INVESTIGATING THE FEASIBILTY OF GEOTHERMAL INVESTMENTS, TAKING INTO ACCOUNT RISKS

THESIS OF DOCTORAL (PhD) STUDY

TÜNDE KATALIN JENEI

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Name of the doctoral school	Doctoral School of Economics and Organisational Sciences
Scientific scope:	Economics and Organisational Sciences
Head of the school:	Dr. József Lehota
	university lecturer, MTA doctor
	SZIU, Faculty of Economics and Social Sciences
	Institute of Business Sciences
Supervisor:	Dr. Judit T. Kiss
	associate professor, phd
	University of Debrecen
	Faculty of Engineering, Department of Engineering Management and Enterprise

....	....
Head of the Doctoral School's signature	Supervisor's signature

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1. ANTECEDENTS OF THE WORK, OBJECTIVES

1.1 Significance and relevance of the subject

The significance and relevance of the subject is justified by the energy policy of the European Union and more specifically the objective of European Commission to produce 20% of energy consumption within the EU from renewable energy sources by 2020. Following the period from 2020 to 2050, the objective of the Commission is to achieve 75% from renewable energy sources of the gross energy consumption in the EU.

Hungary has significant thermal water resources with several decades of experience in exploitation and use for energetic purposes (greenhouses, heating plastic tunnels). Our existing and economically exploitable thermal water resources are used in direct utilisation of heat (buildings, housing estates).

Geothermal district heating systems in various sizes and outputs suitable for heating buildings are in operation in a total of 25 locations according data from 2015 in Hungary (TÓTH 2015). Only a little over 1% of our energy demands are met using geothermal energy in 25 different locations (SZITA 2017).

In my thesis, I examine the Hungarian regulations of direct geothermal energy use for district heating, the method of utilisation as the process of investment and the risks arising during process from the aspect of how these promote or inhibit the implementation of geothermal projects. I seek the causes why despite the large geothermal energy resources available in Hungary, only small number investments have been implemented thus far. Unlike other investments in other renewable energy sources, it is typical of geothermal investments that investors calculate with such geological risks arising in the early stages of implementation that determine the outcome and effectiveness of the entire investment. During the decision making on the implementation of the investment other aspects including social „usefulness" beyond profitability must also be considered. These aspects also include state involvement, reduction of environmental pollution (e.g.: CO_2 emission) and various aspects of social usefulness as well.

1.2 Research objectives

I approached the questions of my research at three levels: I carried out research at the level of the European Union with respect to a few countries at national levels and to one specific investment. The criteria system of the examination can be divided fundamentally into three units according to areas influencing the implementation of geothermal investments: *on the one hand* the legal environment of the investment (national, international legislation, laws), *on the other hand* the financial resources of the investment (economic calculations, cost-benefit analysis, sensitivity analysis), *thirdly* the risks arising during implementation (technical, economic, geological) and the management of these risks.

I set the following **objectives** during the research of the feasibility of geothermal investments:

- To reveal how existing permit requirements influence a geothermal investment implementation process.

- To confirm that project financing as a risk management method can be applied in case of geothermal investments.
- To examine how SWOT-analysis can be used in the preparation for decision making process as a tool of risk analysis.
- To examine how the return on investment of a planned Hungarian geothermal investment develops from the aspect of the Investor, the State and Society.
- To reveal how financial loans affects the cash flow of the investment.

1.3 Hypotheses of the research

I defined the following hypotheses based on the overview of geothermal literature and my own examinations.

HYPOTHESIS 1: It is time consuming to obtain the required permits for the implementation of geothermal investments, involves several authorities which means costs for the investor.

HYPOTHESIS 2: Project financing as a risk management method can be applied in case of geothermal investments, except for the initial (research) stages of the investment.

HYPOTHESIS 3: SWOT-analysis can be applied as a tool for risk assessment in preparation for decision making of geothermal investments.

HYPOTHESIS 4.1: The return on investment changes from the aspect of the investor if beyond own funds other resources (state aid, bank loan) can also be obtained for financing the investment.

HYPOTHESIS 4.2: Funding geothermal investments does not result significant financial returns for the state. Tax obligations do not have a counterincentive effect for the investor.

HYPOTHESIS 4.3: The investment makes a return considering the social effect of the investment.

HYPOTHESIS 5.1: If the ratio of the loan increases in the financing portfolio of the geothermal investment to be examined, then risk effect affecting the return of the investment originating from the increase in interest rate on the loan. Furthermore, if interest rate on the loan increases, the effect reducing the return of the investment is greater in case of a change from the higher level of interest rate.

HYPOTHESIS 5.2: The reducing effect of a one percent increase in the discount rate is greater regarding the net present value of the geothermal investment to be examined than what a one percent increase of the interest rate results with no change in all other factors.

HYPOTHESIS 5.3: The absolute value of the flexibility coefficient of the rate of the investment regarding the net present value increases in case of the investment to be examined with an increase in the loan, i.e. that the effect of the change in the rate of the loan for the investment regarding profitability also increases. The elasticity coefficient according to discount rate of the NPV in case of a return on investment increases along with an increase in discount rate, i.e. that the effect reducing profitability originating from a change in discount rate has a stronger influence with a higher ratio of loan than with a lower loan ratio.

2. MATERIAL AND METHOD

I reviewed the national and international literature on the subject in order to have theoretical foundation for my research. I carried out research of sources to reveal practical questions of the implementation of geothermal investments. I collected data and analysed various EU directives, work documents, national and international legislations in the process. I summarised and organised the findings of independent studies, and defined additional conclusions described in these studies. I relied on own empirical experience during the analysis of a specific geothermal investment which I collected during the research project of three geothermal investments.

Table 1. Materials and methods used to verify the hypotheses

The system of examination	**Objective**	**Material**	**Method**
The legal environment of the investment	– To reveal how existing permit requirements influence a geothermal investment implementation process.	Related literature, national laws, statutory regulations, and some EU directives	Analysis of literature and document
Investment risks and their management	– To confirm that project financing as a risk management method can be applied in case of geothermal investments. – To examine how SWOT-analysis can be used in the preparation for decision making process as a tool of risk analysis.	EU studies (GEOFAR, GEOELEC, ALTENER), other relevant analysis, articles, data.	SWOT analysis, document analysis, literature review.
Sources of financing the investment; economic calculations	– To examine how the return on investment of a planned Hungarian geothermal investment develops from the aspect of the Investor, the State and Society. – To reveal how financial loans affects the cash flow of the investment.	Data and informations collected by research projects	Net present value, calculation of internal return. Investigation of linear, polynomial and exponential function relationships.

Source: own editing

I used data collected during my research work and other official information in order to support the analyses of the situation and state and main tendencies, development directions.

We can formulate a general idea from the results obtained during the feasibility study of a local government geothermal investment on the expected risks, factors inhibiting geothermal investments in Hungary, and opportunities for financing the investment.

Information, data related to the objectives defined in the thesis and the methods of processing these are summarised in Table 1 in a way that objectives are classified according to areas influencing the feasibility of geothermal investments primarily based on the aspects of the examination.

