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The Competitiveness of Geothermal Power as Seen by Steam Producer, Power Producer and Electricity Buyer

Herman Darnel Ibrahim[1)] and Antonius RT Artono[2)]

[1)] Ex-Chairman of Indonesian Geothermal Association (INAGA), Director of T & D – PT. PLN (Persero) – Jl. Turnojoyo Blok M I/135 – Jakarta - Indonesia, Herman.Darnel@pln.co.id

[2)] Member of Indonesian Geothermal Association (INAGA), Business Development Senior Manager – PT. Indonesia Power – Jl. Gatot Subroto Kav. 18 – Jakarta 12950, antonius.artono@indonesiapower.co.id

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ABSTRACT

This paper discusses three simple approaches representing each main concern to each parties in determining geothermal steam price : (i) Steam Field Investment Cost Based Approach, this approach determines the steam price based on investment cost in the steam field and is the main interest of the Steam Producer, (ii) Oil Price Based Approach, this approach determines the steam price through its competitiveness to the steam produced by oil, whichmay the interest of the Power Producer, and (iii) Electricity Price Based Approach, in this approach the steam price can be determined through calculation of oil-based power plant at certain electricity tariff. This approach is the main interest of the Power Purchaser.

Using each of the approaches a competitive geothermal steam price range could be determined which then each of them will give competitive investment cost range, expressed in USD/kW, in the corresponding steam field. These approaches are very useful guides for the Steam Producer to justify what is the minimum well capacity in the field and maximum investment cost of well to achieve a competitive geothermal steam price. The approaches are also useful guides to the Power Producer and the Electricity Buyer in determining electricity price before they decided to purchase geothermal steam or the electricity generated by geothermal power plant.

1. INTRODUCTION

In a non-integrated geothermal power plant project, there are three parties who have strong influence to pull and push the geothermal steam price : (i) Steam Producer, (ii) Power Producer, and (iii) Electricity Buyer. First, the Steam Producer will pull the steam price in a manner that it will represent his investment cost in the steam field with certain level of return. Next, the Power Producer will pull the electricity tariff in such a way that it will represent generation cost including geothermal steam cost and a certain level of return to cover his business risk in investing the power plant. In the same time, the Power Producer will also push the steam price to keep the price at a competitive level to the steam produced by other primary energy sources such as oil. Finally, the Electricity Buyer will push the electricity tariff of geothermal power plant in a manner that it must be more competitive than other power plant types.

All over this business line, the geothermal electricity business can survive along the project life, if its steam price is set at a level that can give a profit margin to Steam Producer, Power Producer and Electricity Buyer. It means, before developing a geothermal field, a Steam Producersalso has to consider whether its geothermal steam can compete with other power plant or not.

Firstly, geothermal steam price together with its related steam field investment cost refers to electricity price is assessed. A similar assessment is then applied to the other two approaches – i.e. referring to fuel oil price and that to investment in steam field. A competitive investment cost is selected by comparing these three pricing approaches.

2. COMPETITIVENESS REFERS TO ELECTRICITY PRICE : AS SEEN BY ELECTRICITY BUYER

2.1 Analysis Approach

In this approach, a competitive geothermal steam price and its related investment cost on the field are derived from the electricity price of a power plant that can be achieved by Electricity Buyer (EB), as illustrated by **Figure–1**. Accordingly electricity generated by geothermal steam can compete with generated electricity of SPP, only if its maximum production cost is equal to the electricity price minus non-boiler investment and O & M cost components. If *X* is competitive electricity price in USD/kWh, *P* is non-Boiler investment and O & M cost components of SPP (i.e. Turbine and its auxiliaries) also in USD/kWh, a competitive geothermal steam price can be defined as *(X – P)*.

