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## Risk insurance fund for geothermal energy projects in selected European countries – operational and financial simulation

### Introduction

Geothermal risk insurance funds, GRIF, belong to efficient measures mitigating risks in geothermal projects, including resource risk. Such funds already exist in a limited number of European countries. Geothermal energy is regarded as one of the most prospective low-emission sources for heating purposes. This is expressed by, among others, over 330 geothermal district heating systems operating in EU countries, about 150 systems in investment stages in 2020, many more planned and expected in the coming years, as well as the development of geothermal power generation (2020 EGEC Geothermal Market Report 2021).

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GRIF can ease and contribute to the wider development of geothermal energy projects. On this basis, the H2020 Project “Developing Geothermal and Renewable Energy Projects by Mitigating their Risks”, GEORISK ([www.georisk-project.eu](http://www.georisk-project.eu)) aimed to promote the establishment of GRIF as one of forms of risk mitigation schemes (RMS) for these projects in the next three target countries, namely Greece, Hungary, and Poland (Dumas et al. 2019). In this context, an important task of the Project was a 10 years’ long-term operational and financial simulation to prove the financial sustainability of a proposed public fund in each of the listed countries.

The simulation process started with the determination of the premises, involving national specialties, as presented below:

- ◆ making decisions on the scope of the insured geothermal projects, eligible geological structures, lithological types of reservoir rocks, as well as the contract types,
- ◆ determination of the assumptions of the proposed GRIF, e.g., the insurance premium, the risk coverage, estimated success rate,
- ◆ calculation of the fixed costs of the GRIF: fund launching, overheads, operational and project evaluation costs.

The next step was the identification of the planned and expected geothermal projects which could be covered by GRIF in the following 10 years. They were recorded during the earlier stages of the GEORISK project. However, since the deep geothermal projects of the following 10 years have not been planned in detail so far, the majority of the data concerning them were based on realistic authors’ estimations of a number of projects developing identified geothermal resources.

That process was followed by drafting the 10 years’ operation of GRIF, i.e. a description of the events of the projects as well as of the annual cash flows. Although an estimation, it represents a realistic operation of the considered GRIF.

The fixed costs, the costs for projects evaluation, the revenue from insurance premium fees and the compensation payments for the unsuccessful projects altogether constitute the 10 years’ cash flow.

The first draft of GRIF was formed with the exact Hungarian assumptions and inputs of fixed costs and also with average project data, thus making it appropriate to perform sensitivity analyses on:

- ◆ insurance premiums,
- ◆ success rates,
- ◆ risk coverages.

After that analysis, three complete simulations were implemented for the three target countries: Hungary, Poland and Greece.

The paper includes the key results for all three target countries and shows also the similarities and differences among them. The presented model and simulation serve as a template for any country that aims to establish a new, financially sustainable risk mitigation scheme for geothermal energy projects.

## 1. The GEORISK project background

Geothermal risk insurance funds have already been operating in some European countries, namely France, Germany, Iceland, the Netherlands, Denmark, Switzerland, and Turkey (Dumas et al. 2019). Most recently a pilot stage of such a fund was established in Hungary, with the first call for applications in June 2021. Except for these countries, geothermal project developers have very little capability to manage this financial risk.

As mentioned above, the EU-funded GEORISK project aims to promote Risk Mitigation Schemes (including risk insurance fund) for geothermal energy projects all over Europe, as well as in some third countries, to cover risks associated with the development and the operation of deep geothermal projects.

Geothermal projects have several risky components, the most important one being the resource risk. Beyond exploration, their bankability is threatened by two kinds of resource risk:

- ◆ the short-term risk of not finding an economically sustainable geothermal resource after drilling,
- ◆ the long-term risk of the geothermal resource naturally depleting rendering its exploitation economically unprofitable.

Until the first well has been drilled into the geothermal reservoir, developers cannot be sure about the exact basic parameters (water temperature and flow rate) of the planned geothermal heating, cooling or electricity project. Once drilling has taken place, in situ pumping tests, temperature and hydrological measurements then reduce the resource risk and make it possible to attract external capital.

The risk mitigation schemes (including GRIF) must be designed according to the geothermal energy market maturity and:

- ◆ facilitate the transition of already existing GRIF in Europe (France, Germany, Turkey, Switzerland, Denmark, The Netherlands),
- ◆ replicate and promote GRIF for target countries in Europe (Hungary, Poland, Greece, Belgium, Croatia, Slovenia, Spain, etc.),
- ◆ adapt and present GRIF and other RMS in selected countries on other continents – America (Chile, Mexico, Canada) and Africa (Kenya).

One shall point out that several European countries have geothermal energy resources prospective especially for heating and, to some extent, for electricity generation. However, these resources can be used on a wider scale than so far. About 5000 district heating grids (DH) have been operating in the EU countries and – if geothermal heat would be introduced even only to some percentage of them – a significant effect would be achieved. According to the 2020 EGEC Geothermal Market Report (2021), in 2020 about 330 geothermal district heating systems, geoDHs, were operating in 25 EU countries and more are expected in the coming years. For this to happen, not only appropriate reservoir conditions are needed, but also appropriate support measures and schemes aimed at mitigating the resource risk related to the geothermal projects. As mentioned above, such schemes in forms of GRIF have been

successfully operating in several European countries and contributed to the geothermal heating deployment.

In the countries such as Greece, Hungary and Poland the geothermal heat markets can be treated as juvenile ones or in transition, so up to now the main measures of supporting these markets' development and limiting the resource risk have been public grants and loans. In line with the expected development of these markets, it is necessary to introduce other appropriate RMS forms, including GRIF (Dumas et al. 2019). Initially, they shall be of a public type relevant to the early stage and in transition geothermal market maturity (Figure 1).

