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Impact of policy instruments on the development of the Belgian geothermal energy sector (ALPI project)

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ABSTRACT

Finance is one of the main critical issues for the development of a low carbon society especially during times of economic recession. Closing this green investment gap will require policy intervention. The ALPI project will concentrate on analysing and designing relevant instruments to accelerate the transition towards a low carbon society. Five case studies were set-up to cover different economic sectors (electricity, housing, transport, green public procurement and geothermal energy), with a common methodology.

As a showcase of emerging technologies in Belgium, the Hasselt University and the Geological Survey of Belgium are investigating the regional potential for geothermal electricity production. Deep geothermal energy appears to be currently on the edge of a take-off. But the actual emergence of this technology is subject to developments in legislation and incentives from regional governments. Different risk/return expectations across stages of the investment continuum exist and the financial structures that are employed at each stage may require different types of public support.

The investigation starts with a broad stakeholder consultation (policy makers, sector federations, industry, researchers, banking sector, investors, etc.). A techno-economic evaluation then is realized by real options valuation. As the development of deep geothermal energy is a complex process, a detailed stochastic calculation is made of a project decision tree. The decision tree replicates the consequent development of different deep geothermal energy projects, with their different success rates and interdependencies in terms of technological knowledge accumulation, decreasing uncertainty for single basins, and increasing public acceptance.

This approach allows to investigate measures, such as insurances or government guaranteed, to reduce project risk, in order to increase the interest of investors in this sector. Secondly, this approach is combined with an evolutionary step development to analyze the potential growth of the sector over the coming decades. Finally, different fiscal measures are designed in collaboration with stakeholders, and their effectiveness to stimulate the transition to a low carbon society is evaluated. Giving the high geological uncertainty, this combined geological-economic analysis is arguably the most realistic way to calculate project performance, and simulate the future development trajectory of the geothermal sector subjected to different policy measures.

1. INTRODUCTION

Belgium is a small (30 500 km^2) but densely populated country (11.13 million in 2012, World Bank Figures 2014) and highly industrialized, particularly in the North. The country is governed by a federal parliamentary democracy, the level at which international energy targets, and importantly the European Union 20-20-20 targets, are set. However, primary responsibility for legislation directly concerning geothermal energy lies with the three Regional Governments of Flanders, Wallonia and Brussels. The ambitious European 20-20-20 goals have played an important role in incentivizing the upward trend of RES (Renewable Energy Sources) and geothermal energy in Belgium. These targets require 13% of total energy consumption in Belgium to be produced from RES in 2020. In 2011 RES comprised 5.1 % of total energy consumption, but current estimates indicate this could be 31 % in 2020. RES also provide an additional advantage to Belgium since they represent a domestically sourced energy supply in a country that is currently highly dependent on imported energy. The past five to ten years have seen a substantial effort in geothermal research and development (R&D) in Belgium (14.42 US$ between 2010 and 2015). Five national, regional and cross-European projects have mapped shallow and deep geothermal potential and focused on the transferal of skills and education to the market. These show that despite being in an intra-continental setting, large regions of Belgium have potential for deep and shallow geothermal energy. Due to its independence from climatic conditions, geothermal energy, for heat or electricity production, can be used 24 hours a day and 7 days a week with an overall price of production remaining relatively constant. In the report "Green Investing, towards a clean Energy Infrastructure", from the World Economic Forum, geothermal is explicitly quoted as one of the eight key renewable energy sectors, due to its predictable "base-load power". In this context, geothermal energy is totally legitimated to contribute to a new energy mix in Belgium.

The current investment in deep geothermal research and development has focused on characterizing the sub-surface potential, yet a great deal of uncertainty remains due to the lack of deep exploration boreholes that have been drilled, leading to high risk (as demonstrated by the failure of the Meer well in the 1980s). This has led to a bottleneck of geothermal projects at this stage. It is expected that the result of recent (Balmatt project in Flanders) and future drilling in the Mons basin will provide better estimation of the subsurface characteristics and result in an opening up the deep geothermal market in Belgium and aid in the transition from R & D towards pilot installations with a clear market focus. While the current industry is rather limited it is likely to increase as the industry develops. This will necessarily be supported by a more conducive regulatory structure.

