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Dissertation Thesis Abstract

Possibilities of using energy performance contracting for retrofit of apartment houses

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Abstract

The presented thesis deals with the possibility of using the Energy Performance Contracting (EPC) in the renovation of apartment buildings as one of the financing options. In Slovakia, as well as in the world, the need to reconstruct original buildings is necessary, in some cases inevitable. A frequent problem is the financing of a more complex reconstruction, which would help to improve the condition of the building as well as to improve the internal environment of the buildings.

Within the framework of the thesis, 4 main objectives were set, which consisted of defining the calculation method and creating a calculation tool in the MS Excel program. This calculation tool was further used in the calculation of the energy balance of a selected sample of buildings for which an inspection of their current state was carried out. The next step was the design of energy-efficient measures and their assessment in terms of the suitability of implementation using the EPC.

The work was also focused on assessing the impact of changes in input parameters on the final profitability of individual packages of retrofit measures, as the determination of input data for the calculation is an important part of the correct determination of project profitability. The profitability of individual packages of retrofit measures is expressed by the net present value, net present value coefficient, discounted return and, in the case of assessment of suitability for the Energy Performance Contracting project, also the EPC payback. In this case, the maximum payback period for the EPC project was set at 15 years.

Based on changes in the economic situation, five scenarios of economic development were proposed, which represent different starting points in terms of investments and energy prices. The project was significantly more profitable in scenarios with negative economic development, mainly due to expected higher energy prices. The results indicated that for all five apartment houses, the financing of the renovation through EPC was realistic. However, for some buildings, EPC only scenarios that included unfavourable economic developments could be recommended. Other proposed scenarios showed that profitability fell dramatically when the price of energy was relatively low, while investment was higher.

One of the main objectives was to assess the impact of financing through four different methods (own capital, bank loan, renewable resource grant and grant from the EU recovery plan). The most common scenario is a loan from a company providing the EPC. The thesis showed that a combination of a small share of own capital, a grant of at least 30% and a commercial loan for the rest of the funding could represent a realistic and appropriate financing scheme for the modernization project through EPC.

Keywords: energy performance contracting, profitability, building retrofit, funding, apartment house

Abstrakt

Predkladaná práca sa zaoberá možnosťou využitia garantovanej energetickej služby (GES) pri obnove bytových domov ako jednou z možností financovania. Na Slovensku, ako aj vo svete je potreba obnovy pôvodných budov potrebná, v niektorých prípadoch nevyhnutná. Častým problémom je financovanie komplexnejšej obnovy, ktorá by dopomohla k zlepšeniu stavu budovy ako aj k zlepšeniu vnútorného prostredia budov.

V rámci práce boli stanovené 4 hlavné ciele, ktoré pozostávali z definovania výpočtovej metódy a vytvorenia výpočtového nástroja v programe MS Excel. Tento výpočtový nástroj bol ďalej použitý pri výpočte energetickej bilancie vybranej vzorky budov, pre ktoré bola vykonaná obhliadka ich súčasného stavu. Ďalším krokom bol návrh energeticky efektívnych opatrení a ich posúdenie z hľadiska vhodnosti realizácie pomocou garantovanej energetickej služby.

Práca bola zameraná aj na posúdenie vplyvu zmien vstupných parametrov na výslednú ziskovosť jednotlivých balíkov opatrení, nakoľko je stanovenie vstupných údajov do výpočtu dôležitou súčasťou správneho stanovenia ziskovosti projektu. Ziskovosť jednotlivých balíkov opatrení vyjadruje čistá súčasná hodnota, koeficient čistej súčasnej hodnoty, diskontovaná návratnosť a v prípade posúdenia vhodnosti pre projekt garantovanej energetickej služby aj GES návratnosť. V tomto prípade bola stanovená maximálna dĺžka návratnosti pre GES projekt 15 rokov.

Na základe zmien ekonomickej situácie bolo navrhnutých päť scenárov ekonomického vývoja, ktoré predstavujú rôzne východiská z hľadiska investícií a cien energií. Projekt bol podstatne ziskovejší v scenároch s negatívnym ekonomickým vývojom, najmä v dôsledku očakávaných vyšších cien energií. Výsledky naznačili, že pre všetkých päť budov bolo financovanie obnovy prostredníctvom GES reálne. Pri niektorých budovách však bolo možné GES odporučiť len pre scenáre, ktoré zahŕňali nepriaznivý ekonomický vývoj. Ďalšie navrhnuté scenáre ukázali, že ziskovosť dramaticky klesla, keď bola cena energie relatívne nízka, pričom investície boli vyššie.

Jedným z hlavných cieľov bolo posúdenie vplyvu financovania štyrmi rôznymi metódami (vlastný kapitál, bankový úver, grant na obnoviteľný zdroj a príspevok z plánu obnovy EÚ). Najbežnejším scenárom je pôžička spoločnosti poskytujúcej garantovanú energetickú službu. Práca ukázala, že kombinácia malého podielu z vlastného kapitálu, grantu vo výške aspoň 30 % a komerčnej pôžičky na zvyšok financovania by mohla predstavovať realistickú a vhodnú schému financovania projektu modernizácie prostredníctvom GES.

Kľúčové slová: garantovaná energetická služba, ziskovosť, obnova budov, financovanie, bytový dom

1 INTRODUCTION

Buildings are an essential part of our lives because we live and work indoors most of the time. A comfortable and productive indoor environment costs energy. The high energy consumption of buildings in the European Union (EU) has led to incentives to develop solutions to improve their energy performance. In Slovakia, reducing consumption mainly means increasing the efficiency of HVAC systems and insulation of building structures. This should go hand in hand with improving thermal comfort and indoor air quality (Dipasquale et al., 2019). Furthermore, as most of the energy in the building sector is consumed by existing buildings, the European Commission has pointed out in the European Environment Convention the need to increase the rate of renovation of buildings as one of the measures to reduce emissions. Currently, the rate of replacement of existing buildings by new construction is low. Complex or in-depth renovation of a building is typically carried out 30 to 40 years after its construction or previous recovery. Therefore, special attention must be paid to the quality of current construction or retrofit of buildings, so that they can provide their users with a safe and healthy environment under economically affordable conditions even in 2050.

A significant obstacle to investing in quality building retrofit is, among other things, the low incomes and budgetary constraints of residents (Cupák and Strachotová, 2015), businesses, and the public administration. At the same time, Slovakian households spend the most on energy in the European Union relative to their income (Budovy pre budúcnosť, 2018).

Due to the plan of the Slovak Republic to renovate 3% of public buildings per year (approximately 220 million euros per year), it is necessary to ensure a financial stabilization process that will help to fulfil this plan continuously even without European funds. Energy performance contracting (EPC) could be used as one of these stabilization processes tools. EPC is a contract between an Energy Service Company (ESCO) and the recipient of this service. ESCO must guarantee certain energy savings over the duration of the contract. These savings are used to finance the retrofit measures and pay a profit to the ESCO. The present thesis aims to assess the possibilities of using EPC for financing the retrofit of apartment buildings.

2 STUDY AIMS AND OBJECTIVES

This doctoral thesis aims to add to the present knowledge by evaluating whether and under what conditions EPC could be a suitable tool for financing the retrofitting of existing residential buildings. The results are elaborated for the conditions of the Slovak Republic, but are also applicable on an international level. The specific objectives of the doctoral thesis are defined as follows:

1. Define a calculation procedure that will serve for subsequent calculations of the energy savings and profitability of the retrofit measures and packages. The procedure for energy calculations

should be primarily based on calculation algorithms according to the latest set of European standards (CEN).

2. Evaluate the suitability of various retrofit measures for financing through EPC for a given set of buildings. Create a potentially suitable combination of retrofit measures to be financed by EPC for each building in the given set of buildings. Evaluate the feasibility of these combinations for EPC taking into account various scenarios of development of economic parameters.
3. Determine the effect of various financing sources, including subsidies, on the suitability of the selected retrofit package for financing through EPC.
4. Estimate the effect of different calculation procedures on the calculated energy savings and profitability. Specifically, compare the results obtained when using a simulation tool with an hourly time step and a custom-made tool with a monthly time step. Discuss the main differences.

3 SELECTION AND ANALYSIS OF THE BUILDING

As part of the dissertation, 5 buildings were selected, which represent a sample of buildings most often constructed in Slovakia. For each of the selected buildings, an energy audit was carried out, which is an essential part of the EPC project, or part of a project to reconstruction of buildings from European funds or government subsidies. The energy audit includes energy and economic calculations, which were preceded by a building inspection and the related collection of energy consumption data. *Table 1* contains a list of buildings selected for a detailed inspection for the purpose of subsequent energy and economic calculations. All buildings are located in Bratislava.

