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# Examining the Development of a Geothermal Risk Mitigation Scheme in Greece

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**Abstract:** Geothermal project development entails a number of risks, the most significant of which is the geological risk. The introduction of a risk mitigation scheme (RMS) might enable project developers to shift some of the geological risk to public or private entities. Keeping the above in mind, the objective of this study is to examine the development of an effective and financially feasible geothermal risk mitigation scheme in Greece, i.e., a country with no such scheme available. In this respect, the existing status of the geothermal sector in the country is presented, followed by an evaluation of the financial sustainability of a potential RMS, taking into account different insurance premiums, risk coverages, and project success rates. The results indicate that alternative insurance premium, risk coverage, and success rate requirements would result in different financial preconditions for the foundation either of a public or a private fund. Keeping in mind that in most examined scenarios the initial RMS capital is expended before the end of the ending of the scheme, it is suggested that such a plan can only be initiated by the public sector, which is typical of countries with little-developed geothermal markets.

**Keywords:** geothermal energy; risk mitigation scheme; financial sustainability; success rate

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**Citation:** Karytsas, S.; Mendrinos, D.; Oikonomou, T.I.; Choropanitis, I.; Kujbus, A.; Karytsas, C. Examining the Development of a Geothermal Risk Mitigation Scheme in Greece. *Clean Technol.* **2022**, *4*, 356–376. https://doi.org/10.3390/cleantechnol4020021

Academic Editor: Luigi Aldieri

Received: 24 February 2022
Accepted: 29 April 2022
Published: 7 May 2022

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## 1. Introduction

Geothermal project development entails a number of risks, the most significant of which is the geological risk (also known as resource risk) [1–3]. Geological risk covers (a) the short-term risk of not discovering a commercially sustainable geothermal resource upon drilling, and (b) the long-term risk of natural geothermal resource depletion, rendering extraction economically unattractive [4,5]. The geological risk, which is a widespread concern throughout Europe, determines the efficiency and economic viability of geothermal projects [6,7]. This is especially the case for deep applications with a high capital cost and high failure risk, whereas shallow geothermal projects have relatively low capital cost and risk [8–10]. Besides, risks related to renewable energy projects are different from those of traditional projects [11], whereas in the case of deep geothermal projects, the situation is more complicated in relation to other renewable-energy power plants, due to typically longer payback periods and higher capital costs [12].

Strengthening our ability to measure and define geothermal (resource) risk and uncertainty could result in more successful projects in the long run [13]. There are several tools available to mitigate the risks of investing in renewable energy projects [14]. Risk mitigation schemes (RMS) (e.g., geothermal guarantees, risk insurance, capital grants) have already been established in some European countries (Denmark, France, Germany, Iceland, the Netherlands, Switzerland, and Turkey), allowing project developers to transfer geological risks to public or private entities. Except for these seven nations, individuals in charge of geothermal project development have rather few financial risk management capabilities [15].

Public, private, and PPP (private–public partnership) schemes are the three categories of risk mitigation schemes. A public scheme usually has a legal foundation, such as an act, an ordinance, or a decree. In PPPs, government or energy agencies regularly require public banks or insurance corporations to provide low-interest loans or loan guarantees, often in partnership with commercial private companies. The legal foundation in this situation comprises both corporate and banking rules, as well as public legislation. The articles of the organization outline the legal and regulatory framework for a private scheme, stating whether the private entity can act as a provider of insurance services [16].

Based on the abovementioned, the H2020-funded GEORISK European project (October 2018–September 2021) focused on the creation of such RMSs across Europe, as well as in a few strategic target third countries, to handle primarily the exploitation phase and the initial drilling. A total of 15 partners from eight different countries took part (France, Germany, Greece, Hungary, Poland, Switzerland, and Turkey) [4]. It is worth mentioning that the following GEORISK-participating countries had active RMSs for geothermal projects at the start of the project: France, Germany, Switzerland, and Turkey. Hence, the project partners made substantial efforts and took the required measures to launch the development and foundation of RMSs in the remaining three countries: Greece, Hungary, and Poland [17].

An important issue, addressed by the GEORISK project, is matching RMS to market maturity. An RMS must be designed according to the market maturity of the addressed sector in the country. The market maturity level is shifting from emerging markets to mature markets. In emerging markets, there are no private insurance schemes available, since technological and financial risks are not well defined and cannot be priced. On the other hand, in mature markets, there is a low rate of failure, and the risks can be quantified; therefore, private insurance exists, as it may be profitable [18].

There are different RMSs that could be adopted in each country. Speer et al. [19] and Sanyal et al. [20] presented various RMS types provided by different countries for geothermal energy projects, and Apak et al. [21] presented the financial risk management instruments that can be applied in the different phases of renewable energy projects. In Figure 1, these schemes are presented in relation to the corresponding market maturity. As shown in this figure, in juvenile markets, the most appropriate RMS is grants. Beginning with direct grants, the schemes may progress to repayable grants in the event of success, and then to convertible grants to fund, for example, the second well. In intermediate markets, an RMS such as public risk insurance is more suitable, whereas in more mature markets, public–private partnership schemes could be established. Finally, in highly mature markets, private risk insurance schemes are the most appropriate [4].

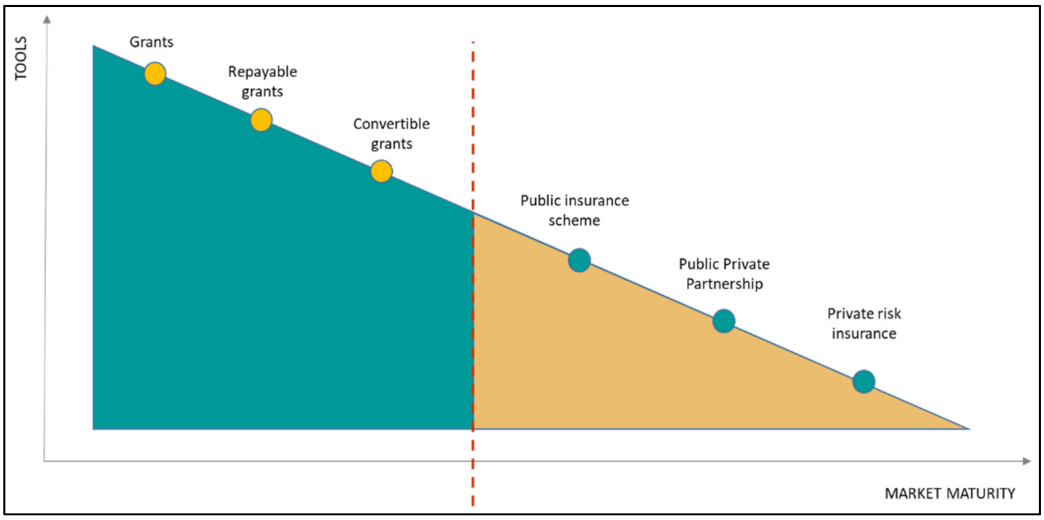


**Figure 1.** Presentation of an RMS in relation to the market maturity level (source: modified from [4]).

Previous research has worked towards the identification and assessment of risk mitigation tools related to RES (renewable energy source) investments. A first set of research has examined this subject for RES in general. MARSH [22] provided an overview of the barriers and risks affecting RES projects' investments, the available risk management tools, and instruments that could be developed to reduce project uncertainty. Agrawal [1], dealing with the risk mitigation strategies for the financing of RES projects, presented an outline of risks associated with such projects, as well as means for their mitigation. Liebreich [23] addressed the issue of risk management in financing renewable energy projects, presenting the project risks and risk management approaches in the different stages of an RES project.

A second set of research has examined RES risk mitigation methods, with a focus on specific case studies. In this regard, Abba et al. [24] reviewed RES risks and risk mitigation methods, with a focus on Sub-Saharan African countries; based on the review findings, a "holistic multi-dimensional investor risk management framework" was introduced, aimed at the structured identification of investment risk mitigation measures. Holburn [25], concentrating on the regulatory-related risks of RES, introduced a conceptual framework for the assessment of regulatory risks that focus on the institutional processes governing policymaking; the framework was tested through the comparison of RES policies in Ontario (Canada) and Texas (U.S.A.).

