When Smaller is Better— Cost/Size/Risk Analysis of Geothermal Projects

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[1]Enex
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ABSTRACT

When we consider the cost of projects, then we have two types of cost, technical and financial where each can be split into two subcategories giving four major cost components:

1. Technical cost, here predominately capital expenditure
2. Technical cost as operational cost
3. Financial cost as interest rate of loans
4. Financial cost as required rate of return on equity

We have five major effects that influence the profitability of a power plant.

1. It is a common knowledge that bigger plants are cheaper pr. energy unit produced, we say that cost pr. kW is lower for larger plant.
2. The cost of operation and maintenance is also lower for each kW produced for larger plants.
3. We have on the other hand the timing of the investment; larger plants start to deliver income later, this means higher risk both due to the time and less flexibility to adapt to the real outcome of the geothermal resource. These effects lead to higher interest rate required on larger plants and higher equity ratio requirement. This also influences the profitability of the project due to time value of money.
4. The risk for larger plants is also higher due to proportionally lower scrap value, if someone has to change or remove the plant. Higher retained value in removed plant can also lead to other financing opportunities like leasing.
5. Last but not least is the type of project or company to be financed at each time. If on builds larger plant in one go then we have the total risk for a development company, putting the required rate of return quite high in contrast to financing a small development company in the beginning and then enlargement of existing utility company after that.

This paper addresses these five above effects and gives concrete examples of "when smaller can be better."

Introduction

Most of these issues above apply to different markets and different types of plant also. We can have long wearing debate about flash, binary and Kalina processes and about this or that market, high or low NCG content, this or that type of cooling but these differences can change the quantitative outcome not the qualitative. In order to limit our study and to keep the complexity to level then we decided to do this study for high enthalpy resource with low gas content that in harnessed with conventional flash plant with wet cooling.

Investment Cost

According to Sanyal (2004) at GeothermEx [1, pg. 2] then the cost of a Geothermal Power Plants in the size range of 5 to 150MW is dependent on the size according to the function:

CC=2500e-0.0025(P-5): [1, pg. 2, eq 1]

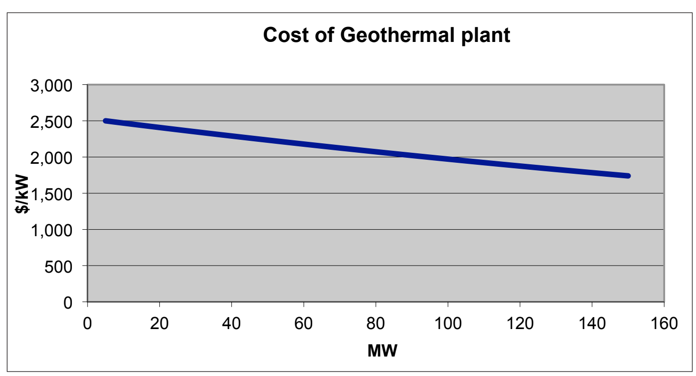

Figure 1. Cost of geothermal plant in relation to size.

"Based on the experience of GeothermEx and data presented by Entingh and McVeigh (2003), the unit capital cost today is estimated to vary from $1,600/kW to $2,500/kW depending on project size and other project-specific criteria. We believe, for the smallest project size of 5 MW considered here, a unit capital cost of $2,500/kW and for the largest considered project size of 150 MW a cost of $1,600/kW to be reasonable values. We have further made the permissive assumption that within the above range of values, unit capital cost declines exponentially with plant capacity. This assumption leads to the following correlation between unit capital cost in $ / kW (cd) and plant capacity in kW."

This would mean that ten 5MW plants would cost roughly 25.6% more than single 50MW one, (given by NREL that plant is 46.58% of project cost [2, pg. 4]and other costs of projects are equal).

This difference could be reduced further through learning. Learning curve tells us that we can expect roughly 80% learning curve for product like this. Each twofold in production would then require 80% of the labor. [3: Linda Argote and Dennis Epple; Learning Curves and Manufacturing]. This means that for 10x more units produced at each time then we can expect to use up-to 55% less of the labor. Taking the cost difference pr. produced MW down to zero.