Table 1 List of selected buildings – apartment houses

Building	Heat source	Heated floor area (m^2)	Heated volume (m^3)
Building I	Gas boiler room	1 886	32 992
Building II	Gas boiler room	415	5 513
Building III	District heating	1 662	36 140
Building IV	Gas boiler room	1 636	29 135
Building V	District heating	373	13 649

Over time, all buildings were partially renovated at the expense of the building owners. The renovations focused mainly on replacing the original opening structures with newer ones with better thermal insulation properties. In the case of Building II, the insulation of the perimeter walls of the building was also implemented. Although these renovations led to a reduction in energy consumption, they only partially helped the building as such. In this case, it is better and more appropriate to comprehensively reconstruct the building. Building II, Building IV and Building V have a natural gas boiler as a heat source, which is in its original condition. These heat sources are owned by the owners and largely affect the energy efficiency of the buildings, and are therefore among the typical shortcomings. In the case of Buildings, I and III, the heat source is a centralized heat supply, with a transfer station in the building, but they are not the property of the building owners.

The first goal of the thesis was to define the calculation procedure, which will be further used to calculate energy savings, the design of retrofit measures and their profitability. The MS Excel program was used as a calculation tool, in which energy and economic calculations based on the set of CEN standards were defined.

An important step in the calculation of the energy audit is the determination of the basic, comparative consumption, the so-called *baseline*. It requires an estimate of consumption, the correct internal temperature in the building, etc. A correctly estimated baseline is important for evaluating future savings. A comparison of the calculated need and the measured consumption is shown in Fig. 1. In the case of a large difference between the measured and calculated data, a calibration of the calculations was necessary, which consisted primarily of adjusting the internal temperature and the rate of air infiltration in the buildings. The determination of the baseline consisted in setting the internal temperature and the rate of infiltration.

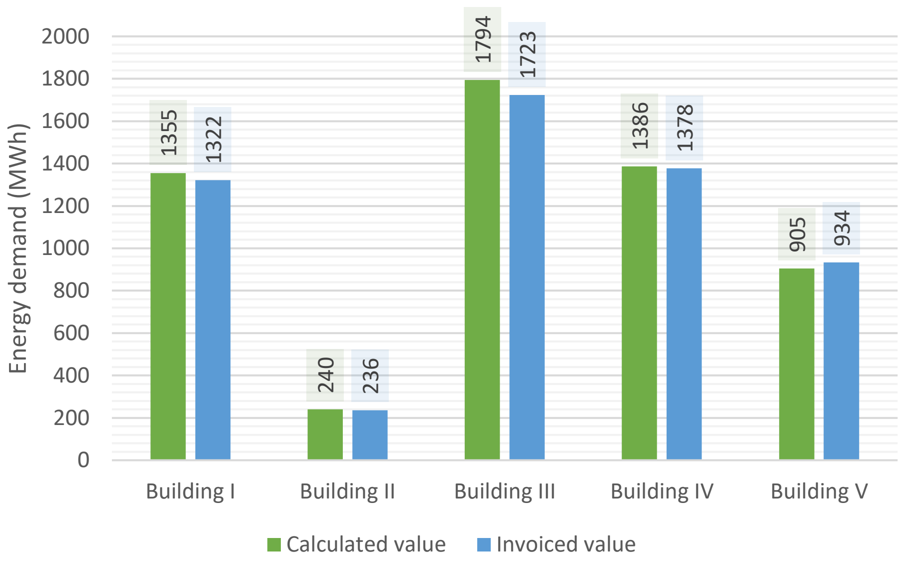

Figure 1 Energy balance of buildings

3.1 Proposal of retrofit measures

Retrofit measures could be divided into measures for building structures and measures for technical equipment of buildings. Among the most frequently proposed measures on building structures are the insulation of perimeter walls, roof structures, the ceiling above the unheated basement and the replacement of original opening structures. For the five buildings under consideration, measures on the perimeter envelope were designed according to the current condition and level of insulation.

Among the most frequently proposed measures to save energy within the technical equipment of buildings are reconstruction or replacement of the heat source, insulation of heating and hot water distribution systems, replacement of old technology in the boiler room, replacement of circulating pumps with new ones with frequency converters, installation of an energy management system (EMS), adjustment of temperature the slope of the heating system or hydraulic regulation and thermostatization. Retrofit measures for the technical equipment of buildings can also include the modernization of the lighting system, the use of rainwater or the use of renewable energy for the production of electricity or heating of domestic hot water. The proposed retrofit measures are shown in Tab. 2 and were designed separately for each solved building.

Table 2 Retrofit measures and sub-packages considered

System	**Retrofit measure**	**Sub-package**
Building structures	Replacement of opening structures	*EEM0*
	Insulation of perimeter walls	
	Insulation of roof	
	Insulation of floor above basement	
	Insulation of attic floor	
Space heating	Replacement of heat source	*EEM1*
	Insulation of piping	
	Hydraulic regulation and temperature control	
	Adjustment of temperature gradient (supply/return)	
	Renovation of measurement and control system	
Domestic hot water (DHW)	Insulation of piping	*EEM2*
	Replacement of circulating pump	
Indoor lighting	Renovation of lighting system	*EEM3*
Rainwater	Use of rainwater	*EEM4*
Renewable energy sources (RES)	Solar thermal system	*EEM5*
	Photovoltaics	*EEM6*
Energy management	Energy management system (EMS)	*EEM7*

3.2 Selection of appropriate combinations of measures

The methodology used in the design of retrofit measures was based on the need for complex renovation of buildings and the selection of appropriate measures that would reduce consumption and costs. In the case of measures aimed at improving the thermal insulation properties of structures, it was necessary to consider the parameters of the resulting structure that correspond to the latest legislative requirements. As part of the dissertation, three combinations of retrofit measures were created, where Combination I contain measures on building structures and the implementation of an energy management system in buildings, while the calculations pointed to the high payback of these measures and thus their unsuitability for implementation using EPC, as the maximum payback should represent 15 years. Combination 2 contains measures that are aimed at modernizing and improving the state of the technical equipment of buildings. The combination of these measures represented, similarly to Combination I, a payback of more than 15 years in some cases. Based on this, Combination 3 was created, which represents measures suitable for implementation using EPC. These three alternatives were used in the design of measures for all addressed buildings.

The dissertation also dealt with the calculation of profitability indicators for individual proposed retrofit measures. These indicators include net present value (NPV), net present value coefficient (NPVQ), discounted payback (PB) and, within the framework of the use of EPC, EPC payback. At the same time, the uncertainty of the calculation due to changes in input parameters such as a change in the discount rate, a change in the inflation rate, a change in energy prices and a change in the heat transfer coefficient U of the structure was determined.

3.3 Eligibility criteria and selection of measures for EPC

The duration of the contract should be at least eight years and must be defined in the contract. The typical duration is 10 years, but contracts with a duration of up to 15 years are no longer unusual (MFSR, 2022).

One of the most important criteria for the suitability of retrofit measures for EPC is the payback compared to the duration of the contract. The estimated payback must be lower than the duration of the contract, even taking into account the uncertainties in the calculations. A longer duration may be more appropriate but indicates a greater risk for the EPC provider. If the client is trustworthy, such as a public institution, a longer contract duration may be appropriate. On the other hand, if the object is a building that was previously partially renovated and its consumption is relatively low, the payback would be too long and therefore not suitable for an EPC project.

Table 3 Recommended durations of Energy Saving Performance Contracts

Duration of EPC project	Suitable for EPC	Slightly risky	Suitable with trustworthy client	Not suitable for EPC
up to 8 years	✓	✖	✖	✖
8 to 10 years	✖	✓	✖	✖
10 to 15 years	✖	✖	✓	✖
more than 15 years	✖	✖	✖	✓

3.4 The impact of input parameters:

When calculating, it is important to take into account uncertainty and errors that may occur, for example, in the calculation of energy savings, design of measures, etc. Errors may also occur in the economic evaluation phase due to changes in input parameters such as the energy prices, discount rate or initial investment. Some input parameters change over time and cannot be accurately predicted. A constant value of the inflation rate and the discount rate is usually used in the calculation, and for that reason it is appropriate to develop an analysis of the sensitivity of profitability to various input parameters. In the dissertation, the impact of the following input parameters for the package of measures proposed for Building IV was examined:

- discount rate (RAT_{disc});
- initial investment;
- energy price;
- energy savings;
- combined effect of initial investment and energy price.

Table 4 Input data for sensitivity calculations

Deviation from reference value (%)	Energy price (€/MWh)	Initial investment (€)	Energy savings (MWh/a)
-10%	135	653 972	504.9
-5%	142	690 303	482.0
0% (reference)	**150**	**726 635**	**459.0**
5%	157	762 967	436.1
10%	165	799 299	413.1

The influence of each of the input parameters was examined for three discount rates, for this reason, the effect of the discount rate itself was first examined. The effect of the discount rate on the payback is shown in Fig. 2. Naturally, the discount rate of 1% is the most profitable. The difference in payback between 1% and 3% and between 3% and 5% is up to 1.5 years. A change in the discount rate by 1% therefore results in a change in the payback of approximately 7 months.