The implementation of this type of new technologies does not only depend on the economic benefit that appropriate fiscal instruments can contribute, but also to the change in risk. Pioneer applications can be profitable when operational, but the risks related to these initiatives are much higher. Considerations about investment costs and risks underline that the financing of the exploration and (pre)feasibility studies are an important barrier: unsuccessful drilling is an important risk that has to be taken and to be paid. Drilling costs represent a non-negligible part of the overall project costs. Whereas the consideration of profitability is a key point for an investor, the operating plants have to create revenue from sales of electricity or heat or selling both or sometimes for selling of by-products. Deep geothermal energy appears to be currently on the edge of a take-off in Belgium. But the actual emergence of this technology is subject to developments in legislation and incentives from regional governments. Different risk/return expectations across stages of the investment continuum exist and the financial structures that are employed at each stage may require different types of public support (Kalamova, et al., 2011).

The current situation is that high uncertainty and high risk makes geothermal investment unattractive. New solutions are possible, but it is not clear what the optimal combination of policy instruments is. The actual impact of new policy combinations on profitability risk reduction of profitability has yet to be calculated. This paper proposes a methodology to refine the probability of success for a geothermal investment. This approach is tested to compare the influence of two public instruments.

2. METHODOLOGY

2.1 ALPI project

The ALPI project evaluate policy instruments based on case studies in different economic sectors, within the expertise of the consortium members (Hasselt and Gent Universities, Tax Institute of Liege, Geological Survey of Belgium). Case studies tackle energy-efficiency and renewable energy potential.

Furthermore a variety between new, 'more expensive' and already established technologies are chosen. Five case studies were set-up to cover different economic sectors (electricity, housing, transport, green public procurement and geothermal energy as case for "new technologies"), with a common methodology. The overall objective of the ALPI project is twofold: 1- to contribute to science by quantitatively simulating and comparing the impact of different user-defined policy instruments on investment decision and on emission reductions and 2- at the same time give Belgian policy makers scientifically sound evidence of the impact of these instruments and how they are best designed, implemented and streamlined with other policies to maximize their economic and environmental impact.

Case-studies are selected as such that firstly different economic sectors are covered, that secondly type of instruments can vary and that thirdly investments in energy-efficiency and renewable energy are tackled. Cases and instruments are selected to maximize what can be learned in the period of time available for the study. The ALPI project starts with an exploration phase, in which at the one hand interesting policy instruments will be screened to test in the case studies and on the other hand a common methodology will be designed to make sure that protocols for stakeholder consultation and methodological approaches within the case studies are streamlined. This will guarantee a comparison and overall discussion of lessons learnt in the final integration work package bearing in mind that generalization based on case studies is difficult and often critized (Woodside, 2010). Each case-study will run through the same subtasks (Tellis, 1997).:

- Stakeholder consultation: Workshops will be organized to discuss and select the instruments that will be tested. Stakeholders are case dependent and can include policy makers, sector federations, bank and insurance experts, consumers organizations, etc.
- The economic evaluation will be case and instrument dependent.
- For the environmental assessment, case study specific methodologies will be used but the IPCC guidelines for national greenhouse gas inventories will be employed in all case studies. As such each evaluated policy instrument can give the amount of GHG reduction per euro invested or per euro public support.

- The legal context: the desired outcome of instruments resulting from the earlier subtasks will be challenged on its legal feasibility. How can the effect of proposed measures be guaranteed on a national level, what is the effect of differences between the Regions and what lessons can be taken from the European jurisprudence on free movement and is there a risk of dilution for accorded stimuli or can effects be focused on a Belgian/Flemish market? It will be important to take into account legislative competences, public finance prerequisites, as well as the accordance of tax instruments with domestic, European and possible treaty constraints.