3. RESEARCH RESULTS

In my Thesis I focused on the Hungarian practices of implementing geothermal energy investments. I considered the entire geothermal investment as one process and divided the investment process into phases for the examination. The analysis of individual questions justified the division of the process into phases (e.g.: legislations, risk assessment or methods of financing).

3.1. Examining the official and legal background of geothermal investments

Following the review of the legal background related to geothermal investments and assigning the permit procedures to investment phases, I concluded that the investor is obligated to initiate several permit request procedures in order to establish and operate an investment utilising geothermal heat. I examined permit processes related to the establishment and operation of these types of energy investments based on the effective laws and regulations. I sought to answer how effective permit procedures enforced by authorities influence the process of implementation of geothermal investment.

I examined the effect of legislation on geothermal investments, identified what permit procedures are required in specific phases of the process then summarised the various types permit procedures in table 2, which arise during the implementation of geothermal investment. I assigned these those authorities where various permit requests have to be submitted and where permits are issued at the end of the process. Legal rules determine the length of administrative authority procedures, which are listed beside the authorities; different durations apply to each permit procedure.

Table 2: Service fees for each authorization procedure and duration of administration

Description of use procedures	**Name of the competent authority conducting the procedure**	**Authority's statutory administration time**	**Procedural, service fees payable to the authority**	**Period of validity of issued licenses**
1. Environmental licensing procedures (Government Regulation No. 347/2006. Government Regulation No. 314/2005.)	Environmental, Nature Conservation and Water Inspectorate (in brief: Inspectorate)	Preliminary environmental study: **33 days**	Preliminary investigation prior to the environmental authorization procedure: **250 000 HUF**.	As a result of the preliminary environmental investigation, based on the decision of the authority within two years, the applicant may apply for an environmental or uniform environmental permit. This two-year deadline can be extended once.
		In case of public hearing: **45 days**	Mandatory environmental impact assessment procedure **900 000 HUF**. (Category 1)	The single environmental permit for a fixed term, but at least ten years. The requirements and specifications contained in the permit shall be reviewed at least every five years according to the rules of the environmental review.
		Time for application procedure for obtaining environmental permit, environmental impact assessment: at most **90 days**	Environmental impact assessment procedure required by the preliminary decision of the Inspectorate **750 000 HUF** (Category 3)	

	Environmental, Nature Conservation and Water Inspectorate (in brief: Inspectorate), such authority gives permission.	Administrative deadline per license type: **60 days.** The deadline to remedy the deficiencies in the notice of receipt of the request **10 nap**.	Conceptual water licence **36 000HUF.**	The principle of a water license shall be valid until the legal authority for the establishment of the water work or water facility specified therein is valid, but for a maximum of one year, which may in one case be extended by a maximum of one year.
2. Water licensing procedures (Government Regulation No. 147/2010.)	Environmental, Nature Conservation and Water Inspectorate (in brief: Inspectorate) as the state-owned water operator gives permission.	The Board of Directors and the Trustee do not set a legal deadline, because they are involved not as an authority but as an owner or as a manager of state property.	Water facility construction license geothermal water use **500 000 HUF.**	The water facility construction license valid for the period specified in. The period of validity may be extended according to the rules for amending the license.
	Hungarian State Holding Company, such as groundwater owner gives permission.		Water Operating Permit is 80% of the license fee for the installation license, in case of geothermal water use **400 000 HUF**	The water license operating license is valid for the period specified in the permit. When establishing the validity period of the permit, the water authority will assess and consider the water management purpose, technical characteristics, operational and other conditions of the facility.
		Conceptual building permit process: **22 workdays**	Fee for a building permit procedure, - for each individual destination, up to 250m² of useful floor space **20 000 HUF**.	The final conceptual building permit is valid for one year. During validity of the request may be renewed once for up to one year.
3. Building licensing procedures (Government Regulation No. 343/2006.)	Territorial Competent Authority of the Hungarian Trade Licensing Office Territorial Measurement and Technical Safety Authority is the Building Authority for structures connected to water facilities.	Building permit process: **45 workdays**	It has a useful floor area of more than 250m² per individual destination **100 000 HUF**.	The final building permit is valid for one year. It may be extended once upon request for a maximum period of one year during its validity.
			In case of building an object, every 100m² started **10 000 HUF** or per meter **1000 HUF.**	
		Usage licensing process: **22 workdays**	The fee for the permission procedure is the same as for the building permit procedure.	The authorization for use is for an indefinite period.
4. District heat production and service licensing procedure (Government Regulation No. 320/2010. Government Regulation No. 157/2005.)	Hungarian Energy and Public Utility Regulatory Authority	District heating plant establishment and operating authorization procedure: **90 days**	The payment of the fee depends on the performance of the facility. At less than 5MW: **200 000 HUF** 5MW-50 MW in case of heat output: **500 000HUF**	The permit for the establishment of a district heating installation shall be valid for the period specified in the permit. The license can be extended - upon request - once for the same duration as the building permit, but for a maximum of two years.
				The operating license required for the operation of the district heating plant is for an indefinite period.

Source: JENEI (2016)

Administrative fees paid by the applicant to the authorities as well as the length of the administrative procedure are regulated by law. These fees are to be paid with each permit request to the authority. The amount and projection basis of procedural costs differs with each authority. In some cases these are to be paid in a lump sum and in other cases the fees are determined based on various parameters of the installation e.g.: the performance of the installation.

The authorities issue permits as a result of the procedures, which enables the investor to initiate a new procedure or the implementation of the investment continues within the legal framework supported by permits.

Obtaining the required permits in case of a geothermal investment is a complicated process; the investor must complete authorization procedures with high administrative fees in multiple steps. The implementation of investments is made longer by the complex official administration that are not transparent as time requirement of preparation and the actual implementation of the investment can be prolonged.

My findings based on the examinations are the following:

- There is no contradiction in the regulations and there is such area or activity which is not covered by regulations.
- The individual permits are built upon each other; one is a prerequisite of another in the procedural process of authorities. The order in which they have to be obtained is regulated by law. The one that is required the earliest must be requested first and the following permit request procedure can only be initiated when the previously requested permits are obtained.
- The procedure is a complicated, lengthy system, which slows down implementation. Therefore, a new law regulating renewable energy use should be made which could regulate and provide a framework for establishing and operating renewable energy investments. Thereby, investors, producers and consumers in this segment of the energy sector could work in a predictable and transparent environment.

3.2. Possibilities of risk management in case of geothermal investments, application of project financing and decision tree

I consider events slowing down the investment from the events essentially influencing the geothermal investment as risk. I assigned the risks occurring during the investment process to the steps set in the phases of the investment. The examination of the risks pointed out that the risks can be classified into three groups according to quality. Geological risks belong to one of the groups, which include such risks that cannot be predicted and at the same time require immediate decision making. Primarily economic risks belong to the other group while technical risks into the third one. Geological risks are linked to main parameters of locating the geothermal reservoir and the usability of the geothermal reservoir (yield, temperature, pollution). If sufficient amount and quality of thermal water is not found, some parameters do not meet the expectations of the investor then exothermic well cannot be developed, in which case a new drilling is performed with additional costs or the exploration (thus the project) comes to an end.