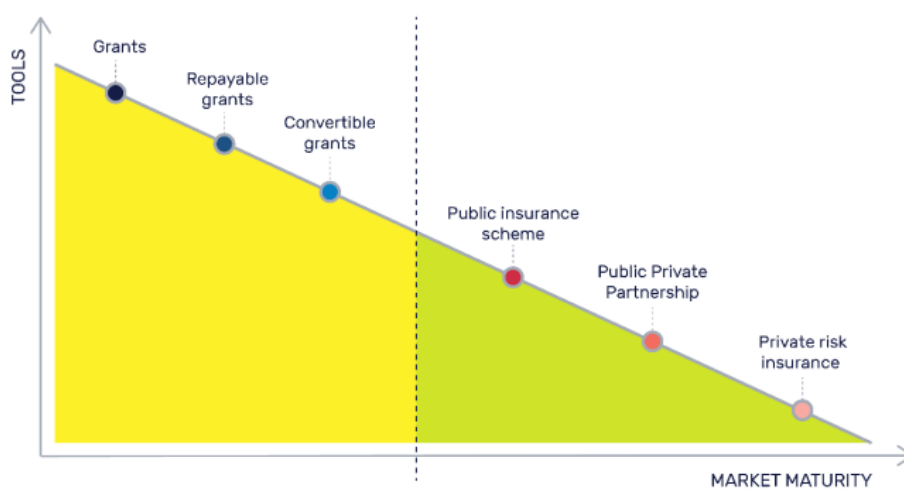


Fig. 1. Risk mitigation schemes for geothermal projects according to geothermal energy market maturity (Dumas et al. 2019)

Rys. 1. Sposoby ograniczania ryzyka w projektach geotermalnych w zależności od stopnia dojrzałości rynku energii geotermalnej

Considerations and discussions on GRIF with various stakeholders and proposals directed to decision-makers in this regard have been ongoing in several countries covered by the GEORISK Project. The introduction of suitable risk mitigating measures (de-risking measures) tailored to the stage of the geothermal heating market's maturity should stimulate their development. This applies also to the above-mentioned three target countries, where, apart from grants and loans, the public risk insurance fund will be the most adequate tool in the near future. So far no such funds have been established in two of these countries (Greece, Poland) while in Hungary a pilot stage was launched in 2021.

Within the framework of the GEORISK project, following the best practices of already existing GRIF in some European countries, the 10 year simulations of the sustainable operation of such funds were conducted for the Hungarian, Greek and Polish cases. The expected realistic numbers of geothermal projects within a 0 year perspective in each of these coun-

tries were assumed (based on a survey aimed at identification of ongoing and possible projects), as well as several variants of other basic factors (i.e. founders, initial capital, premium fees, success rates, etc.). The results, conclusions and recommendations, briefly presented in this paper, are important for potential investors, decision-makers, financing institutions, insurance companies, etc.

## 2. Objectives of the simulation

The general objective of the financial simulation was to calculate a 10 year cash flow of a proposed GRIF. To calculate a cash flow, it was necessary to determine the operation actions that affect it. These actions depend on the premises of the fund. Therefore, the establishment process embraces the following steps:

- ◆ determination of the legal forms of the projects eligible for GRIF, the aimed technical issues (risks), and the operating forms of the management of the risk insurance fund,
- ◆ estimation of the suppositions of the key parameters influencing the projects covered by GRIF, and also the costs of the management of the fund.

Having determined and calculated all these inputs, the simulation can be run. One can determine the financial level of the key parameters to set the fund operation financially sustainable, or can determine the financial support demand on a 10 year term.

## 3. Methods

The 10 year operational and financial simulation of GRIF for Greece, Hungary and Poland was conducted on a basis of the following general assumptions (input data):

- ◆ launching amount of the fund (initial capital),
- ◆ number of wells to be insured,
- ◆ success rates,
- ◆ insurance premium,
- ◆ risk coverage,
- ◆ time span of the geothermal drilling project,
- ◆ overhead costs of the GRIF,
- ◆ project expert costs.

Detailed values or the ranges of each input data are given in chapter 3 related to particular countries concerned. For the simulation calculations, the authors used the algorithm developed by themselves (which can be made e.g., in an excel sheet).

A 10 year period was assumed for the simulation as generally sufficient for the operation of a public fund (and thus the involvement of public funds as initial capital), which then, along with the growth of geothermal energy market maturity, may turn into public-private, and ultimately into a private type.

The GEORISK Project activities included, among others, three national workshops in each target country to collect the opinion from the key stakeholders, inform them about the results of the project's works, to discuss the issues related to the establishment of the GRIF including the assumptions for the simulation (input data and their values).

Two questionnaires were issued to the stakeholders to collect the stakeholders' ideas and interests related to the GRIF. The questionnaires were evaluated and decisions were made on the following aspects: geothermal risk insurance fund types, geological structures and the lithological types of geothermal reservoirs to be covered, available contract types, hypothetical possibilities. Moreover, after the evaluation of the questionnaires and the discussions, the assumptions of the key parameters such as insurance premium, percent of risk coverage and estimated success rate could be adjusted to a realistic rate accepted by the interested stakeholders.

The first simulation was prepared for the Hungarian case (Figure 2). To make it as simple as possible, the cash-flow with average project data and also with basic premises was calculated: 30 projects in 10 years, insurance premium 10%, risk coverage 75%, estimated success rate 90%. This is a model of a sustainable GRIF, i.e. a model of its effective operational prospectivity). However, the 10% insurance premium is rather high, therefore the authors also analyzed the model by its key parameters.

The insurance premium strongly influences the financial sustainability of the GRIF: 10% seems to be enough to maintain the assets of the fund. However, in the case of 4% or less, the fund is to be supported in every decade, so the determination of the premium is a strategic question (Figure 3).

The determination of risk coverage is mainly important for the project developers; they have to finish the project with this amount (Figure 4). Therefore, this is chiefly a technical question, depending on the costs of the technological solutions.

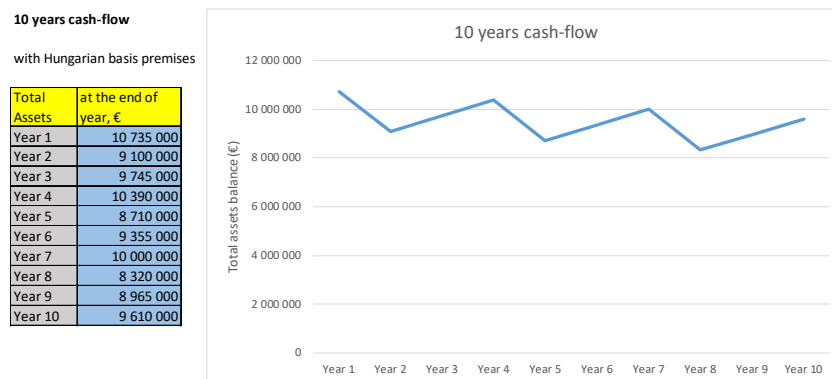


Fig. 2. The Hungarian case with average project data and basic premises for a 10 year operational and financial simulation of risk insurance fund for geothermal projects

Rys. 2. Przypadek Węgier dla średnich wartości danych projektowych oraz podstawowych założeń symulacji operacyjnej i finansowej na 10 lat działania funduszu ubezpieczenia od ryzyka w projektach geotermalnych

10 years cash-flow (€)