2.2 Decision tree methodology for geothermal case study

The probability of success of a deep geothermal project is low, especially when this is executed in regions where only little information is available on characteristics of the deep subsurface. In order to investigate the success rate, and the influence of governmental instruments, the point of view of a private investor is taken. This investor analyses one single case study to be executed in a defined region, and has to optimize the outcome in terms of return on invested capital. Policy instruments are considered as external factors that change the investment conditions. During the elaboration of such a project, the investors and the project team go through several stages. Each stage is based on the information gained from the previous stage, and each stage contains the risk that the project fails or is abandoned.

In order to simulate this process of knowledge growth, a decision tree procedure is optimal. A decision tree distinguishes a development in distinct steps. New pathways are chosen, based on the results of the previous step. It is important to maintain the detailed step sequence in the simulation and not to calculate the expected profitability of the geothermal project for all situations in exactly the same fashion. The main advantage of the decision tree is to incorporate the liberty that the investor has to redirect or abandon the project during the execution stage. This liberty allows to avoid costly mistakes, and increases the overall value of the project. If the results are disappointing - for instance of the seismic survey - the investor can stop the project, and take the expenses of the preparation as sunk costs. This prevents much higher losses in case the project would proceed. The simulation method has to incorporate these discrete decisions.

This decision tree approach is in this case combined with Monte Carlo simulation. This numerical stochastic method uses random sampling to approximate distributions of the outcome. The probability distributions, as designed during the stakeholder involvement, reveal highly irregular distributions of the expected groundwater temperatures, flows, and soil characteristics. These probability distributions cannot be simulated with analytic density functions. The Monte Carlo approach takes a random point within each distribution, and calculates the complete decision tree of the geothermal project development. This process is repeated for a sufficiently large number of times until the full distribution of probable outcomes is generated, and the total final density of outcomes can be approximated.

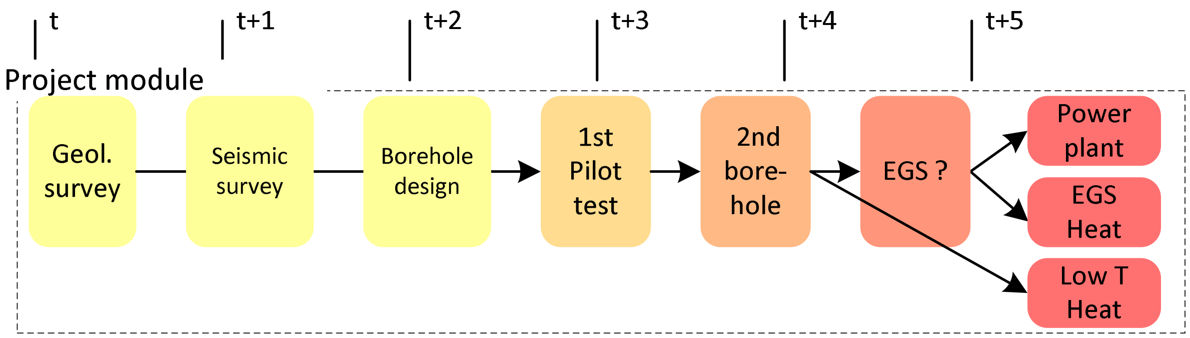

Figure 1: Decision model for the generic deep geothermal project.

2.3 Description of the practical application in this case

In this case a generic development has been taken as the basis for a decision tree model that runs through all steps of a deep geothermal project. The generic case study (see Figure 1) is applied to the Campine Basin in Belgium, similarly to the deep geothermal project that is currently under development at the Balmatt site (Mol, Belgium).

The model incorporates three large phases: (i) a preparatory survey phase, (ii) the actual drilling of the doublet, (iii) the optional application of EGS and installation of a power plant. The survey phase is split in three parts, and comprises a geological survey, a seismic survey and the detailed borehole design. This set-up assumes that the project is executed in a region that has already been relatively well studied, so there is no need for a preliminary optimization of the project location in the region.