If Ap and Bp are define as investment and O & M cost components of non-boiler in SPP respectively - expressed in USD/kWh, then a competitive geothermal steam price can be achieved once the value of *(X – P)* is equal to the value of *(X - Ap – Bp)* :

$$(X - P) = (X - Ap - Bp) \quad (1)$$

If *Ar* and *Br* are defined as investment and O & M cost components in the steam field in USD/kWh, then :

$$(X - P) = Ar + Br = X - Ap - Bp \quad (2)$$

If the power plant is operated at capacity factor of *CF*, over operational period of one year or 8,760 hours, then annual revenue *(An)* made by Steam Producer - expressed in USD/kW/year, can be defined as :

$$An = 8{,}760 \times CF \times Ar \quad (3)$$

Investment cost on the steam field *(IC)*, expressed in USD/kW, over the project life of *n* years and return of *r* %, shall equal to the present value of *An* at return of *r* and a period of *n* :

$$IC = PV(An, r, n) \quad (4)$$

In SPP, investment is required to finance the following activities such as : engineering and design as well as purchasing : turbine, generator, boiler and balance of plant,

etc. Similar to that of SPP, investment in GPP is required to finance : engineering activity and purchasing the power plant. By assuming all of those input parameters in the steam field and SPP, competitive steam price and steam field investment for a certain profit level and installed capacity can be calculated.

2.2. Calculation Summary.

Figure - 2 illustrates the result of calculation if the steam price and investment cost in the field is based on Electricity Price, using the following assumptions :

1. Geothermal PP :
   - Power Plant Capacity = 55 MW.
   - CF = 80 %.
   - Project Life = 25 years.
   - Return = 15 %/years.
   - & M Cost component = 0.005 USD/kWh
2. Power Plant :
   - Investment Cost of Non Boiler Component = 700 USD/kW.
   - O & M cost of Non Boiler Component = 0.004 USD/kWh
   - Specific Fuel Consumption (SFC) = 0.28 lt/kWh.

Assuming that the electricity price is in the range of 3.0 – 6.0 cUSD/kWh, then a competitive geothermal steam price should in the range of 1.055 – 4.055 US¢/kWh, which corresponds to the steam field investment cost range of 251 – 1,610 USD/kW.

3. COMPETITIVENESS REFERS TO OIL PRICE : AS SEEN BY POWER PRODUCER.

3.1. Analysis Approach.

In this approach, a competitive geothermal steam price and its related investment cost on the field are derived from steam production cost of steam power plant (SPP), as illustrated by **Figure – 3**. In other words, geothermal steam can only compete to boiler steam of SPP, if its maximum production cost of geothermal steam is equal to production cost of boiler steam. If *Cb* is fuel cost component in USD/kWh - as a function of international crude oil price *(y)*, at certain thermal efficiency, *Ab* and *Bp* are Boiler investment and O & M cost components of SPP, both in USD/kWh, then competitive geothermal steam *(X – P)* as defined in eq. 1, will be :

$$(X - P) = Cb(y) + Ab + Bb \qquad (5)$$

Then the investment cost component on steam field – *Ar* as defined by eq. 2, becomes :

$$Ar = Cb(y) + Ab + Bb - Br \qquad (6)$$

Annual revenue to Steam Producer – *An*, and competitive steam field investment *(IC)* can be calculated using eq. 3 & 6 respectively.

3.2. Calculation Result

The result of Oil Price approach is illustrated by Figure - 4, the assumptions used are :

1. Geothermal PP :
   - Power Plant Capacity = 55 MW.
   - CF = 80 %.
   - Project Life = 25 years.
   - Return = 15 %/years.
   - O & M Cost component = 0.005 USD/kWh
2. Steam Power Plant :
   - Investment Cost of Boiler = 300 USD/kW.
   - O & M cost of Boiler side = 0.002 USD/kWh.
   - SFC = 0.28 lt/kWh.
   - MFO Price is 78 % that of crude oil price.

Assuming that the crude oil price in a normal market is in the range of 10 – 25 USD/Barrel, then competitive geothermal steam price should be in the range of 2.24 – 4.30 US¢/kWh, which also corresponding to a competitive steam field investment cost in the range of 786 – 1,719 USD/kW.

4. COMPETITIVENESS REFERS TO INVESTMENT COST : AS SEEN BY STEAM PRODUCER.

4.1. Analysis Approach.

In this approach, a competitive steam price is purely derived from investment cost in the steam field, with certain return. Investment base will guarantee an adequate return on the investment, which is very important aspect to drive investor involvment in the project development.

In developing a steam field, investment is required to finance some activities: site survey; prepare a feasibility study; drill exploratory wells, monitoring wells, re-injection wells, production wells, and make up wells; land purchasing; build steam line and other general facilities such as access road, administration building, etc.

