# AN ANALYSES ON GEOTHERMAL ELECTRICITY COMPETITIVENESS

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**Key Words: Geothermal steam price, electricity price, reservoir investment and competitiveness**

***ABSTRACT***

*This paper discusses geothermal electricity competitiveness through a combination of three different approaches i.: refers to steam field investment cost that might be applied to steam producer, ii. Refers to oil price that may of interest of power producers, which has options to utilize oil fired steam, and iii. refers to electricity price, which is of interest and concern of electricity end user. By analyzing through these three approaches then the competitive geothermal steam price range can be estimated, which also corresponds to the competitive investment range of the geothermal well per kilowatt. This analyses is of useful tools for Steam Producer to justify what is the minimum well capacity in the field and the maximum investment cost of well to achieve a competitive geothermal electricity price. As drilling cost on production well is more or less the same, then capacity of each well will be as important aspect to achieve competitiveness of its steam price. The discussion also covers briefly how to level geothermal steam to the fuel oil whilst subsidy is still an issue*

## 1. INTRODUCTION

Three parties who have strong business relationship in geothermal steam price establishment are Steam Producer, Power Producer and Electricity Buyer. For Steam Producer, steam price shall represent the steam field investment cost with certain return, as compensation on its business risk. For Power Producer, steam price will be considered as cost component, then it shall compete with other steam produced by other energy resources. Power Producer also want that the electricity price shall also represent the operational cost and return on power plant investment. For Electricity Buyer, the electricity of geothermal power plant shall compete to other power plant type, which then can be achieved by market after considering operational and investment cost on transmission and distribution.

All over this business line, the business can survive along the project life, if the steam price is set at a level in which can give a profit margin to Steam Producer, Power Producer and Electricity Buyer. It means, before developing a geothermal field, Steam Producers shall also consider, in what level its geothermal steam able to compete with other power plant. In other words, the Steam Producer shall recognize what is the investment cost on steam field to create a competitive steam price, before developing a geothermal area. This competitive investment cost on steam field can be used as a guide to justify whether the field is competitive to other power plants type or not.

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

## 2. COMPETITIVENESS REFERS TO ELECTRICITY PRICE

### 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**. In other words, geothermal steam can only compete to generated electricity of SPP, if production cost of geothermal steam is maximum 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, then 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, if 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 :

$$Ar = X - Ap – Bp – Br \quad (2)$$

If power plant is operated at capacity factor of $CF$, over operational period of one year or 8,760 hours, then annual revenue $(An)$ to 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 equals to the present value of $An$ at return of $r$ an period of $n$ :

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

in SPP, investment is required to finance the activity such as : engineering and design as well as purchasing : turbine, generator, boiler and balance of plant. By assuming all of those input parameters in the stem field and SPP, competitive steam price and steam filed 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 on the field is referred to Electricity Price, according on the following assumptions :

a. Geothermal PP :
- Power Plant Capacity = 55 MW.
- CF = 80 %.
- Project Life = 25 years.
- Return = 15 %/years.
- O & M Cost component = 0.005 USD/kWh

b. 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 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 cUSD/kWh, which corresponds to the steam field investment cost of 251 – 1,610 USD/kW.

## 3. COMPETITIVENESS REFERS TO OIL PRICE

### 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 production cost of geothermal steam is maximum 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, shall equals to :

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

Then 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 & 5 respectively.

### 3.2. Calculation Result

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

a. Geothermal PP :
- Power Plant Capacity = 55 MW.
- CF = 80 %.
- Project Life = 25 years.
- Return = 15 %/years.
- O & M Cost component = 0.005 USD/kWh

b. 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 the crude oil price is in the range of 10 – 25 USD/Barrel, then competitive geothermal steam price should in the range of 2.24 – 4.30 cUSD/kWh, which also corresponding to a competitive reservoir investment cost in the range of 786 – 1,719 USD/kW.