Table 1 shows the risk reduction during the different steps. These risks have been determined through qualitative interviews with experienced investors that have been involved in the elaboration of deep geothermal projects. The risk reduction has to be interpreted as follows. The investor starts a project with a certain risk level. At every step, knowledge is gained and the total risk that the project will fail is reduced. At the end, the risk has been reduced by 100% at the delivery of the installation. First, this does not imply anything for the profitability of the installation. The risk only indicates the probability of preliminary failure of the project. Secondly, the risk reduction is given in relative terms. The absolute total probability that the project will fail preliminary can be about 70% at the start. This means that the geological survey can reduce the risk with 10%, or it can reduce the absolute value of risk to 63%. The total absolute value is not fixed, but depends on the reservoir and underground characteristics.

The three survey steps can each yield results that force the investor to abandon the project. If the project continues, the drilling phase starts. The largest risk is taken during the execution of the first borehole. There are several risks associated with this step, but their implication for the decision can be broadly split in two options. First, the execution of the borehole can fail, forcing the abandonment of the project. Secondly, the execution can encounter technical difficulties that make the investor incur steep additional costs, but the borehole is executed in the end. It is assumed that from the moment the first borehole has been successfully executed, the second borehole is launched as well. The additional costs of the first borehole might render the entire project unprofitable, but the second borehole is still executed, even if it is to recover partly the incurred costs.

	Survey			Drilling		EGS & power plant
Probabilities and risk reductions	Geological survey	Seismic survey	Borehole design	1st pilot	2nd borehole	
Stepwise risk reduction	10%	10-15%	10%	40%	20%	5%
Total risk reduction before the step	0%	10%	30%	40%	80%	95%
Options after the step	1: Abandon 2: Continue	1: Abandon 2: Continue	1: Abandon 2: Continue	1: Abandon 2: Continue	1: Continue 2: Finalize without EGS	1: Finalize project
Risks for additional costs during the step	/	/	/	Drilling problems increasing cost with N(30%,10%)		EGS success variable

Table 1 : Step characteristics and gradual risk reduction during the project development

Finally, the third phase allows the installation of an Enhanced Geothermal System (EGS), and a power plant based on an ORC (Organic Rankine Cycle).

Once the entire project is executed, there is still the option of the investor to choose between different applications for the heat. Depending on the resulting water temperature and the final flow rate, the investor disposes of several options:

- Failed : Whenever the flow and temperature are too low, the project fails
- LT Heat plant: At low temperatures, but with sufficient flows, the heat can be applied for Low-enthalpy heating applications, such as residential heating networks.
- HT heat plant: At higher temperatures, the installation can be used for both low- and high-enthalpy applications.
- EGS and PP: At the highest temperature ranges, the installation of a power plant can be considered, combined with the effect of a EGS to increase the flow rate to a sufficient level.
- Power plant: Whenever both the temperature and flow rates are sufficiently high, a combination of electricity generation and HT applications can be created.

The dependence of these options on the final water temperature and flow can be mapped out in theory as in Figure 2. These distinctions are preliminary indications. In practice, all five scenarios are calculated for each case and the owner decides on the most profitable solution at the point of installation, based on the final values for Temperature and flow. The borders also shift depending on policy instruments to stimulated renewable heat or electricity production.

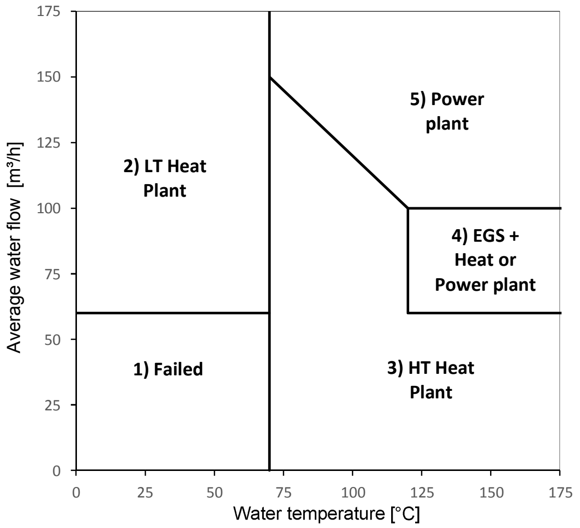

Figure 2: Theoretical decision borders between different applications for geothermal heat.