If IC is investment cost in the steam field, then competitive geothermal steam price (expressed in USD/kWh) can be defined as the annual payment of *IC* at return of *r* and period of *n* divided by generated electricity of *CF* for the operational period of 8,760 hours :

$$(X - P) = \{PMT (IC, r, n)\} / (CF \times 8{,}760) \qquad (7)$$

Some important variables that may be significant in calculating investment cost of the field are :

1. Well capacity (MW per well), the higher the well capacity the lower the number of production wells required to supply an adequate steam to power plant that will result in a lower investment cost.
2. Success ratio, defined as the ratio of the successfulness of the steam producer to drill wells, the higher the success ratio the lower the number of drilled wells and investment cost.

3. Ratio of Field capacity to Power plant capacity, defined as the percentage of the field capacity that shall be provided to achieve a high availability of steam supply to the plant. The higher the Field to power plant capacity ratio the higher the number of production wells and the investment cost.

4. Draw down speed, defined as the percentage of reducing capacity of the wells per year. A higher draw down speed will require more make up wells to keep a constant availability and capacity of the power plant.

Well capacity calculation result as drawn in **Figure – 5** is carried at different well capacity, while the investment cost on each well is assuming constant. It means well capacity dictates the number of production wells that shall be drilled to supply an adequate steam flow to power plant.

4.2. Calculation Summary.

Assumptions used in calculating the steam field investment cost and steam price are tabulated in **Table – 1.**

The calculation demonstrates that at 1 MW well capacity the resulting investment cost of 6,931 USD/kW, it corresponds to the steam price of 15.8 US¢/kWh, which illustrates that geothermal steam is not competitive. Conversely, at well capacity of 20 MW/well and resulting investment cost and steam price of 299 USD/kW and 1.16 US¢/kWh respectively, there is high competitiveness for geothermal steam.

5. ANALYSIS ON OVERALL COMPETITIVENESS.

Result comparisons among those three different pricing approaches are shown by **Figure - 6.**

1. Geothermal steam price is unattractive, if its steam price is higher than the production cost of boiler steam fueled by the most expensive International Fuel Price (i.e. assuming 25 USD/barrel), which corresponds to a steam field investment cost of higher than 1,719 USD/kW and a related steam price of higher than 4.3 US¢/kWh or well capacity of lower than 3.5 MW/well.

2. Geothermal steam price will be very attractive, if its production cost is cheaper than the production cost of boiler steam fueled by the cheapest International Fuel Price (i.e. 10 USD/barrel), which corresponds to a steam field investment cost of lower than 786 USD/kW and a related steam price of lower than 2.24 US¢/kWh, or well capacity of higher than 7.8 MW/well. This situation is also similar to the situation of subsidized fuel price, with the meaning that the price of local fuel is cheaper than the price of the International Market.

3. Well capacity in the range of 3.7 up to 7.8 MW/well can still give a promising competitiveness for geothermal steam, i.e. its production cost is equal to that of boiler steam fueled by an international fuel price, which also can still be achieved by Electricity Buyer. This situation corresponds to a steam field investment cost range of 786 - 1,610 USD/kW and steam price in the range of 2.24 - 4.05 US¢/kWh.

It must be well kept in mind, that all the above calculations are referring to a vapor dominated steam field. Application to a water dominated field may needs a certain adjustment considering the difference of the investment cost on both fields, such as : Separators, number of re-injection wells, pipe diameter, etc.

The following highlights are also important to understand the accuracy of the approaching :

1. The calculation does not include taxation of the steam producer. In Indonesia, a Steam Developer pays 34 % after Net Operating Income as a tax to the Government. This 34 % tax rate could increase the steam price by 0.5 US¢/kWh at an IRR of 15 %. The reason for neglecting the tax rate in the calculation is based on the consideration that tax rate is an adjustable cost component, which has no direct relationship to the field activity. It may also vary between one country to another. Therefore it is more accurate to assess the pricing without considering tax first, otherwise the calculation result can not be applied to common situations.