## 4. COMPETITIVENESS REFERS TO INVESTMENT COST

### 4.1. Analysis Approach.

In this approach, a competitive steam price is derived purely 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 involving in the project development.

In developing steam field, investment is required to finance some activities: site survey; prepare a feasibility study; drill an 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 all of those investment cost components *(∑IC)* has been known, then investment cost per unit capacity *(Cp)* is :

$$IC = (\sum IC)/Cp \qquad (7)$$

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 :

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

There are some important variables that may significant in calculating investment cost of the field :

1. Well capacity (MW per well), the higher the capacity the lower the number of production wells, which then resulting a lower investment cost.
2. Success ratio, defined as the ratio of the successfulness of the steam producer in drilling production wells, the higher the success ratio the lower of the number of the 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. The higher the draw down speed will require more make up wells to keep a constant availability and capacity of 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 to be constant, as it may not vary too much. It means well capacity dictates the number of production well 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 by **Table-1**.

The calculation demonstrates that at 1 MW well capacity will resulting investment cost of 6,931 USD/kW, it corresponds to the steam price of 15.8 cUSD/kWh, which illustrates there is no competitiveness to geothermal steam. Conversely, at well capacity of 20 MW/well resulting investment cost and steam price of 299 USD/kW and 1.16 cUSD/kWh respectively, indicating a high competitiveness to 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 the steam field investment cost of higher than 1,719 USD/kW and the related steam price of higher than 4.3 USD/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 the steam field investment cost of lower than 786 USD/kW and the related steam price of lower than 2.24 USD/kWh, at 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 that of price of International Market.
3. Well capacity in the range of 3.7 up to 7.8 MW/well can still give a promising competitiveness to 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 the steam field investment cost range of 786 - 1,610 USD/kW and steam price in the range of 2.24 - 4.05 cUSD/kWh.

It must be strongly remembered, that all the calculations refer 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 high light also important to understand the accuracy of the approaching :

1. The calculation was not applying Taxation to the steam producer. In Indonesia, Steam Developer shall pays 34 % after Net Operating Income as a tax to the Government. This 34 % tax rate could increase steam price of 0.5 cUSD/kWh at IRR of 15 %. The reason on the neglecting tax rate in the calculation is based on the consideration that tax rate is an adjustable cost component, which is no direct relationship to the field activity. It may also vary between one country to another. Therefore its more accurate to assess the pricing without considering tax first, otherwise the calculation result can not be applied for most common situation.
2. Rate of return to the Steam Producer may different to that of Power Producer, as the return shall represent the risk that shall be born by each party. The calculation was based on the similar rate of return whether to the Steam or Power Producers. Moreover, rate of return for the Investment Coat Approach may also shall different to that of the Oil Price Approach. Investment Cost Approach is analog 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 lower than that of Oil Price Approach, which is depend on the uncertainty of the fuel price in the international market. Increasing of IRR by 5 % will also increase of steam price by 0.7 cUSD/kWh.
3. Environmental cost component, emission level on geothermal PP is different to that of SPP. This aspect is more difficult to be accounted, what is the environmental base to account the environmental cost, as each power plant has different emission standard. It is fair enough to consider, that there should no additional cost for both power plants as long as they can meet its environmental standard.

## 6. IDEA TO DRIVE MORE COMPETITIVE GEOTHERMAL PP

This idea may applicable under the situation of the electricity business in Indonesia only, which is the fuel oil is subsidized by Government. Some alternative to level the platform of geothermal steam with fuel oil are :

*Short term :*

1. Electricity tariff to End User currently is at about 3.0 cUSD/kWh, indicating this is not attractive business to the Electricity Buyer (PLN) as well as Power Producer and supposed also to the Steam Producer. It means this is not the level in which the Electricity Buyer, Power and Steam Producers collect an adequate return event more creating an ability to re-invest its business. 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 is to bear the worse impact under the current electricity tariff, then return of 34 % tax rate to the Electricity Buyer or Power Producer under the special mechanism will be very significant to the create attractiveness on 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 as much as that of the oil subsidy can also creating an attractiveness alternative of the geothermal business.
3. Some steam purchasing contract may apply TOP clause to guarantee further in how the Steam Developer to get adequate return with a lower minimum risk. It means, steam developer will have a very high security on its investment, but this scheme contradicts to a competitive paradigm. Steam Developer will not be effected by fluctuation in the market demand, which is very normal to occurs in any others business activity.