Furthermore, a third set of studies has dealt with risk mitigation tools, focusing on specific types of RES, with the majority of them concerning wind energy. Leblanc [26], through the application of probabilistic models integrating quantifiable risks in the financing context, valued—from a financial perspective—the insurance for a wind farm business plan. Gatzert and Kosub [27], with a focus on the European market, presented the risks for onshore and offshore wind parks and evaluated the corresponding risk-management instruments. Kitzing [28] dealt with the risk implications of RES support instruments through the comparison of feed-in tariffs and feed-in premiums based on mean-variance portfolio analysis. Moreover, through the application of cash-flow analysis, Monte Carlo simulations, and mean-variance analysis, the risk–return relationships for an offshore wind park in West Denmark were quantified. Waissbein et al. [29] introduced a framework for the quantitative comparison of the impact of different public instruments targeting RES promotion. The framework consisted of four stages, namely, risk environment, public instruments, levelized cost, and evaluation; four case studies (South Africa, Panama, Mongolia, Kenya) examining 20-year targets for wind energy were applied to examine the decision-making process in practice.

Other than wind energy-related projects, Mohamed et al. [30] identified the main risks of solar energy project implementation in Kerala, India, assessed the significance using the analytic hierarchy process (AHP) technique, and provided a set of broad risk-mitigation recommendations. Lastly, when referring to geothermal projects, Imolauer and Ueltzen [31] compared the public risk funds set up in different countries to promote the development of geothermal markets, considering models from Germany, France, Indonesia, Switzerland, and East Africa.

Against this background, it is the first time that the development and financial sustainability of a scheme aiming at the mitigation of geological (resource) risk are being examined. A successful RMS should be tailored to the specific characteristics and needs of each country. Keeping this in mind, the objective of this study is to examine the development of an effective and financially feasible geothermal risk mitigation scheme in Greece, i.e., a country with no such scheme available.

The process for the development of a geothermal RMS is presented in Figure 2 and was formed by taking into account the necessary input, theoretical procedures, and practices [31–34]. The concept of this process is followed in this paper, focusing on the examination of the development of a geothermal RMS in Greece. Hence, Section 2 presents the existing status of the geothermal sector in the country, including the geothermal resources, the existing market conditions, and the potential risks related to the development of a geothermal plant, which are identified and assessed. Then, the geothermal legislation and policies are assessed, and those applicable to the establishment of an RMS are identified. Section 3 deals with the materials and methods applied to evaluate the establishment and operation of a geothermal RMS in Greece. Following that, Section 4 presents the results of a 10-year financial operation simulation of a potential RMS in Greece, and discusses the main findings derived from the current work, and Section 5 presents the work's main conclusions.

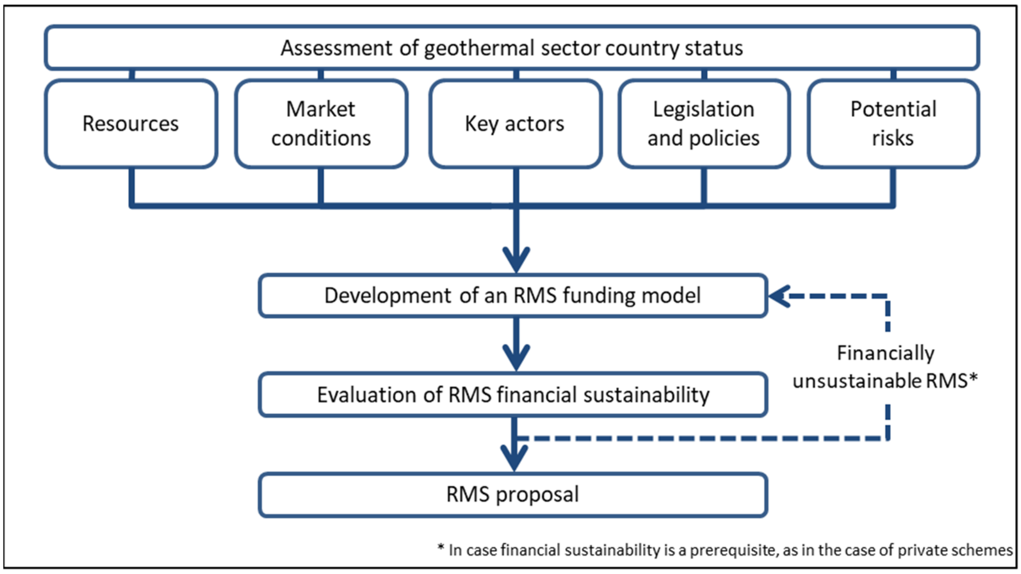


**Figure 2.** Process for the development of a geothermal RMS (own creation).

## 2. Country Status

### *2.1. Geothermal Assessment*

In 1970, geothermal exploration started in Greece. It was primarily conducted by the Greek Public Power Corporation (PPC) for medium–high temperature (100–350 °C) resources up to 2 km depth for power generation, and by the Institute of Geological and Mineral Exploration (IGME)—now the Hellenic Survey of Geological and Mineral Exploration (EAGME)—for low-temperature (100 °C) resources up to 600 m depth for agricultural applications. Except for Milos and Nisyros islands [35], it should be noted that limited data are available for the medium- and high-temperature reservoirs mentioned above, as no or limited geothermal drilling exploration has been carried out, and in many cases, estimated reservoir temperature values have been calculated by geothermometer analysis.

Hydrothermal resources in Greece are found in Quaternary or Miocene volcanism zones and continental basins with high heat flow [36]. Based on active volcanic activity, high-temperature (>200 °C) resources have been proven to be tapped in Milos (150 MWe potential) and Nisyros (50 MWe potential) islands, and also indicated in Thera (Santorini) island and Methana peninsula. Numerous low-temperature (<100 °C) reservoirs have been detected in other locations, utilized mainly for balneology and/or greenhouse/soil heating. Additionally, potential deep medium-temperature resources (100–200 °C) have been identified by drilling exploration in the Alexandroupolis, Xanthi-Komotini, and Nestos River basins. Moreover, potential medium-temperature resources are inferred by geothermometers and volcanic outcrops in the Xanthi-Komotini and extended Sperchios River basins, Sousaki, and Samothraki, Chios, and Lesvos islands. Figure 3 provides an illustration of the main geotectonic structures in Greece, and Figure 4 depicts the geographical distribution of geothermal fields.