Analysis by premium

Total Assets	Premium 10%	Premium 8%	Premium 6%	Premium 4%
Year 1	10 735 000	10 549 000	10 363 000	10 177 000
Year 2	9 100 000	8 728 000	8 356 000	7 984 000
Year 3	9 745 000	9 187 000	8 629 000	8 071 000
Year 4	10 390 000	9 646 000	8 902 000	8 158 000
Year 5	8 710 000	7 780 000	6 850 000	5 920 000
Year 6	9 355 000	8 239 000	7 123 000	6 007 000
Year 7	10 000 000	8 698 000	7 396 000	6 094 000
Year 8	8 320 000	6 832 000	5 344 000	3 856 000
Year 9	8 965 000	7 291 000	5 617 000	3 943 000
Year 10	9 610 000	7 750 000	5 890 000	4 030 000

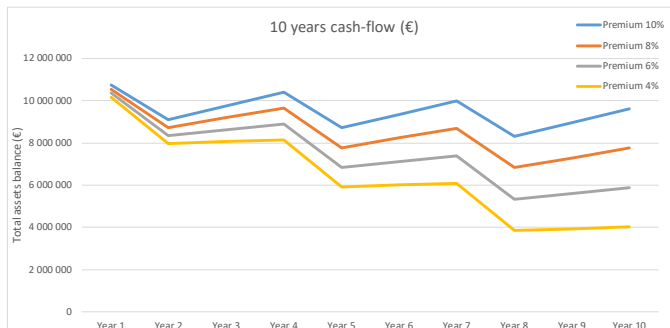


Fig. 3. Analysis by key parameters: insurance premium

Rys. 3. Analiza według kluczowych parametrów: wysokość składek ubezpieczeniowych

10 years cash-flow (€)

Analysis by risk cover

Total Assets	Risk cover 75%	Risk cover 80%	Risk cover 60%	Risk cover 50%
Year 1	10 735 000	10 735 000	10 735 000	10 735 000
Year 2	9 100 000	8 945 000	9 565 000	9 875 000
Year 3	9 745 000	9 590 000	10 210 000	10 520 000
Year 4	10 390 000	10 235 000	10 855 000	11 165 000
Year 5	8 710 000	8 400 000	9 640 000	10 260 000
Year 6	9 355 000	9 045 000	10 285 000	10 905 000
Year 7	10 000 000	9 690 000	10 930 000	11 550 000
Year 8	8 320 000	7 855 000	9 715 000	10 645 000
Year 9	8 965 000	8 500 000	10 360 000	11 290 000
Year 10	9 610 000	9 145 000	11 005 000	11 935 000

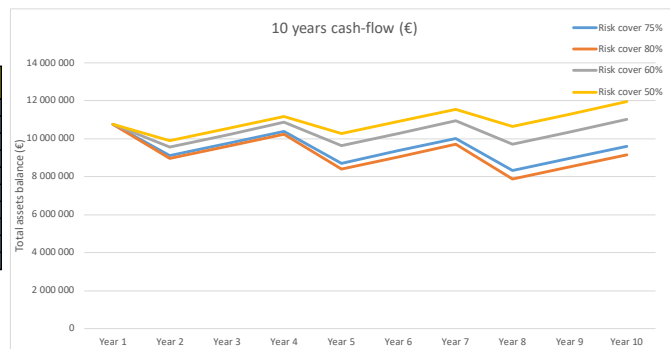


Fig. 4. Analysis by key parameters: risk coverage

Rys. 4. Analiza według kluczowych parametrów: pokrycie ryzyka

10 years cash-flow (€)

Analysis by success rate

Total Assets	Success Rate 90%	Success Rate 80%
Year 1	10 735 000	10 735 000
Year 2	9 100 000	9 100 000
Year 3	9 745 000	7 420 000
Year 4	10 390 000	8 065 000
Year 5	8 710 000	6 385 000
Year 6	9 355 000	4 705 000
Year 7	10 000 000	5 350 000
Year 8	8 320 000	3 670 000
Year 9	8 965 000	1 990 000
Year 10	9 610 000	2 635 000

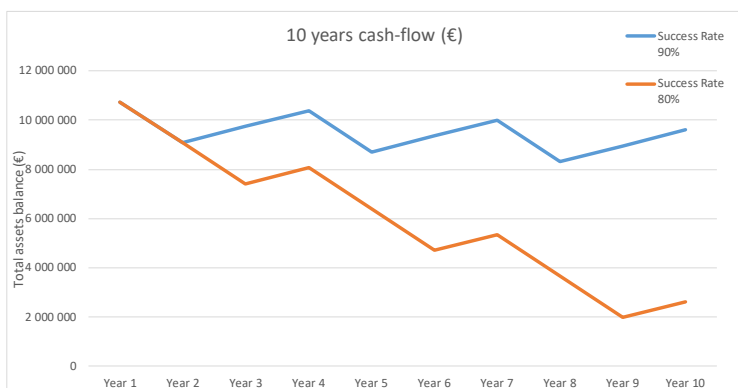


Fig. 5. Analysis by key parameters: success rate

Rys. 5. Analiza według kluczowych parametrów: wskaźnik sukcesu

As expected, the success rate is the most sensitive parameter (Figure 5). A key strategic expectation is to maintain the 90% success rate (one of ten projects has a failure) to achieve financial sustainability. Below this success rate, regular funding is necessary.

The next step of the simulation process was to simulate GRIF cash-flow separately in the target countries with their own legal, financial and natural background as well as with their expected projects.

## 4. Results and discussion of the simulation for the target countries

### 4.1. Hungary

Hungary is a well-explored country with more than 8000 hydrocarbon and 1000 geothermal wells. The database of these wells ensures enough geological and geophysical data for fairly detailed regional and areal underground recognition. Therefore, only extremely deep (5–6 km) enhanced geothermal systems (EGS) projects belong to high-risk projects.

Based on the opinion of key stakeholders, the following selected premises were taken into consideration:

- ◆ projects eligible for the GRIF: all deep geothermal projects are included. Short-term risks, including drilling and testing wells,
- ◆ all possible geological structures and lithological types of reservoirs are to be covered,
- ◆ the preferred contract type: grant, subsidized premium in advance, fee post-financed.