I collected those conditions from the literature dealing with geothermal investments, which could be sources of risk during the implementation of the project. I listed risks according to the order previously determined in the phases of the geothermal investment, in the chronological order as they are expected to arise (JENEI 2012/1).

I summarised these possible risks in table 3 (JENEI - KOCSIS 2011/2), then assigned risk management tools, methods to the individual risks of the geothermal investment.

The columns in Table 3 show the main decision situations, the decision points in case of a geothermal investment. I assigned those risks to the individual decision points, which have to be considered in the given point when making a decision. The method of risk management has to be decided in these points. The decision made in the individual decision points is an action closing the previous phase or activity, which at the same time opens the next phase or activity (MSZ EN 62198:2013).

Following the systematisation of risks, I characterised the possibilities of geothermal risk management according to the feasibility of the investment. Within this I determined that two risk management strategies can be applied considering its internal structure:

- The method of project financing: risk management based on future cash flow.
- Decision tree: application of yes-no decisions.

The two risk management strategies can be characterised with following from the aspect of the geothermal investment.

- The method of project financing cannot be applied in the research phase, at the same time it can be applied well in the other three phases. The explanation for this is that the significance of geological risks is lower in the other three phases and risks can be more or less predicted well.
- The method of decision tree can be applied well in the research phase, at the same time it can be used in the other three phases it is more practical to apply some risk management strategy (avoidance, devolution, reduction, and acceptance) that can be regarded as traditional, however. Predominantly, geological risks dominate in the exploration phase, which on the one hand cannot be predicted on the other hand the investment up to that point is „lost" in case of an unsuccessful drilling.

It can be stated, based on the results of the examination, that neither traditional risk management nor project financing which is generally regarded as risk management can be applied for the management of geological risks belonging to the exploration phase. In this case, the decision tree as risk management strategy can be applied.

Table 3: The matrix of the relationship between geothermal investment risks and investment decision points

		A	B	C	D	E	F	G	I	J
		Decision to prepare the investment	Deciding on investment	Accepting the preliminary business plan	Determining the location of the research wells	Deciding on drilling the first production well	Decision of the first reinjection well drilling	Deciding on the number of wells	Deciding on the way of utilization and the surface investments	Operation - Review of Business Plan
1.	**Research phase - geological risks**									
1.1	Reservoir temperature and heat content of liquids				x	x				
1.2	Permeability of the geothermal reservoir				x	x				
1.3	Geothermal liquid gas content, gas composition				x	x				
1.4	Acid and salt content of geothermal fluid				x	x				
1.5	Reinjection risk				x		x			
1.6	Project area control / ownership		x							
2.	**Research phase - economic risks**									
2.1	Inflation	x								
2.2	Risk of borrowing rates	x								
2.3	Exchange rate risk	x								
2.4	Regulatory and administrative risks		x							
2.5	Energy market risks		x							
2.6	Credit borrowing opportunities availability			x						
2.7	Operation of state support system			x						
3.	**Design phase - geological and economic risks**									
4.	**Construction phase - geological risks (during trial run)**									
4.1	The temperature of the reservoir and the heat content of the liquids are reduced								x	
4.2	The permeability of the geothermal reservoir is reduced								x	
4.3	Gas, acid and salt content of geothermal fluid increases, gas composition changes								x	
4.4	Decrease in power of the producer, the re-injection well								x	
5.	**Construction phase - economic risks**									
5.1	Lack of end-user declaration of intent to purchase the energy produced, volume and price risks							x		
5.2	Exceeding the planned investment costs								x	
5.3	The risk of a general contractor contract								x	
5.4	The lack of non-repayable grants (state aid, grant funds)								x	
5.5	Supplier contracts-, price changes, late delivery								x	
5.6	Delays in completion of the project								x	
6.	**Operational phase - geological risks**									
7.	**Operational phase - economic/technical risks**									
7.1	Operating costs will increase significantly									x
7.2	Revenue is reduced during operation									x
7.3	Some units and tools of the power plant fail, they are ruined									x
7.4	Unsatisfactory performance level after completion of construction									x
7.5	Government decisions that change the requirements for obtaining licenses and approvals									x
7.6	Environmental problems arise that lead to the payment of a penalty, the closure of a power plant									x
7.7	Disasters - Risk of fire, explosion, etc.									x

Source: own editing based on JENEI – KOCSIS (2011/2)

3.3. The place and the role of SWOT-analysis in geothermal investment

SWOT-analysis classifies the characteristics of the investment according to two aspects. One classification applies to favourable and unfavourable concepts; the positive ones are considered advantages and the negatives as disadvantages. The second classification applies to external factors independent of the investment and factors dependent on the investment i.e. internal factors. Based on the assessment of these factors it can be concluded that weaknesses can be considered as internal while threats as external risks.

I examined whether SWOT-analysis can be applied in the process of preparing a decision as a method risk assessment. The SWOT-analysis is the heuristic characterisation of processes with the help of positive and negative characteristics as well as external (independent of the investment) and internal (dependent on the investment) parameters. Based on these

- I compiled the cross table of the geothermal investment based on the general characterisation of geothermal investments,
- I presented the application of the SWOT-analysis through two Hungarian examples (Létavértes, Kistelek).

I selected three-three findings from the findings listed four (strengths, opportunities, weaknesses, threats) elements of the SWOT-analysis, which I included in the so-called cross-table (see Table 4).

The customised SWOT-analysis and cross-table of each and every investment can be prepared based the „general cross-table" complied for the geothermal investment.

Table 4: General cross-table of geothermal investments

			Opportunities			**Threats**		
			1.	2.	3.	4.	5.	6.
			In Hungary, the untapped geothermal energy is the direct utilization the most suitable.	By using geothermal energy sources, a fossil energy source can be replaced, thus reducing the country's energy import dependency.	There is a significant reduction in energy costs for communities that already use geothermal energy.	Without a transparent and coordinated support system, especially in the absence of subsidies for heat supply, the share of geothermal energy use is slowly increasing.	In the energy and heat generation market, there is strong competition with large traditionally operating energy market companies.	The system of current legislation is difficult to follow, making investors, users, complicated regulatory procedures, and the duration of Hungarian projects uncertain.
Strengths	1.	Favorable natural conditions in the use of geothermal energy sources.	×					×
	2.	Clean, environmentally friendly energy source, affordable technologies.		×		×		
	3.	The use of geothermal energy is a reliable source of energy supply throughout the year.			×		×	
Weaknesses	4.	High investment costs, which are coupled with unpredictable risks.	×					×
	5.	Stationary energy, not transportable for long distances.			×		×	
	6.	Currently, the low share of geothermal energy in energy consumption.		×		×		

Source: own editing based on JENEI (2012)

The analysis of relationships among findings included in the cross-table provides information on how strengths can help in exploiting opportunities and also in which areas can strengths make it possible to eliminate threats. From weaknesses which are the ones that stall the exploitation of opportunities and the elimination of actual threats. Weaknesses can be interpreted as an internal risk factor while threats as external risk factors in case of geothermal investments.