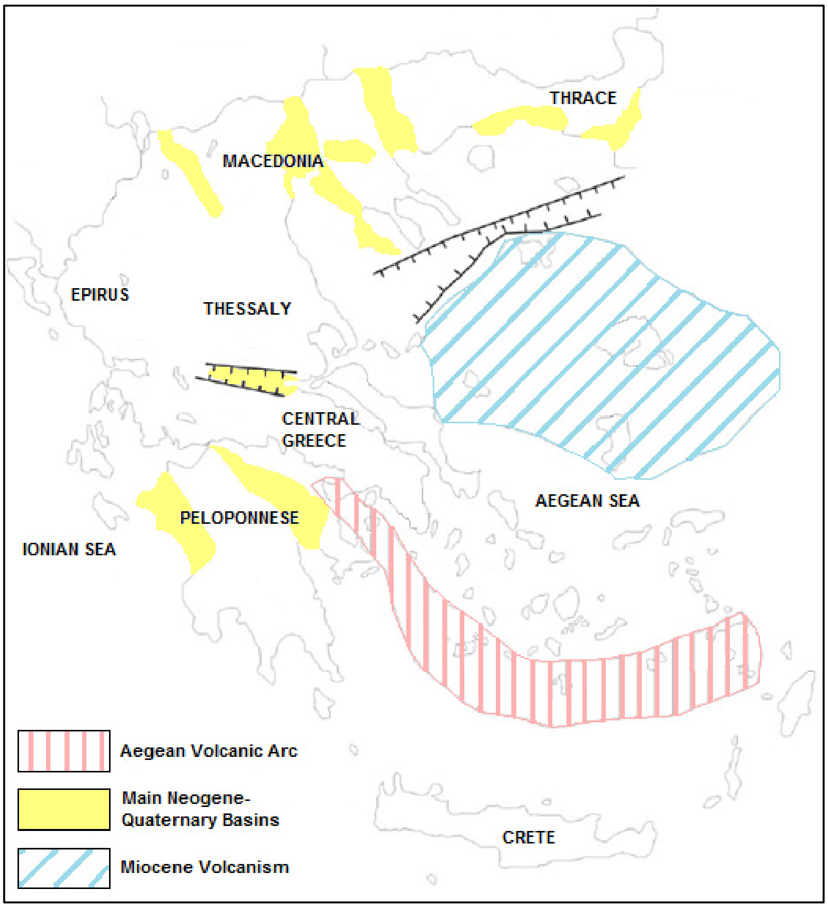


**Figure 3.** Greece's principal geotectonic structures (Source: [37]).

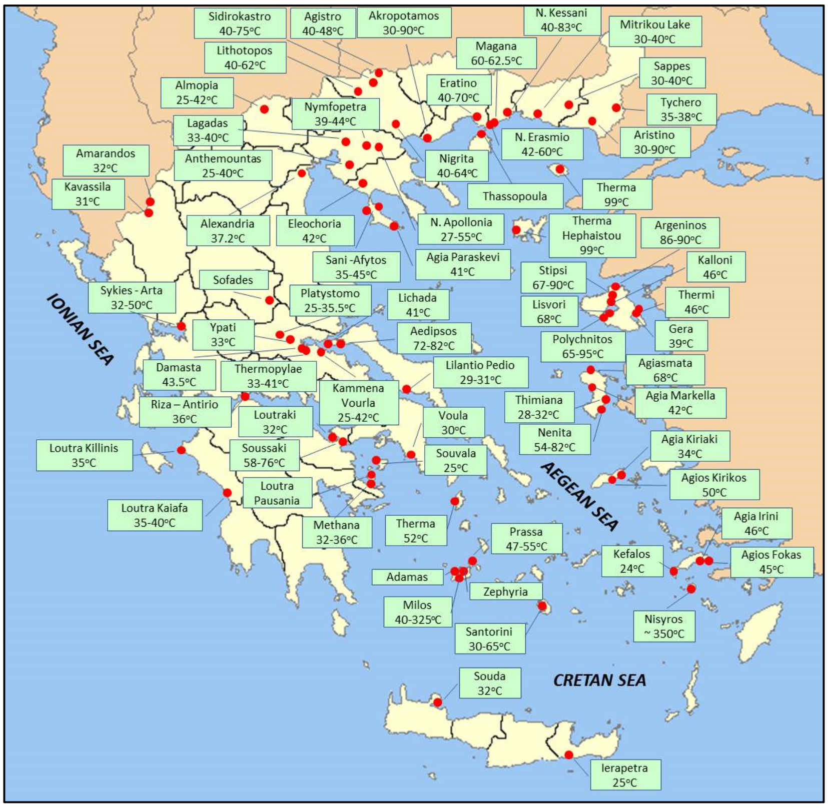


**Figure 4.** Geographic coverage of Greece's geothermal fields (Source: [37]).

The most appropriate geothermal areas for power generation are sites positioned on the active Aegean volcanic arc (Milos, Nisyros, and Santorini islands; possibly Kimolos Island, Methana, and Sousaki), on islands of the North Aegean with Miocene volcanism (Chios, Lesvos, and Samothraki), and in northern Greece's sedimentary basins (Alexandroupolis, Xanthi-Komotini, and Nestos River), as determined by the above exploration results [36].

### 2.2. Market Conditions in Greece

Greece is defined by large geothermal potential, especially for the production of electricity. However, as a result of economic and other non-technical barriers, the development of geothermal energy in Greece progressed slowly during the previous decades. The geothermal industry is on a positive track in Greece, with a renewed interest in geothermal heating and cooling and geothermal power generation. The sector attracts small private operators seeking to produce geothermal heat (especially for agri-food applications), public authorities investing in district heating, and corporate private developers [38].

As presented in Table 1, in 2020, deep geothermal for heating represented 45 MWth for agricultural use, corresponding to 17 MWth of two corporate-owned greenhouses, plus 28 MWth of family-owned agricultural enterprises. There were also spa units operating at 45 locations equivalent to 43 MWth of heat use, but no geothermal electricity projects in operation.

**Table 1.** Geothermal heat use in Greece per application in December 2020.

| | No | Geothermal Capacity (MWth) | Geothermal Energy Use (TJ) |
|---|---|---|---|
| Small family-owned agricultural enterprises | 22 | 28 | 274 |
| Corporate-owned greenhouses | 2 | 17 | 187 |
| Spas | 45 | 43 | 260 |
| GSHPs | 3700 | 175 | 1050 |

Source: [39,40].

### 2.3. Key Public Institutions

Greece's geothermal high-temperature and low-temperature resources are both state-owned. The Ministry of Environment and Energy is in charge of both high- and low-temperature field exploration, with support from EAGME and CRES (Center for Renewable Energy Sources and Saving). The abovementioned Ministry has the responsibility of issuing exploitation licenses for high-temperature deep geothermal resources, whereas the secretary-general of the corresponding decentralized administration is in charge of potential and proven low-temperature deep geothermal resources. Both public and private entities may exploit geothermal fields of high and low temperatures for a specific period through a lease. To do so, a call for a tender process issued by the Ministry or the relevant decentralized administration is necessary, which is initiated either by state attempts to develop a field or by the ambition of a single public or private body [37].

The geothermal concessions include 17 geothermal fields (July 2019), with the majority located in northern Greece. PPC has the exclusive right to explore, exploit, and manage the high-temperature potential in the Milos–Kimolos–Polyegos islands area, Nisyros and Lesvos islands, and the Methana peninsula. Moreover, the right to explore or utilize the low-temperature potential up to 90 °C (99 °C in Aristino) in five main geothermal fields in Macedonia and Thrace (Lithotopos, Sidirokastro, Akropotamos, Eratino, and Aristino) has been leased to the local municipalities [39,40].

Local authorities have had an essential part in the development of all geothermal areas, either favorable or unfavorable. Northern Greece has drawn significant investment, as local authorities and residents regard geothermal energy as a means of economic, environmental, and social development. In addition, in certain cases, as in the geothermal fields of Aristino and Eratino, municipal authorities have become directly engaged in programs of exploration and exploitation and are already working as field managers and/or heat distributors [39,40].

### *2.4. Risk Assessment*

The precise classification of the types of risks that need to be handled is a critical step in the establishment of an RMS, as different financial and insurance instruments may be used to cover the various risks recognized. With this in mind, the work of Seyidov [41] identified the potential risks threatening Greek geothermal projects. Based on this analysis, three types of geothermal reservoirs were considered as a result of this analysis: (a) shallow geothermal resources in Macedonia and Thrace, (b) deep sedimentary reservoirs, and (c) the Aegean volcanic arc. The first two are found in sedimentary rocks, whereas the third is found in volcanic rocks. Drilling risks, operational and geological risks, and socioeconomic risks are the three types of risks that have been recognized.

The geothermal resources in the Macedonia and Thrace regions range in depth from shallow to medium (0–2000 m). Projects targeting such depths, according to the risk evaluation (see [41]), present medium-level risks. Financial uncertainty is seen as the greatest impediment to future progress in terms of socioeconomic risks. It is worth noting that such projects are strongly dependent on energy prices and the availability of financial resources, and that the regulatory environment might pose an additional risk to geothermal development. However, it seems that geological risks do not pose a severe threat, with the exception of chemical composition issues (i.e., the presence of aggressive compounds in the water should be regarded) and aspects related to the reinjection procedures. Drilling risks were assessed as the least significant in the assessment, meaning that they would not constitute a substantial threat to geothermal project development.

Deep sedimentary reservoirs (depths from 2000 to 5000 m) [41] are thought to provide substantial, if not larger, risks than shallow–medium-depth reservoirs (Macedonia and Thrace regions). Social acceptability and political attitude are the most prominent socioeconomic risks, followed by the lack of clients and know-how, and insufficient design quality. The most crucial elements of operational and geological risks, according to the review, are fluid chemistry (which might result in accelerated corrosion), the risk of not discovering the anticipated geothermal resources (i.e., short-term resource risk), and the possibility of surface leakages. Damage to the well/reservoir during drilling or testing, trajectory complications, wellbore instability and well-casing collapse, equipment failure, and hazardous emissions because of gases and fluids are all considered medium-level drilling risks.

The Aegean volcanic arc stretches from Nisyros and neighboring islands to the islands of Santorini and Milos, extending inland in the Methana peninsula and the Soussaki volcano, and farther north with extinct volcanoes. Its geothermal potential is rather high as a result of the volcanic activity, offering the opportunity for power generation. Due to the lack of operating geothermal plants, respondents' evaluations are based on exploratory data. As stated by Seyidov [41], respondents argued that developing geothermal projects in the region is unfeasible because of strong public opposition, which severely impedes the initiation of any new projects. Apart from this risk, regular alterations in the legislative and policy framework pose a considerable socioeconomic risk. Simultaneously, despite the high potential for power production, the local infrastructure is insufficient to handle and distribute electricity to the mainland. Due to these hurdles, the development of geothermal energy in the region has proven to be extremely difficult, necessitating government aid at this time.