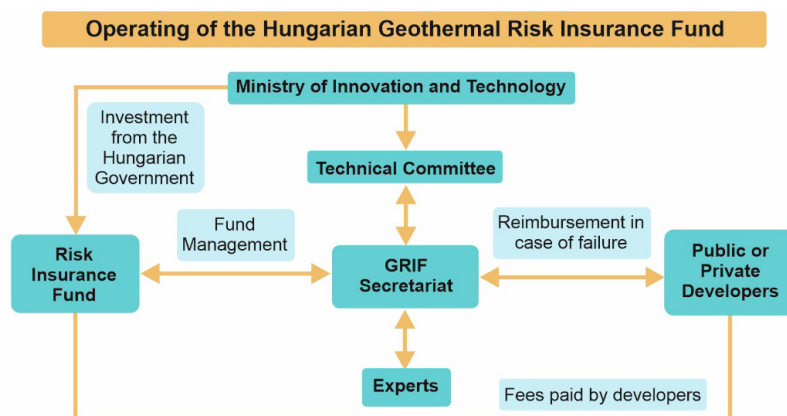


Fig. 6. The proposed organization and management chart of the Hungarian Geothermal Risk Insurance Fund

Rys. 6. Proponowany schemat organizacji i zarządzania węgierskim funduszem ubezpieczenia od ryzyka w projektach geotermalnych



The planned launching amount of the proposed Hungarian GRIF was EUR 10 million. Its operating costs included the costs of the fund, the secretariat, the technical committee and the experts. Figure 6 illustrates the proposed organization and management chart of the Hungarian GRIF. Recently the Ministry of Innovation and Technology authorized the Hungarian Office for Mining and Geology to ensure the functions of the GRIF secretariat. The draft chart of the proposed GRIF is similar to the operating French system (presented in chapter 3.4).

Thirty expected projects were selected for the operational and financial simulation of the GRIF in the following 10 years (Figure 7). The simulation was run for not yet fully planned, but realistic projects data. The result was similar to the case of the average project, because the key premises were the same: insurance premium: 10%, risk coverage 75%, estimated success rate 90%. This is an opportunity if the sponsor of the GRIF wishes to operate a financially sustainable fund.

**10 years cash-flow (€)**

With the Hungarian expected project costs

Total Assets	at the end of year, €
Year 1	10 435 000
Year 2	8 375 000
Year 3	8 800 000
Year 4	9 445 000
Year 5	7 825 000
Year 6	8 800 000
Year 7	9 545 000
Year 8	8 250 000
Year 9	8 905 000
Year 10	9 610 000

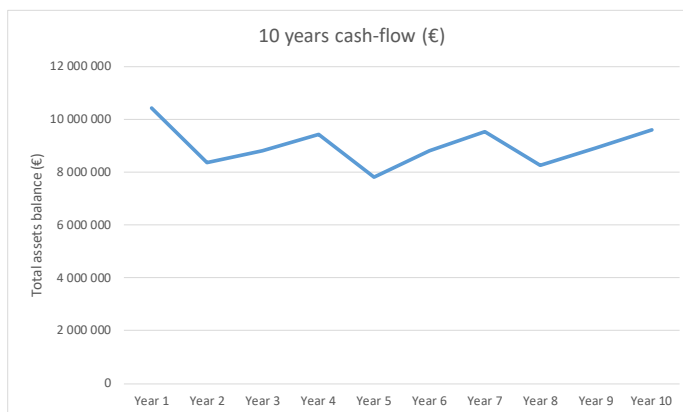


Fig. 7. The Hungarian case for the expected realistic 30 projects in the following 10 years

Rys. 7. Przypadek Węgier dla przewidywanych realistycznie 30 projektów geotermalnych podczas kolejnych 10 lat

### 4.2. Greece

The geological conditions in Greece resulted in the natural occurrence of a significant number of geothermal fields, corresponding to an important geothermal potential. However, its utilization is rather limited, as it is exploited only for low enthalpy (<100°C) direct heat uses, presenting the total absence of electricity generation plants (Karytsas et al. 2019). Hence, the aim of the establishment of a risk mitigation scheme in Greece would be to

“unlock” private investments in the geothermal sector, and particularly for medium (100–150°C) and high enthalpy (>150°C) applications.

Until now, more than 55 geothermal fields have been identified in total, distributed across Greece. However, their level of exploration differs significantly. Geothermal resources proven by wells tapping their reservoirs are recognized by national legislation and correspond to two high enthalpy (>300°C) ones (Milos and Nisyros islands), and several low enthalpy (<90°C) ones, located mainly in the Northwest part of the country (Mendrinou et al. 2010). Bearing this in mind, the performed simulation treats the estimated success rate of each potential project differently; hence the initial success rates taken into account consist of: 90% for high enthalpy proven fields (Milos and Nisyros), 67% for high enthalpy unexplored fields (Chios, Lesbos, Methana, Sousaki, Samothraki, and Thera), and 90% for proven low enthalpy fields (Akropotamos, Aristino, Erasmio, Erateino, Heraklia, Nea Kessani, Nigrita, Sidirokastro).

The development assumes the drilling, completion and operation of one successful doublet in each one of the above high enthalpy fields for power generation and three successful doublets in each one of the above low enthalpy fields for district heat supply. A number of failed wells are also considered based on the above success rates. Indicative well costing was done based on local geologic and reservoir conditions, with rather conservative estimates, being in the lower part of the cost range. Each insured project comprised one well, either production or reinjection.

The 10 year simulation for Greece was carried out based on a scenario including the drilling and completion of 55 production and reinjection wells in the abovementioned fields – with the corresponding success rate in each case, and with an initial capital of EUR 10 million for the insurance fund. In this context, the 10-year cash flow was calculated based on different combinations of insurance premiums (8, 10 and 12%) and risk coverages (65, 75 and 85%). Figure 8 presents the relevant results of the nine different scenarios; it should be noted that when taking the specific success rates into account (90%/67%/90%), the insurance scheme is financially unsustainable for the specific pairs of premiums and coverages, making it clear that in all cases the total assets' balance is represented by a negative-slope trend line. However, a distinction should be made between the cases where the scheme still has enough funds to operate after 10 years, compared to the cases where the scheme has financially “collapsed” before the 10-year mark.