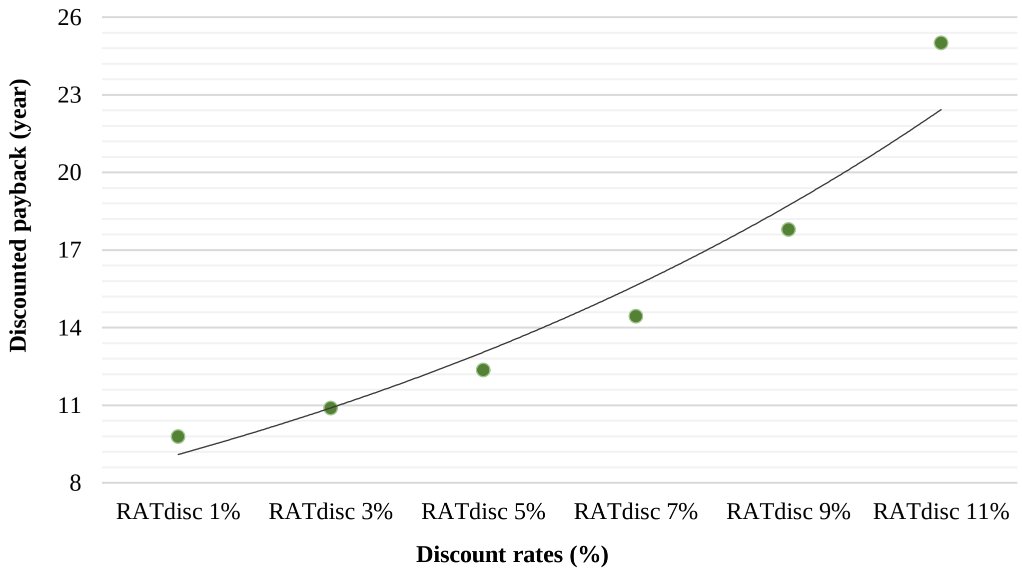

Figure 2 Effect of discount rate on discounted payback

The combined effect of energy price and initial investment is shown in Fig. 3. The energy price as well as the initial investment was increasing, which is an approximation to the real situation in the economy. It is seen that the effects partially cancel each other, so the effect on the payback was lower than in the case of just one of the parameters changing.

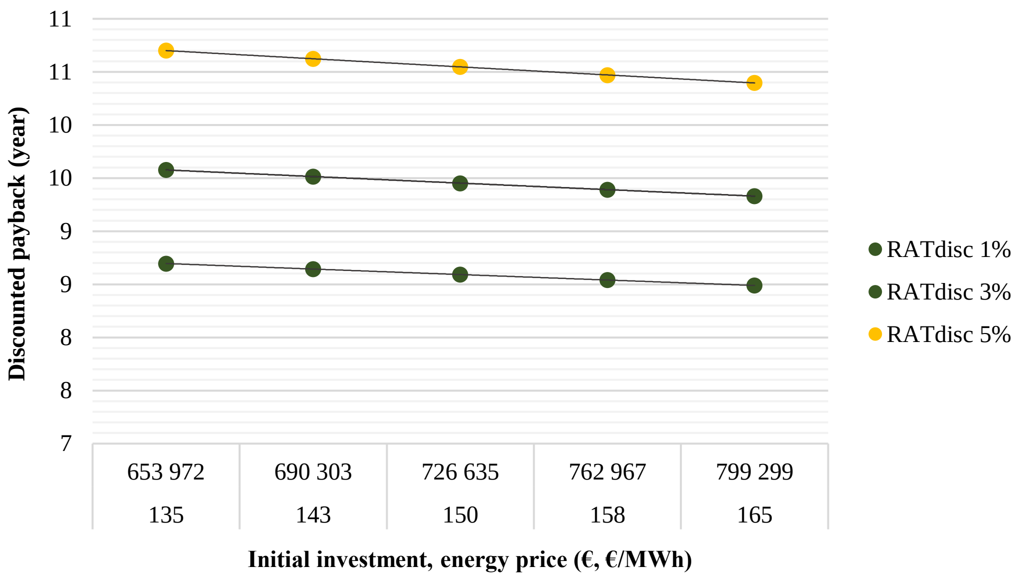

Figure 3 The impact of energy prices and initial investment changes

In general, it can be seen that changing each input parameter by just 10% led to a change in the discounted payback of about 1 to 1.5 years, depending on the discount rate. In the case of a combination of changes in several parameters, there is a difference of several years. Uncertainty was also shown to increase with the discount rate. This means that the combined error due to uncertainty in the input parameters worsens when the inflation rate is high. On the other hand, uncertainties can partially cancel each other out, for example rising investment costs and rising energy prices result in much lower incidence of uncertainty over several months, as shown in Fig. 3. This is likely to be the case in practice where investments are growing simultaneously with energy prices. These impacts should be considered when evaluating the impact of various parameters on profitability.

4 THE IMPACT OF DIFFERENT CALCULATION SCENARIOS

Unfortunately, it is not possible to precisely catch the current situation because it is constantly changing. For example, most of the calculation inputs were prepared, and calculations were performed during a relatively stable economic situation. Recently, the economic situation became turbulent. The prices of building materials have been increasing, as have the prices of energy. It is not clear how the situation will develop in the future. To at least partially cover this uncertainty, several scenarios were devised to capture possible developments.

Five basic scenarios were devised to cover the range of possible developments of the economy. They are briefly described as follows:

- **Optimistic** – Favourable development of the economy, when materials are abundant and relatively cheaper compared to the baseline. In addition, there is enough energy available so that its price is relatively favourable. This scenario is unlikely to occur, but it is included for comparison.

• **Baseline** – This is the basic scenario which assumes realistic input parameters based on the searches and documents available in the phase of input preparation. It reflects the situation during the Covid-19 pandemics before prices started to steeply increase. It serves as a reference for the other scenarios.

• **Negative** – Means negative future perspectives. The investments and energy costs are several tenths of percent higher than in the Baseline scenario. In the present situation, this scenario is likely to be more realistic than the Baseline scenario.

• **Pessimistic** – This scenario mimics an unfavourable development of economic parameters. It assumes a substantial increase in the prices of investment costs due to the increase of building materials and services. Simultaneously, it assumes that the energy prices double compared to the Baseline scenario. Sadly, the present economy and geopolitical development suggests that this scenario is realistic.

• **Extreme** – least favourable of all scenarios. It assumes that the investments double and that the energy prices increase by as much as 150%. This may seem extreme at the moment, but if the problems in the economics escalate, it can also be realistic.

A median, upper and lower value was calculated for each scenario. The middle value represents the input parameters. The upper and lower values indicate the estimated range of parameters to assess the uncertainty of the calculation. The input parameter ranges were chosen to be realistic, not too low to account for calculation errors, but not too high so that the calculated payback is specific enough to allow conclusions to be drawn. The discount rate was chosen at 3 and 0%. The change in the amount of the investment was in the amount of ±10%, the change in the energy price was in the amount of ±20% and the change in energy savings was also in the amount of ±20%. The profitability results of the package of retrofit measures were expressed as a discounted payback. This is the most relevant profitability parameter for ESCOs, as it shows whether the burn package will pay back during the contract period.

The results for Building I are visualized in Fig. 4, where it can be seen that the deterioration of economic conditions does not negatively affect the profitability of reconstruction. This is due to the fact that as the initial investment increases, so does the price of energy. This can be considered realistic, as it is likely that in times of economic crisis the price of energy will grow faster than the price of the investment.

The payback of the optimistic scenario is almost identical to the payback of the baseline scenario. However, in the current situation, neither of these two scenarios is likely to occur in the near future. The more pessimistic scenarios 3, 4 and 5 are more likely to occur. It can be seen that with the negative development of the economy, i.e., from scenario 3 to scenario 5, the payback decreases up to five years. Regardless of the scenario considered, the payback was reasonably low, indicating a potential suitability for EPC. The potential suitability is preserved even if we take into account the ranges of uncertainty indicated by the error bars in Fig. 4. For the EPC project, the upper range of uncertainty is important because it means the risk that the restoration project will exceed the duration of the contract. Uncertainty decreases as the economic situation worsens. In scenarios 3 to 5, which are much more likely to occur than in scenarios 1 and 2, the upper range of uncertainty is 2 to 3 years. In scenarios 4 and 5, the expected payback is up to seven years, even when uncertainty is taken into account. This indicates the suitability of the project for implementation using EPC.