2. Rate of return to the Steam Producer may be different to that of Power Producer, as the return shall represent the risk carried by each party. The calculation was based on a similar rate of return whether to the Steam or Power Producers. Moreover, the rate of return for the Investment Cost Approach may also be different to that of the Oil Price Approach. Investment Cost Approach is analogous to the concept of cost plus fee, i.e. Steam Producer is borne at lower risk, as all of the field investment will be transferred into steam price. Therefore rate of return to Investment Cost Approach shall be lower than that of Oil Price Approach, as in the fuel price approach there is uncertainty of the fuel price in the international market. Increasing the IRR by 5 % will also increase the steam price by 0.7 US¢/kWh.

3. Environmental cost component, of the emission level of a geothermal PP is different to that of SPP. It is difficult to quantify, what is the environmental base from which to account for the environmental cost, as each power plant has different emission standards. It is fair enough to consider that there should be no additional cost for either power plants as long as they can meet their environmental standards.

6. IDEA TO DRIVE MORE COMPETITIVE GEOTHERMAL PP.

This idea may applicable under the situation of the electricity business in Indonesia only, where fuel oil is subsidized by Government. Some alternatives to levelize the playing field for geothermal steam compared with fuel oil are :

Short term :

1. Electricity tariff to End User currently is at about 3.0 US¢/kWh, indicating that this is not an attractive business to the Electricity Buyer (PLN) or the Power Producer and hence for the Steam Producer. It means that this is not a level at which the Electricity Buyer, Power and Steam Producers are able collect an adequate return which will create an ability to re-invest in its business. The tax rate is one of the easiest variables that can be adjusted with minimum impact to the party involved in the business, except the Government side. Currently, the power producer and Electricity Buyer bear the worse impact under the existing electricity tariff. Thereturn of a 34 % tax rate to the Electricity Buyer or Power Producer under the special mechanism will be very significant to creating an attractive geothermal business line.

2. Alternatively, as utilization of geothermal power plant will assist the Government to reduce the volume of subsidized fuel oil, then an incentive to the Power Producer equal to that of the oil subsidy can also assist in making the geothermal business an attractive alternative.

3. Some steam purchase contracts may apply Take Or Pay clauses to guarantee further how the Steam Developer will to get an adequate return with a lower minimum risk. It means that the steam developer will have a very high security on its investment, but this scheme contradicts a competitive paradigm. Steam Developer will not be affected by fluctuation in the market demand, which is a very normal to occurance in any other business activity.

Medium term :

1. Insurance during exploration of the field. Exploration risk of each geothermal area varies between one and another. Governmental Body is the only independent side that can share the risk among the geothermal areas. Foundation of Insurance Company under the control of Government or similar agency will create a risk sharing during the exploration activity of the field, which is identified as the highest risk in developing the field.

2. In developing steam field, Steam Producer may build an access road, bridge and other infrastructure facilities that may also be utilized by the nearby community in creating a higher economic growth to the local community. It may be possible to account for these facilities as a tax deduction to the Steam Producer to create geothermal steam competitiveness.

7. SUMMARY AND CONCLUSION

Considering that geothermal steam is not an exportable commodity and is unable to be stored like fuel oil and coal, then the geothermal potential can only be utilized if it is able to compete with other energy sources.

In order to make the oil price approach applicable, then a careful arrangement to compensate for the subsidy on fuel oil is required. At the same time an adjustment to the electricity tariff shall also applied.

The most effective strategy in developing geothermal potential is to give the first priority for geothermal areas, which have a competitive investment cost, then continue to the more expensive reservoir areas once the fuel reserves have diminished, indicated by a constant increasing fuel price.

Geothermal steam price is unattractive if its investment cost in the field is higher than 1,719 USD/kW, the related steam price is higher than 4.3 US¢/kWh and well capacity is lower than 3.5 MW/well.

Geothermal steam price will be very attractive, if its steam field investment costs lower than 786 USD/kW, the related steam price is lower than 2.24 US¢/kWh and well capacity is higher than 7.8 MW/well.

Well capacity in the range of 3.7 up to 7.8 MW/well can still give a promising competitiveness of geothermal steam price. This situation corresponds to the steam field investment cost range of 786 - 1,610 USD/kW and steam price in the range of 2.24 - 4.05 US¢/kWh.