Having examined the effect of different rates of coverage and premium, the next step was to evaluate the impact that different success rates of the projects could have on the 10-year cash flow of the presented scenario. With this in mind, four scenarios were prepared: three of them maintained the same success rate of 90% for all proven fields, high enthalpy and low enthalpy ones, with different values of the success rate (50%/67%/75%) examined for the high enthalpy unexplored fields; the 4<sup>th</sup> scenario assumed that geothermal developments will take place only in proven fields, either Milos and Nisyros high enthalpy ones or the low enthalpy fields, with the corresponding success rate equal to 90%. In all cases, premium and coverage rates were held constant, 10% and 75% respectively. Undoubtedly, the effect of the

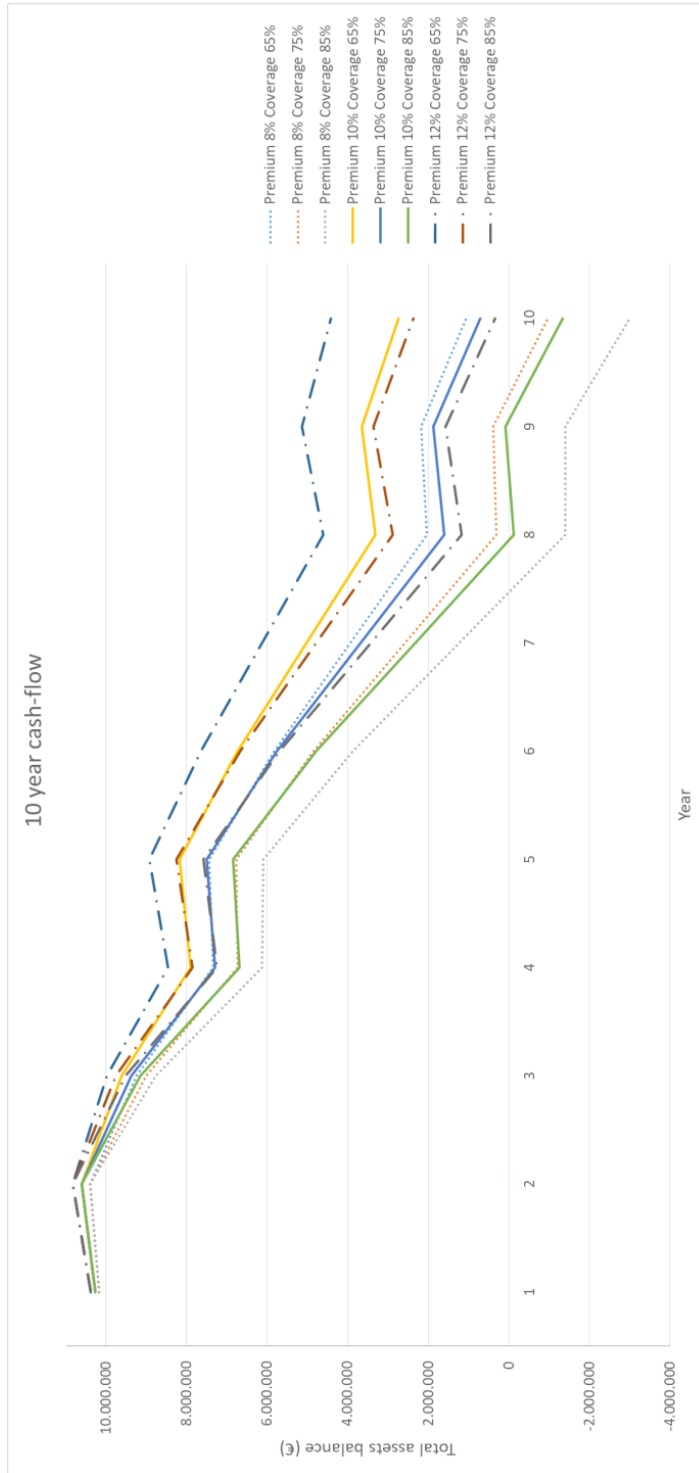


Fig. 8. The Greek case: scenario of insuring 55 geothermal wells expected to be drilled in the next 10 year period; success rates 90% for high enthalpy proven fields, 67% for high enthalpy unexplored fields, 90% for low enthalpy fields

Rys. 8. Przypadek Grecji: scenariusz ubezpieczenia 55 odwiertów spodziewanych do wykonania w okresie najbliższych 10 lat; wskaźniki sukcesu 90% w potwierdzonych obszarach ze zbiornikami geotermalnymi o wysokiej entalpii, 67% w obszarach niezbadanych ze zbiornikami geotermalnymi o wysokiej entalpii, 90% dla obszarów ze zbiornikami geotermalnymi o niskiej entalpii

projects' success rate plays the most important role in the overall sustainability of the insurance scheme; as presented in Figure 9, a scheme based on the overall 90% success rate scenario could even be characterized as financially sustainable (capital of approx. EUR 9.9 million after 10 years of operation). On the contrary, a scenario of a 50% success rate for the high enthalpy presently unexplored fields would lead the GRIF to fall apart after the 7<sup>th</sup> year of operation. Of course, it should be noted that the particular evolution of the cash-flow in each scenario also depends on the years that the projects are assumed to fail (based on the corresponding success rate); assuming the existence of the failed developments in different years throughout the 10 year period could lead to a different cash-flow which, in any case, would eventually have the same result  $\pm 2$  years.

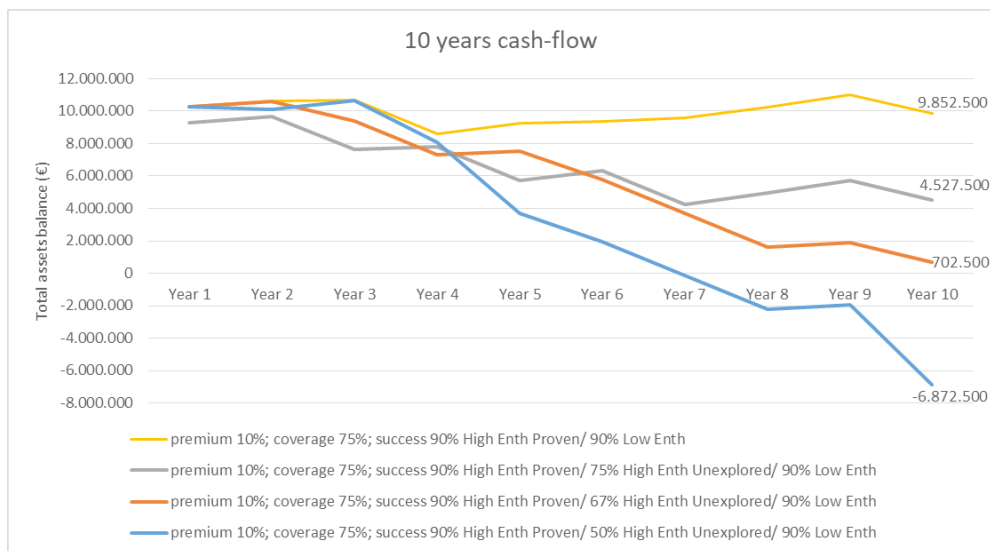


Fig. 9. The Greek case: effect of different success rates on the 10-year cash-flow

Rys. 9. Przypadek Grecji: wpływ różnych wskaźników sukcesu na przepływy pieniężne w okresie 10 lat

Based on the above analysis, some initial results could be indicated. As previously mentioned, a EUR 10 million GRIF with a 10% premium and 75% coverage would not be financially sustainable, as after 10 years less than EUR 1 million would remain in the fund (90%/67%/90% success rates scenarios). However, such a scheme would make sense to be launched as a public fund, in the context of a 10-year development policy for the Greek geothermal sector. In addition, in case the insurance premium (10% in the examined case) is considered as rather high to be covered by the private developers, a 50% public subsidization of the premium could also be provided, as a policy measure towards geothermal development. Indeed, such a public GRIF (EUR 10 million + 50% premium subsidy,

i.e. 5% premium in the specific case), would lead to significant leverage of public investment towards geothermal development, equal to 6.21, as, based on the considered scenario, EUR 83.65 million of total funds will be mobilized, by EUR 10 million public fund, plus EUR 4.1825 million premium subsidization minus EUR 0.7025 million residual funds after 10 years.