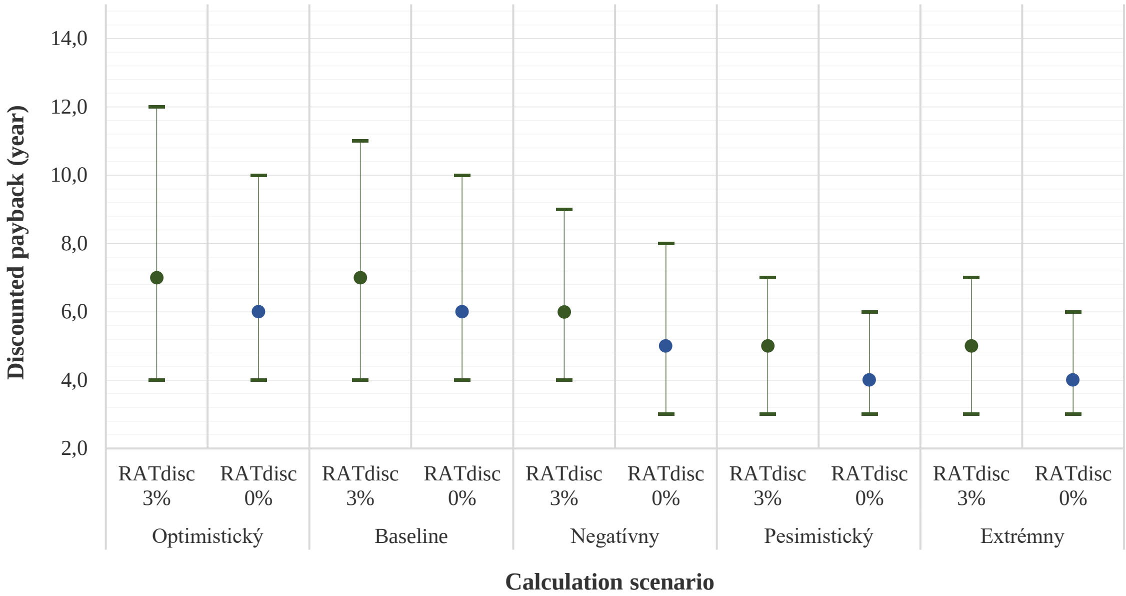

Figure 4 Discounted payback for different scenario - Building I

For Building II, the trend is similar to that for Building I, that is, the payback is improving with an increasingly negative economy outlook. Specifically, the middle payback is reduced from 10 years for Scenarios 1 and 2, whereas it drops down to seven years for Scenarios 4 and 5. The upper uncertainty intervals show a certain risk at the baseline economic development because the payback of 15 years already equals the maximum recommended duration of the contract. However, when a more negative outlook of economic development is considered, the upper uncertainty limit indicates suitability of the retrofit project for EPC, even at the less favourable discount rate of 3%.

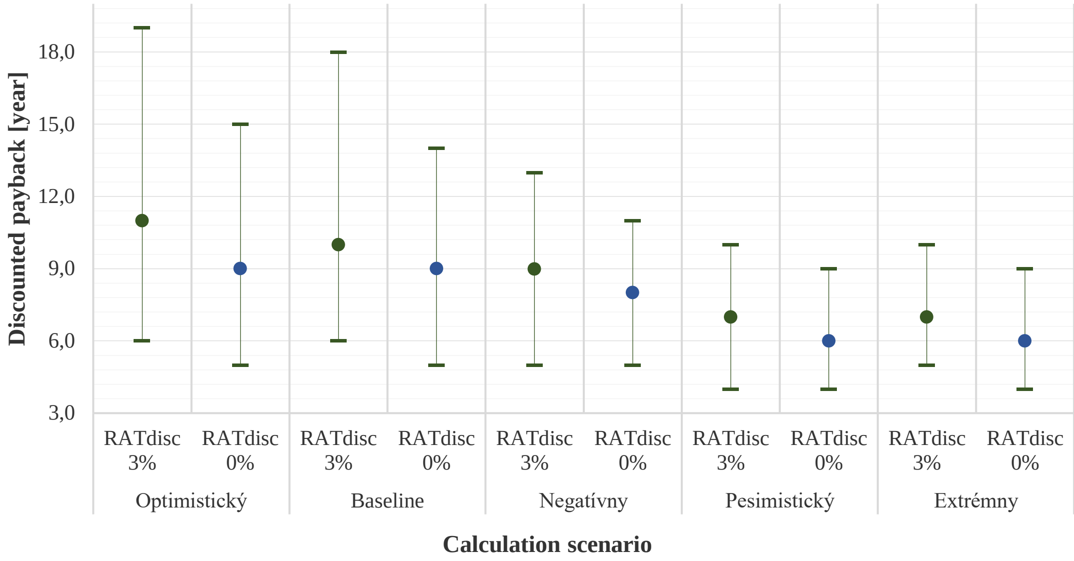

Figure 5 Discounted payback for different scenario - Building II

The payback is longer for Building III than for Buildings I and II. The middle value ranges from 13 years for the unlikely optimistic scenario down to 9 years for the pessimistic scenario, assuming a discount rate of 3%. In Scenarios 1 and 2 that represent a more positive economic outlook, the upper uncertainty range is high, meaning that these cases are especially sensitive to changes in the input data. The situation is slightly better in the case of Scenario 3. These results suggest that for Building III, only scenarios that involve a negative economic development make the retrofit project suitable for EPC, and only in cases where the duration of the contract is 15 years, which is the longest duration considered in this study. Otherwise, the investment could be too risky for the ESCO.

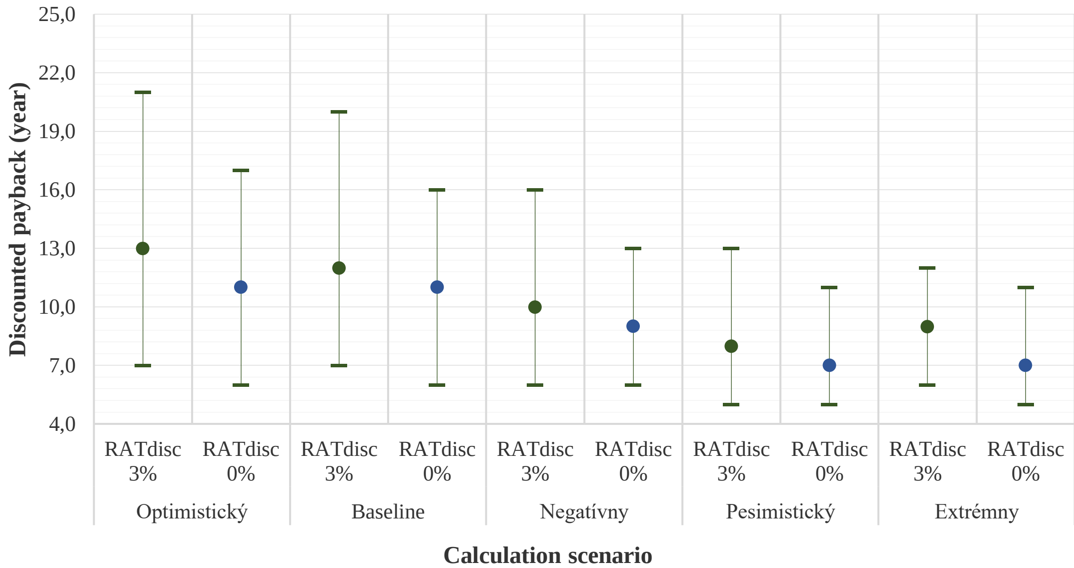

Figure 6 Discounted payback for different scenario - Building III

For Building IV, Optimistic economic development is not favourable for EPC. In the most optimistic scenario, the middle value of the payback was us much as 14 years, which is on the edge of the maximum contract duration of 15 years. Taking also the uncertainty into account, the investment may be well above 15 years, not only for Scenario 1, but also for Scenario 2. The payback starts to be potentially suitable for EPC assuming a negative outlook of the economic development, when the upper uncertainty interval is at 15 years at a discount rate of 3% (Fig. 7). The most favourable payback was obtained for Scenarios 4 and 5, when the middle value of the payback period was eight years and the upper uncertainty range was 12 years.

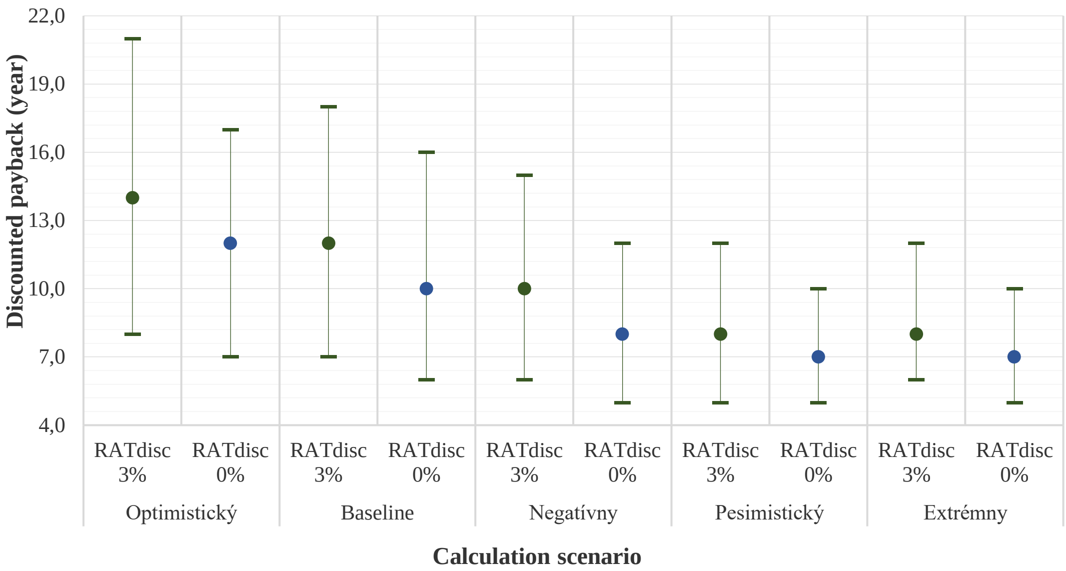

Figure 7 Discounted payback for different scenario - Building IV

The results for Building V are similar to those for Building IV. The more optimistic scenarios (1 and 2) are not suitable for EPC, whereas the more negative scenarios (3, 4 and 5) are potentially suitable, especially Scenarios 4 and 5. The middle payback is eight to nine years for Scenarios 4 and 5, and the upper calculation uncertainty is 12 years.