### *2.5. Legislation and Policies*

#### 2.5.1. Geothermal Legislative Framework

The National Renewable Energy Action Plan (NREAP) launched in 2010 established the primary goals for the integration of renewable energy sources in the Greek energy sector. The plan makes only a passing reference to geothermal energy for potential future developments in industrial heat and the services sector. However, more measures are foreseen for geothermal energy development under the new National Energy and Climate Plan (NECP) for 2030, which came into force in 2019. For geothermal energy, it is foreseen that by 2030 the installed capacity for electricity production will be 100 MWe [42].

In turn, the Energy Performance of Buildings Regulation (EPBR) of 2010 is known to be the primary regulatory instrument for supporting RES schemes for tertiary and domestic heating and cooling.

In 2003 the Greek government enacted a law establishing a particular regulatory framework for the "exploitation of geothermal energy" (Law 3175/2003), supplemented in 2009 by two ministerial decrees defining the requirements and procedures for the leasing of the right for geothermal energy exploration and management, and replaced in March 2019 by the new geothermal law (Law 4602/2019) entitled "Exploration, exploitation, and management of the country's geothermal potential." The comprehensive concession processes, terms, conditions, royalties, etc., will be regulated via secondary regulations and ministerial decrees, which will replace the ones mentioned above. The new ministerial decrees defining the requirements and procedures for the leasing of the concession rights for geothermal energy exploration, exploitation, and management are in the final stage of development. Additionally, a new regulation for geothermal works was enforced in May 2021.

### 2.5.2. Support Schemes for Geothermal Energy

Law 4414/2016 provides the current support scheme for RES, harmonizing Greek legislation with European (EE C200/28.6.2014). The "new support scheme for renewable energy power plants and high-efficiency combined heat and power plants" seeks to establish a new support system for RES and CHP (combined heat and power) electricity power generation to put to use the national potential for RES electricity power production. According to this law, as modified in March 2020, the reference price for geothermal power plants $\leq$5 MWe is 134 EUR/MWh, and 104 EUR/MWh for geothermal power plants >5 MWe; based on this reference price, the feed-in-premium is calculated monthly. Since geothermal power plants are excluded from auction procedures, the feed-in premium for geothermal energy has the same function as the previous feed-in tariff scheme.

Geothermal electricity is mainly promoted through the feed-in premium scheme as described above. According to a decision by the Regulatory Authority for Energy (RAE) in 2013, electricity production is allowed for geothermal fluid temperature above 85 °C. For electricity production, a production license from RAE is needed. For direct use, no distribution license is needed for geothermal energy.

Concerning heating and cooling, the "Energy Saving at Home II" program provides interest-free loans and subsidies for the installation of RES plants and energy-saving measures aimed at improving the energy performance of residential buildings. Additionally, geothermal installations are eligible for income tax relief for natural and legal persons who have performed an energy upgrade of their building.

Furthermore, the development law (4399/2016) that came into force in July 2016 foresees support in the form of subsidies and tax exemptions for CHP plants and self-production using RES, including geothermal.

Figure 5 presents the decision process in Greece, referring to the establishment of an energy-related support scheme. The first step of the whole process is the submission of a proposal for the establishment of an RMS by an interested party, public or private. Following this, the relevant ministry evaluates the proposal. If the initial evaluation outcome is positive, specific steps follow, starting by assembling an administering committee responsible for producing a scheme proposal. After the necessary public body and public consultations and the corresponding modifications, a final document is delivered. If approved by the government authorities in control, the scheme takes the form of a legislative act and takes legal effect when issued in a government gazette.

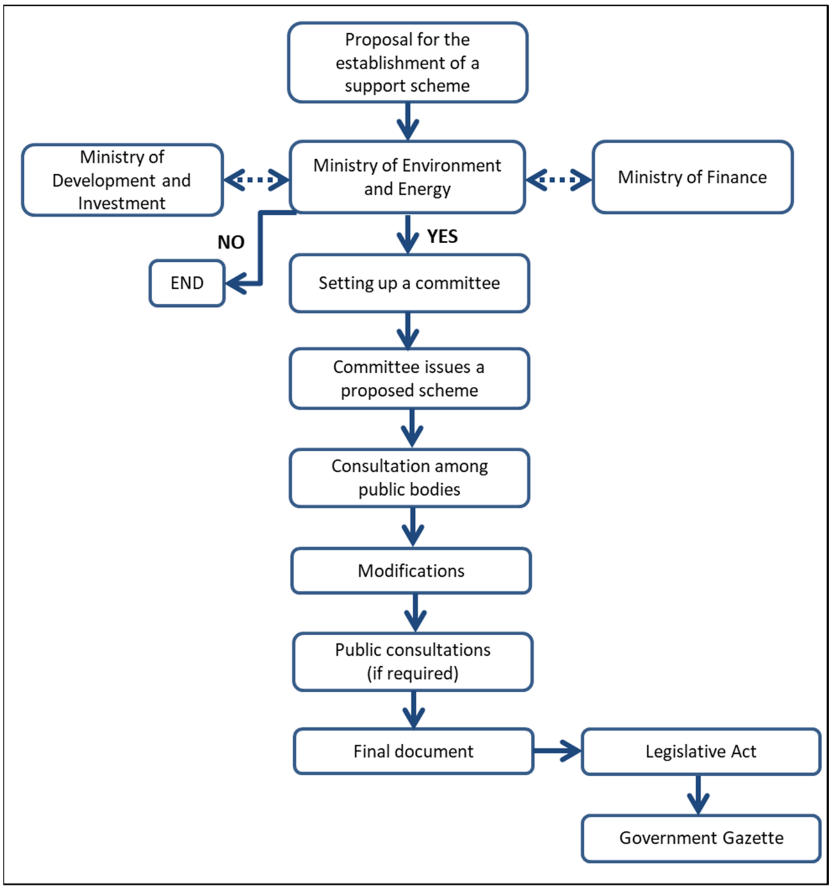


**Figure 5.** Mapping of the decision-making process in Greece, referring to the establishment of an energy-related support scheme (own creation).

### 2.5.3. Legislation and Policies on Geothermal RMS

At the moment (February 2022), no risk mitigation schemes are available in Greece for geothermal projects. However:

- The Hellenic Survey of Geology & Mineral Exploration has been performing exploration activities throughout low-temperature (<90 °C) geothermal fields in Greece; thus, through public funding, the possible exploration and geological risks are reduced for potential investors.
- Municipalities, with funds from the National Strategic Reference Framework (NSRF), develop infrastructure for district heating networks. Thus, costs related to lack of funding and relevant aspects are reduced.

Furthermore, the content of the NECP could strengthen a discussion on the introduction and implementation of geothermal-focused RMS. The plan, issued by the Ministry of the Environment and Energy [42], includes a section on risk factors and challenges for renewable energy sources (RES) in general. This section, being directly related to the potential creation of RMS for RES and energy-saving actions, could assist with the creation of a geothermal RMS in Greece, as it:

- Acknowledges the importance of risk mitigation;
- Proposes the use of preferential loans through special funds;
- Proposes the provision of insurance for the initial collateral damage of loaning schemes.

In addition, it should be mentioned that the newly issued Greek law on the research, exploitation, and management of the geothermal potential of the country (Law 4602/2019) includes an article dealing with incentives for the development of geothermal energy. This article proposes incentives to support geothermal development, without, however, mentioning the type of incentives; in this regard, RMS could also be included within the proposed incentives/measures.

Apart from the above, there are several laws, ministerial decrees, and reports that, although not directly related to the establishment of an RMS, are associated with the alleviation of several social, financial, environmental, and technical risks related to geothermal project exploration, development, and operation, as documented by Le Guenan et al. [43]. For instance, Law 3468/2006 and Law 4602/2019 target social acceptance of RES projects through the provision of monetary benefits to the local authorities. Moreover, it could be indicated that Law 4414/2016 deals with potential financial risks that developers could potentially face by setting specific selling prices for RES and CHP. Furthermore, ministerial decree Δ9B/Φ166/23880/ΓΔΦΠ4211/2011, through its provisions, deals with potential safety and environmental risks by setting relevant safety and environmental protection rules.

Moreover, there is a set of several regulations and documents that either provide technical information (location, surface, temperature, depth, flow rate) of specific recognized geothermal fields or set the rules for the future collection of the relevant information. The recording and presentation of this data are of high importance, as they can (a) assist with the reduction of potential technical failures by providing specific information for each specific field and (b) provide technical input utilized for the establishment of potential RMS.