Regarding the establishment of a private GRIF, based on the specific conditions, a premium not less than 21% should be applied, to at least maintain financial sustainability (i.e. fund approx. EUR 10 million after 10 years of operation). In this case, and bearing in mind that an acceptable premium for the private developers would be around 5%, the public should subsidize the remaining 16 percentage points, in the context of a geothermal market acceleration policy. In this case, public funding of EUR 13,384 million would lead to EUR 83.65 million as private investments in geothermal projects, hence leverage of 6,25 would be achieved (approximately the same level as the case of the public fund proposed above). Of course, this 21% premium would be adequate only to reach the profitability threshold, meaning that a private scheme would of course require a higher premium, *ceteris paribus*.

With that said, it should be indicated that different preconditions concerning the premium, coverage and success rates would, of course, lead to different financial requirements and results concerning the initialization of a public or a private fund, either assisted or not by a public risk premium subsidization scheme.

### 4.3. Poland

According to the published information (e.g., Dziadzio et al. 2020) and information derived from other sources, in the coming 2020–2030 decade, one may expect (with various probability levels) the implementation of up to 40–60 geothermal projects targeting district heating, heating and other direct applications in Poland. However, some of the already ongoing and potential projects (especially aimed at geoDHs and heating) will be implemented only when non-repayable public grants will be awarded. Since 2016 several big public priority programs offering such forms of support (which can be treated also as risk mitigation measures at a juvenile stage of geothermal market development) have been launched ([www.nfosigw.gov.pl](http://www.nfosigw.gov.pl)), like: Geology and mining (by 2019), Polska Geotermia Plus (since 2019), accessing geothermal waters in Poland (since 2020), FM EEA Constructing heat sources using geothermal energy, deep geothermics (2020–2021). In the next years local governments – which would be main beneficiaries and implementers of geoDHs' projects – will most likely show a low interest in them if no public non-repayable grants (or preferential loans) are available (which take over the financial risk from entrepreneurs in case of unsuccessful geothermal drilling and not finding proper geothermal resource). Taking this possible situation into account, 20 and 30 of the identified larger number of potential projects (well drillings) were assumed as a basis for the 10 year operation simulation provided they are not eligible for public support in the form of non-repayable grants – and will be financed

in other forms and from other sources. In this case, a public GRIF is an appropriate tool for these projects' de-risking, attractive for the group of other potential investors (private, etc.) interested in entering the geothermal heating market.

The results of the 10 year operation simulation are presented in this section for the following assumptions (the most probable under geological end economic conditions as well as an early stage of geothermal heat market development in Poland):

- ◆ launching amount of the fund EUR 11.28 million. This is three times the average cost of drilling a geothermal well, estimated on the basis of the value of drilling projects qualified for public non-repayable grants and loans (average depth ca. 2600 m),
- ◆ number of wells being insured: 20 and 30 in the 10-year perspective,
- ◆ success rate: 80% (16/4 and 24/6 successful /unsuccessful wells, respectively),
- ◆ insurance premium: 4, 6, 8 and 10%,
- ◆ risk coverage: 70% and 75%,
- ◆ time span of the geothermal drilling project: 3 calendar years,
- ◆ overhead costs of the GRIF: EUR 150,000, annually.
- ◆ project expert cost: EUR 10,000 per ongoing project, annually.

The analysis of the operation of the proposed GRIF is presented in Figures 10 and 11 for 20 and 30 projects covered by GRIF, respectively. In almost every case, the fund's base amount, supplemented by contributions by geothermal developers (insurance premium)

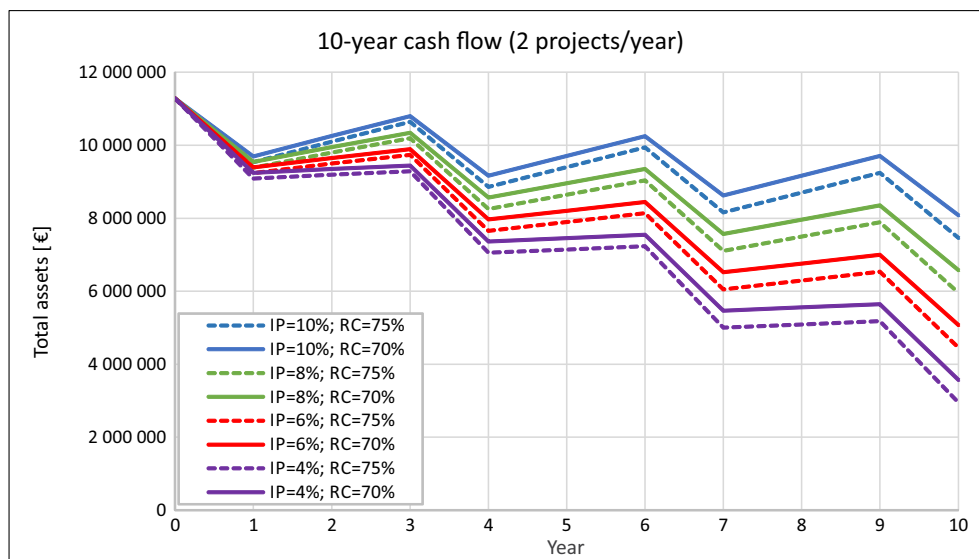


Fig. 10. The Polish case: 10-year cash flow of the proposed geothermal risk insurance fund: 2 projects/year with a success rate of 80%, 20 projects in total. IP – insurance premium, RC – risk cover (based on Kępińska et al. 2021)

Rys. 10. Przypadek Polski: 10-letnie przepływy pieniężne w proponowanym funduszu ubezpieczenia od ryzyka dla projektów geotermalnych: 2 projekty rocznie ze wskaźnikiem sukcesu 80%, łącznie 20 projektów. IP – składka ubezpieczeniowa, RC – pokrycie ryzyka