I prepared the SWOT-analysis of two investments, where the investors are such municipal governments (Létavértes, Kistelek), which have geothermal wells. In both places the aim was to reduce heating costs of local municipality facilities in the first phase of the project by replacing natural gas with the utilisation of geothermal energy.

During the analysis I listed and ranked those characteristics (strengths, weaknesses, opportunities, threats) of the geothermal projects in these settlements, which can describe the SWOT-analysis of investments.

The following conclusion can be made after the analysis of cross-tables: characteristics given as opportunities in a planned (Létavértes) project appear as strength in a completed (Kistelek) project.

3.4. Analysis of financing and return of a geothermal investment

I examined the available financial tools for financing geothermal investments according to *four aspects*:

1. What financial tools are available and which are the tools, which are typically used by several European countries in case of implementing geothermal energy investments.

I concluded that a few financial tools (e.g.: price of purchasing electricity from renewable sources), which promote investments into geothermal projects, but the majority of these tools do not specifically apply to geothermal energy projects, thus the opportunities of financing do not take the characteristics of such energy investments into account. I collected the areas of geothermal investments in Table 5 that are questionable from a financing aspect, which have to be considered in the financial planning of the investment. I assigned the currently available financial tools to these characteristics. If we look at the financial tools in Table 5, then it can be said that all the listed tools are not accessible at the same time in any country. Only one or two tools are available for financing investments in the EU, therefore the combination of tools to be applied cannot be chosen for a specific project.

Table 5: Financial instruments applicable to the areas of geothermal investment

Essential areas of geothermal investment from financial point of view	**Proposed financial instruments for use**
Financial support for geological risks in the research phase of projects to reduce investment risk	Subsidized insurance risk-sharing schemes, other state aid schemes
There are a number of risks to the outcome of the project during the implementation of the project for high investment costs	Direct state subsidy Venture Capital Loan Commercial bank loans with low interest rate (implementation phase)
The found geothermal energy source found is not suitable for the intended use	Guaranteed feed-in tariff Tax reduction, tax exemption for other recovery mode

Source: JENEI (2015/2)

Table 6: The purpose and condition of using the described financial instruments

Financial tool described	**Purpose of application**	**Which stage can be applied**
Direct state subsidy	Sufficient support	Available at every stage of the project
Tax reduction, tax exemption	The investment to promote	Can be used in the construction and operation phase
Guaranteed feed-in tariff	In the long term insured income	It can be used in the operational phase of the investment
Commercial bank loans	Opportunity to finance high value investments	Not available at the research stage without insurance scheme
Risk-sharing insurance	To help finance the research phase	An individual insurance scheme for each project is prepared (No working insurance model developed)

Source: JENEI (2015/2)

See Table 6 for the examined financial tools and their characteristics, as well as for their associated investment phases. It can be stated that despite the wide range of financial opportunities, the tools of financing do not cover all phases of the geothermal projects. The development of financial tools considering the financing of individual investments and the special characteristics of geothermal energy projects can be a good solution for promoting investments into such energy projects at European levels.

2. I analysed through a specific example (investment in Létavértes) what opportunities there are for the investor to access external financial resources (loan/state aid) beyond own resources. I also analyse how return on investment changes with the various combination of these resources.

The implementation of investment using geothermal energy requires significant capital investment for the local government, which is not possible relying entirely on own resources therefore involving external financial resources are necessary.

During the analysis I was primarily interested in finding the changes in financing factors that have the greatest impact on the return of a geothermal investment. I examined, with the help of a model, the financing variations of the investment. The investor is the local government of a small settlement (Létavértes), which has limited financial resources. Therefore, I examined through a financial model how the internal return rate and net current value indicator change if the ratios of own resources/external resources change. The obtained results show that the investment from own resources result low return with the selected discount rate. If the ratio of non-repayable state aid is 65%-35% and 55%-45% with own resources (Table 7 columns V. VI.) a profitable investment can be achieved with the applied discount rate. The results of the calculations are included in Table 7.

Table 7: Development of NPV and IRR when using own resources and support Units: thousand HUF

Denomination	I.	II	III.	IV.	V.	VI.
Subsidy	0%	5%	15%	25%	35%	45%
		64 650	193 950	323 250	452 550	581 850

Own resources	100%	95%	85%	75%	65%	55%
	1 293 000	1 228 350	1 099 050	969 750	840 450	711 150
IRR %	**0,82**	**1,14**	**1,84**	**2,66**	**3,65**	**4,89**
NPV	**-370 004**	**-305 354**	**-176 054**	**-46 754**	**82 546**	**211 846**

Source: Jenei (2018)

After these I prepared a funding portfolio: I planned taking out a loan with the limited own resources and subsidy. The various resource combinations showed that the investment can be implemented regardless of which combination is chosen by the local government (Table 8). The selected resource combination is largely influenced by the amount of own resources available for the local government that can be used for this investment.

Table 8: Various combinations of own resourses-subsidy-loan include the evolution of NPV and IRR

Units: thousand HUF

Denomination	I.	II.	III.	IV.	V.
Subsidy	45%	45%	45%	45%	45%
	581 850	581 850	581 850	581 850	581 850
Loan	45%	35%	25%	15%	5%
	581 500	452 550	323 250	193 950	64 650
Own resources	10%	20%	30%	40%	50%
	129 300	258 600	387 900	517 200	646 500
IRR %	**4,95**	**5,16**	**5,48**	**5,85**	**6,6**
NPV	**166 816**	**177 030**	**190 448**	**196 985**	**204 720**

Source: JENEI (2018)

Next I examined the net present value changes of the resource combinations financially suitable for financing the investment by changing the discount rate. It can be stated based on the results that the investment makes a return in case of the planned revenues and expenditures only with the low expected return (table 9). Thus the investor, namely the local government must assess what expectations to have regarding the return on own capital with a given investment.

Table 9: NPV calculations for different "r" Units: thousand HUF

Denomination	NPV 100% in case of own resources	Change of NPV in case of 45% subsidy				
		45% loan; 10% own resources	35% loan; 20% own resources	25% loan; 30% own resources	15% loan; 40% own resources	5% loan; 50% own resources
r = 0,02	-220 663	**247 396**	**272 923**	**301 925**	**323 412**	**346 030**
r = 0,03	-370 004	**166 816**	**177 030**	**190 448**	**196 985**	**204 720**
r = 0,05	-592 318	**56 131**	**41 485**	**29 583**	**11 863**	-4 590
r = 0,06	-675 418	**18 470**	-6 294	-28 511	-56 100	-82 411
r = 0,07	-744 720	-10 952	-44 596	-75 871	-112 118	-147 087

r = 0,1	-893 938	-66 431	-120 945	-173 530	-230 116	-285 471
r = 0,15	-1 031 183	-104 016	-180 714	-255 992	-334 175	-411 276

Source: Jenei (2018)

3. I also examine through the same specific example what aspects of the return of the investment can be validated from the aspect of the state and society.