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List of Abbreviations :

1. Ab = Investment Cost of Boiler, expressed in *USD/kWh*
2. An = Annual Revenue, expressed in *USD/kW/year*
3. Ap = Investment Cost of non Boiler, expressed in *USD/kWh*
4. Ar = Investment Cost Component in the steam field, expressed in *USD/kWh*
5. Bb = Operation and Maintenance Cost of boiler, expressed in *USD/kWh*
6. Bp = Operation and Maintenance Cost of non boiler, expressed in *USD/kWh*
7. Br = Operation and Maintenance Cost of steam field, expressed in *USD/kWh*
8. Cb = Fuel Cost component in the boiler, expressed in *USD/kWh*
9. CF = Capacity Factor, in %
10. IC = Investment Cost, expressed in *USD*
11. n = number of year or project life
12. P = Non Boiler Investment and O & M cost, expressed in *USD/kWh*
13. PV = Present Value
14. PMT = Payment Value
15. r = internal rate of return, in %
16. X = Electricity Price, expressed in *USD/kWh*
17. y = Crude Oil price, expressed in *USD/barrel*

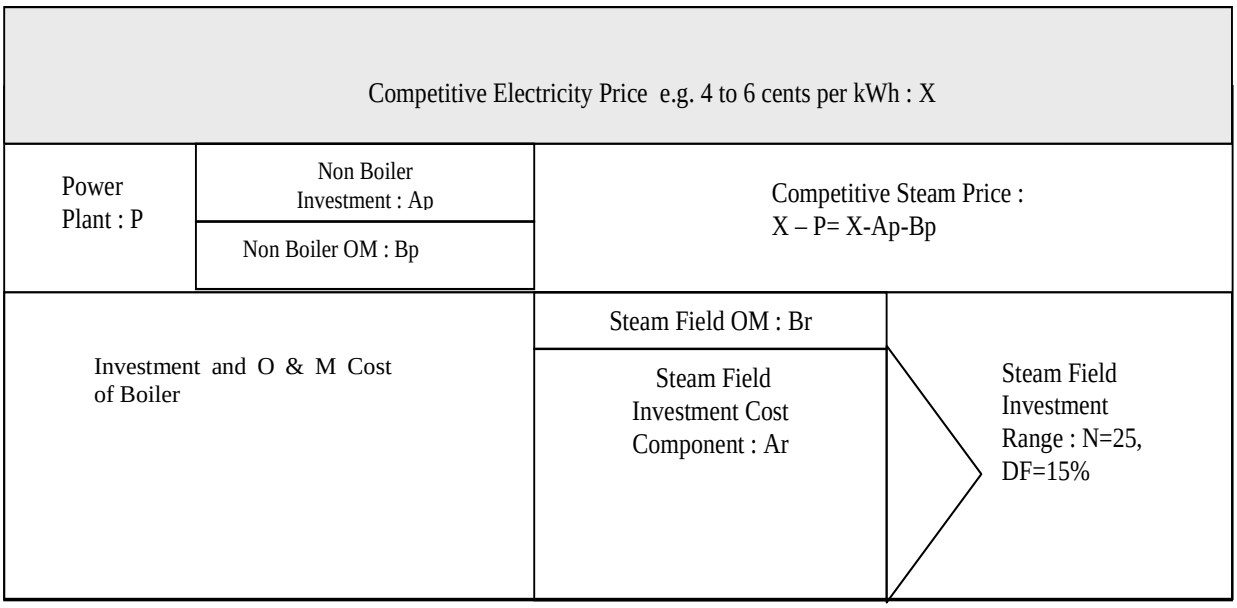


Figure – 1 : Illustration of Electricity Price Approach.