<u>*Medium term*</u> :

1. Insurance during exploration of the field. Exploration risk of each geothermal area may vary between one to others. 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 enables to create a risk sharing during the exploration activity of the field, which is identified as the most risky in developing the field.
2. In developing steam field, Steam Producer may build an access road, bridge and other infrastructure facilities that may also can be utilized by the nearby community in creating a higher economic growth to the local community. Then these facilities can be accounted as a tax deduction to the Steam Producer.

## 7. SUMMARY AND CONCLUSION

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

In order to make oil price approach is applicable, then there should be no more subsidy for fuel oil. At the same time there shall also no more subsidy to the electricity tariff.

The most effective strategy in developing geothermal potential is to give the first priority for geothermal area, which has a competitive investment cost, then continued by the more expensive reservoir area once the fuel reserves has 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 and the related steam price of higher than 4.3 cUSD/kWh, at well capacity lower than 3.5 MW/well.

Geothermal steam price will be very attractive, if its steam field investment cost lower than 786 USD/kW and the related steam price lower than 2.24 USD/kWh, at well capacity 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 cUSD/kWh.

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## 9. BIOGRAPHY

**Herman Darnel,** was born in Payakumbuh, 15 April 1954. Graduated from Bandung Institute of Technology on Electrical Engineering in 1979; Master degree on Electrical Engineering from University of Manchester Institute of Science & Technology in 1988. Working experience in PLN started as Supervisor of Protection and Telecommunication - Head Office PLN (1979 ~ 1987); Head of PLN Distribution Dispatch, South Sumatera (1987 ~ 1990); General Manager of PLN Tanjung Karang Branch Office (1990 ~ 1991); Deputy Head of PLN Regional Offices IV (1991~ 1994); Deputy Head of PLN Regional Offices East Java Distribution (1994 ~ 1995); Manager of Planning & Development PLN PJB I (1995 ~ 1998); Director of Development & Commerce PLN PJB I (1998 ~ 2000), Director of HRD – PT. Indonesia Power (2000 – up to now).

**Antonius Resep Tyas Artono,** was born in Blitar, 26 October 1963. Graduated from Institute of Technology of 10 November Surabaya on Chemical Engineering in 1986, Diploma degree in Geothermal Energy Technology – Geothermal Institute – University of Auckland – New Zealand – 1994. Working experience started as Laboratory Supervisor in Activated Carbon Industry (1987 ~ 1988); Utility plant Supervisor and continued as Chlor Alkali Plant Superintendent in Paper and Pulp Industry (1988 ~ 1993). The career in PLN was started as Chemical Engineer in PLN – Kamojang (1993~1994); Evaluation and Planning Engineer – PLN Kamojang (1998 ~ 1999); Marketing Staff – PT. PLN PJB I – Head Office – (1999 ~ 2000). Power Plant Business Development – PT. Indonesia Power (2000 – up to now).