Operational Cost

Operation and maintenance cost is also size dependent. We have traditionally looked at 1 to 2% of the investment cost as maintenance cost depending on size at Enex but we use here again information from Sanyal [1; pg. 2]:

"Similarly, based on GeothermEx's experience, we believe the representative unit O&M cost approximately ranges from 2.0¢ / kWh for a 5 MW plant to 1.4¢ / kWh for a 150 MW plant. Assuming an exponential decline in unit O&M cost in ¢ / kWh (co) with plant capacity in kW (P), we get:

$$C_o = 2.0\ e\text{-}0.0025(P\text{-}5)\ [1,\ pg.\ 2,\ eq\ 2]$$

This would mean that the O&M for ten 5MW plans is expected to be cost 25.6% more than for single 50MW plant, given that other cost of O&M than from the plant it self does not change with size.

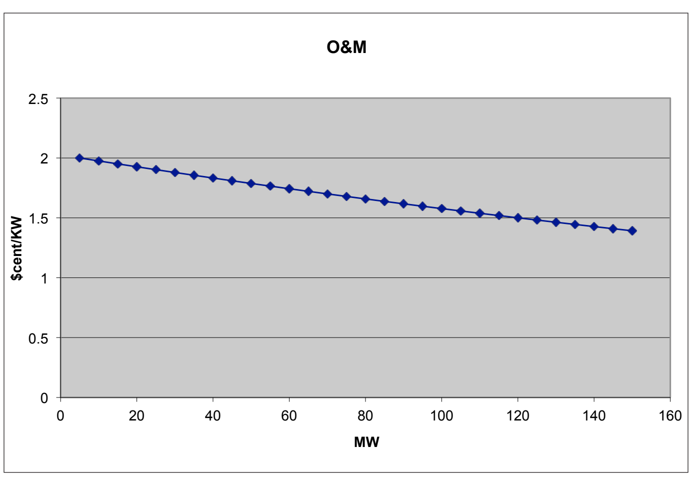

Figure 2. O&M cost of geothermal plants in relation to size.

Financial Cost

NREL states in its report [2, pg 26] that:

"Financing issues for independent developers include: exploration financing (investor may want returns equal to multiples of investment), require an investment-grade power purchaser, construction financing (interest rates may be up to 10% or more, construction lender requires "take out" guarantee at commissioning), term financing usually based on 30% equity/70% debt, IRR in the high teens, interest 7% or more for 15 years."

Dolo [5, pg. 9] states in 2005 that "ODA loans enhance the financial viability of geothermal projects because they offer low interest rates and long grace periods before the start of loan repayments. WB loans normally are at 5% to 7.5% per annum and offer 5 years grace period and 10 years repayment. Regular JBIC loans offer 3% p.a. Dolor Financing projects in the Philippines 10% interest rate, 10 years grace period and 20 years repayment. On the other hand, commercial loans available from Export-Import banks are normally at interest rates of 2% to 4% above LIBOR and have short maturities, with repayment over a period of 5 years. Commercial loans to the private sector are used to finance turnkey power projects and other arrangements such as BOT projects."

We assume for this study that first time project requires 30% equity 7% interest rate on 12 year majority with 3 year grace period on first project loan and 25% equity, 6% interest and same majority for subsequent projects.

Variance and Risk

The risk reduces as the project progresses along, as can be seen in the graph form DOE/Deloitte [5, fig 11, pg. 19]

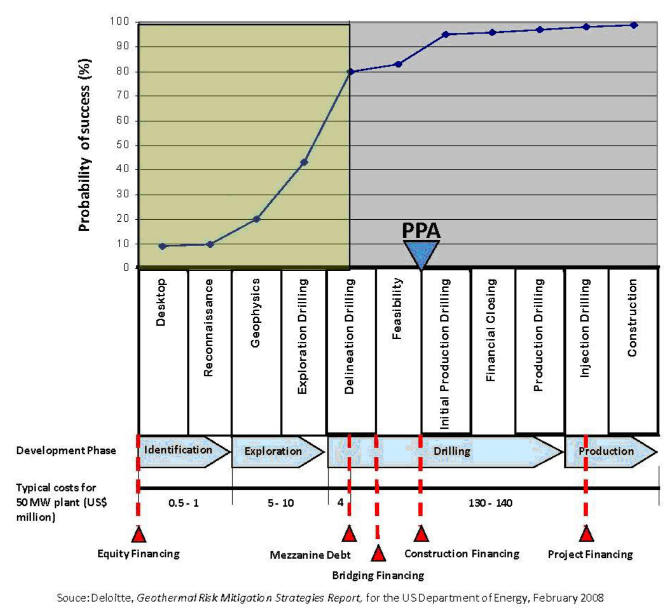

Figure 3. Likelihood of success of geothermal projects.