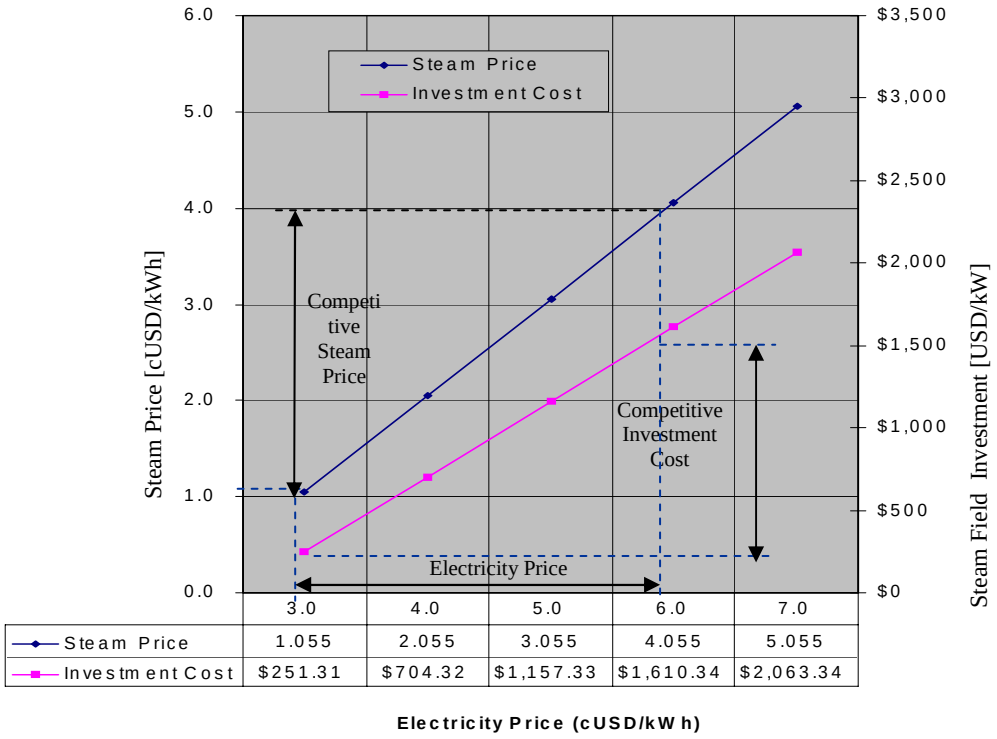


Figure 2 : Electricity Price Vs Steam Field Investment Cost and Steam Price According to Electricity Price Approach