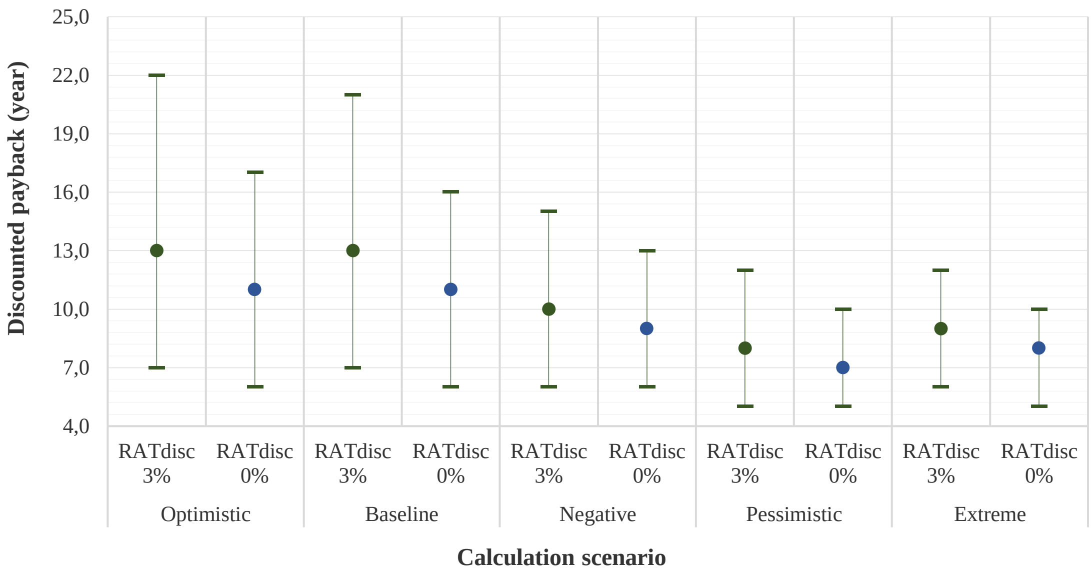

Figure 8 Discounted payback for different scenario - Building V

Five scenarios of economic development were proposed. Each scenario represented a different starting point for the calculation of investments and energy prices. The project was significantly more profitable in terms of payback for scenarios that included a negative economic development outlook. The reason was mainly the expected higher energy prices. The results indicate that for all five buildings, financing the renovation through EPC is realistic. However, for Buildings IV and V, EPC can only be recommended for scenarios that included adverse economic developments.

If energy prices increase sufficiently, the profitability of modernizing the building can be so high that it is possible to consider financing the reconstruction of the building envelope through EPC. This is especially true if high energy prices are combined with cheaper insulation material. Additionally, it should be noted that the median payback was 1-2 years shorter when assuming a discount rate of 0% instead of 3%. The findings show that a negative economic outlook (especially rising energy prices) and an incentive for energy-efficient modernization to support the economy and reduce fuel import dependency (the incentive is a zero-discount rate) may make EPC a suitable way to finance building renovations.

Other scenarios were proposed to monitor the impact of high investments at a relatively low energy price and, on the contrary, high-energy prices at lower investment costs. The results are demonstrated on Building I and Building V, which represent the remaining buildings. V. NPV and NPVQ were calculated for better visualization of the profitability of the proposed packages of measures. The NPVQ results showed that profitability dropped dramatically when the energy price was relatively low while investment was higher.

The maximum duration of the EPC contract in the dissertation is considered to be 15 years. Therefore, a positive NPV and NPVQ for the calculation period of 10 years indicates that the project is potentially suitable for EPC even after taking into account the uncertainty of the calculation. The NPVQ for scenario 2 (pessimistic) taken from the previous section shows a positive NPVQ, i.e., a profitable investment, even at a discount rate of up to 7%. In the case of NPVQ, the lower uncertainty interval is relevant to determine whether the investment is profitable. If the lower range of uncertainty is negative, it means that there is a risk of an unprofitable investment within the given limits of the calculation. A discount rate of 7% is also shown for illustration. This discount rate was included to demonstrate the impact of high inflation on the value of future earnings. The results show that with such a high rate of inflation, NPV and NPVQ decrease significantly, which means that the value of earnings decreases significantly. In scenario 1, investment increases dramatically, but energy prices rise at a much lower rate. This leads to the risk of a negative NPVQ, indicating that under these conditions the project is less suitable for EPC, although it may still be profitable and worth the investment, especially for longer contract durations. On the other hand, the high energy price and lower initial costs lead to much more favourable NPVQs, indicating that the project is suitable for EPC, even with a contract duration of 10 years. It should be noted that the results refer to a situation where the initial energy price is high, and hence the annual inflation rate is 3%.

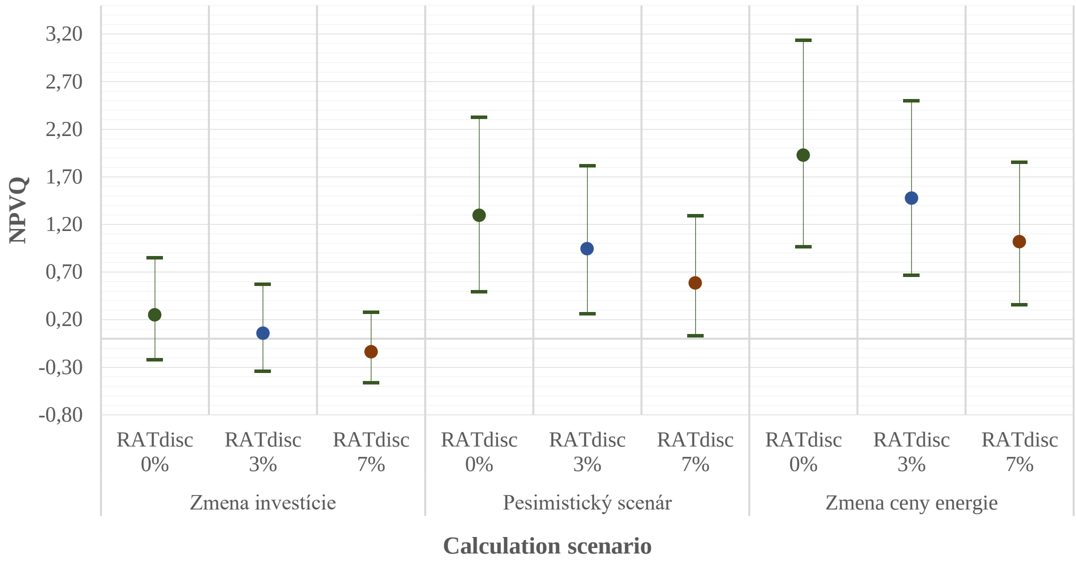

Figure 9 NPVQ for alternative scenarios - Building I

Compared to Building I, Building V has its own boiler room as the heat source, and therefore the price of heat assumed in the calculation was different (lower). For Scenario 2 (Pessimistic), the project was only slightly profitable assuming a 10-year contract, with the lower uncertainty interval in negative numbers (Fig. 10). At a very high discount rate of 7%, even the middle value was negative. Still, the project could be suitable for EPC, especially if a longer contract duration is assumed.

The project is not recommended for EPC in Scenario 1, where the investment is higher and the energy price is lower. Financing through EPC might be possible for longer contract durations than the 10 years assumed in the calculation. This illustrates the difference between the buildings, because for Building I, the profitability indicators were considerably more favourable. A lower investment and higher energy price, on the other hand, make financing through EPC much more viable, although the profitability is still lower compared to Building I.