## 3. Materials and Methods

Examining the financial sustainability of a geothermal RMS over time is a critical step toward its development. To do so, a financial simulation was performed with the main goal of estimating the cash flows of a proposed RMS for 10 years. As no relevant tool taking into account all the different parameters necessary for implementing such a simulation was available, the whole financial simulation process was set up using the Microsoft Excel spreadsheet software. To set up and run the financial simulation, several assumptions referring to both the RMS and the planned geothermal projects were made, keeping in mind that, at that moment, neither such an RMS had been officially planned/proposed by any public or private institution, nor were any high-temperature geothermal projects under development in Greece. These assumptions were specified based on the country-status information presented in Section 2. Against this background, the assumptions concerning the launch and operation of the geothermal RMS are presented in Table 2.

**Table 2.** Assumptions concerning the geothermal RMS.

| | **Assumption** |
|---|---|
| Project types | All deep geothermal projects are included, both low and high enthalpy, and short term contracts, including drilling and testing wells. |
| Project definition | High-enthalpy field: drilling, completion, and operation of one successful doublet for power generation.<br>Low-enthalpy field: three successful doublets for the delivery of district heating. |
| Geological structures | All possible formations. |
| Type of contract | Grant, insurance premium paid in advance, and fee financed afterward. |
| Hypothetical result of the project | Successful, unsuccessful |
| RMS launching capital | EUR 10,000,000 |
| RMS fixed costs (not directly related to the projects) | EUR 240,000 (See Table A1 in Appendix A for analysis.) |
| Drilling costs | Estimated based on local geological and reservoir settings; the estimates are somewhat conservative, corresponding to the lower end of the cost spectrum. |
| Insurance premium | A range from 1% to 20% was taken into consideration (sensitivity analysis performed). |
| Risk coverage | A range from 5% to 100% was taken into consideration (sensitivity analysis performed). It is paid when a geothermal project is considered unsuccessful (it does yield desired heat output). |

Greece's geological settings have resulted in a multitude of geothermal fields, indicating a significant geothermal potential. However, it is underutilized since it is exclusively used for low-enthalpy (90 °C) direct heat uses and there are no power-generating facilities [37]. As a result, the goal of a potential RMS should be to encourage private-sector investments in geothermal energy, especially in medium-enthalpy (100–150 °C) and high-enthalpy (>150 °C) uses.

In Greece, more geothermal fields have been discovered, distributed all around the country (Figure 4). However, it should be noted that the level of exploration may be considerably different. Greek legislation recognizes geothermal resources proven by wells tapping their reservoir; these resources include two high-enthalpy (>300 °C) fields (Milos and Nisyros islands) and many low-enthalpy (≤90 °C) fields (mostly in Northwest Greece) [36].

The simulation addresses the estimated success rate of each potential project differently depending on the provided criteria. As a result, the assumed initial success rates (see Scenario B in Table 3) are 90% for proven fields with high enthalpy (Milos and Nisyros) or low enthalpy (Akropotamos, Aristino, Erateino, Lithotopos, Nea Kessani, Neo Erasmio, Nigrita, Sidirokastro), and 67% for high-enthalpy unexplored fields (Chios, Lesvos, Methana, Samothraki, Sousaki, and Thera).

**Table 3.** Success rate per geothermal field type.

| | High-Enthalpy Proven | High-Enthalpy Unexplored | Low Enthalpy |
|---|---|---|---|
| Scenario A | 90% | 50% | 90% |
| Scenario B | 90% | 67% | 90% |
| Scenario C | 90% | 75% | 90% |
| Scenario D | 90% | No development | 90% |

In particular, the characteristics and assumptions made concerning the development of geothermal projects within 10 years are presented in Table A2 in Appendix A. For each of the 10 years of the performed simulation, five to seven specific projects (either production or reinjection wells) were assumed to be implemented; it should be highlighted that this time-related classification was made only in the context of the simulation-related assumptions. For each project, information concerning its identification (geothermal field), type (production/reinjection), geological formation, assumed contract duration, data availability, project capacity, expected production, and assumed insured cost are presented.

A significant aspect of the financial simulation is the success rate of each geothermal field type. In this regard, four different scenarios were taken into consideration, as presented in Table 3.

Based on each success rate scenario, the projects were assumed to be either successful or unsuccessful; as presented in Table 3, the estimation of different scenarios affected the number of successful/unsuccessful high-enthalpy unexplored projects. It should be noted that the outcome of each project (successful/unsuccessful) was randomly selected based on the corresponding Excel function, taking into account the overall assumed success rate for each project type, and was not related to any other characteristics of each specific project. Hence, each project's expected outcome is applicable only in the context of the performed simulation and does not imply a successful or unsuccessful project in reality.

After the determination and calculation of the input, the simulations were performed, focusing on the estimation of the 10-year cash flows, which depend on the scheme's launching capital, fixed and variable costs, and the revenues from insurance fees. The estimations were made by applying Equation (1) "$\mathrm{RMS\_CASH\_FLOW}_{n-year}$," representing the scheme's aggregate cash flow at the nth year, expressed in EUR:

$$\mathrm{RMS\_CASH\_FLOW}_{n-year} = \sum_{t=1}^{n} (AR_t - FC_t - VC_t) + LC \quad (1)$$

where:

- t: year under consideration, taking values from 1 to n;

- n: the upper-year limit of the RMS, taking values from 1 to 10; in the examined RMS 10-year cash flow scenarios, n = $t_{max}$ = 10;
- $AR_t$: the scheme's annual revenue, expressed in EUR; it is the product of the applied insurance premium (ranging from 1% to 20%; see Table 2) and the projects' annual insured capital (as presented in Table A2);
- $FC_t$: the scheme's annual fixed cost, expressed in EUR; it includes staff cost, office costs, travel, overhead, operating cost of the technical committee, cost of experts', depreciation costs, and other costs; it is independent of the number of projects insured and was set to EUR 240,000 in all scenarios (see Table A1 for analysis);
- $VC_t$: the scheme's annual variable cost, i.e., the cost resulting from the reparations for the failed projects (the number of failed projects each year depends on the success rates assumed by each scenario; see Table 3), and is expressed in EUR; it is the product of the applied risk coverage (ranging from 5% to 100%; see Table 2) and the insured capital of failed projects.
- LC: the scheme's launching capital, set to EUR 10,000,000 in all examined scenarios.

## 4. Results and Discussion

The 10-year simulation was based on the assumption that 55 production or reinjection wells would be drilled and completed in the fields listed in Table A2 of Appendix A. Against this background, the 10-year cash flow was assessed in reference to various insurance premium, risk coverage, and success rate combinations.

Taking as a basis Scenario B in reference to the success rates, different 10-year cash flows were assessed, taking into account different insurance premium (8, 10, and 12%) and risk coverage (65, 75, and 85%) combinations; the outcomes of the nine distinct combinations are presented in Figure 6. It should be highlighted that on the basis of Scenario B success rates (i.e., high-enthalpy proven: 90%; high-enthalpy unexplored: 67%; low enthalpy: 90%) under all conditions, the RMS is not financially viable for any selected combination of insurance premium and risk coverage. In all settings, this is illustrated by the negative slope trend pattern of the total asset balance. Nonetheless, it is necessary to distinguish between cases in which the scheme still has finances to run after the 10 years and cases in which the system has financially collapsed before the 10-year mark.

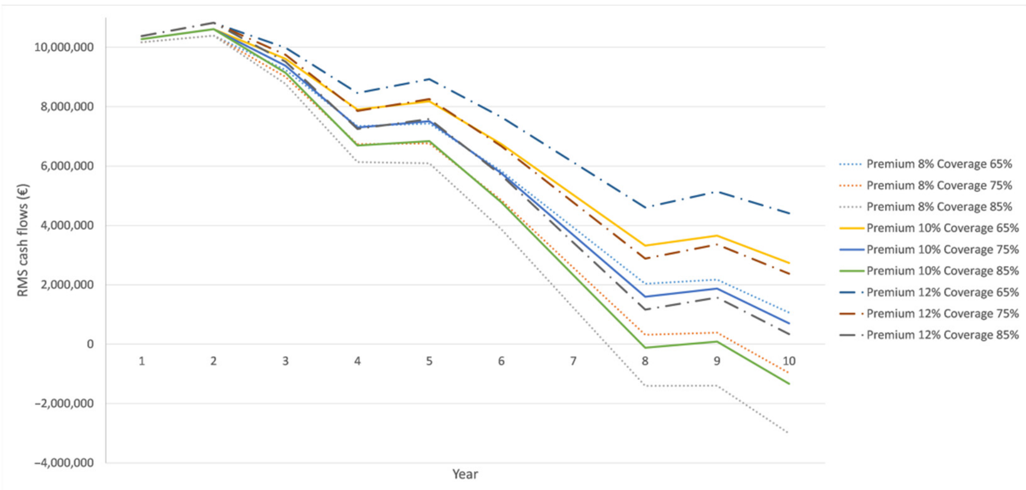


**Figure 6.** Simulation of RMS 10-year cash flows. Success rates: Scenario B; insurance premium: 8, 10, 12%; risk coverage: 65, 75, 85%.

