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FINAL ECONOMIC CONSIDERATIONS

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ABSTRACT

Final estimation of the economic liability of a geothermal project should be based on evaluation of influence of a list of factors, which are different by nature, by the importance, time frame location and interactions or impact to other influencing factors, appearing during the project development. Normally, it begin with the resource characteristics, conversion technology to be applied, planned use (electricity production or direct use), finance construction to cover the investment costs, charactersistics of the energy consumption, costs of regular exploitation, local economic environment, social and environ-mental factors. Neglecting any one of them before taking the final decision can later on have crucial impact to the further destiny of the project.

Through a step by step identification of influencing factors for different types of geothermal energy use, evaluation of their importance and estimation of possible influence to the final economy of geo-thermal project exploitation, a kind of procedure for checking the value of previous investigations is made and value of partial conclusions estimation. In that way, estimation of the quality of final decision is enabled, needed to locate eventual risks with possible influence to the economy of future project exploitation and development.

INTRODUCTION

Known disadvantages of geothermal projects development are the presence of different risks during the project development and extremely high participation of investment costs in the final price of produced energy. In fact, the cost of capital can be as high as 75% of the annual operating expense for a new geothermal district energy project with O&M (15%) and ancillary energy provision (10%) making up the balance. That is the reason that final estimation of economic viability of a geothermal project conditions requests detailed investigations and evaluation of all influencing factors. The factors that must be considered when assessing the economic viability of a geothermal project vary from project to project, from conversion technology to conversion technology, and especially from electrical generation to direct use. There are, however, a number of factors common to all projects, although actual cost and impact on project economics will be, to a large extent, dependent upon resource characteristics and national or even local political and economic circumstances.

The economic factors that are common to all projects include: provision of fuel, i.e., the geothermal resource; design and construction of the conversion facility and related surface equipment, in the case of district heating the distribution system and customer connections; financing; and of course the generation of revenue. The cost of obtaining the required fuel supply, together with the capital cost of the conversion facility, will determine the amount that must be financed. Revenue generated through the sale of electricity, by-products, thermal energy, or product produced, e.g., vegetables, plants, or flowers from a greenhouse, minus the cost of O&M of the fuel supply and conversion facility, must be sufficient to meet or exceed the requirements of the financing package and expected rate of return on investment.

Specialized banks and consulting firms have developed special methodologies for performing as much as possible detailed estimation of different influencing factors influence to the final economy of the project, i.e. it's ability to return the high investment costs in acceptable terms of time. Mostly, such methodologies are more concentrated to the projects for electricity generation and less to direct application projects. Reasons for that are connected to the initial orientation that electricity generation is much more interesting and that, in general, direct application projects are much simpler and easier. However, if going deeper in the problem, both statements are not acceptable, i.e. present situation at the energy market increase more and more the importance of heat production in different life sectors and complicated process to reach necessary annual heat load factor in order to get positive economy of direct application projects, plus appearance of unpredictable factors in the proper organization of their exploitation, introduce additional complications in the process of estimation of their economic viability. These factors are under special attention in this paper.

1. SUMMARY OF ECONOMIC CONSIDERATIONS (according to Bloomquist, 2004)

The economic factors that are common to all projects include: production of energy, i.e., the geothermal resource completion; design and construction of the conversion facility and related surface equipment (in the case of district heating the distribution system and customer connections); financing; and of course the generation of revenue. The cost of obtaining the required energy supply, together with the capital cost of the conversion facility, will determine the amount that must be financed. Revenue generated through the sale of electricity or heat, minus the cost of O&M of the energy supply and conversion facility, must be sufficient to meet or exceed the requirements of the financing package and expected rate of return on investment.