3. STAKEHOLDER CONSULTATION

3.1 Stakeholder consultation for validation of ALPI methodology

In this case study, we decided to consult stakeholders in interviews instead of focus groups to facilitate exchange due to a certain reluctance to freely speak (confidential data). EGEC (European Geothermal Energy Council) IDEA (Mons Inter-municipality), UMons (Mons University, Geology department), Earthsolutions (Mons area deep geothermal project's manager), SPW-DGO4 (Walloon Public administration in charge of Geothermal energy) were consulted (10 people).The stakeholder consultation started with EGEC, on the EU Best Pratices, on financing projects and on strategies for the sector development. A standard geothermal project development is divided into 4 key phases: exploration, resource development, construction, and commissioning, operation and maintenance.

A geothermal project is a capital-intensive technology that needs 5-7 years to become operational from the start of the permitting process until commissioning. The significant upfront investment is related to the drilling and to the need to cover the geological risk at the beginning of the exploration. This is true for all deep geothermal projects. Beyond exploration, the bankability of a geothermal project is threatened by the geological risk. Risk insurance funds for the geological risk already exist in some European countries (France, Germany, Iceland, The Netherlands and Switzerland). The geological risk is a common issue all over Europe. For the European Geothermal Energy Council, Policy instruments/incentives have to be adapted in function of the level of the market development (juvenile (0-6 geothermal wells), intermediate (6-60 wells), or mature market (>60 installed wells in the country). Financial support should firstly aim at the take-off of the first deep geothermal projects for a juvenile market (state of the Belgium market) with repayable grants (investment support) for covering initial risk of the exploration phase (geophysics surveys and the 1st well) and a feed-in tariff (operating support, a fixed and guaranteed price paid to eligible producers of electricity) or a quota system when projects emerge in sufficient number, to compensate for market failures and mobilize private financing. Geological risk can only be covered by the Public as so few projects are concerned.

When the market is moving towards an intermediate maturity the support schemes should be adapted, a feed-in premium and public risk insurance are suitable. The more costs are competitive and markets mature, the less financial support is needed. The ultimate support, as long as the internal market is not fully completed, will be a grid premium where geothermal is rewarded for stabilizing the grid with its base load and flexibility, as more generation comes from fluctuating resources. Support schemes must be predictable in the long term to encourage investments (No stops & go policy).

The Belgian stakeholders consultation allowed to finalize the methodological framework of the ALPI project, to improve the generic case study adapted and focused on Belgian case and finally to highlight which policy instruments have to be evaluated for the geothermal energy sector development in Belgium. It appears after discussion with project owners that the public implication in the sector implementation and development is essential. Two different strategies are envisaged: a public-private partnership or a "deep underground reserved for public interest".

3.2 Experts judgement on Belgian reservoir parameters

Two geothermal reservoirs were targeted: the Carboniferous Limestone Group of the Campine basin and the Upper and Middle Devonian limestones and shaly limestones of the Givetian and Early Frasnian of the Mons basin. Inputs for the techno-economic calculation were provided by expert judgements (Lin & Bier, 2008; Bier, 2004; Henrion & Fishoff, 1986). This methodology is based of capacity assessments for geological storage of CO_2 (Piessens, 2011; Piessens, 2012; Piessens & Dusar, 2004 a and b), presented in Welkenhuysen et al. (2013). The reservoir concept is described by probabilistic distributions for 10 parameters: the geotechnical failure of the reservoir, depth, total thickness, productive thickness, the geothermal gradient, transmissivity, flow rate, effective porosity, the distance between the doublets and the distance between the wells. Using the expert judgements on a basic reservoir concept allows to fully describe a reservoir and incorporating the full current state of knowledge including all uncertainties that are at hand, without the need for highly detailed data.