Following the investigation of the implications of different coverage rates and insurance premiums on specific success rates (i.e., Scenario B), the next stage was to evaluate the impact of different project success rates on the 10-year cash flow (Figure 7). Provided this, the four scenarios presented in Table 3 were examined: The first three scenarios (A, B, and

C) preserved a 90% success rate for all high-enthalpy and low-enthalpy proven fields and varying success rates (50%, 67%, and 75%) for high-enthalpy unexplored areas. Scenario D proposed that geothermal projects would only be developed in proven fields, referring to either high-enthalpy (Milos and Nisyros) or low-enthalpy resources, with a 90% success rate. In all examined cases, the insurance premium and coverage rates remained constant, equivalent to 10% and 75%, respectively.

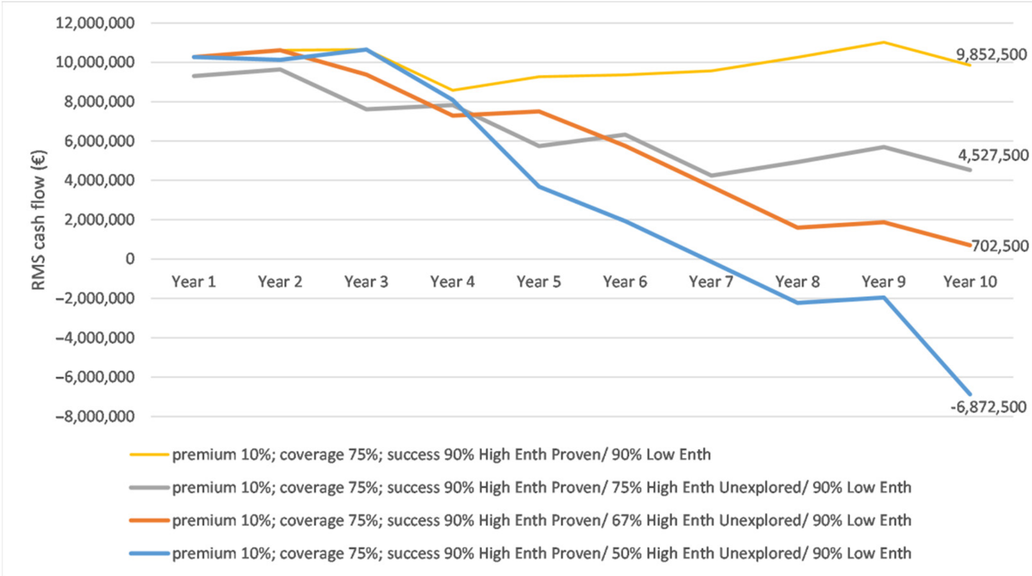


**Figure 7.** Success rates' impact on the 10-year cash flow.

Without a question, the project success rate is the most essential factor in the insurance scheme's financial viability. Figure 7 shows that a 90% overall success rate is financially sustainable, with a remaining capital of about EUR 9.9 million after 10 years of operation. A 50% success rate scenario for the presently unexplored high-enthalpy fields, on the other hand, would almost surely result in the scheme's financial collapse after seven years. It is critical to note that the exact cash-flow progression in each scenario is influenced by the individual years in which the projects are anticipated to fail, depending, of course, on the corresponding success rate. This implies that, in the context of the simulation, setting different years for the failed projects might result in different cash flows, but still result in the same final result within ± two years.

Some initial findings can be drawn from the analysis described above. It has already been suggested that a EUR 10 million insurance scheme (10% insurance premium; 75% risk coverage; Scenario B success rates) would be financially unviable, as the fund would hold less than EUR 1 million after 10 years. However, such a system would be meaningful when implemented as a public fund as part of Greece's 10-year geothermal development program. Furthermore, in the event that an insurance premium (10% in the studied case) is regarded as too high for private developers to bear, a 50% public subsidy of the premium could be established as a policy instrument to incentivize geothermal development. A public scheme of this size (EUR10 million + 50% premium subsidy (meaning 5% premium in this case)) would result in considerable leverage, equivalent to 6.21, of public investment in geothermal development. This conclusion was determined based on the assumption that, after 10 years of operation, the application of EUR 10 million in public funds + € = EUR 4.1825 million premium subsidization—EUR 0.7025 million residual funds will mobilize EUR 83.65 million total funds.

Table 4 presents the results of a sensitivity analysis between risk coverage and insurance premium (based on Scenario B drilling exploration success rates) concerning the balance of the total asset after 10 years of operation of a EUR 10 million risk insurance scheme. Assuming the goal is to form a private fund using the conditions specified in the preceding paragraph (i.e., 75% risk coverage; Scenario B success rates), based on the sensitivity analysis, an insurance premium higher than 20% should be set to ensure at least financial viability (i.e., after 10 years of operation, the fund is valued at around EUR 10 million). In such a circumstance, and given that private investors would normally accept a premium of up to 5%, the public would have to subsidize the additional 16 percentage points (to attain a 21% premium) in terms of a policy aimed at geothermal market growth. In this situation, public funding of EUR 13.384 million would result in a private investment of EUR 83.65 million in geothermal projects. As a result, leverage equal to 6.25 would be reached, almost similar to the public fund described previously. In any case, the 21% insurance premium would be just enough to break through the profitability barrier, suggesting that even if all other factors remained constant, a private system would require a higher premium to operate.

The scheme assumes that large-scale geothermal exploitation is stimulated by the presence of the risk management scheme itself—as Sweerts et al. [44] mentioned, "financial de-risking is thus a key ingredient for unlocking the renewable energy potential"—also aided by strong political (necessary for the issuing of the geothermal concession permits) and local support (which is required for the long-term sustainability of the geothermal exploitation plant). In addition, it follows Compernolle et al. [45], who mentioned that the absence of a support system would lead to a 45% probability of a project's abandonment after the first drilling, as well as with Sanchez-Alfaro et al. [46], who indicated that the absence of public incentives dealing with financial risks is one of the main barriers to the development of geothermal energy projects. Hence, such exploitation during the next 10 years will include initial geothermal development for power generation of the eight most important areas with proven or inferred high-enthalpy resources, as well as initial or further development of district heating of five of the 10 most important low-enthalpy geothermal fields identified in the country (Aristino, Akropotamos, Nea Kessani, Nigrita, and Lithotopos).

The fact that despite the relatively high premium charged, in most cases the initial RMS capital of EUR 10 million is consumed before the 10 years are over, implies that such a scheme can only belong to the public sector, which is typical for countries with no geothermal market developed. Although it should be highlighted that it is of high importance to involve both private and public actors in the RMS [47], the study's result follows the outcomes of Imolauer and Ueltzen [31], who indicated that in geothermal projects public fund systems cover the financial risk of early-stage exploration, thus stimulating the market and leveraging investments in geothermal-based infrastructure. The study's results are supported by the theory of institutional change [48], according to which laws and policies imposed by the government are keys to economic performance.

The results of the study also imply that the proposed RMS is a mixture of financial incentives and risk insurance schemes, keeping in mind that investing in de-risking measures seems to be cost effective when compared to offering direct financial incentives to compensate investors for higher risk [29].