Production of energy

In difference to the other energy sources, when geothermal energy resource is in question, fuel or energy cannot be purchased on the open market, legislated into existence, bought from a local utility, or transported over long distances from a remote field. That means that whether the steam or hot water is to be provided, the geothermal field and conversion facility are under one ownership, i.e. by a resource company or the final user, the geothermal energy is only available after extensive exploration, confirmation drilling, and detailed reservoir testing and engineering. Once located, it must be used near the site and must be able to meet the energy requirements of the project in question and for the lifetime of the project. Even before exploration can begin, however, the project developer may have significant costs, and a number of extremely important legal, institutional, regulatory, and environmental factors, which must be fully evaluated and their potential economic impacts considered before coming to the situation to be able to supply energy and to take the exploitation costs in consideration.

Regulatory approvals

In order to obtain rights to explore for and develop geothermal resources, access must be obtained through legal procedure from the state and surface owners. In most countries, the state claims rights to all land and to all mineral and water resources bellow the soil surface. In order to reach clear title to both surface and subsurface estates, the geothermal developer has to perform a legally conditioned procedure, which is neither simple nor short lasting. In areas where there is significant competitive interest, competitive bidding is normally used to select the developer. Normally, royalties (concession costs) are assessed on energy extracted or elec-trical or thermal energy sales. Whatever the system, it will have an impact upon project economics and should be carefully considered in terms of overall economic impact. For Middle European conditions, and according to the declared politics of support to renewable energies development, these royalties are still of symbolic value.

The second factor that will have an impact on overall project economics are the costs of obtaining all regulatory approvals, including the completion of all environmental assessments and the securing of all required permits and licenses, including the water right. Increasing concern for the environment in all EU countries has resulted in sharply increased costs for preparing the necessary environmental documents and acquiring all necessary permits and authorities. A complete environmental assessment and possibly impact statement is now required and costs for preparation and realization of necessary interventions can exceed up to 20% of the total necessary investments. Although most direct-use projects will be some-what simpler to permit, the cost and time required to fulfill all requirements can be substantial. Because so many environmental decisions are now contested, a contingency to cover the legal costs related to appeals must be included in any economic analysis; depending upon the issues and the financial and political power of those appealing a decision, the cost of obtaining necessary approvals can easily significantly increase. However, and due to the fact that most direct-use projects are more limited in scale and, therefore, in environmental impact, these costs may be only a small fraction of the cost incurred by the proposal for a major power generation project. However, even such reduced, these costs can be significant in relationship to the scale of the project, and the economic impact should not be underestimated. Unfortunately for the project developer, most of the cost related to obtaining access and environmental and regulatory approval must be incurred early in the process of the project development, and even before detailed exploration or drilling can begin, and with no clear indication that any of the costs will or can be recovered. This is one of the project risks, which cannot be covered by any insurance scheme.

Exploration works

After getting all necessary approvals, project developer may initiate the necessary exploration program, employing increasingly sophisticated techniques that should lead to the drilling of one or more exploration wells. Hopefully these wells will be capable of sustaining a reservoir testing program, and possibly also serving as preliminary discovery and production wells. Reconnaissance includes such activities as a literature search, temperature gradient measurements in any existing springs or wells, spring and soil sampling and geochemical analysis, geologic reconnaissance mapping, air-photo interpretation, and detailed regional and local geo-physical studies. Costs incurred are quite high and may range from a low of about 50.000 € to 200,000 € or more, depending on geological complexity, and the scale of the proposed project and whether or not the intended use is electrical generation or direct application.

After the wider location has been selected, direct exploration activities for siting concrete deep exploration well(s) should be performed, including detailed geologic mapping, lineament analysis, detailed geochemical analysis, including soil surveys and geochemical analysis of all springs and wells, temperature gradient and/or core drilling, and geophysical surveys, including for example resistivity, magnetotellurics, gravity, and seismic. Related costs increase with the complexity of the techniques and as the details of the surveys become more focused. For large, direct-use projects, costs of 200-300,000 € or more can be incurred. For projects directed toward electrical generation or even major industrial process uses, the cost of this phase of the work can easily exceed several hundred thousands, up to several millions €.

