. When creating an energy audit program in accordance with the specification requirements described above, there are possible additions and improvements that should be foreseen and planned as future system improvement tasks:

- the program is combined/linked with the Construction Information System, thus both energy auditors and clients, as well as employees of control and inspection institutions work on the same platform where all related information is circulated,

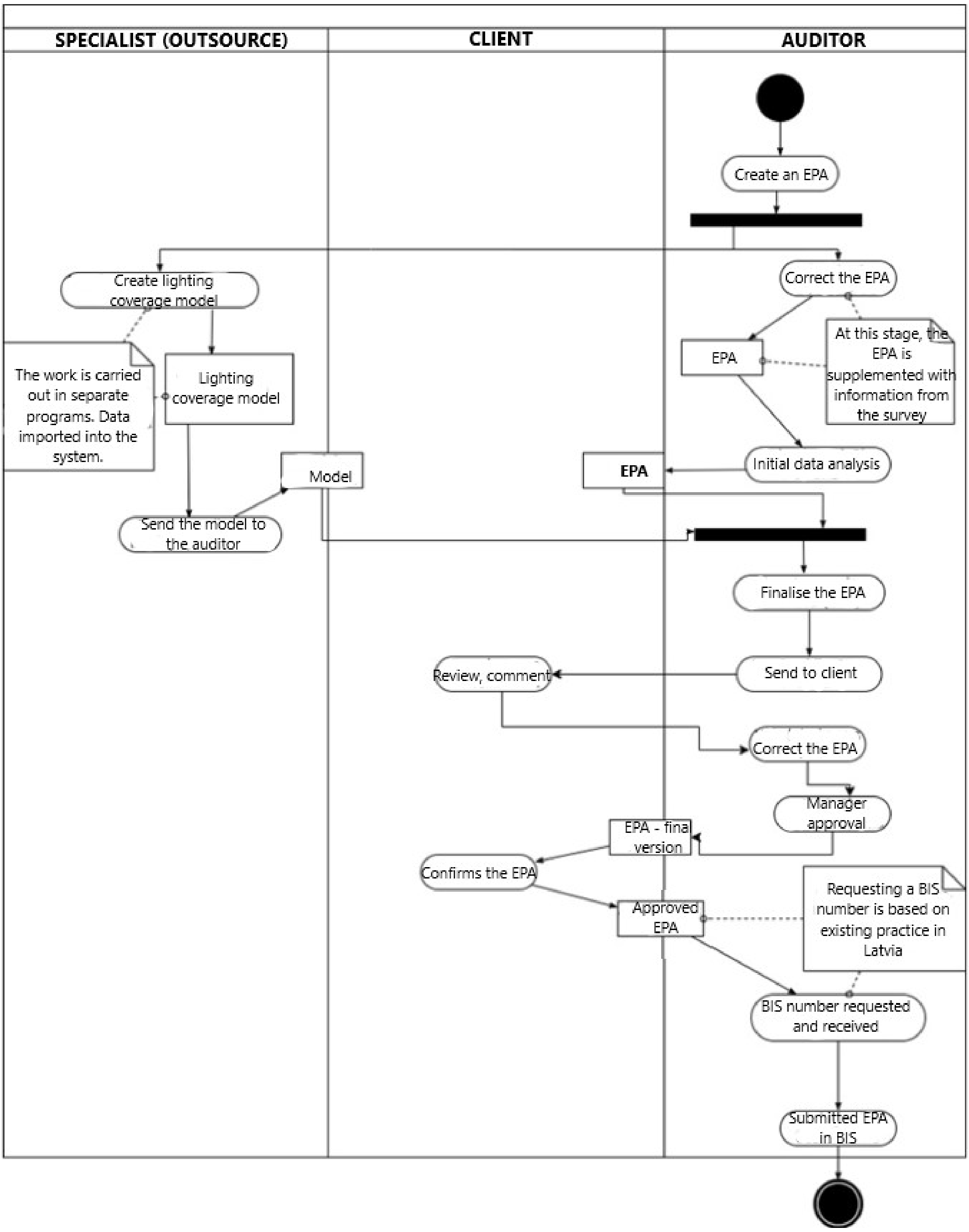

Fig.3 Diagram of status transitions (created by the authors)

- an added building energy certificate program (Heatmod or a similar program) suitable for development and approval of building energy certificates,
- a portal/section of innovative solutions has been created, which gathers offers of energy-efficient and innovative products and solutions, providing an opportunity for companies and organizations to familiarize themselves with them and implement them in their practice,

- include additional steps for auditors – audit planning, receiving data immediately on the portal, etc.,
- import data from both building modelling systems and monitoring equipment, thus enabling energy audits to be performed on a larger scale and faster.