**Table 4.** Total assets balance after 10 years of operation of a EUR 10 million risk insurance scheme (in thousands of EUR): sensitivity analysis between risk coverage and insurance premium; Scenario B drilling exploration success rates.

| | | **PREMIUM** | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1% | 2% | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% | 11% | 12% | 13% | 14% | 15% | 16% | 17% | 18% | 19% | 20% |
| **COVERAGE** | 5% | 7.419 | 8.256 | 9.092 | 9.929 | 10.765 | 11.602 | 12.438 | 13.275 | 14.111 | 14.948 | 15.784 | 16.621 | 17.457 | 18.294 | 19.130 | 19.967 | 20.803 | 21.640 | 22.476 | 23.313 |
| | 10% | 6.402 | 7.238 | 8.075 | 8.911 | 9.748 | 10.584 | 11.421 | 12.257 | 13.094 | 13.930 | 14.767 | 15.603 | 16.440 | 17.276 | 18.113 | 18.949 | 19.786 | 20.622 | 21.459 | 22.295 |
| | 15% | 5.384 | 6.221 | 7.057 | 7.894 | 8.730 | 9.567 | 10.403 | 11.240 | 12.076 | 12.913 | 13.749 | 14.586 | 15.422 | 16.259 | 17.095 | 17.932 | 18.768 | 19.605 | 20.441 | 21.278 |
| | 20% | 4.367 | 5.203 | 6.040 | 6.876 | 7.713 | 8.549 | 9.386 | 10.222 | 11.059 | 11.895 | 12.732 | 13.568 | 14.405 | 15.241 | 16.078 | 16.914 | 17.751 | 18.587 | 19.424 | 20.260 |
| | 25% | 3.349 | 4.186 | 5.022 | 5.859 | 6.695 | 7.532 | 8.368 | 9.205 | 10.041 | 10.878 | 11.714 | 12.551 | 13.387 | 14.224 | 15.060 | 15.897 | 16.733 | 17.570 | 18.406 | 19.243 |
| | 30% | 2.332 | 3.168 | 4.005 | 4.841 | 5.678 | 6.514 | 7.351 | 8.187 | 9.024 | 9.860 | 10.697 | 11.533 | 12.370 | 13.206 | 14.043 | 14.879 | 15.716 | 16.552 | 17.389 | 18.225 |
| | 35% | 1.314 | 2.151 | 2.987 | 3.824 | 4.660 | 5.497 | 6.333 | 7.170 | 8.006 | 8.843 | 9.679 | 10.516 | 11.352 | 12.189 | 13.025 | 13.862 | 14.698 | 15.535 | 16.371 | 17.208 |
| | 40% | 297 | 1.133 | 1.970 | 2.806 | 3.643 | 4.479 | 5.316 | 6.152 | 6.989 | 7.825 | 8.662 | 9.498 | 10.335 | 11.171 | 12.008 | 12.844 | 13.681 | 14.517 | 15.354 | 16.190 |
| | 45% | −721 | 116 | 952 | 1.789 | 2.625 | 3.462 | 4.298 | 5.135 | 5.971 | 6.808 | 7.644 | 8.481 | 9.317 | 10.154 | 10.990 | 11.827 | 12.663 | 13.500 | 14.336 | 15.173 |
| | 50% | −1.739 | −902 | −66 | 771 | 1.608 | 2.444 | 3.281 | 4.117 | 4.954 | 5.790 | 6.627 | 7.463 | 8.300 | 9.136 | 9.973 | 10.809 | 11.646 | 12.482 | 13.319 | 14.155 |
| | 55% | −2.756 | −1.920 | −1.083 | −247 | 590 | 1.427 | 2.263 | 3.100 | 3.936 | 4.773 | 5.609 | 6.446 | 7.282 | 8.119 | 8.955 | 9.792 | 10.628 | 11.465 | 12.301 | 13.138 |
| | 60% | −3.774 | −2.937 | −2.101 | −1.264 | −428 | 409 | 1.246 | 2.082 | 2.919 | 3.755 | 4.592 | 5.428 | 6.265 | 7.101 | 7.938 | 8.774 | 9.611 | 10.447 | 11.284 | 12.120 |
| | 65% | −4.791 | −3.955 | −3.118 | −2.282 | −1.445 | −609 | 228 | 1.065 | 1.901 | 2.738 | 3.574 | 4.411 | 5.247 | 6.084 | 6.920 | 7.757 | 8.593 | 9.430 | 10.266 | 11.103 |
| | 70% | −5.809 | −4.972 | −4.136 | −3.299 | −2.463 | −1.626 | −790 | 47 | 884 | 1.720 | 2.557 | 3.393 | 4.230 | 5.066 | 5.903 | 6.739 | 7.576 | 8.412 | 9.249 | 10.085 |
| | 75% | −6.826 | −5.990 | −5.153 | −4.317 | −3.480 | −2.644 | −1.807 | −971 | −134 | 703 | 1.539 | 2.376 | 3.212 | 4.049 | 4.885 | 5.722 | 6.558 | 7.395 | 8.231 | 9.068 |
| | 80% | −7.844 | −7.007 | −6.171 | −5.334 | −4.498 | −3.661 | −2.825 | −1.988 | −1.152 | −315 | 522 | 1.358 | 2.195 | 3.031 | 3.868 | 4.704 | 5.541 | 6.377 | 7.214 | 8.050 |
| | 85% | −8.861 | −8.025 | −7.188 | −6.352 | −5.515 | −4.679 | −3.842 | −3.006 | −2.169 | −1.333 | −496 | 341 | 1.177 | 2.014 | 2.850 | 3.687 | 4.523 | 5.360 | 6.196 | 7.033 |
| | 90% | −9.879 | −9.042 | −8.206 | −7.369 | −6.533 | −5.696 | −4.860 | −4.023 | −3.187 | −2.350 | −1.514 | −677 | 160 | 996 | 1.833 | 2.669 | 3.506 | 4.342 | 5.179 | 6.015 |
| | 95% | −10.896 | −10.060 | −9.223 | −8.387 | −7.550 | −6.714 | −5.877 | −5.041 | −4.204 | −3.368 | −2.531 | −1.695 | −858 | −22 | 815 | 1.652 | 2.488 | 3.325 | 4.161 | 4.998 |
| | 100% | −11.914 | −11.077 | −10.241 | −9.404 | −8.568 | −7.731 | −6.895 | −6.058 | −5.222 | −4.385 | −3.549 | −2.712 | −1.876 | −1.039 | −203 | 634 | 1.471 | 2.307 | 3.144 | 3.980 |

## 5. Conclusions

The geological (resource) risk is the most critical of the risks associated with geothermal project development, especially when referring to deep geothermal projects. The geological risk might be either short-term when a commercially sustainable geothermal resource is not discovered after drilling, or long-term when the geothermal resource is naturally depleted.

Various tools are available for the mitigation of such risks; indeed, geothermal-focused risk mitigations schemes (RMS) have been established in a few European countries, allowing project developers to transfer a portion of the geological risk to public bodies, private bodies, or PPPs. In any case, the type of body undertaking the implementation of the RMS, as well as the form the RMS will take (e.g., geothermal guarantees, risk insurance, capital grants) depend on the level of the geothermal market maturity of each country.

Based on the above, and in the context of the H2020-funded GEORISK European project (October 2018–September 2021), the goal of this study was to investigate the foundation of an effective and financially viable geothermal RMS in Greece, i.e., a country with no such scheme available. The steps toward this goal included (a) the examination of the Greek geothermal sector in terms of geothermal resources, existing market conditions, potential risks related to the development of a geothermal plant, and geothermal legislation and policies, and (b) the setup of a suppositional geothermal RMS, followed by a 10-year financial operation simulation evaluating its effectiveness and financial viability.

The potential geothermal RMS was set up for the Greek geothermal situation, taking into consideration the project types and geological structures covered by the scheme, the type of contract, the capital required to launch the scheme, the scheme's fixed costs, and the operational costs of each project. The financial viability of the proposed RMS was assessed for 10 years under the possible risk coverage (5% to 100%), insurance premium charged to the investor (1% to 20%), and drilling success rates (four different scenarios were evaluated). All scenarios assumed a 90% drilling success rate for a geothermal doublet, which is typical when drilling into an already explored geothermal field, according to international experience. A well is considered successful when it achieves its desired temperature and flow rate objectives. The base scenario (Scenario B) assumed a 67% success rate in unexplored areas, corresponding to three wells drilled for each doublet, implying that only one of the three achieves desired production objectives, but that at least one of the other two can be utilized for reinjection.

Hence, based on the above preconditions, the financial viability of the potential RMS was evaluated in terms of a 10-year aggregated cash flow, taking into account the scheme's annual revenue (derived from the applied insurance capital and the projects' annual insured capital), the scheme's annual fixed cost, the scheme's annual variable cost (derived from the applied risk coverage and the insured capital of failed projects), and the scheme's launching capital.

According to the simulation results, alternative insurance premium, risk coverage, and success rate criteria would result in various financial preconditions and outcomes for the creation of a public or private fund, regardless of whether a public risk premium subsidization plan would be approved or not. Keeping in mind that, despite the relatively high premium charged, the initial RMS capital of EUR 10 million is in most cases expended before the 10 years are up, this suggests that such a plan can only be initiated by the public sector, which is typical of countries with little-developed geothermal markets. In this case, and based on the low Greek geothermal market maturity, a potential RMS could be based on the provision of grants, with the possibility of transitioning to repayable or convertible grants. Such an RMS could have as its main objective to provide an initial boost to the deep geothermal market (as part of Greece's 10-year geothermal development program), and—potentially—making possible the establishment of a more mature RMS in the future.