The final phase in any geothermal exploration program involves the drilling and testing of deep exploratory wells, in order to locate drilling of production and re-injection wells.

Well Drilling

Well cost can vary from a low of a few tens of thousands of € for small direct-use projects, to several millions € per well for wells required to access high-temperature resources for electricity generation and in some cases large district heating applications. Success ratios for production wells can be expected to exceed 60%; however, the risk of dry holes in the exploration phase remains high (≈ 80%) and can have a significant economic impact. Even one dry hole can cause a project to be seriously delayed or even abandoned by a risk adverse or undercapitalized developer. Even in developed fields, 10 to 20% of the wells drilled will be unsuccessful (Baldi, 1990). Drilling cost is typically 30-50% of the total development cost for an electrical generation project and variations in well yield can influence total development cost by some 25%. (Steffanson, 1999.) For many direct-use projects, well costs comprise the largest single expenditure and might exceed 80% of the entire project cost. Prospective developers must anticipate and prepare for the eventuality that despite an investment ranging from a few hundred thousand dollars to several million dollars in lease fees, environmental studies, licenses and permits, and exploration and drilling activities, an economically viable geothermal reservoir may not be discovered.

If, however, drilling is successful, the reservoir must then be tested to determine its magnitude, productivity, and expected longevity. Only after such testing can a determination be made as to the eventual size and design of the generating facility or direct-use application, and financing for project construction be secured.

Well field development

Well field development for an electricity generation project or in some cases large direct use projects can last from a few months to a number of years, depending upon the size and complexity of the project, the speed at which procurement cotracts can be let (Koenig, 1995), and the availability of drill rigs. At this stage it also becomes of increasingly critical importance to collect detailed data and to refine the information available on the reservoir. Of course, for most projects this will include both production and injection wells. Many projects experience unnecessary difficulties and delays in obtaining financing or in milestone review because of either incomplete or inaccurate data collection, analysis, and/or interpretation (Koenig, 1995). Coincidental with well field development will be the construction of well field surface facilities.

Costs associated with both drilling and the construction of well field surface facilities will be affected by the availability of skilled local labor and by geologic and terrain factors. Labor costs can be expected to increase by 8-12% in areas where most of the labor must be brought in or a construction camp erected to provide housing and meals. Terrain and geologic factors can add from 2-5% if special provisions must be made for work on unstable slopes or where extensive cut-and-fill is required for roads, well pads, sumps, etc.

Over half of the total production cost over the lifetime of most projects will in fact be expenses associated with the well field. Because of this, it is imperative that wells must be properly maintained and operated to ensure production longevity. But even with proper O&M, many wells will have to be periodically worked over and, for most power generation projects, 50% or more of the wells will likely have to be replaced over the course of the project, adding considerably to the initial well field cost and, of course, to the cost of generating power. For example, if 60% of the wells must be replaced over the economic life of the plant, it would have the effect of increasing the levelized cost of electricity by 15 to 20% (Parker et al., 1985).

For small to medium-sized direct-use projects requiring only one or two production and injection wells, costs will generally be much lower. Because the water chemistry of most geothermal resources that are developed for direct-use applications is of generally higher quality than that available for power production, well life can be expected to be much longer and few, if any, wells will have to be worked over or re-drilled during the economic life of the project.

Listed activities in project development are treated as most risky, which has significant influence to the final conditions of financing the project completion. That is the reason that in more developed countries (France, Germany…) special systems for risk covering are developed in order to support geothermal energy deve-lopment. However, no one of them covers full costs of unsuccessful works for explorations and production wells completion.

2. DEVELOPMENT OF THE ENERGY USER PART OF THE PROJECT

Completion of the energy source is only a part of the geothermal project completion.