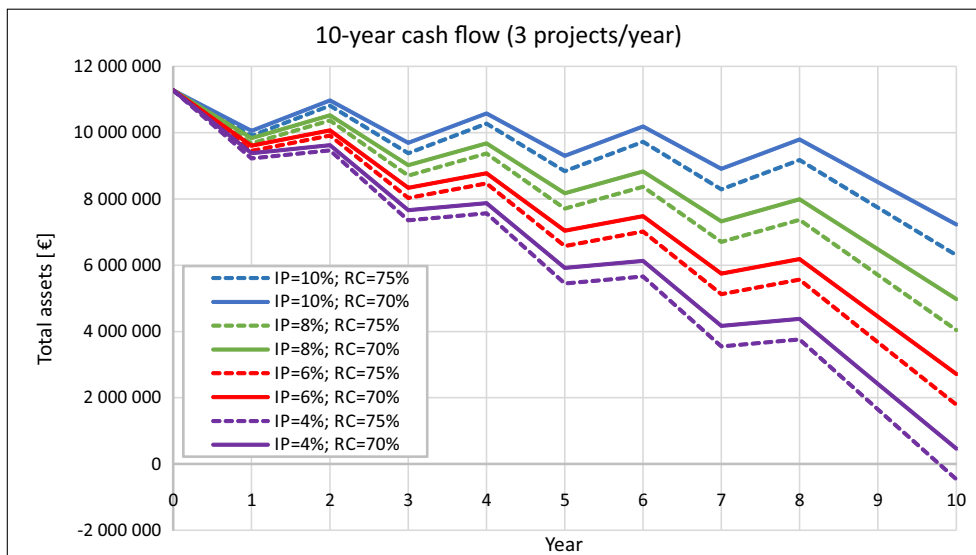


Fig. 11. The Polish case: a 10-year cash flow of the proposed geothermal risk insurance fund: 3 projects/year with a success rate of 80%, 30 projects. IP – insurance premium, RC – risk cover

Rys. 11. Przypadek Polski: 10-letnie przepływy pieniężne w proponowanym funduszu ubezpieczenia od ryzyka dla projektów geotermalnych: 3 projekty rocznie ze wskaźnikiem sukcesu 80%, łącznie 30 projektów. IP – składka ubezpieczeniowa, RC – pokrycie ryzyka

would allow even a 75% reimbursement of incurred costs to those projects that would fail (assuming a success rate of 80%). Only in an exceptional case, the fund assets would be entirely used before the end of the 10-year perspective (4% premium; 75% risk coverage; 3 projects/year). Such a solution should be encouraging both for private and other investors and for state bodies that would set up the fund, not only due to increasing the chances of a larger number of geothermal drilling projects being developed but also due to reducing the involvement of public funds. At this same time, these would bring significant leverage effects: EUR 8.00 investment/ EUR 1 public in case of 24 positive projects and EUR 5.33 investment/ EUR 1 public in case of 16 positive projects (success rate 80%).

#### 4.4. A country with long GRIF experience: France

The late 1970s saw the birth of a heat-producing industry in France built on the use of vast geothermal resources located 2,000 meters under the Greater Paris Region. This home-grown source of energy at a time when the price of fossil fuels was exploding, in the wake of the first oil crisis of 1973, offered temperatures of 60 to 85°C, therefore directly usable for heating residential complexes with or without shared heating networks.

In the early 1980s, a mechanism for covering geological hazards was set up, initiated by the Ministry of Industry with, in 1981, the creation of the Long Term Guarantee Fund to cover the operating life of geothermal works. This duration was initially planned to last for 15 years (before later being extended to 25 years). The fund was managed by SAF-Environment – a subsidiary of the Caisse des Dépôts et Consignations, a state bank (Boissavy 2017; Boissavy and Grière 2017).

If low-temperature geothermal energy is what it is in France today, with – despite the infancy troubles encountered – a large number of operations kicked off some 35 years ago and still in operation today, this is thanks to public support and technical expertise developed progressively by the operators. It has also become what it is, thanks largely to the determining part played by the guarantee mechanisms put into place.

Regarding the guarantee mechanism created in the early 1980s, one needs to stress the usefulness of such a mechanism in relation to the public purse. Hence, for the Short Term Fund, investments worth EUR 198 million were guaranteed for the drilling phase, with EUR 4.7 million paid by the public purse to the Funds, which means that for every EUR 1 paid by the State, EUR 42 of investments were guaranteed.

Lastly, with this guarantee tool that was both a forerunner and a rather innovative one, France gained real-life experience that can easily be transposed outside this country, as was the case with the Netherlands a few years ago (Heijnen et al. 2015). Although the production of geothermal heat is coming second in renewable energy contributions to heat production worldwide, widely distributing this experience would no doubt allow further increasing its contribution.

In the case of the 10 year operation simulation of the GRIF in France, real numbers were used. They were based on data referring to 30 geothermal doublets of wells (i.e. production and injection wells) drilled for district heating in the past ten years: real success rate at 90%; the cost of one doublet was around EUR 10 million (mainly drilling costs); 3,5% insurance

10 years cash-flow of the French Fund

Total Assets	at the end of year, €
Year 1	10 000 000
Year 2	6 960 000
Year 3	7 690 000
Year 4	8 420 000
Year 5	4 650 000
Year 6	5 380 000
Year 7	6 110 000
Year 8	2 340 000
Year 9	3 070 000
Year 10	3 800 000

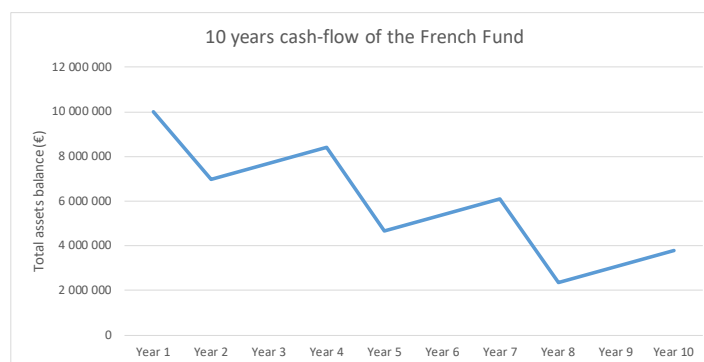


Fig. 12. The French case: a 10 year geothermal risk insurance fund operating cash flow with a 3.5% insurance premium

Rys. 12. Przypadek Francji: przepływy pieniężne z działalności operacyjnej GRIF w ciągu 10 lat ze składką ubezpieczeniową 3,5%



premium representing a charge of EUR 350,000 per insured doublet. Figure 12 shows that the operating simulation of the GRIF is rather close to the 35 years of the existing fund with the need in a period with low inflation to refuel the fund after 11 to 12 years of operation. In that case, the impact of the GRIF is huge with EUR 8 million financed by the French state for a total investment in geothermal of about EUR 300 million which shows a very effective leverage effect of the public grant (Boissavy 2017; Boissavy and Grière 2017).