Possible state involvement can be evaluated from two aspects in case of an investment. The investor receives non-repayable resource through the state subsidy, while the state receives revenue through taxation, which is psubsidy by the investor. I also examined whether the subsidy psubsidy by the government to the investor to finance the investment makes a return. The calculations showed that the investment by the state does not make a return from taxation as the tax associated to the investment is low. Consequently, it can be ssubsidy that the investment is not worth it to the state strictly from a financial point of view, paying taxes is not a financial burden for the investor, however. In order to subsidy my statement, I calculated the effective tax rate, which is the difference between pre-tax (gross) and after tax (net) individual return rates expressed in gross return percentages.

The results of calculations show that the difference between the two examined (gross and net) return rates is very low, consequently the data regarding the effective tax rate show a very low value.

The effect of tax liabilities is subsidyed by calculations determining effecfive tax rate (ETR). Based on this, the assumption made on the effect of taxation can be confirmed that tax liability for the investor does not result in counter-incentive effect regarding the implementation of geothermal investments for the investor.

The effective subsidy rate (ESR) gives difference of the gross individual return rate of the investor (r_g = return rate calculated based on the pre-tax result) and the gross return rate withour the state subsidy (r_t = the return rate of investment implemented strictly from own resources) expressed in the percentage of gross individual return.

The scale of the ESR indicator expresses what effect the state subsidy has on the return of the investment. The scale of the subsidy increases as the rate of the subsidy requested by the investor increases (Figure 1), this means that the use of state subsidy has a favourable effect on the return of the investment.

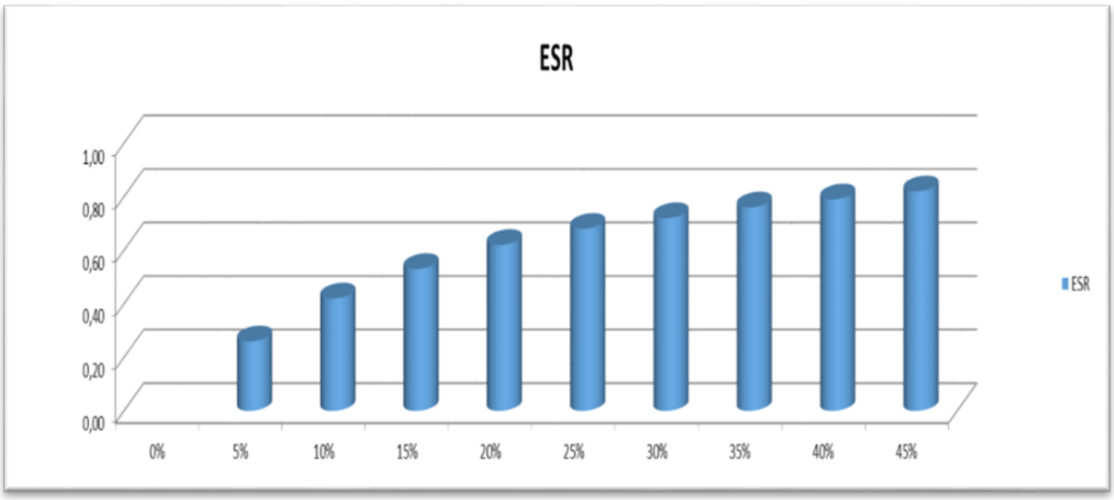

Figure1: Effective subsidy rate for different levels of subsidy
Source: own calculation

I considered the reduction of CO_2 emissions as a favourable social effect. The social impact must be expressed in monetary value when analysing cost-profit of the investment to calculate social return and social profitability. Based on the calculations of the indicators it can be concluded that the investment makes a return with maximum (45%) state subsidy if we consider social impacts as well.

4. What financial risks must be taken into account regarding the financing of geothermal investments if loan is taken out from financial markets to finance costs related to the investment or if state subsidy is requested beyond the two resources (loan/state subsidy).

To examine financial market risks, it is necessary to analyse the effect of financial market borrowing rate changes, in other words how the return indicators change if the financial market borrowing rates change and how sensitive the investment is regarding the abovementioned changes in borrowing rates. I examined the effect of financial market borrowing rates in two forms:

– the initial expenditure of the investment is provided by the combination of the investor's own funds and financial market loan;
– the initial expenditure of the investment is provided by the combination of the investor's own funds and the scale of state subsidy and financial market loan.

I concluded, based on the results of calculations regarding the net present value, that the investor cannot achieve a positive net present value with the examined discount rates. It can be stated based on the data that own resource – with the given combination of financial market loans that of discount rates increase, then the net present value decreases (Figure 2).

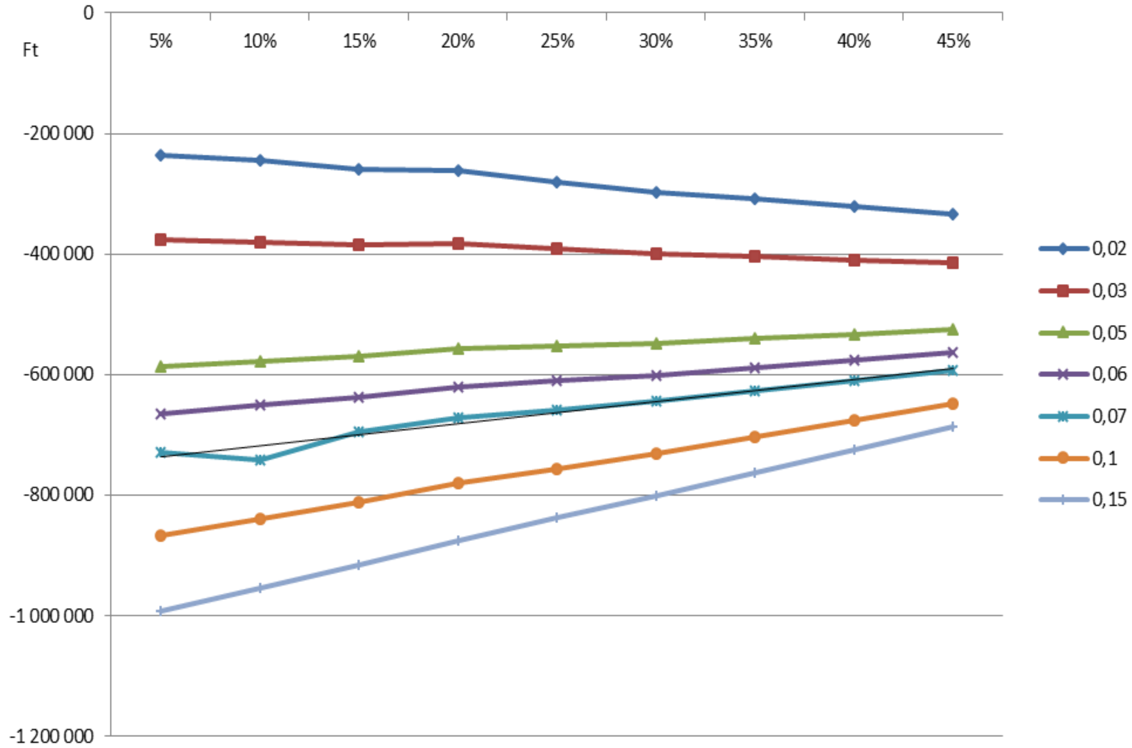

Figure 2: The development of net present values is different with the own funds - money market credit and with different discount rates
Source: own calculation