The probability of success is therefore quite different from where you are in the process. Note that the probability of success is roughly 87% when one orders the big plant but roughly 96% when one orders the small plant as the exploratory well can serve as production well. Ordering subsequent small units can also be done as the drilling progresses.

Scrap value of a large plant is normally estimated to be 10% or so while the makers of modular smaller plant claim that to be as high as 70%.

If one has to stop the plans for project after decision to build the plant then your cost is likely to be in the range of 10-80% of the total cost for the large plant, depending on when does that the decision to back off. The loss for smaller plant, if by modular design would be in the range of 10-30%. If we take the lowest possibility for both options the risk for large plant is 1.3% of loss of total investment but 0.4% for the smaller plant. That would lead to minimum 4.3% required security margin on required rate of return on equity for the large plant but 1.3% on the smaller plant. Putting it in blunt words, shareholders are likely demand to at least 3% higher internal rate of return for projects (IRRP) under consideration if one is installing one 50MW plant rather than ten 5MW plants.

We can then calculate the WACC for large plant as (given 30% income tax rate):

$$WACC_{50}=.07*.7*.7+.15*.3+.043*03=9.22\%$$

And for the first of the small plants:

$$WACC_5(1st)=0.75*.7*.7+.15*.25+.014*.25=7.75\%$$

And the latter of the small plants:

$$WACC_5(latter)= 0.75*.6*.7+.15*.25+.014*.25=7.23\%$$

Time Schedules

From Hance [6, pg. 36 fig 4] the likely time of geothermal project.

Table 1. Cost of developing geothermal projects over time.

Years	Exploration	Confirmation	Site Development		Actual Value of Expenses
0	150				100
1	176	150			326
2	240	176	1050		1466
3	281	240	1154^{66}	1050	2725

Glitnir has similar findings [7, pg. 10, fig 6] but somewhat longer time

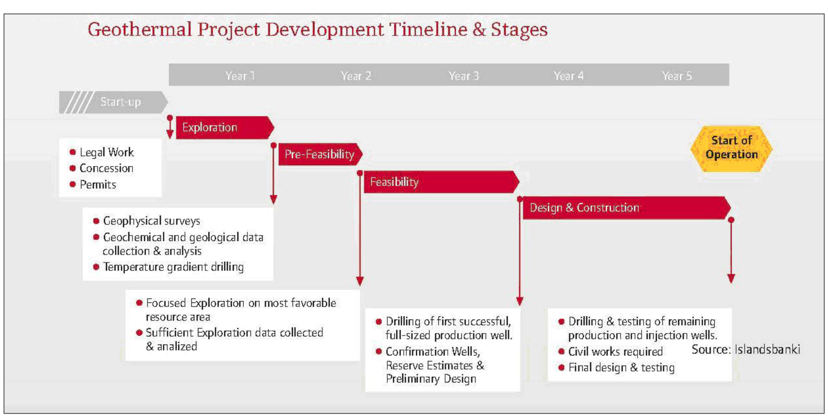

Figure 4. Development time.

Thoroddsson has also a bit longer time [7, pg 12]
Challenges to geothermal development

- High initial investment
- Big initial risk
  - Exploration risk
  - Long developing time 5+ years
- Limited knowledge, few experts
- Long delivery time
  - Turbines > 2 years
  - Wellheads > 1 year
- Few vendors
  One to three in most critical parts

Both are in line with the optimistic projection by Steingrimsson & Co.[8, pg 7, fig 7]

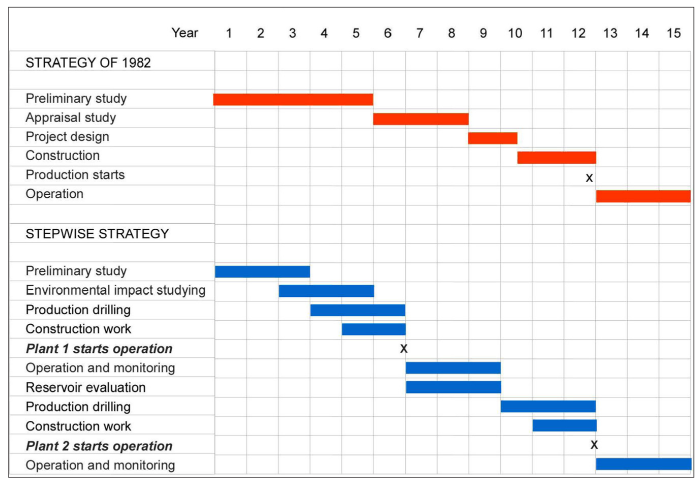

Figure 5. Geothermal power plant project development in stages.