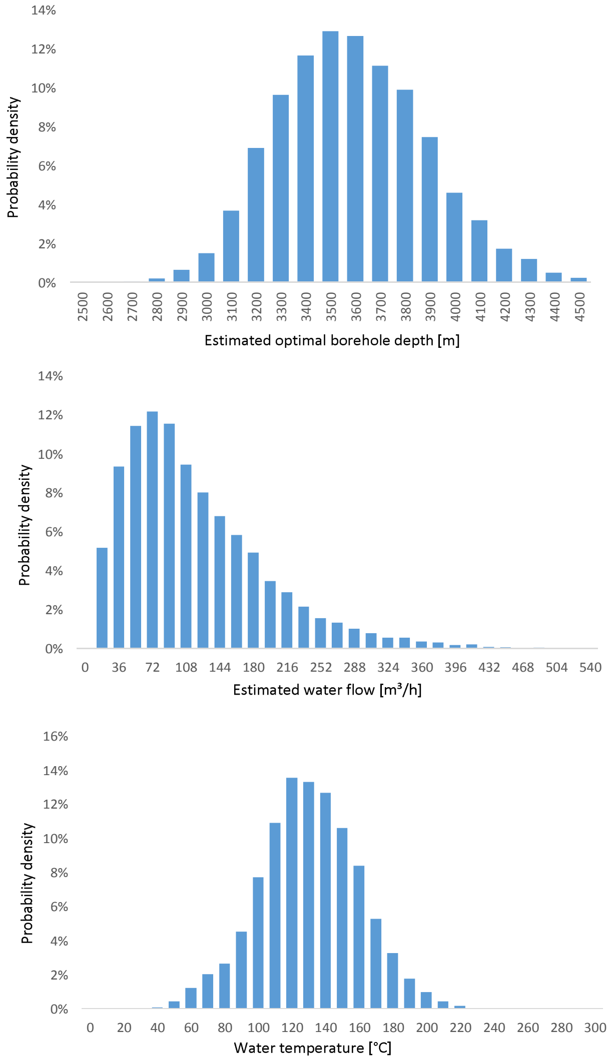

Figure 3 : Probability distributions of the estimated values for borehole depth, water flow and temperature resulting from the expert questionnaires. (For the Balmatt site (Campine Basin), Belgium)

Five independent experts from three Belgian scientific institutes were addressed for the current exercise: three experts from the Geological Survey of Belgium, one from VITO (Flemish institute of technological research), and one from the University of Mons. All experts have an academic background in geology and are well acquainted with the deep geology of Belgium. Experts were free to indicate whether they had sufficient knowledge on each reservoir separately for making judgements. Data was collected in spring 2016, and none of the experts were directly involved in the setting up of the methodology and processing of results.

The probabilistic input of the different experts is combined by averaging with equal weights, assuming that the every expert's opinion is equally valuable. The probability distributions of the estimated values for borehole depth, water flow and temperature resulting from the expert questionnaires are presented on Figure 3.

The analytical model for geothermal heat recovery from doublet systems developed by Gringarten (1978) was used as a basis. With this model, the extractable heath and optimal configuration of a single doublet system and a field of doublets can be calculated. This model was turned into a stochastic model by randomly changing the input values as supplied by the averaged expert input distributions. Known and unknown correlations between input parameters are maintained by using a single random value for every parameter within a single Monte Carlo iteration. In total, 10.000 Monte Carlo iterations were performed. In the current research, the reservoir's temperature, and optimal flow and depth are calculated (Figure 3). Because the parameters in the questionnaire and the calculated parameters overlap, the model results can be tested against the expert input. This provides additional confidence in the expert input and the model. The results of the geothermal model are input for the economic decision tree model.

4. CASE-STUDY SIMULATION AND PROBABILITY DISTRIBUTIONS

The first part of the research derived estimated probability distributions of the main subsurface parameters. Based on these distributions, the decision tree for the geothermal project development has been executed. These calculations are repeated for 50.000 runs to approximate the final distribution of outcomes.