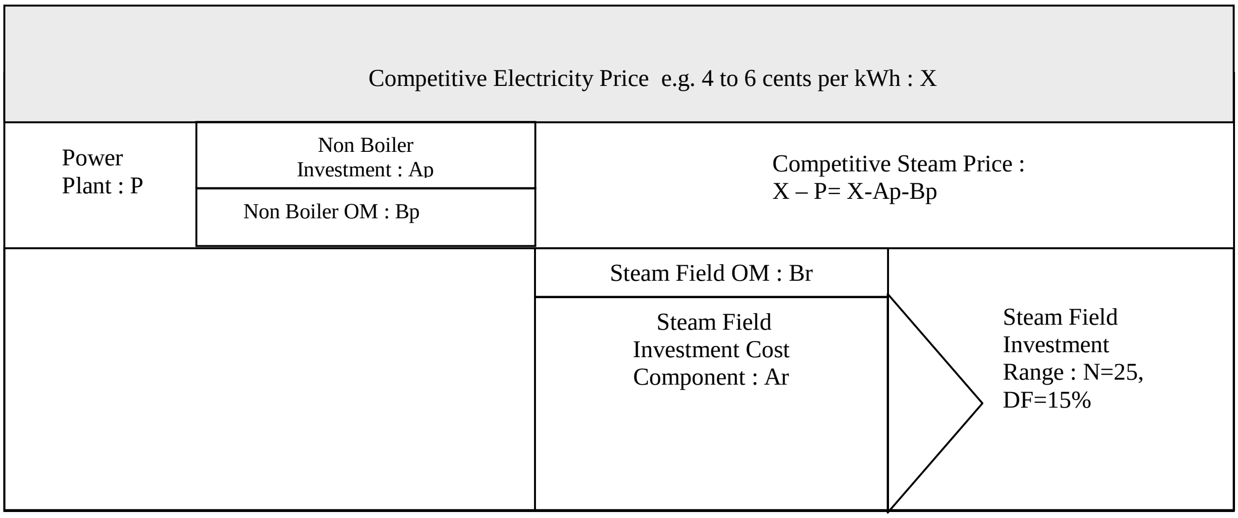
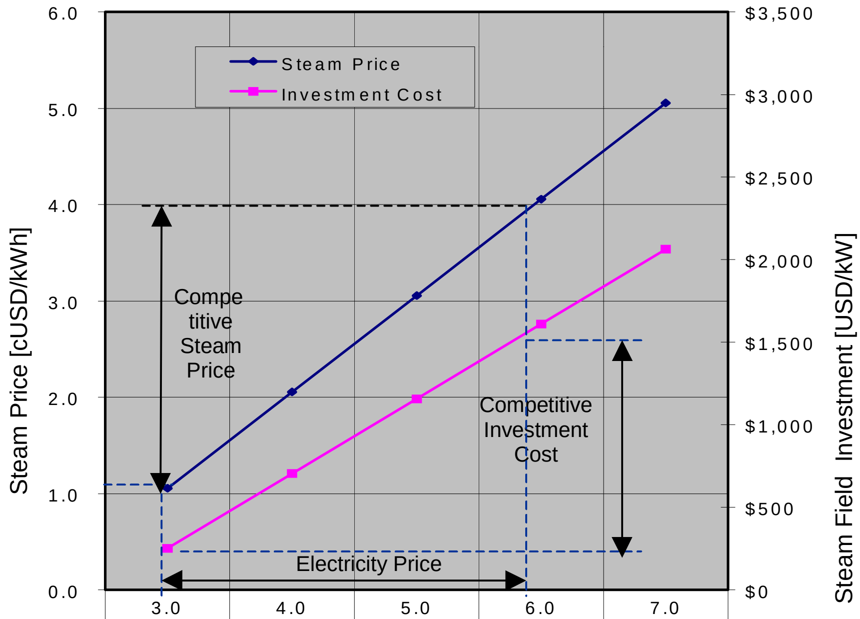



Figure-1
Illustration of Electricity Price Approach




| | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 |
|---|---|---|---|---|---|
| Steam Price | 1.055 | 2.055 | 3.055 | 4.055 | 5.055 |
| Investment Cost | $251.31 | $704.32 | $1,157.33 | $1,610.34 | $2,063.34 |