While developing and formulating the specification of the energy audit information system, the authors of the paper concluded that the initial program development provides for simple program content and functions, which are improved with each subsequent version and practical feedback from program users, so that the program meets the needs of energy auditors and clients of the time, promoting availability and efficiency of energy audits.

Analysis of system creation and maintenance costs

The costs of the creation and maintenance of the energy audit information system EAS have been considered assuming that the program is developed by a private sector company, which uses the program for the provision of its services and offers its licenses to other companies after the program's verification period.

Potential system users or clients are seven accredited ("Akreditētās institūcijas", N. d.) companies for energy audits and not yet accredited companies. In 2022, these companies in Latvia are: "LBRA" Ltd.; "Efekta" Ltd.; AS "Inspecta Latvia"; "Bureau Veritas Latvia" Ltd.; "Ekodoma" Ltd.; "TUV Nord Baltik" Ltd.; "CMB" Ltd.; "Solution Expert" Ltd.; "Energoaudits" Ltd.; "Building consulting and energy audit" Ltd.

On average, program development from planning to program delivery takes 4-12 months, although 85% of such projects do not meet the expected time frame (Wardynski, 2017). According to the specification of the program developed by the authors, it is assumed that 18 months are needed for the development of the program. Likewise, certain levels of security are also important for this information system, so that it is safe for all users, the necessity of which is also confirmed by Eurobarometer statistical data – respondents are worried about problems related to digital tools and the growing role of the Internet in society, moreover, more than half of the survey participants cybercrime and cyberattacks are a concern ("Digital Rights and Principles", 2021); in addition, 28% of SMEs (the same in Latvia and Europe) have encountered cybercrime, however, in Latvia, these situations are not reported in 57% of cases ("Expectations and Concerns from a Connected…", 2021).

The development process of the EAS program is expected to last for 18 months (i.e., 78 weeks), so the initial software development, excluding database preparation and development, program user training, testing and program maintenance costs for two years, would cost ~727,818 euros.

It should be noted that until the actual development of the program, several factors affecting the price and the development of the program may change, for example, on May 18, 2022, the procurement information "Development of the building energy efficiency calculation information system and implementation of change requests" was published in the Electronic Procurement System ("Elektronisko iepirkumu sistēma", 2022) in order to develop a system in which independent experts in various building energy efficiency assessment processes would perform the necessary calculations in accordance with the requirements of the standards, their national annexes and regulatory acts binding on Latvia and prepare building energy efficiency assessments. The program mentioned in the example can serve as a basis or a part of the basis for an energy audit program to be further improved.

Payback period of the information system. Assuming the scenario that the EAS program is implemented by a private sector company that deals with energy audits. Since the companies in this industry are not large, it is assumed that the company has five employees. The salary of one employee consists of the number of hours worked and the hourly rate:

- the average hourly rate of one employee in the 1st quarter of 2022 was 13.20 euros (profession 214207 "Energy Auditor"),
- average number of hours worked per month – 96 hours,
- monthly salary – 1,267.20 euros.

The amount of work performed by the energy auditors has been adopted based on the author's work experience, and the calculations assume that with the help of the program, one auditor can perform ten energy audits per month, instead of the previous two energy audits.

Using the EAS program, the expected savings would be the monthly salaries of three employees, which amounts to 3,801.60 euros. In the calculations of the payback period for the development and maintenance of the program, the minimum cost threshold, which the authors mentioned above, is assumed to be 727,818 euros, so the payback period would be 15.95 years. It should be noted that licenses for the use of the EAS program could also be offered to other energy audit companies, thus shortening the payback period. The authors of the paper considered three possible scenarios in which the program licenses are sold to energy auditors of other companies to reduce the payback period and make a profit (see Table 1).

The most advantageous scenario is B, which would pay off after two years and would provide the company with a profit of 219,579.760 euros in the third year. According to the authors, however, the most optimal and realistic scenario is scenario C, assuming that every month at least

50 licenses are sold and maintained to energy auditors of other companies (including the companies mentioned at the begging of this chapter). They can also be licenses used by municipalities and state enterprises. By setting the price of one license at 300 euros, the EAS program would have fully recouped its development costs after three full years.