The internal return rate of the investment decreases if the financial market loan – the ratio of loan increases in the own fund combination. If we suppose that the internal return rate, as a dependant variable and percentage ratio of the loan in the initial investment, as the model describing the relationship of the independent variable and percentage ratio is linear with a given borrowing rate, then the estimate based on the regression model regarding the internal return rate if the ratio of financial market loan increases with 5 percentage points, the internal return rate of the investment decreases with 0.158 percentage points with all factors remaining unchanged (figure 3). Based on the data of estimated internal return rate, the value of internal return rate is still positive with a ratio of 29% financial market loan and 71% own funds although it barely exceeds zero value. However, if the there is a 1 percentage point increase in the ratio loan in the portfolio from the abovementioned ratio, then the value of internal return rate becomes negative. Both the results of calculations and estimates indicate that if the initial expenditure is financed 100% from own funds then the internal return rate of the investment does not reach 1% (0.82%, 0.92%).

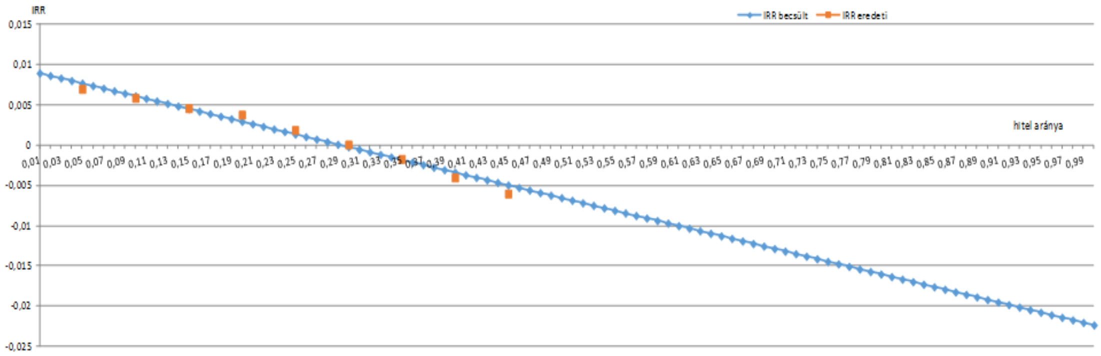

Figure 3: The calculated and estimated internal rate of return of the geothermal investment at a different level of own funds - money market credit

Source: own calculation

Upon examining the elasticity coefficient of internal return rate according to interest rate on loan, I wanted to explore how the internal return rate of the investment changes if the value of interest rate on loan increases by one percent with different scale of loan and own fund combinations, while everything else remains unchanged. I made the following conclusions based on the results of the calculations:

1. If the investor finances the investment with 45% state subsidy and the combination of specified own funds – loan and the investment makes a return with different borrowing rate, then the elasticity coefficient of internal return rate is negative. In this case, three groups can be separated based on the absolute value of the indicator: flexible based on the IRR interest rate on loan ($|\varepsilon_{IRR,r}| > 1$), unit flexible ($|\varepsilon_{IRR,r}| = 1$), inflexible ($|\varepsilon_{IRR,r}| < 1$).

2. If the investment does not make a return, i.e. the value of elasticity coefficient is positive with negative values of the IRR. In case of low rate of loan (5%), the absolute value of internal return rate elasticity coefficient is lower than one, i.e. the IRR is inflexible regarding the changes of borrowing rate, and the permanent negative relationship can be given between the percentage change of loan and the percentage changes of the IRR. At the same time, in case of increasing the

ratio of loan in the funding portfolio considering a profitable investment, the value of elasticity coefficient increases and the relationship becomes flexible exceeding a $\frac{\beta_0}{2 \cdot \beta_1}$ threshold value.

3. If the scale of loan increases in the funding portfolio with all other factors remaining unchanged, then the absolute value of elasticity coefficient also increases, which means that in case of a profitable investment the financial risk originating from the increase in interest rate on loan with the increasing indebtedness with respect to the return of investment.

4. In case of a profitable investment, the absolute value of elasticity coefficient increases with an increase in interest rate on loan, i.e. the effect of interest rate on loan is greater with a higher value with respect to its return.

If the degree of loan increases in the funding portfolio of the investment, i.e. the degree of indebtedness is greater, then the risk effect originating from the change in borrowing rate affecting the return of the investment is greater, and the reducing effect originating from the shift in the higher level of interest rate on loan reducing the return on a profitable investment is greater.

Next I examined how the profitability of the investment changes from the aspect of the investor, namely how the net present value of the investment changes depending on different amount of loan, interest rate on loan and different discount rate applied when calculating net present value.

I assumed that the investor receives 45% non-repayable state subsidy, while the remaining amount is financed from different combinations of own funds and financial market loan. I assigned 175 pieces of values for each variable to examine relationships regarding net present value and degree of loans, as well as for discount rates, i.e. I possess 700 pieces of observation values based on the previously presented calculations. During the specification of the function I presume a linear and log-linear function relationship, where the net present value of the investment (NPV), as a dependant variable, while the degree of loan (Hm), the interest rate on loan (r_h) and the discount rate (r_d), were included as independent variables.

$$NPV = \beta_0 + \beta_1 \cdot Hm + \beta_2 \cdot r_h + \beta_3 \cdot r_d + u_i.$$

In case of the first model I took all the observed values into account. I limited the number of data in the second model, considering that I made an effort to limit my examinations to profitable cases, i.e. positive net present value cases, which means that values of 5% and below 5% discount rates are given in the second model. The separation was justified by the fact that only profitable investment opportunities can be taken into account with a log-linear model:

$$NPV = \beta_0 \cdot Hm^{\beta_1} \cdot {r_h}^{\beta_2} \cdot {r_d}^{\beta_3} \cdot u_i,$$

$$\log NPV = log\beta_0 + \beta_1 \cdot \log Hm + \beta_2 \cdot \log\ r_h + \beta_3 \cdot \log r_d + logu_i.$$

Estimates for the net present value determined with a 5% or lower discount rate, as an independent variable, prepared for the linear and log-linear models gave results reliable at a 95% level. At the same time I must conclude that the fit of linear models proved to be more reliable compared to the logarithmic model.

The effect of the cost of the capital alternative on the profitability of a profitable investment, originating from the change in discount rate, is stronger compared to the effect originating from the changes in borrowing rate with all other factors remaining unchanged. Specifically, the rate of decline in the net present value of the investment over one percentage point increases in the discount rate exceeds the rate of decline resulting from a one percentage point change in the borrowing rate.