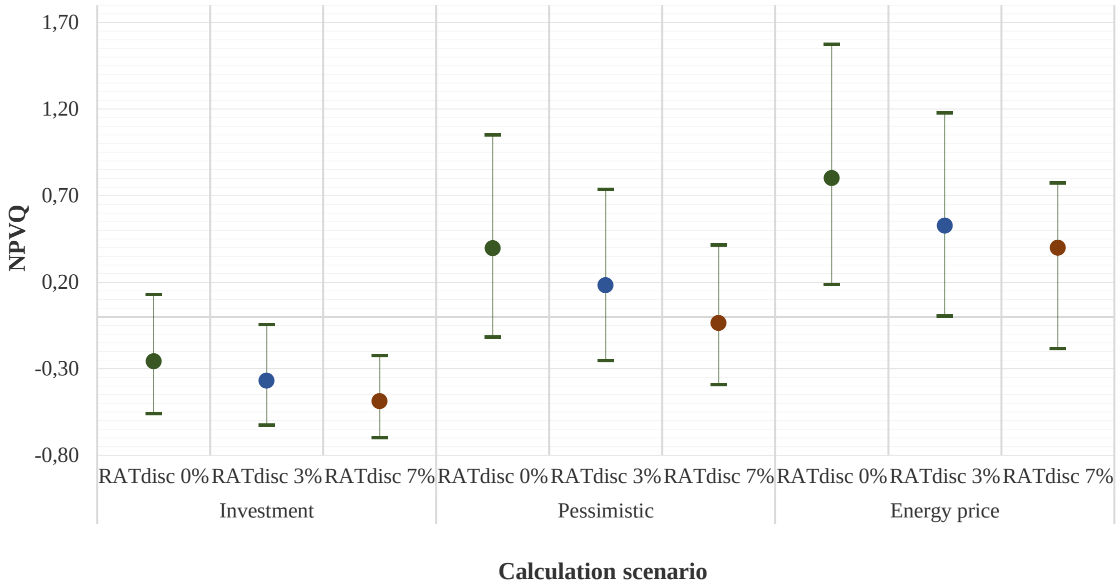

Figure 10 NPVQ for alternative scenarios - Building V

5 FUNDING METHODS AND COMBINATIONS

Financing a renovation project through EPC can be expensive and risky. It requires that the ESCO has enough own capital to invest in the measures, or that the ESCO borrows money from a commercial institution (bank). Therefore, it would certainly help to reduce the risk and improve the profitability of the EPC project if there were any grant schemes or subsidies available. Although ESCOs themselves may not be eligible to incorporate grants and subsidies into their cash flows, depending on the legislative framework, this is only a formal hurdle that could be resolved if there is sufficient incentive.

There are several sources of financing that can or could potentially be used to finance a building renovation investment. ESCOs usually have two options, to finance the EPC project through own capital or through debt, with debt financing being more common. In this work, we also considered the possibility of co-financing from other sources, such as grants for the use of a solar system for heating DHW and a grant from the building renovation plan for the EU.

5.1 Different calculation funding scenarios

Based on these facts and assumptions, several scenarios (Tab. 5 and Tab. 6) of funding including different percentages of different search sources were proposed. All scenarios are very calculated for Building I and Building. A solar grant was only considered for Building V, as a solar thermal system was not proposed for Building I.

Table 5 Definition of funding scenarios for Building I

Funding	Scenario (Building I)						
	1	2	3	4	5	6	7
Own capital	100%	0%	30%	10%	10%	10%	50%
Bank loan	0%	100%	70%	80%	60%	40%	0%
Solar grant	0%	0%	0%	0%	0%	0%	0%
Next Gen	0%	0%	0%	10%	30%	50%	50%

Table 6 Definition of funding scenarios for Building V

Funding	Scenario (Building V)						
	1	2	3	4	5	6	7
Own capital	100%	0%	0%	0%	0%	0%	29%
Bank loan	0%	100%	79%	69%	39%	29%	0%
Solar grant	0%	0%	21%	21%	21%	21%	21%
Next Gen	0%	0%	0%	10%	30%	50%	50%

The combination of buildings, financing scenarios and economic development scenarios resulted in 28 cases that cover a range of situations that could arise in practice. Some of these combinations correspond to common practice, while some of them are somewhat hypothetical, to trace the effect of funding. The results are discussed separately for Building I and Building V.

The profitability of the EPC project is represented by NPV and NPVQ. Paybacks were not included because it is not a suitable indicator of profitability in cases where a substantial part of the investment money is borrowed. In such cases, the payback was always zero or almost zero, which is misleading because it does not reflect the true profitability of the EPC project. The selected scenarios are graphically represented in Figure 11. The error bars represent the lower and upper range of uncertainty due to the combined uncertainty in initial investment, energy price and energy savings.

The impact of a 100% loan can be seen by comparing scenario 2 (100% bank loan) with scenario 1 (100% own capital). In the first case, the project is significantly less profitable, the lower uncertainty interval is even negative (unprofitable). Therefore, the EPC project may be risky for this building and financing method. Fig. 11 shows that for a contract duration of 15 years, scenario 2 becomes more profitable, but the difference with scenario 1 is even more significant. On the other hand, the initial investment was estimated at half a million euros, and 100% own capital financing is highly unlikely.

Scenario 3 represents a realistic compromise between scenarios 1 and 2, where 30% of the investment is financed by own capital and the rest is financed by a loan from the bank. This significantly improves profitability compared to scenario 2 (100% bank loan), but the lower uncertainty range is still negative, indicating potential risk. Scenarios 4 to 6 represent different combinations of own capital (only 10% investment), loan and grant. It is clear that if one-third of the funding is covered by a grant, the profitability of the project will increase substantially, even with a 60% loan (scenario 5). Such a composition of financing would make EPC a very interesting option for financing the restoration of the building. The project is most profitable in scenario 7 (50% own capital and 50% grant from the EU recovery plan), although this option may not be very realistic. This is illustrated in Figure 11, which shows that the net present value in this scenario is more than one million euros over the 15-year contract life.

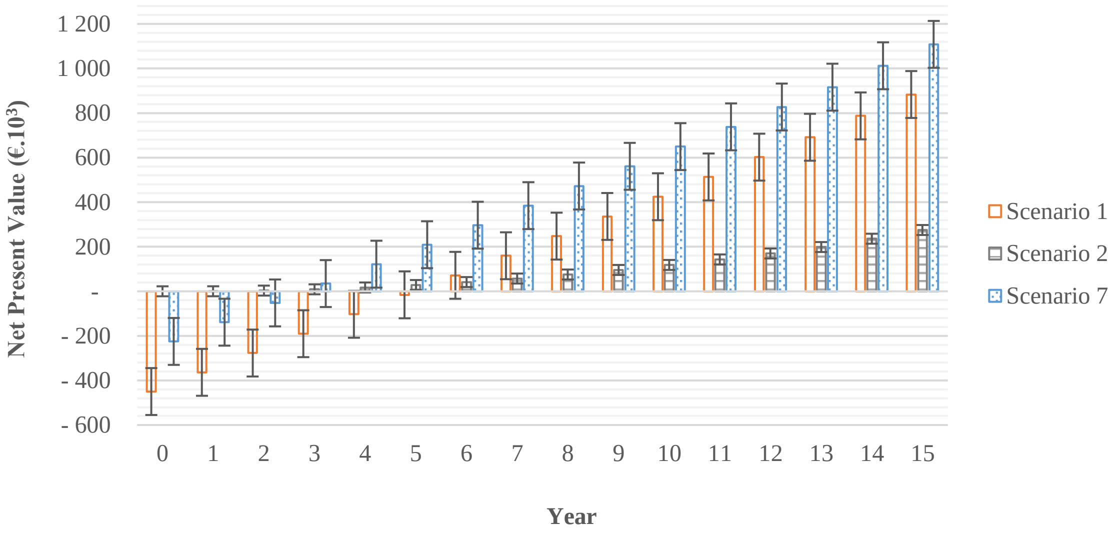

Figure 11 Comparison of funding scenarios for economic development scenario "Pessimistic" – Building I

Profitability indicators significantly worsened in the case of more optimistic economic development (baseline scenario). In the case of 100% own capital financing, the project could still be suitable for EPC, especially for the duration of the contract of 15 years (Figure 12). This is not the case in scenario 2, where a 100% bank loan is used for financing. Fig. 12 shows that in this case the net present value is negative even after a 15-year period. Adequate profitability was achieved only in scenarios 6 and 7, but these scenarios assume that 50% of the initial investment is financed by a grant from the EU recovery plan.