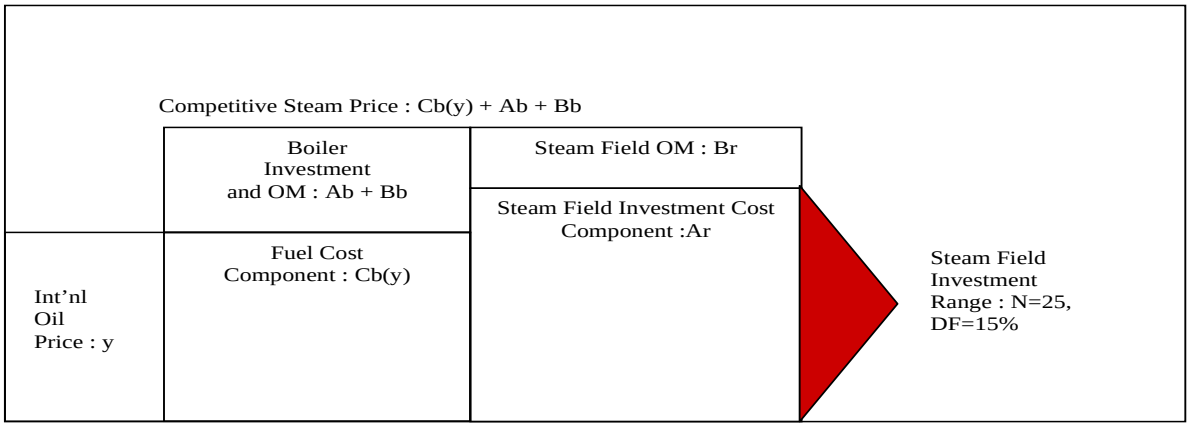


Figure – 3: Illustration of Oil Price Approach

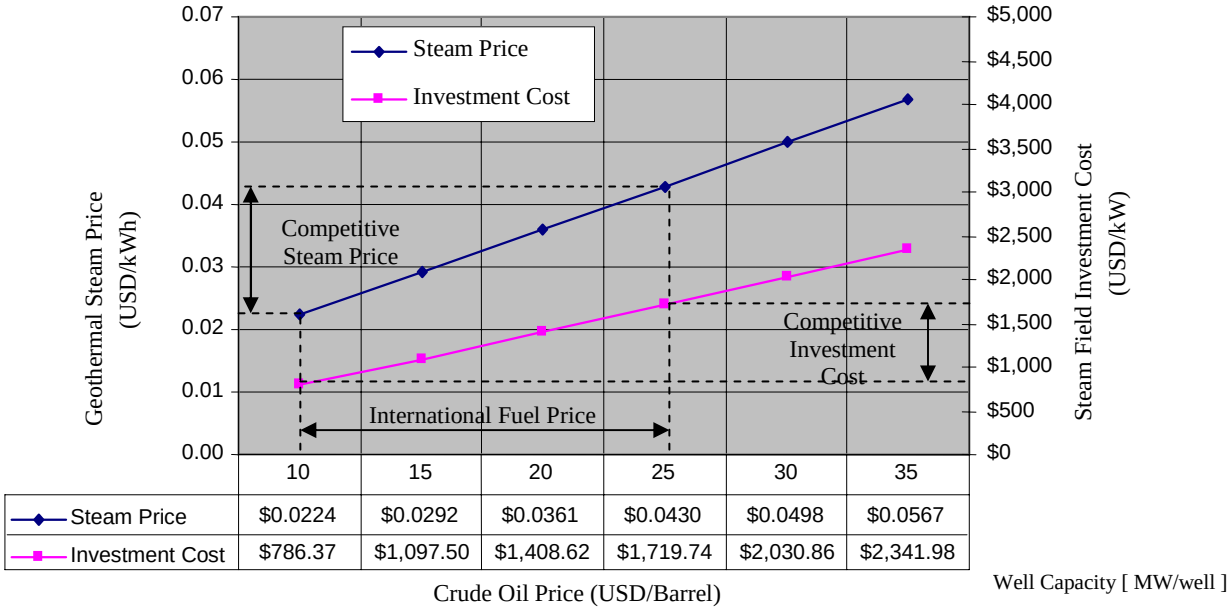


Figure – 4 : Crude Oil Price Vs Steam Field Investment Cost and Steam Price According to Oil Price Approach

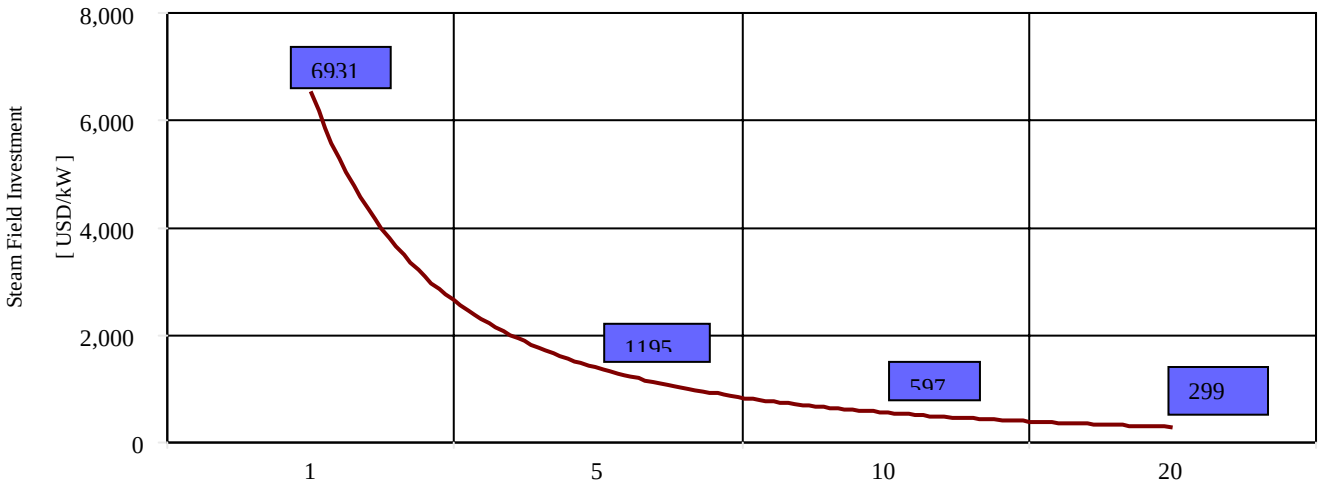


Figure – 5 : Well Capacity Vs Steam Field Investment Cost.