At the same time, the absolute value of the loan-to-net elasticity coefficient increases with the increase in the loan, which means that the impact of borrowing changes on the profitability of the investment increases with the increase in the loan amount. The discount rate for the NPV increases with the return on investment, and the impact on the profitability resulting from the change in the discount rate is more pronounced than for the lower loan level.

4. EVALUATION OF HYPOTHESES

Below I review the hypotheses and their justification previously defined in the dissertation.

H1. The process of obtaining permits for the implementation of a geothermal investment is a long, process involving several authorities with costs for the investor.

A detailed examination of the geothermal investment process has shown that in case of a geothermal investment, in comparison with other construction and energy-producing investments, significantly more regulatory procedures have to be carried out.

The administration is time-consuming, each individual application for authorization is a separate procedure, with separate laws regulating the time of administration of the given authority for each procedure. In addition, there are two organizations that do not have a deadline to meet their obligations (Ministry of Environment and Water Management as the owner of state-owned waters and Hungarian National Asset Management Inc. as the owner of groundwater), so it is unpredictable how long the evaluation of applications might take. Hence, the first hypothesis was confirmed.

H2. Project financing as a risk management method can be used for geothermal investments, with the exception of the initial (research) phase of investment.

The overview and grouping of risks shows that in the case of geothermal investments the risks can be divided into three main groups. The three main groups are geological, economic and technical risk. The risk analysis also showed that geological risks - the realization of the investment, the financing of the investment - are risks other than technical and economic risks.

These risks can be characterized by the unpredictability of the project and the failure of the project in the event of certain risks (e.g. drilling failure). These risks are at the exploration stage. At the same time, there are risks that require a 'yes-no' decisions: a geothermal reservoir is either suitable for heat production or not.

At the planning stage, there are no geological risks, no geological risks occur in the implementation and operation phases, or the geological risk already entails a slight decrease in system characteristics and usually gives rise to a decision that is different from a 'yes-no' decision. This substantial difference in risk management and investment financing requires a different approach and fundamentally separates the research phase from the other three stages.

While project funding is not applicable to the research phase, project funding is an applicable form of financing for the other three phases of geothermal investment, and a more general approach to risk management. The decision tree method is a good decision-making method for the research phase, but it is not justified in the other three stages. The applicability of project financing as a risk management method was proved in the second hypothesis.

H3: SWOT analysis can be used as a tool for risk assessment in the decision-making process of geothermal investments.

Among the findings listed in the SWOT analysis, four (strength, opportunity, weakness, danger) elements, I selected three or three statements, which are included in the so-called cross-table. The analysis of the relationship between the findings in the table showed how strengths can help exploit opportunities, and also where strengths enable risk prevention. Which are the weaknesses that hinder the exploitation of certain opportunities and the elimination of actual threats. Weaknesses can be interpreted as internal risk factors and threats as external risk factors for geothermal investments. When we aim to prevent risk, we typically analyse weaknesses and threats. In the case of geothermal investments, the table can be used to list the factors that make it possible to implement a project or to facilitate or hinder the achievement of this objective. The SWOT analysis, which primarily provides an in-depth reflection method for preparing the investment, taking into account different economic and social aspects, can be applied well in both the research and the other three phases. Based on the above, the third thesis was confirmed.

H4.1: From the investor's point of view, the return on investment will change if other sources (state subsidy, bank loan) can be included in the financing of the investment.

In the course of the analysis, I considered that the investor used 100% of his own resources to implement the project. The results of the calculations proved that if the investment would only come from own resources, the return would be realized at a very low level (NPV = -370 004 thousand HUF, IRR = 0.82%). It is necessary to involve an additional external source, so in the second step I wanted to find out if the investor can also involve the state in the financing, then how the return on investment changes. On the basis of the calculations it can be concluded that the investment only makes a return if high ratio (35-45%) of subsidy is provided for the investment.

In addition to own resources and state subsidy covering the initial capital requirement of the investment, I also considered the possibility of loans. The use of the loan as a source may be necessary because the previously analysed resource composition is not beneficial to the municipality for involving significant own resources. In terms of borrowing, I investigated how the local government takes out investment and development loans in addition to the subsidies, then the return on investment and profitability of the examined investment changes.

In the sensitivity analysis carried out with the maximum amount of state subsidy available (45%), it can be established on the basis of the profitability and return of the different ratios of own funds loans according to different ratios that any source composition results a financially feasible construction. The sensitivity analysis confirmed the first statement of the fourth hypothesis.

H4.2: State subsidy for geothermal investments does not result in financially significant return on investment. For the investor, the tax liability does not have a counter-incentive effect.

I examined what kind of incentive effect the state has to play in subsidying geothermal energy investments. Examining the issue deserves special attention from the aspect that investments associated with the use of geothermal energy are subject to significant risks, which may be mitigated by state presence, and the potential for state subsidy or state involvement may have a greater incentive effect for the investor.

In addition to the state subsidy examined earlier, I took into account the budget return of the investment on the side of the state's role and analysed how profitable the investment subsidy for the state could be. I took into account the investor's corporate tax liability on the investment, while the cost of the one-off state subsidy for the initial investment was calculated.

The calculations of the rate of return on the budget resulted in negative values for all the state subsidy rates examined, with the exception of the 5% -95% government and own resource combination. If the state subsidy rate is 5% of the start-up cost, then the state receives a 1.02%

return on investment. Consequently, subsidy for geothermal investments does not represent a significant return on investment for the state from a financial point of view. Based on the results of the effective tax rate (ETR) and the net effective tax rate (NETR), it can be confirmed that the effect of taxation on the investor is not an incentive for the implementation of geothermal energy investments. The second assertion of the fourth hypothesis is confirmed by the calculations described.

H4.3: The investment pays off taking the social impact of the investment into account.

If the investment is made with the help of EU subsidy, the social impact of the investment should be taken into account in the cost-benefit analysis of the investment. The social benefits of local, small, regional and national ones include (e.g.) a reduction in carbon emissions. In calculating the social net present value (ENPV) and the social rate of return (ERR), besides quantifying the ssubsidy social impact, project benefits need to be estimated.

For the calculation of the ENPV and ERR indicators of the investment, the European Union sets a social discount rate of 5%. If the investment subsidy is changed from 5% to 45%, the ERR reaches the EU 5% social discount rate with a subsidy rate of between 40% and 45%. Regarding the values of ENPV, I found that a positive net present value can be found for discount rates of 5% or discount rates below 5%. In addition to the 5% discount rate, only one combination of funds (55% own resources, 45% subsidy) has a positive net present value. The results of the social rate of return and the net social present value confirm the third assertion of the fourth hypothesis.

H5.1: In the financing portfolio of the geothermal investment to be examined, if the loan ratio increases, the risk impact of the increase in the investment rate due to the increase in the loan rate also increases. Furthermore, if the borrowing rate rises, the effect reducing the return on investment is higher in case of a shift from a higher level of interest rate is greater.