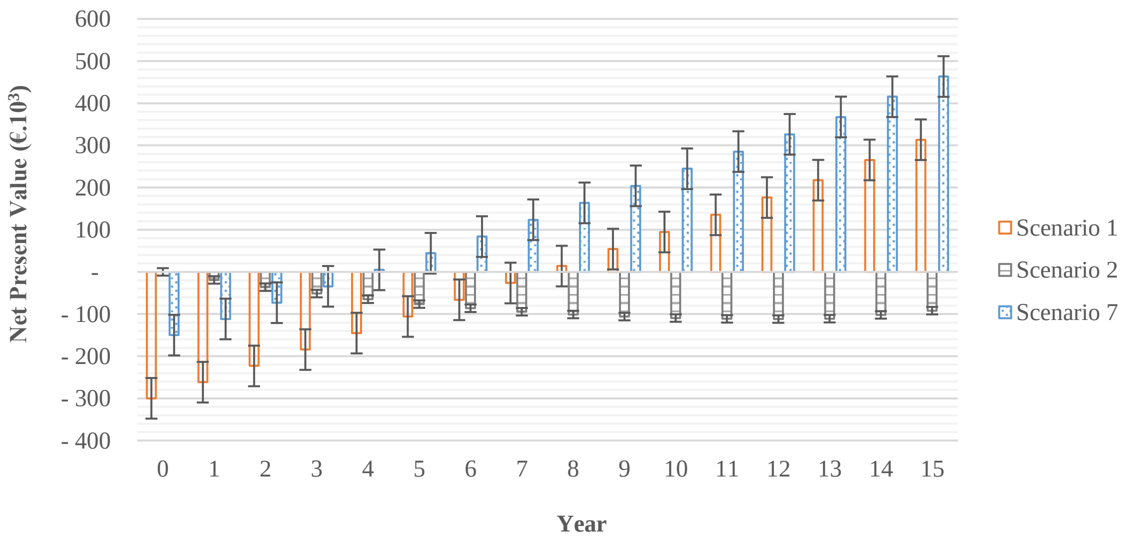

Figure 12 Comparison of funding scenarios for economic development scenario "Baseline" – Building I

Assuming a pessimistic economic development, own capital financing of the EPC project does not seem to be very profitable with a 10-year contract duration. Figure 13 shows that this could be suitable for EPC if the contract duration is up to 15 years. However, this situation is not very realistic, because the ESCO usually has to borrow a significant part of the initial investment. With 100% investment borrowed through commercial credit, profitability will deteriorate further and even a 15-year period is not enough to make the recovery package profitable. In this case, the investment does not seem to be worth the risk.

Scenario 3 also assumes the use of a loan from the bank, but this time a solar grant of 21% will also be used. This helps improve profitability, but the mean NPVQ is still relatively low and the lower uncertainty interval is negative (unprofitable). In the following scenarios, part of the financing is covered by a solar grant and part of the investment is covered by a grant from the EU recovery plan. In scenarios 4 to 6, the proportion of the grant from the EU recovery plan gradually increases from 10 to 50%. This has a significant impact on profitability, but only when funding from the EU Recovery Plan grant reaches at least 30%. Scenario 7 has the same percentage of subsidies as Scenario 6, but the rest is financed by own capital. This is the most profitable scenario. The NPV is more than €300,000 assuming a 15-year contract, which means a saving of €20,000 per year on average, making it a profitable project.

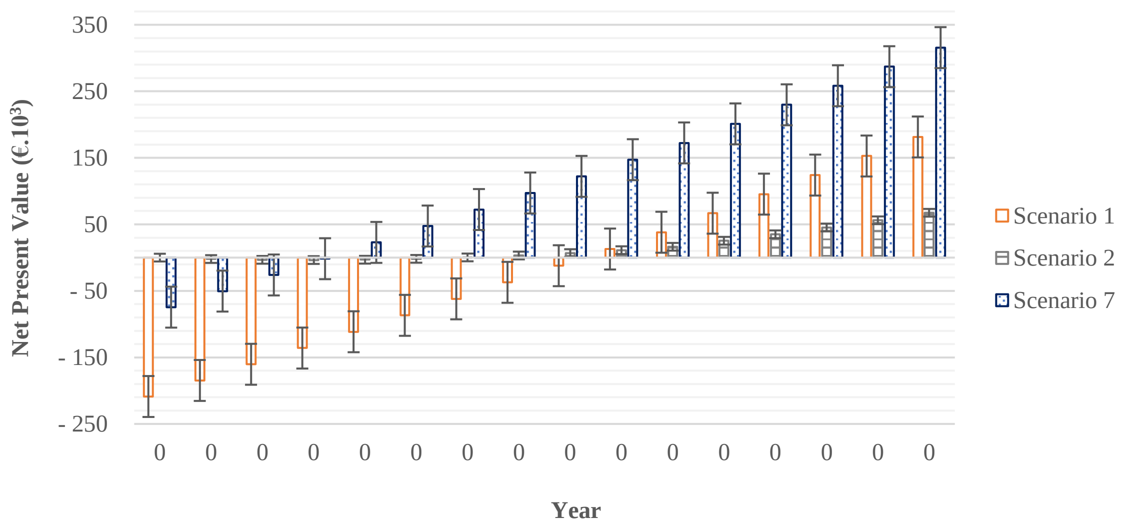

Figure 13 Comparison of funding scenarios for economic development scenario "Pessimistic" – Building V

Profitability and suitability for EPC assuming a contract duration of up to 10 years is much worse for the baseline scenario than for the pessimistic scenario. A sufficiently profitable scenario appears to be the scenario of co-financing of own capital, a loan from a bank and a grant.

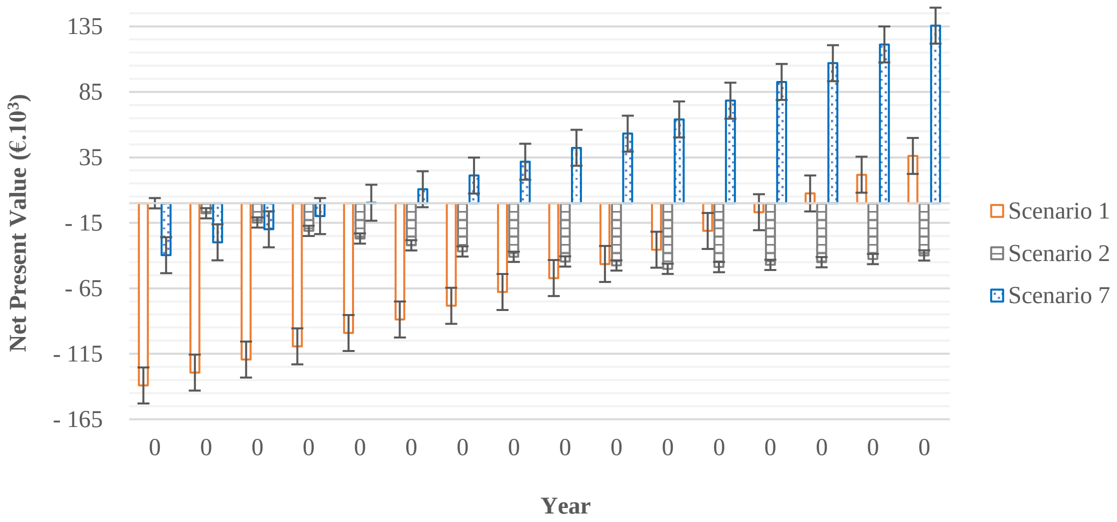

Figure 14 Comparison of funding scenarios for economic development scenario "Baseline" – Building V

6 EFFECT OF ENERGY CALCULATION METHOD

The last objection of the dissertation was to compare the results obtained for different methods of calculating the energy balance. It is also intended to briefly evaluate the suitability of using computer simulations as a tool in the design of retrofit measures. Specifically, the results of the calculation method according to CEN standards were compared with the results of the simulation program for dynamic calculations of the energy balance of buildings. The DesignBuilder program was used for calculations, which uses EnergyPlus as a calculation platform. The potential advantage of the simulation program is an accurate and verified physical model, the possibility to enter detailed calculation inputs and a small calculation step. On the other hand, the advantages of the calculation tool MS Excel are that it takes into account items that are not included in the simulation program, it was tailor-made for the needs of this thesis, the results of the calculations are relatively easy to understand and it is much less demanding to enter the input parameters. The building was modelled directly in DesignBuilder and was modelled as one thermal zone for the following reasons: most of the building served the same purpose (accommodation); the exact internal temperature in individual zones was not known and therefore it would not be useful to define multiple zones; this approach is commonly used in the energy audit of buildings; the building was also modelled as one zone in the Excel calculations.

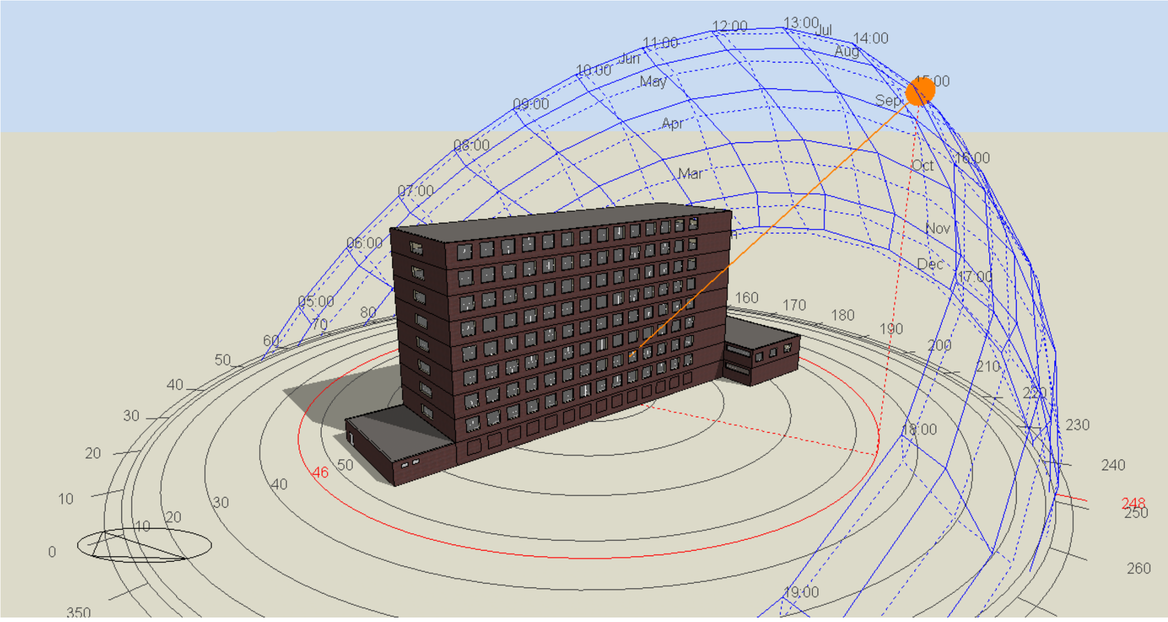

Figure 15 The finished building model

After the completion of the modelling of the building, the implementation of the current state and the design of retrofit measures followed. In this case, we focused on retrofit measures within Combination 1, the aim of which was to improve the thermal performance of the building envelope. The energy saving measures proposed in Combination 1.