Table 1. Program payback period scenarios (EUR; created by the authors)

Criteria		Month	Year	Total
Program development costs		-	-	727 818.0
Program savings for the company		3 801.6	45 619.2	-
Scenario A				
License costs	1 license cost	800.0	9 600.0	-
	20 license cost	16 000.0	192 000.0	-
Payback period	1. year	-	-	-490 198.8
	2. year	-	-	-252 579.6
	3. year	-	-	-14 960.4
	4. year	-	-	222 659.0
Scenario B				
License costs	1 license cost	150.0	1 800.0	-
	150 license cost	22 500.0	270 000.0	-
Payback period	1. year	-	-	-412 198.8
	2. year	-	-	-96 579.6
	3. year	-	-	219 040.0
Scenario C				
License costs	1 license cost	300.0	3 600.0	-
	50 license cost	15 000.0	180 000.0	-
Payback period	1. year	-	-	-502 198.8
	2. year	-	-	-276 579.6
	3. year	-	-	-50 960.4
	4. year	-	-	174 659.0

Based on the analysis of financial data on the development, maintenance and payback period of the program, the authors concluded that the development and maintenance of such a program do not pay off for a private sector company in the real market situation. It would be necessary to analyse the possibility of developing and maintaining this program at the national level, which would allow the program to operate at the same level and in connection with BIS, thus allowing for easier implementation of environmental and political issues. Under the best-case scenario, this program could be merged/added to BIS, which would allow the easier collection of national compliance and enforcement statistics, and no data import/export, resulting in one efficient and complete program for all parties involved.

Conclusions and proposals

Conclusions

1. Based on the fact that the concept of an energy audit is widely used in the literature and its explanations are different, the authors of the paper formulated a definition of energy audit appropriate for the study: energy audit – a comprehensive assessment of the company's energy, which collects various types of energy – electricity, thermal energy, fuel, water, etc. (information for a two-year period) – changes in consumption structures in buildings, processes or equipment, energy flow and provides recommendations for the implementation of economically sound energy efficiency improvement measures.
2. The energy audit process consists of four stages: a collection of energy consumption data, a survey, data analysis, preparation, and approval of the audit report. Each stage consists of its own unique information and data, the analysis of which is the basis for improving the company's energy performance.
3. After reviewing foreign energy audit programs, the authors concluded that several energy audit programs have been developed and established since 2012. The most popular of them are EMAT, TREAT, and Energy Analysis Software.
4. Summarizing the direction of energy policies and their relationship with energy audits, the authors of the work concluded that energy policy should be more widely applicable, including not only to large companies and large energy consumers; in addition, the wider availability of energy audit data (within certain criteria) would help to set more precise regional and national strategies and achieve the defined goals related to energy and climate neutrality in the environmental fields.
5. Latvian and foreign studies show specific calculation data that prove that energy efficiency measures carried out based on an energy audit or an energy efficiency system are financially beneficial for companies.
6. There have been several attempts to develop and use energy audit tools in Latvia, such as EFA2 and Heatmod; however, these programs and tools are focused on energy audits of buildings and the development of energy certificates.
7. The proposed hypothesis – the need and creation of a new energy efficiency information system is economically beneficial – was partially confirmed. Based on the theoretical analysis of the energy audit, its process, and the provided results, including the evaluation of energy audit tools at the world and national level, the need for a new and unified energy efficiency information system will be confirmed. However, the creation of such a system is not economically beneficial because the payback period,

calculated from the minimum cost threshold of the program – 727,818 euros, is 15.95 years.

Proposals

1. An order to perform efficient and accurate calculations of energy audit data and automatically transfer them to BIS, thus reducing errors in manual calculations, it is necessary to develop a unified energy audit program in which data can be entered on an online platform and calculations based on current regulatory enactments can be performed.
2. The development and maintenance of energy audit tools should be done at the national level because the development of such a tool does not pay off financially for energy audit firms.
3. When creating an energy audit program, future improvements and additions to the system should also be envisaged and planned:
   3.1. the program is combined with BIS, thus both energy auditors, clients, and employees of control and inspection institutions work on the same platform where all information is available,
   3.2. an added building energy certificate program Heatmod or a similar program suitable for developing and validating building energy certificates,
   3.3. a portal/section of innovative solutions has been created, where offers of energy-efficient and innovative products and solutions are collected so that companies have the opportunity to familiarize themselves with them and implement them in their practice,
   3.4. improved functionality – a built-in opportunity for auditors to plan energy audits and receive data immediately on the unified portal,
   3.5. perform data import – both from building modelling systems and from monitoring equipment; this would allow a wider and faster audit.

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