Two cases were tested:

- A reference case of a regular geothermal project without any public investment or subsidies to stimulate renewable energy production.
- A subsidy case where additional subsidies are granted for renewable electricity production, for an amount of 250 EUR/ MWh.

The subsidy scenario is a test case for the effect of electricity stimulating policies. The level of subsidy is similar to the subsidies granted for photovoltaic panels during the emergence of this technology. The rationale behind this approach is that heat-based projects such as geothermal heat plants are intrinsically limited by the amount of heat that can be sold in the area close to the well. Heat transport requires large investments and is very limited in distance. The consequence is that the total heat demand has an absolute limit. It is often speculated that transforming heat to electricity can by-pass this limitation, because the electricity can always be transmitted to the national grid and will meet a larger demand. By stimulating the production of electricity, it is hoped that a larger number of geothermal projects will become profitable, making the emergence of this technology easier.

The results in Table 2 show the distribution of outcomes for each case. These show already that there remains a very large risk of failure in the elaboration of the geothermal project. Over 80% of the projects does not survive the preliminary survey phase or the execution. The remaining 20% of the projects is for a large majority focused on delivering HT heat. When an added stimulus is created for the production of electricity, there is a moderate shift from HT heat to the power plants. But the overall success rate of projects remains exactly the same. So the subsidy does not change the overall success rate of the project. The exact effect of the stimulus can be analyzed by looking at both cases individually.

Table 2: Distribution of outcomes over the different end-uses of geothermal energy

Scenario	Reference case	Subsidy case
1) Failed	80.3%	80.4%
2) LT Heat plant	0.0%	0.0%
3) HT Heat plant	19.7%	16.3%
4) EGS & PP	0.02%	3.0%
5) Power plant	0.01%	0.4%

4.1 Results of the reference case

In the reference case, most successful projects are executed as HT heat plants. Figure 4 shows the histogram of all the Net Present Values of all successful projects in the reference case (t.i. only 19.7% of all possible outcomes.) This shows that even projects that manage execution can still be very unprofitable. Due to execution problems or unfortunate outcomes of water temperatures and flows, only 81% of all executed projects have a NPV above zero. 19% of the projects do not achieve a positive return on capital. A failed project has to pay for the preliminary survey steps and has in general a negative NPV of -2.3 million Euros. A minority of the successful projects has NPV's that are much lower than those of the failed projects.

When we look at the distribution of successful and failed projects in Figure 5, it shows that successful projects require a good combination of geothermal characteristics. The projects that decide to install a power plant are a tiny fraction with highly optimal combinations of both water temperature and flow.

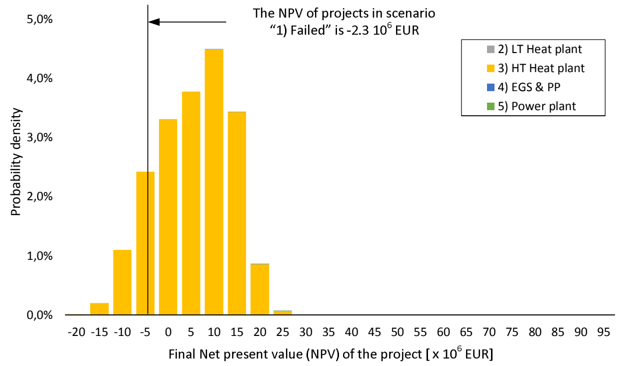

Figure 4 : Histogram of the Net Present Values (NPV) of all successful outcomes for the reference case.

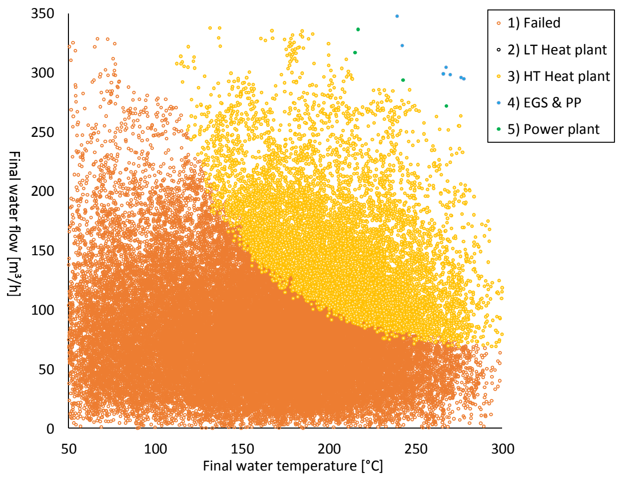

Figure 5: Distribution of all outcomes according to the final water temperature and flow for the reference case.