Due to the substantial differences in inputs between the simulation program and the Excel tool, initially the difference in results between the two calculation methods was large. Therefore, due to the large deviation between the resulting values (energy need for space heating, energy need for DHW heating and total energy need), it was necessary to calibrate the model. In this case, the calibration consisted of adjusting the building's internal temperature and infiltration rate to some extent. However, in order to achieve a very good agreement between the measured and simulated values, the U values were also slightly modified in the simulation software.

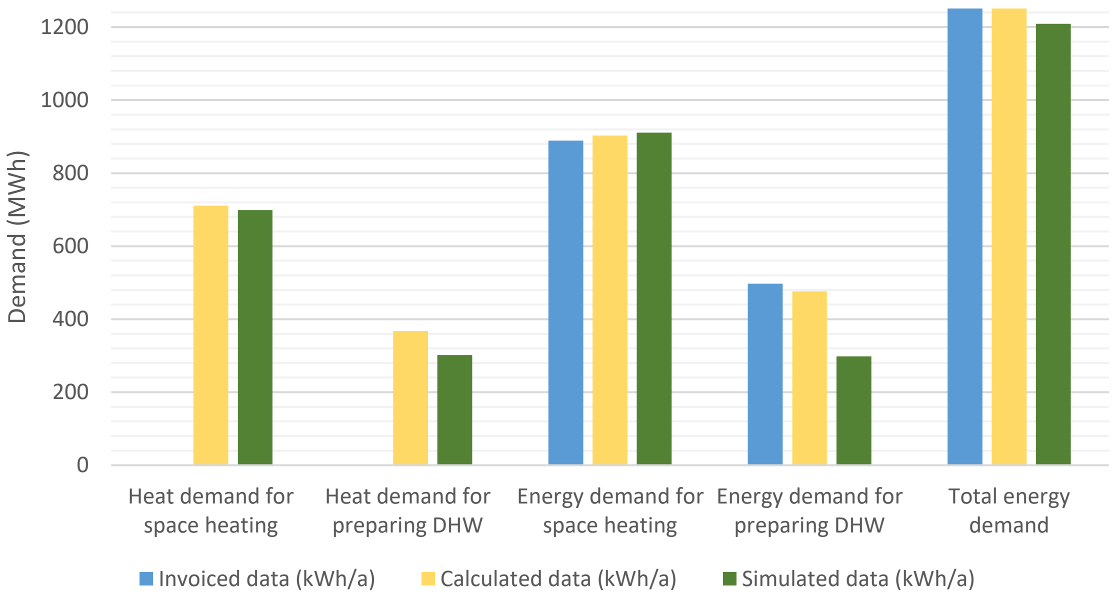

Figure 16 Heat and energy demand comparison

Profitability indicators were calculated for Building IV for Combination 1. Profitability indicators are shown in Tab. 7. Energy savings refer to the reduction of heat losses by insulating building structures. It can be seen that energy and, consequently, financial savings are very similar to those calculated in MS Excel. However, it is at the price of substantial modifications to the simulation model, which does not fully correspond with the MS Excel program. The calculation procedures of different calculation tools are hardly comparable, and without substantial modification of the simulation model to suit the measured data and the MS Excel program, the results of the energy calculations would be very different. This would also lead to very different values of profitability indicators.

Table 7 Comparison of the calculated and simulated profitability indicators - Building IV

	Calculated data	**Simulated data**
Discount rate (RAT_{disc})	1%	1%
Initial investment (€)	726 635	734 642
Inflation energy price (%)	3%	3%
Heat price (€/kWh)	0.045	0.045
Electricity price (€/kWh)	0.150	0.150
Energy saving (MWh/a)	459.0	372.5
Financial saving (€/a)	20 655	16 762
NPV (€)	-62 357	-102 900
NPVQ	-0.09	-0.13
PB (a)	32.0	33.0
$EPC_{payback}$	-108.6	-96.9

7 CONCLUSION

The aim of the thesis was to discuss the possibilities of financing the modernization of existing buildings through the energy performance contracting. In the case of work, five apartment buildings were selected, which represented the majority of buildings built in Slovakia. Based on the physical inspection of the buildings and the energy and economic evaluation, results were obtained that can be beneficial both for current research and for practice.

Due to the long payback period of the renovation of building structures, measures were proposed to modernize the technical systems for financing through the EPC. The profitability of each proposed package of measures depended on the specific case. In a certain situation, each of the packages could be profitable. Therefore, potentially feasible packages of restoration measures were designed individually for each building. The measures could be combined in such a way that none of the resulting combinations had a payback period ($EPC_{payback}$) longer than 15 years.

Five scenarios of economic development were proposed, which represent different starting points in terms of investments and energy prices. The project was significantly more profitable in scenarios with negative economic development, mainly due to expected higher energy prices. The results indicated that, for all five buildings, the financing of the renovation through EPC was realistic. However, for some buildings, EPC could only be recommended for scenarios that included unfavourable economic developments.

The payback was 1-2 years shorter assuming a discount rate of 0% instead of 3%. These findings suggest that negative economic developments (especially energy price increases) and the incentive for energy-efficient upgrades to support the economy and reduce dependence on fuel imports (represented by the zero-discount rate) could make EPC a very suitable way to finance building renovations.

Other scenarios showed that profitability dropped dramatically when the price of energy was relatively low while investment was higher. It turned out that when there is a shortage of materials and labour, which represents a high initial investment, but the supply of energy is stable and the price of energy is low, as in the situation during the Covid-19 pandemic, the project is less suitable for EPC. Conversely, if the price of energy rises sharply while construction materials and labour are relatively affordable, as in mid-2022, a renovation project may be a good fit for EPC.

A grant, either a grant for the use of renewable energy or a contribution from the EU recovery plan, would significantly help the profitability of the EPC project and reduce the risk of the project. Only 10% helped improve cashflow and a 30% contribution significantly affected profitability. A combination of own capital, a grant of at least 30% and a commercial loan for the remainder could represent a feasible and realistic financing scheme for the modernization project through EPC.

The most common scenario, where the ESCO borrows money from the bank, appears to be slightly profitable for the project and only in the case of negative economic development (pessimistic scenario), i.e., in the case of relatively high energy prices. At the same time, uncertainty intervals indicate that the investment may be risky. This situation applies to a contract duration of 10 years, while the project appears to be significantly more profitable with a contract duration of 15 years. Therefore, in this case, a contract duration of more than 10 years can be recommended.

The grant would greatly help the profitability of the EPC project and the reduction of risk. Whether it would be a grant for the use of renewable energy or a contribution from the EU recovery plan. As little as 10% will help improve cashflow, and a 30% grant contribution will significantly affect profitability. The thesis showed that a combination of a small share of own capital, a grant of at least 30% and a commercial loan for the rest of the funding could represent a realistic financing scheme for the modernization project through EPC.

It turned out that the methodology for calculating the energy balance of buildings has a huge impact on profitability results. Not only the methodology, but also the inputs have a fundamental influence on the results. However, these inputs are not known and must be based on an educated guess. It would be appropriate to summarize the different methodologies of energy calculations in energy audits of buildings and examine their impact in more detail, and thus it would be appropriate to establish recommendations on preferred procedures in calculations.

This thesis confirmed that the modernization of technical systems can be more suitable for EPC than the modernization of building structures. Energy calculations in practice usually involve a monthly step, as it is a compromise between accuracy and labour intensity. However, calculation procedures usually do not allow a detailed energy balance of technical systems, such as heat emission, distribution and accumulation in the heating system. In addition, the monthly step may not produce accurate results. Accurate and affordable calculation tools should be explored to support the accuracy of energy audits in practice.

A wider range of input parameters and model scenarios would be needed to provide more detailed information on the possibility of using EPC in the renovation of apartment buildings. Due to time and space constraints, this work explored some but not all possible scenarios. It has been shown that grants and subsidies could significantly increase the profitability of modernization projects and make them attractive to EPC; however, in practice this approach would likely be hindered by legal restrictions.

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