The proposed simulation model was based on various assumptions about the geothermal RMS and potential geothermal projects, considering geothermal resources, existing market conditions, potential risks, and legislation and policies related to the development of a geothermal plant. The model could be extended by further research in other countries, taking into consideration country-specific attributes such as level of geothermal exploration, political status, and investment costs.

**Author Contributions:** Conceptualization, A.K., S.K. and D.M.; methodology, S.K. and A.K.; software, S.K. and A.K.; validation, A.K., D.M. and S.K.; formal analysis, S.K. and D.M.; investigation, S.K. and D.M.; resources, D.M. and I.C.; data curation, D.M. and I.C.; writing—original draft preparation, S.K. and T.I.O.; writing—review and editing, S.K., T.I.O. and D.M.; visualization, S.K. and D.M.; supervision, C.K.; project administration, C.K.; funding acquisition, C.K. All authors have read and agreed to the published version of the manuscript.

**Funding:** This study was implemented in the framework of the European Union's Horizon 2020 GEORISK Project "Developing Geothermal and Renewable Energy Projects by Mitigating their Risks". The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818232—GEORISK. This output only reflects the authors' view, and the European Union cannot be held responsible for any use that may be made of the information contained therein.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available within the article.

**Acknowledgments:** The authors would like to thank Christos Tourkolias from CRES for his contribution to the preparation of Figure 5, "Mapping of the decision-making process in Greece, referring to the establishment of an energy-related support scheme." In addition, the authors would like to thank the anonymous reviewers for their insightful and constructive comments.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Estimated fixed costs (EUR/year).

| Type | Cost |
|---|---|
| Staff cost | 60,000 |
| Project expert cost/year | 90,000 |
| Office costs | 12,000 |
| Travels | 12,000 |
| Overhead services (legal, banking, data, accountant, etc.) | 36,000 |
| Operation costs of the technical committee | 20,000 |
| Depreciation | 5000 |
| Others | 5000 |
| **Total** | **240,000** |

Source: Own estimations [49].

**Table A2.** Characteristics and assumptions concerning the development of geothermal projects within 10 years.

| Year | No. | Project Identification and Type | Geological Formation, Identification of the Aquifer | Contract Duration | Available Data (G&G Studies, Project Concept) | Project Capacity, MW, Expected Production, MWh/year | Insured Cost, EUR |
|---|---|---|---|---|---|---|---|
| 1 | 1 | Milos production well | Metamorphic basement | 4 months | Complete field picture | 10 MWe | 1,600,000 |
| | 2 | Milos reinjection well | Metamorphic basement | 4 months | complete field picture | - | 1,600,000 |
| | 3 | 1st Aristino production well | Andesites | 3 months | Part of field explored | 7 MWth | 650,000 |

**Table A2.** *Cont.*

| Year | No. | Project Identification and Type | Geological Formation, Identification of the Aquifer | Contract Duration | Available Data (G&G Studies, Project Concept) | Project Capacity, MW, Expected Production, MWh/year | Insured Cost, EUR |
|---|---|---|---|---|---|---|---|
| | 4 | 2nd Aristino production well | Andesites | 3 months | Part of field explored | 7 MWth | 650,000 |
| | 5 | 3rd Aristino production well | Andesites | 3 months | Part of field explored | 7 MWth | 650,000 |
| 2 | 6 | Nisyros production well | Marble, limestone | 4 months | Part of field explored | 5 MWe | 1,900,000 |
| | 7 | Nisyros reinjection well | Marble, limestone | 4 months | Part of field explored | - | 1,900,000 |
| | 8 | 1st Aristino reinjection well | Andesites | 3 months | Part of field explored | - | 650,000 |
| | 9 | 2nd Aristino reinjection well | Andesites | 3 months | Part of field explored | - | 650,000 |
| | 10 | 3rd Aristino reinjection well | Andesites | 3 months | Part of field explored | - | 650,000 |
| 3 | 11 | Methana production well | Crystalline basement | 4 months | Geophysics only | 5 MWe | 1,700,000 |
| | 12 | Methana deep well | Crystalline basement | 4 months | Geophysics only | - | 1,700,000 |
| | 13 | Methana reinjection well | Crystalline basement | 4 months | Geophysics only | - | 1,700,000 |
| | 14 | 1st Nea Kessani production well | Base conglomerate | 3 months | Field explored | 4 MWth | 650,000 |
| | 15 | 2nd Nea Kessani production well | Base conglomerate | 3 months | Field explored | 4 MWth | 650,000 |
| | 16 | Low-enthalpy well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| | 17 | 3rd Nea Kessani production well | Base conglomerate | 3 months | Field explored | 4 MWth | 650,000 |
| 4 | 18 | Lesvos production well | Crystalline basement | 6 months | Geophysics only | 8 MWe | 3,700,000 |
| | 19 | Lesvos deep well | Crystalline basement | 6 months | Geophysics only | - | 3,700,000 |
| | 20 | 1st Nea Kessani reinjection well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| | 21 | 2nd Nea Kessani reinjection well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| | 22 | 3rd Nea Kessani reinjection well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| 5 | 23 | Lesvos reinjection well | Crystalline basement | 6 months | Geophysics only | - | 3,700,000 |
| | 24 | Soussaki production well | Limestones | 6 months | New area | 5 MWe | 3,100,000 |
| | 25 | 1st Nigrita production well | Base conglomerate | 3 months | Part of field explored | 4 MWth | 650,000 |
| | 26 | 2nd Nigrita production well | Base conglomerate | 3 months | Part of field explored | 4 MWth | 650,000 |
| | 27 | Low-enthalpy well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |
| | 28 | 3rd Nigrita production well | Base conglomerate | 3 months | Part of field explored | 4 MWth | 650,000 |
| 6 | 29 | Soussaki deep well | Limestones | 6 months | New area | - | 3,100,000 |
| | 30 | Soussaki reinjection well | Limestones | 6 months | New area | - | 3,100,000 |
| | 31 | 1st Nigrita reinjection well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |
| | 32 | 2nd Nigrita reinjection well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |
| | 33 | 3rd Nigrita reinjection well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |
| 7 | 34 | Samothraki production well | Diabases | 6 months | New area | 5 MWe | 3,700,000 |
| | 35 | Samothraki deep well | Diabases | 6 months | New area | - | 3,700,000 |
| | 36 | 1st Lithotopos production well | Base conglomerate | 3 months | Field explored | 4 MWth | 650,000 |
| | 37 | 2nd Lithotopos production well | Base conglomerate | 3 months | Field explored | 4 MWth | 650,000 |
| | 38 | 3rd Lithotopos production well | Base conglomerate | 3 months | Field explored | 4 MWth | 650,000 |
| 8 | 39 | Samothraki reinjection well | Diabases | 6 months | New area | - | 3,700,000 |
| | 40 | Chios deep well | Detrital formations | 6 months | New area | - | 3,700,000 |
| | 41 | 1st Lithotopos reinjection well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| | 42 | 2nd Lithotopos reinjection well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| | 43 | 3rd Lithotopos reinjection well | Base conglomerate | 3 months | Field explored | - | 650,000 |
| 9 | 44 | Chios production well | Detrital formations | 6 months | New area | 5 MWe | 3,700,000 |
| | 45 | Chios reinjection well | Detrital formations | 6 months | New area | - | 3,700,000 |
| | 46 | Akropotamos production well | Base conglomerate | 3 months | Part of field explored | 7 MWth | 650,000 |
| | 47 | Akropotamos production well | Base conglomerate | 3 months | Part of field explored | 7 MWth | 650,000 |
| | 48 | Low-enthalpy well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |
| | 49 | Akropotamos production well | Base conglomerate | 3 months | Part of field explored | 7 MWth | 650,000 |

**Table A2.** *Cont.*

| Year | No. | Project Identification and Type | Geological Formation, Identification of the Aquifer | Contract Duration | Available Data (G&G Studies, Project Concept) | Project Capacity, MW, Expected Production, MWh/year | Insured Cost, EUR |
|---|---|---|---|---|---|---|---|
| 10 | 50 | Thera (Santorini) production well | Crystalline basement | 4 months | New area | 5 MWe | 2,500,000 |
| | 51 | Thera (Santorini) deep well | Crystalline basement | 4 months | New area | - | 2,500,000 |
| | 52 | Thera reinjection well | Crystalline basement | 4 months | New area | - | 2,500,000 |
| | 53 | Akropotamos reinjection well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |
| | 54 | Akropotamos reinjection well | Base conglomerate | 3 months | Part of field explored | - | 650,000 |

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