### Summary and conclusions

The summary and conclusions from the 10 year operational and financial simulation of geothermal risk insurance funds proposed for Greece, Hungary and Poland are given below.

1. The cases presented above prove that the sustainability of the GRIF is well calculable. The calculations show the possibility of sustainability, or the support. The analyses of the 10 year simulation for all three countries demonstrate the significance of the high success rate as the most sensitive factor of GRIF sustainability. A GRIF may be launched and operated only if the highest possible success rate is ensured. However, the premium also affects strongly the cash flow of the GRIF.
2. There are a lot of similarities among the simulation results of the target countries. The key factors behave the same way and their role has the same importance in the sustainability of the system. Apart from the similarities, there are differences in the simulations as well. Greece has different natural conditions than Hungary or Poland. The Greek simulation provided an interesting example on how to handle the well-known and unexplored areas, as well as the fields with high, medium and low enthalpy in a different way.
3. The operating and cash-flow simulation and its results ensure wide-range support in the decision-making process related to launching a new geothermal risk mitigation fund.
4. A risk insurance fund, GRIF, is a very effective way to support the geothermal sector and after a transition time, it can be privatized. Therefore, it has to be an important tool for supporting the geothermal sector. During the planning of a new GRIF, it is important to take the long experience of the former and existing systems into consideration.
5. Since more and more systems will be established, joining an operating GRIF system could be a feasible solution as well. Each operating GRIF has the interest to involve new projects to achieve lower overhead costs. To push the overhead costs and the premium to the lowest level, establishing larger international GRIF seems to be more and more feasible, and a European Geothermal Risk Mitigation System has already been considered. Most recently, in May 2021 the European Geothermal Energy Council together with 16 companies and organizations asked the Executive

Vice-President of the European Commission and Energy Commissioner to introduce the provisions on establishing an EU-wide renewable risk mitigation scheme into the Renewable Energy Directive (which will include geothermal energy) (<https://www.egec.org/policy-documents/joint-letter-for-an-eu-wide-renewable-risk-mitigation-scheme>).

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**RISK INSURANCE FUND FOR GEOTHERMAL ENERGY PROJECTS  
IN SELECTED EUROPEAN COUNTRIES – OPERATIONAL AND FINANCIAL SIMULATION**

Key words

geothermal resource, geothermal projects, risk, insurance fund, simulation

Abstract

The insurance funds belong to efficient measures mitigating risks in geothermal projects, including resource risk. They already exist in some European countries, e.g., France, the Netherlands, Turkey. Recently, the proposals of establishing such funds were elaborated for three countries: Greece, Hungary, and Poland within the framework of the EU-funded project “Developing geothermal and renewable energy projects by mitigating their risks”, GEORISK ([www.georisk-project.eu](http://www.georisk-project.eu)).

A 10 year operational and financial simulation of the proposed public insurance funds was conducted to prove their sustainability in each of three listed states. It started with the determination of the country-specific premises. The numbers of projects in the next 10 years possible to be covered by funds were assumed by the authors on the bases of realistic estimations.

The initial capital, the fixed costs, the costs of the project evaluation, the premium fees paid by the investors, the payment for the unsuccessful projects altogether were taken into account. The first draft simulation was done with the exact Hungarian assumptions and inputs of fixed costs and also with average project data, thus making it appropriate to perform sensitivity analyses on: insurance premiums, success rates and the risk coverages. Then, complete simulations were made for three listed countries.

The results of the simulation show that a resource risk insurance fund can be a sustainable and an effective measure to support geothermal energy sector development. During the planning of a new fund, it is important to make use of long experiences both of the former and existing funds.

**FUNDUSZ UBEZPIECZENIA OD RYZYKA W PROJEKTACH GEOTERMALNYCH –  
SYMULACJA OPERACYJNA I FINANSOWA DZIAŁANIA W WYBRANYCH KRAJACH EUROPEJSKICH**

## Słowa kluczowe

zasoby geotermalne, projekty geotermalne, ryzyko, fundusz ubezpieczenia, symulacja

## Streszczenie

Fundusze ubezpieczenia należą do skutecznych form łagodzenia ryzyka w projektach geotermalnych, w tym ryzyka zasobowego. Funkcjonują one już w niektórych krajach europejskich, np. we Francji, Holandii, Turcji. Ostatnio opracowano propozycje ich utworzenia dla trzech krajów: Grecji, Węgier i Polski, w ramach projektu finansowanego przez UE „Rozwój projektów z zakresu energii geotermalnej i odnawialnych źródeł poprzez łagodzenie ich ryzyk”, GEORISK ([www.georisk-project.eu](http://www.georisk-project.eu)).

Dla każdego z podanych krajów wykonano symulację 10 lat funkcjonowania operacyjnego i finansowego proponowanego publicznego funduszu ubezpieczeniowego, aby udowodnić ich zrównoważony charakter. Symulację rozpoczęto od przyjęcia założeń uwzględniających specyfikę poszczególnych krajów. Liczbę projektów możliwych do objęcia funduszami w trakcie 10 lat przyjęto według realistycznych szacunków dla każdego z krajów.

Symulację wykonano z uwzględnieniem kapitału początkowego, kosztów stałych, kosztów oceny projektów zgłaszanych do ubezpieczenia, składek ubezpieczeniowych, wypłat za nieudane projekty. Pierwszą roboczą symulację wykonano dla Węgier według rzeczywistych proponowanych założeń i danych wejściowych odnośnie do kosztów stałych, a także uśrednionych założonych danych. Wykonano analizy wrażliwości dotyczących składki ubezpieczeniowej, wskaźnika sukcesu i stopnia pokrycia ryzyka. Następnie wykonano pełne symulacje dla trzech podanych krajów.

Wyniki symulacji wskazują, że fundusz ubezpieczenia od ryzyka zasobowego może być zrównoważoną i skuteczną formą wspierania rozwoju energetyki geotermalnej. Przy planowaniu nowego funduszu ważne jest korzystanie z wieloletnich doświadczeń funduszy, które funkcjonowały w przeszłości, i tych, które działają obecnie.