Table 1 : Assumption used in calculating Geothermal Steam Price at Power Plant Capacity of 55 MW

No		Description	Unit	Amount x 1000
1	CF			80%
2	Interest +Risk+Profit			14%
3	**Fixed Component:**			
		Roads & Land	USD	5,000
		Exploration Cost	USD	1,500
		Monitoring Wells, assumimg 4 wells	USD	8,000
		Resource Study	USD	750
		General Facilities	USD	800
		Steam Lines	USD	20,000
		Reinjection well, assuming 3 wells	USD	6,000
		Sub Total	**USD**	**42,050**
4	**Variable Component:**			
		Drilling Wells	USD/well	2,600
		Success ratio		70%
		O & M Charge	USD/kWh	0.005
		Draw down	MW/year	3

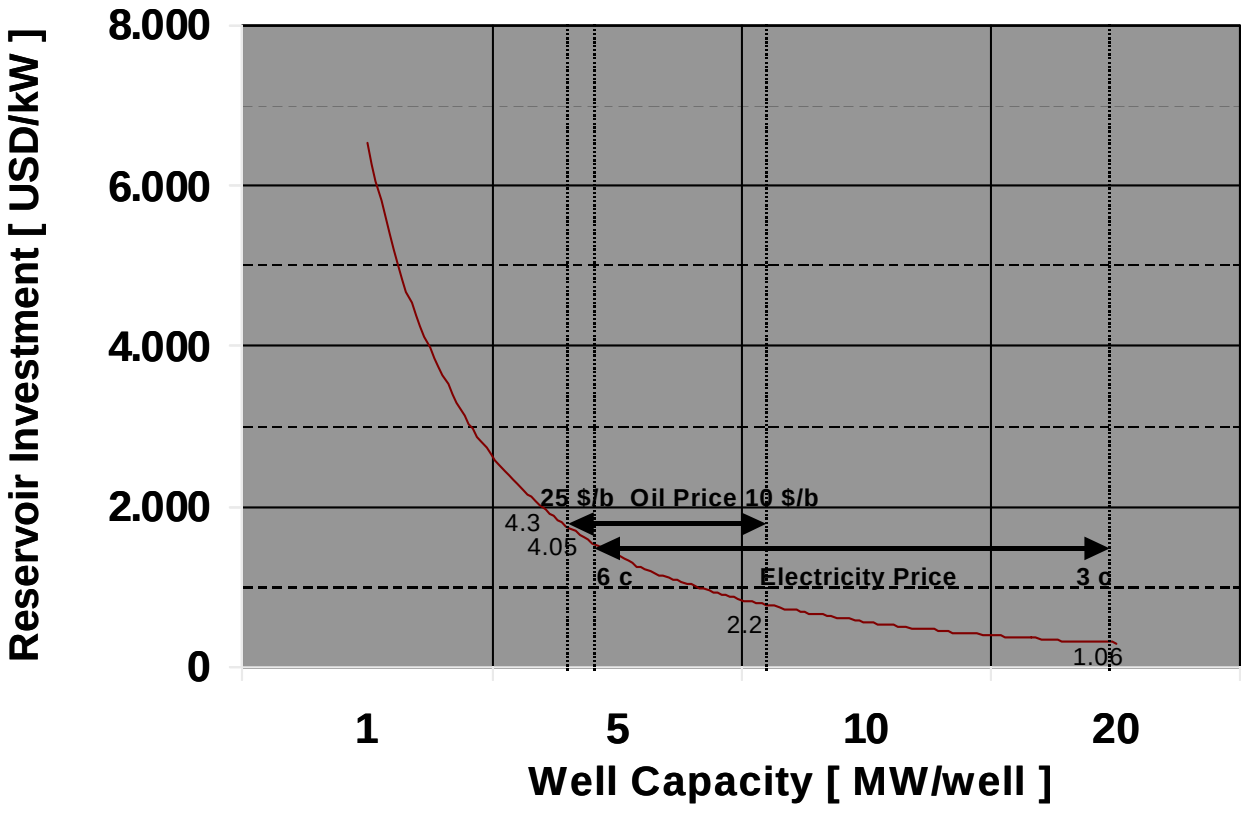


Figure – 6 : Comparison Result of the three Geothermal Steam Pricing Analysis.