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

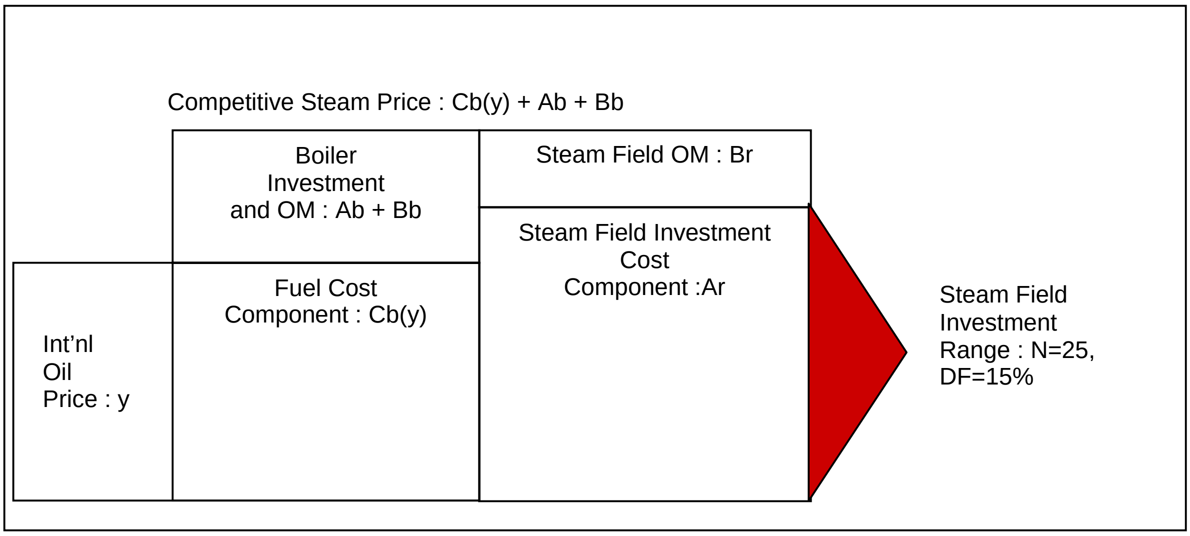
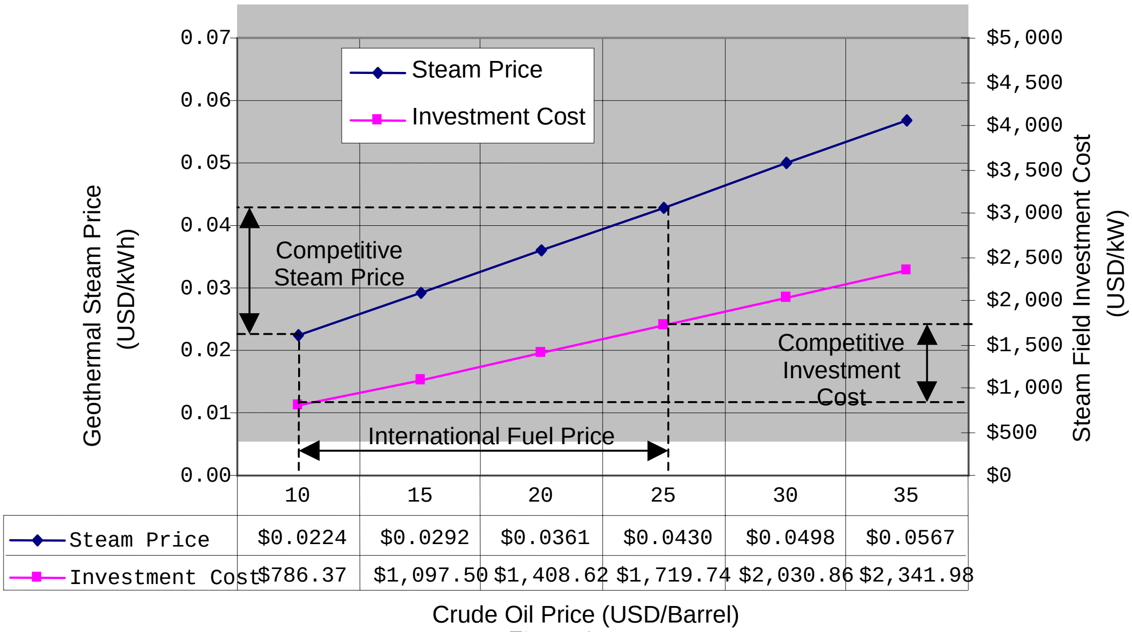