It is our assumption that is takes 1.5 full years to get power on line for small power plant while it takes minimum 3 full years from decision till one sells power from a large plant. It is also assumed that one can have new small plant every 2 months following the first small geothermal plant. We would then have the same 50MW on line in 3 years.

Present Value Calculations

The inputs and assumptions can be seen in Appendix 1 here below. The outcome is that the internal rate of return of the projects are almost identical but not risk identical. The expected value of the internal rate of return is considerably higher when adjusted for the likelihood of the project being scrapped or delayed.

Table 2. Profitability of geothermal projects in relationship to their size.

	NPV/MUSD	IRRE/%	$IRRE_{riskadjusted}$
1×50MW	117	14.51%	10.21%
10×50MW	136	14.77%	13.37%

Conclusion

The benefit of shorter delivery and higher retained value roughly outweighs the higher investment and operational cost of many small units compared to single large one. The multiple small systems become more feasible when considering also the risk of projects being scrapped or delayed somewhere in the process.

It is quite secure that one should start development in new fields with smaller units. Larger units could then become the best option later in time when both the risk of the field and of the development company has been reduced.

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Appendix 1.

Assumption as input in to feasibility model:

	1x50MW BASE	10x5MW BASE
Drilling CAPEX:		
Exploration wells	4,500,000	4,500,000
Production wells	53,500,000	53,500,000
Reinjection wells	13,050,000	13,050,000
Rig setup	2,300,000	2,300,000
Total drilling CAPEX	73,350,000	73,350,000
Build out CAPEX:		-
Plant cost	54,736,842	68,727,579
Steamfield cost	6,578,947	6,578,947
Sub station / circuit breaker	8,000,000	8,000,000
Roading / related infrastructure	400,000	400,000
Contingency	14,306,579	15,705,653
Total build out CAPEX	84,022,368	99,412,179
Total CAPEX	157,372,368	172,762,179

Assumptions	10x5MW	1x50MW
Weighted average cost of capital (WACC)	7.23%	9.22%
Capacity:		
Gross capacity (MWh)	52.63	52.63
Parasitic load factor	5.0%	5.00%
Available plant capacity, year 1	95.0%	95.00%
Available plant capacity, years 2 - 28	96.0%	96.00%
Average hours / year	8766	8766
Electricity pricing:		
PPA price ($/MWh)	$100.00	$100.00
Capacity held in reserve	5%	5.00%
Inflation rate:	0.0%	0.00%
Exploration and production wells:		
Exploration well(s) drilled	1	1
Production well(s) drilled - producing	9	9
Production well(s) drilled - dry hole(s)	1	1
Reinjection well(s) drilled	3	3
Exploration well cost (per well)	$4,000,000	$4,000,000
Exploration well site cost (per well)	$250,000	$250,000
Exploration well testing cost (per well)	$250,000	$250,000
Production well cost (per well)	$5,000,000	$5,000,000
Production well site cost (per well)	$250,000	$250,000
Production well testing cost (per well)	$100,000	$100,000
Reinjection well cost (per well)	$4,000,000	$4,000,000
Reinjection well site cost (per well)	$250,000	$250,000
Reinjection well testing (per well)	$100,000	$100,000
Ship in / ship out cost	$700,000	$700,000
Number of rig shifts (net)	4	$4
Cost per rig shift	$400,000	$400,000
Build out (CAPEX):		
Construction period (years)	2	3
Plant cost (per MW)	$1,305,824	$1,040,000
Steamfield cost (per MW)	$125,000	$125,000
Sub station / circuit breaker	$8,000,000	$8,000,000
Roading and related infrastructure	$400,000	$400,000
Contingency (as % of total CAPEX)	10.0%	10.00%
Operating costs:		
Operation and maintenance costs (per MWh)	$22.85	$18
Reserve charges (per MWh)	$-	$0
Insurance (as % of total CAPEX)	0.10%	0.10%
Ongoing CAPEX:		
Production well replacement (wells)	1	1
Reinjection well replacement (wells)	-	
Service life before replacement (years)	10	10
Total initial investment necessary	$172,762,179	$157,372,368
Debt to equity allocation and debt service		
Debt ratio to assets	75.0%	70.00%
Equity ratio to assets	25.0%	30.00%
Loan length (years)	15	15
Loan interest rate	6.0%	7.00%