The sensitivity analysis of using the variable financial market loan was carried out by taking the borrowing at a financial market rate of 4.18%. In the study, when calculating the ratio of credit to own resources, based on calculations of net present value, I found that the investor could not achieve positive net present value at the discount rates tested. In addition to a given combination of own funds and financial market loans, if discount rates rise, the net present value decreases. At the same time, if the loan rate increases, the net present value increases above a given discount rate (i.e. a given threshold) while falling below that threshold. The results of the calculations subsidy the first statement of the fifth hypothesis.

H5.2: The downward effect of a one percentage point increase in the discount rate on the net present value of the geothermal investment to be tested is greater than what would be obtained by a one percentage point increase in the loan rate, with all other unchanged.

In the rest of the study, I analysed how the sensitivity of the cash flow of the investment to the discount rate develops with different own funds and financial market loan portfolio - at a discount rate of 5% or above 5%. Multivariate regression tests were performed for the study. In case of setting up the model, the development of the net present value is the dependent variable, while the discount rate and the percentage of credit appeared as independent variables. In the case of setting up the multivariate model, I investigated linear, polynomial and exponential function relationships.

Based on the results, I found that a one percentage point increase in the discount rate would have a greater impact on net present value than in the case of a one percentage point increase in the loan rate, with all other components remaining unchanged. The second assertion of the fifth thesis was proved by calculations and functional relationships.

H5.3: In the case of the investment to be examined, the absolute value of the loan-to-net elasticity ratio of the loan increases with the increase of the loan, i.e. the effect of the borrowing change on the profitability of the investment increases with the increase of the loan amount. The discount rate of the NPV according to the discount rate increases in case of a profitable investment with the increase of the discount rate, i.e. the profit-reducing effect resulting from the change of the discount rate prevails at a higher rate of the loan than at the lower credit level.

When determining the elasticity coefficient of the internal rate of return on the loan, I assume that the investor will receive a 45% state subsidy to cover the one-off initial investment amount, and another 55% of the amount required for financing may be provided as a combination of own funds and loans of variable ratios. The internal rate of return of an investment financed by a permanent state subsidy and a combination of a given own resource loan decreases with the increase in the borrowing rate.

To calculate the elasticity coefficient, we estimate the functions describing the relationship between the internal rate of return and the borrowing rate as an independent variable by univariate regression. If the investor finances the investment with a 45% state subsidy and a combination of specific own funds and loans, the investment makes returns at different loan rate levels, the elasticity coefficient of internal rate of return according to interest rate is negative.

If the investment does not make a return, then the value of the internal rate of return (IRR) is positive with the elasticity coefficient being positive. In the case of low rate borrowing (5%), the absolute value of the internal rate of return elasticity is lower than one, i.e. the IRR is inflexible with respect to the change in the borrowing rate, and a permanent negative relationship can be established between the percentage change in the borrowing rate and the percentage change in the IRR.

In case of a profitable investment, the absolute value of the elasticity coefficient increases with the increase in the borrowing rate. The rate of decline in the net present value of the investment over one percentage point increase in the discount rate exceeds the rate of decline resulting from a one percentage point change in the borrowing rate. The absolute value of the loan-to-net elasticity coefficient increases with the increase in the loan, which means that the impact of the change in borrowing on the profitability of the investment increases

5. NEW AND INNOVATIVE RESULTS

The new and innovative scientific results of the Thesis are summarized below:

1. Obtaining the necessary permits for a geothermal investment is a lengthy and costly process, and in some cases uncertain. Due to the lack of transparency in public administration, the implementation time of an investment becomes longer, as the time required to prepare or continue the investment increases. In the literature review of legal and licensing procedures, I found that the existing legal regulations and procedures have an adverse effect on geothermal investments.

2. Project financing, i.e. the contractual sharing of risks and financing based on it, as a risk management method, can be applied to geothermal investments with the following conditions:

Project financing tools are not applicable to the geothermal investment phase; at this stage the decision tree method is suitable for risk management.

Project financing tools can be used for risk in the three additional phases (planning, implementation, operation) as a risk management method.

3. SWOT analysis can be used as a tool for risk assessment in the decision-making process of investments. Based on a SWOT analysis of an already implemented and planned geothermal investment, I found that

- the threats and weaknesses assessed can be managed as a risk for both investments, or
- what is an opportunity in the analysis of the planned investment, it appears as a strength in the SWOT analysis of the implemented investment.

4.1. Analysing the combinations of potential financial resources of the investment (own resources / state subsidy / loan), individual (investor) returns are as follows:

1.) If the local government would implement the investment only by using its own resources and the expected revenues and expenditures, then the results indicate very low returns.

2.) On the basis of the sensitivity analysis of the state subsidy on the profitability of the investment (with a 3% discount rate), it can be concluded that if the investor also uses state subsidy besides own resources, then the investment only makes return with a high (35-45%) subsidy.

3.) In addition to the maximum amount of state subsidy available (45%), I examined the sensitivity of profitability and return on the basis of different sources of own funds / loan. Based on the calculations, it can be concluded that, with constant state subsidy, with any source composition considered, from a financial point of view each combination results in a feasible construction.

4.2. Subsidying geothermal investments does not represent a significant return on investment for the state from a financial point of view, meaning that there is no incentive effect on the state's role in monetary terms. At the same time, it can be stated that the state's presence does not have an incentive effect for the investor by establishing the tax liability.

1.) The effect on the tax liability is also subsidyed by the results of the effective tax rate calculations. Based on the results of effective tax rate calculations (ETR), it can be confirmed that the tax effect is not an incentive for the investor to invest in geothermal energy.

2.) In the case of the examined investment, the net effective tax rate (NETR) assumes negative values for all subsidy ratios (5% -45%). This means that the incentive effect of using state subsidy is stronger than the incentive effect of the tax liability. Consequently, the negative outcomes of the net effective tax rate also confirm that the tax liability has no counter-incentive effect on geothermal investments.

4.3. In order to express the social impact of the geothermal investment at monetary value, I used the „carbon quota" and then determined the rate of social return and examined the profitability. The EU provides subsidy for an investment in the case if the investment has a social return of 5% or more. The return on investment will be 5% if the state subsidy reaches its maximum value (45%).

5.1. In the financing portfolio of the invested investment, if the amount of the loan increases, that is, the level of indebtedness, the risk effect resulting from the increase in the loan interest rate on the investment is higher as well as the effect of the increase in the loan rate, which decreases the return on investment, is higher if the higher level of the interest rate shift.

5.2. In the examined investment, a one percentage point increase in the cost of the capital alternative as a discount rate would have a greater negative effect on net present value than would be obtained with a one percentage point increase in the borrowing rate, with all other factors remaining unchanged.

5.3. The absolute value of the elasticity coefficient regarding the ratio of the loan to the net present value of the examined investment increases with the increase of the loan, which means that the effect of the change in borrowing on the profitability of the investment increases with the increase of the loan amount. The discount rate of the NPV according to the elasticity coefficient increases in case of a profitable investment with the increase of the discount rate, and the effect of decreasing the profitability originating from the change of the discount rate is more pronounced than with a lower level of credit.

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