4.2 Results of the subsidy case

The same figures can be made for the case when subsidies are granted for renewable electricity production. As illustrated in Figure 6, the overall distribution of the NPV's of the successful projects is skewed to the right, indicating that there is a higher proportion of projects that can obtain high a high profitability. The proportion of the successful projects that is profitable remains at 81%.

The reason for this is shown in Figure 77. The electricity generation is attempted in cases with optimal combinations of both water temperature and flow. These projects were already chosen for HT heat plants in the reference case, so the electricity subsidy does not alter the overall success rate of the geothermal projects.

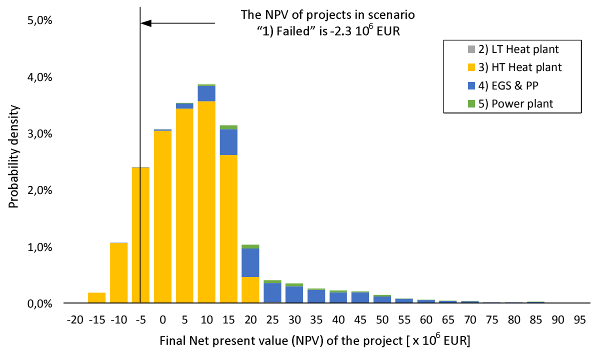

Figure 6: Histogram of the Net Present Values (NPV) of all successful outcomes for the subsidy case

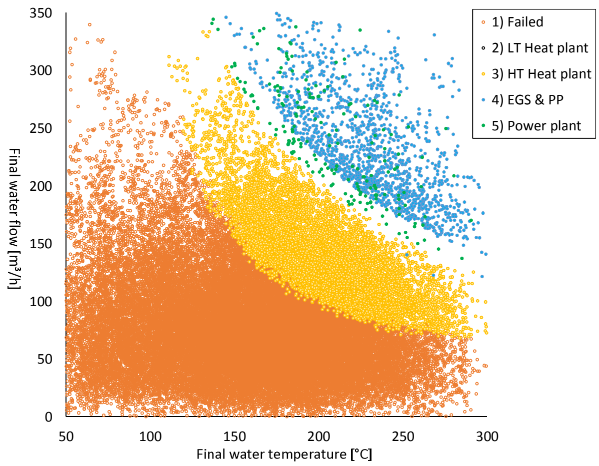

Figure 7: Distribution of all outcomes according to the final water temperature and flow for the subsidy case.

5. DISCUSSION OF POTENTIAL INSTRUMENTS AND PERSPECTIVES

These first results indicate that the one-sided stimulation of renewable electricity from geothermal source is not an optimal policy strategy for the Campine basin. The subsidy increases the profitability of projects that already were successful, but does not change the overall dynamics of the project decision tree. It is possible to make more appropriate instruments by focusing on the heat production from geothermal energy, and on risk-reducing policy instruments.

Although information from two actual projects are being used to realistically define two generic cases, the methodology used in the ALPI project is strictly different and tailored to achieve a fundamentally better understanding of the dynamics of project development under high (geological) uncertainty. Any additional information that comes available from the two actual projects will be dynamically included as updates in the generic cases.

The following steps will allow to test more selected instruments by stakeholder consultations. The development of the geothermal sector in the whole Belgian territory (transferability at a same basin scale and at a country scale) will be modelize. Regarding the legal context, the legal prerequisites for national implementation of instruments and the compliance with and effects of constraints on different policy levels will be analysed.

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