When fossil fuels are in question, this problematic is not responsibility of an energy project developer because there is an already developed system (market) on disposal for a ready for use fuel supply, produced by somebody else. Additional difference is that, when fossil fuels are in question, project developer evaluates the choice of technically/economically optimal fuel for the requests of the energy user in question. When geothermal energy is in question, that is the energy source which directly influence the choice of optimal production technologies of the energy user. And, to make the problem more difficult, each energy source is a problem for itself due to the fact that they are all different. Anyhow, evaluation of economic liability for this part of the project development relates generally to three types of energy users, i.e.

- Direct use of geothermal heat;
- Cogeneration, i.e. production of heat and power; and
- Power generation.

In addition, for all the listed types of use, possibilities for economical combinations with other RES or fossil fuels are also interesting in some particular cases.

Design Considerations

The three uses mentioned above, however, share a number of design considerations and even some equipment components, all having a bearing on the economics of the project. As already said, all are highly dependent upon resource characteristics, including temperature and flow, hydrostatic head, drawdown, and fluid chemistry. The characteristics of the resource will dictate not only the type of project that can be developed, but also the scale of the project and the metallurgy of the components selected.

Direct use projects must be located near enough to the resource site to allow for economic transport of the geothermal fluids from the wells. However, for very large district energy systems and some industrial process applications, this distance may be several tens of kilometers.

Three major design consideration should be carefully investigated before taking final decision for the project completion. These are:

- Choice of economical solution for covering the peak loads of the system;
- Creating composition of heat users , which shall guarantee as higher as possible annual heat loading factor; and
- Planning a reliable development plan, which shall guarantee economical completion of the project in acceptable short period of time.

The first one is not related for the uses with more or less continual energy consumption over the year, as are industrial uses, desalinization or balneology. However, when residential heating, heating of greenhouses, and similar ones are in question, situation is different. Maximal heat loads last very short and annual heat loading factor can be quite low in some climates. For both greenhouse applications and district energy systems, designing the geothermal system to meet 50 - 70% of the peak heating load will still allow the geothermal system to meet 90 - 95% or more of the annual heating requirement in most climatic zones. Introduction of large heat accumulators can be a good solution for some climates but, still, solutions with introduction of additional heat source based on fossil fuel (oil, propane, natural gas, or even coal) boiler for peaking and/or backup should be investigated. In many instances, a strategy where the geothermal system is designed for 'base load only' operation may be the most economical. Another strong argument for meeting peak demand with a non-geothermal system is the need for back up for both greenhouse applications and for district energy systems.

Second one, i.e. creating convenient composition of heat users is the best solution because does not require additional investments in peak-loading systems. Different curves of daily and annual heat loading of customers enable some kind of “ironing” of the total heat load with rather small peak loads appearance.

Third is directly connected to the second one, because systems containing a number of different heat users cannot be completed in short time periods. By the way, that is the problem of any large district heating system. This causes un-economical work of the system during the initial years of development, which significantly decreases total economy of the system during the investigated period, which should confirm the economic liability of it. Therefore, it's of paramount importance to make a reliable plan of development, consisting short initial period of completion.

Power generation projects design considerations are mainly related to the choice of proper production technology, accommodated to the characteristics of the heating fluid and necessary measures for environmental protection. More or less, all necessary information can be get of specialized producers, needed for evaluation of total economy of the system. However, it is always necessary to stress that it is a multidisciplinal problem needing very high level of knowledge and experience. Final decision must be supported by relevant expertises of relevant with positive experience.

Cogeneration projects are the most complicated ones due to the fact that consisting the design consideration problematic of the both power generation and direct use projects. There is still not a wider experience in this field, even the interest for such projects continually arises.

Equipment selection

Equipment selection depends mainly on the chosen system of geothermal fluid use, i.e. direct use of the fluid in the system or indirect one, composed of independent geothermal and heating loops. First one results with continual difficulties with corrosion and scaling, which means use of expensive materials and equipment plus different techniques for decreeasing negative impact of aggressive fluids. Second one results with use of heat exchangers, which enable limitation of negative impact of aggressive fluids only to the initial part of the system.

Problem is particularly important for designing direct use projects. Choice is to design a cheap project with expensive and insecure exploitation or the expensive one with rather simple and cheap exploitation. Normally, for smaller projects, investors prefer the first solution in order to reach lower investment costs. However, experience shows that such projects are quite short lasting and uneconomical at the end.

At last but not least, it is necessary to underline that quite a good knowledge and experience is reached during the last 20 years, enabling successful and high quality design design of heating systems for very different heat users in industry, agriculture, residential heating, aquaculture, desalinization, etc. The same can be said also for power generation pro-jects.

3. REVENUE GENERATION

After finishing economic analyses of all the listed steps of project development, with application of different methodologies for choice of the optimal techno/economical solutions, project developer is coming to the last set of analyses, which shall justify or not all the invested efforts and capital. That is planning the revenue generation.

For power generation projects, the power sales contract establishes the legal framework for revenue generation. However, for direct use projects, the situation is not so "simple". In principle, two different situations can appear, i.e. when the project owner sales heat to other consumers, and when he uses the heat for own purposes. For co-generation projects, the situation is even more complicated because involving production and supply of two types of energy, i.e. power and heat. Problem diserves to be elaborated in more details>

Power generation

In principle, economic viability of a particular power generation project will depend upon its ability to generate revenue, and revenue can only be generated from power sales. Such sales must be equal to or exceed all the costs required to purchase or maintain the energy supply, including any royalties; to cover debt service related to capital purchases; to cover operation and maintenance of the facility; and to meet expected return the investment in acceptable time period. The output from the plant, and hence the source of revenue generated, will be highly dependent upon how well the plant is designed, completed and maintained, how it is operated, and the ability to take maximum advantage of incentives to produce at certain times or under certain conditions. For example, a plant selling into a summer peaking service area must be able to provide maximum possible output when a premium is being paid for output.

Legislation in most of the European countries is quite accommodated to enable convenient treatment of the geothermal energy power producers. Obligations to power distributors to buy power of geothermal origin and to accommodate their distribution to easy connection and continual supply (priority) to power produced from fossil fuels). Part of incentives for supporting development of such energy production is located in this part of the problematic by introduction of convenient "feeding tariffs".

Taking into account that revenue can also be affected by plant availability, dispatchability, and load-following capability, many power purchase contracts provide additional incentive payments for: availability, i.e., the ability to generate at certain levels or during certain peak demand periods; dispatchability, i.e., the ability to go off-line or curtail production when the power is unneeded; or load-following capability, i.e., the ability to match power output to the need for power of the receiving utility. Availability, much like plant capacity factor, can be achieved through the highest possible flexibility and reliability in plant operation, and, as with capacity, is often achieved through the use of redundant equipment. However, possibly as important in terms of revenue generation is the ability of the plant to quickly come on-line after a forced outage, after being tripped off-line, or upon request of the utility to curtail production. However, such interventions are more characteristic for the U.S. energy market than for the undeveloped European one.

Co-Generation

Co-generation, or the simultaneous production of electricity and heat, is becoming increasingly attractive to geothermal developers. Many geothermal power plants can be coupled to direct-use applications in a so-called cascaded use of the resource. The idea, of course, is to maximize the use of the energy that is pumped from the wells in order to enhance the economics of the projects. Depending upon the nature of the project, the electrical generation may either precede the direct-use applications, or generation may be based on the use of the "waste heat" from, for example, a geo-thermal industrial process that requires a high temperatures source, e.g. agriculture product dehydration (bottoming cycle). There is still no real experience with such projects in Europe.

Direct Use

Here, two main group of users can be identified, i.e. large and small scale direct use projects. Further characteristic division depends on the type of the heat user, i.e. residential heating, agriculture, aquaculture, desalinization, industrial uses, district heating, etc. Each one consists important characteristics influencing the choice of optimal technical/ economical solutions.

Most large-scale direct use projects tend to fall into three broad categories: provision of het to district heating systems; industrial processes (including dehydration); and agriculture (including greenhouses and aquaculture). In district heating systems, revenue is generated by the sale of heat to connected heat users. Long-term sales contracts to customers are the norm, and most contracts call for both capacity (fixed) payment and variable payment components. The capacity or fixed portion of the payment is based upon the capital invested, including wells, heat exchangers, thermal storage units, back up or peaking boilers, and the transmission and distribution network. The variable portion of the amount charged relates to O&M, including personal cost, cost for fossil fuels used in the back up and/or peaking boilers, pumping and re-drilling of wells.

However, for the second and third one, when geothermal heating system is developed independently, i.e. for the need of only one user and revenue is generated from the as part of the production costs and realized by sale of a product in question. Ultimately, in both cases, revenue generated and economic viability is totally dependent upon the value and marketability of the end product. However, for the second case, long-term contracts for sale of these products are almost never available, which significantly complicate analyses for final economic liability of the project. The geo-thermal resource developer must therefore not only have a thorough appreciation of the costs involved in developing and operating a geothermal project in an economical manner, but must fully understand what factors ultimately determine the economic viability of the products produced.

Co-Production

Co-production, i.e. the production of silica and other marketable products from geothermal brines, can be a viable source of additional revenue for geothermal project developers, as a key technique for improving project economics by reducing operation and maintenance costs. In the case of, for example, power production, the removal of silica may allow additional geothermal energy extraction in bottoming cycles or, in the case of direct-use, additional uses of low-grade heat that are presently prohibited due to problems associated with scaling. In both cases the economics of the project can be substantially improved.

Some experiences in U.S.A. and Russia have been presented during the recent years but there is still no such information about the experience in European geothermal projects. In opposite, production of CO_2 is already confirmed as a good and economically justified solution (Turkey).

3. FINANCE CONSTRUCTION

At last but not least, even the economic evaluation of each phase of geothermal development is already discussed as crucial part of the estimation of economic viability, it is necessary to underline that all of them are from the beginning strongly influenced by the possible conditions of covering the investment costs, i.e. finance construction of the project.

Development of a geothermal project lasts long period of time, which is rarely shorter than 5 years and normally goes easily to ten and more. In addition, for some types of use (district heating), development period for completion of the market is necessary in order to reach the economic heat loading factor. These are periods without revenue generation or with negative annual economy. That normally results with a negative economic liability for most of the projects, if normal banking conditions for composition of the finance construction are applied.

Being in line with the accepted priority of RES development, most international finance institutions and many countries already developed or are in process in creation of special programs and improving the existing ones, in order to overcome this constraint for development of these "new" and environmentally benign energy sources. Therefore, before beginning the evaluation of economic vianbility of any geothermal project, it is absolutely necessary to study all these possibilities in order to find the most applicable solution for the own project. Furthermore, any positive changes at the finance markets which can be additionally recognized should be incorporated in a maximally possible rate.

4. CONCLUSION

Process of estimation of economic viability of a geothermal project, before going to its realization, is long lasting and very complicated. Even more, due to the fact that economic factors are highly variable, results of estimations are also variable during all the process of project development, completion and exploitation. Each and every project must be evaluated based on reservoir characteristics, exploration and drilling costs, known and expected capital and O&M costs, and of course, potential for revenue generation. Seldom if ever can that evaluation be done prior to project initiation, and then left on the shelf until project completion. It is fact an interactive process with a new evaluation completed at each stage of the project as more and more information becomes available.

Listed complications and long period of project development are the main reason for slow development of this renewable energy source, even competitive to any other one. Neither politicians nor bankers like such type of projects. However, changes of the approach to energy sources in general and to RES in particular slowly change this relation to a positive direction. Proven benefits of geothermal energy use is a fact which cannot be neglected anymore.

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