Figure-3
Illustration of Oil Price Approach




| | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|
| Steam Price | $0.0224 | $0.0292 | $0.0361 | $0.0430 | $0.0498 | $0.0567 |
| Investment Cost | $786.37 | $1,097.50 | $1,408.62 | $1,719.74 | $2,030.86 | $2,341.98 |

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

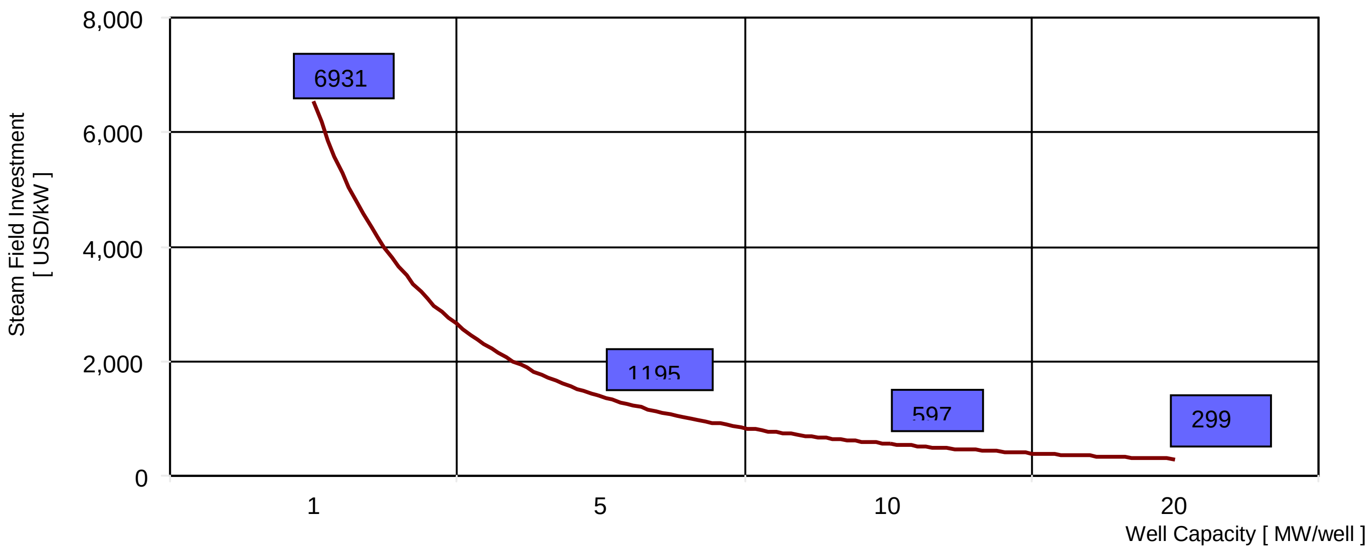



Figure-5
Well Capacity Vs Steam Field Investment Cost

Table-1
Assumption in Calculating Steam Price and Investment Cost of Steam Field

| No | Description | | Unit | |
|---|---|---|---|---|
| 1 | Project Life | | Years | 25 |
| 2 | Power Plant capacity | | MW | 55 |
| 3 | CF | | % | 80% |
| 4 | Interest +Risk+Profit | | % | 14% |
| | *Investment* | | | in 1000 USD |
| 5 | **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** |
| 6 | **Variable Component:** | | | |
| | | Drilling Wells | USD/well | 2,600 |
| | | Success ratio | % | 70% |
| | | O & M Charge | USD/kWh | 0.005 |
| | | Draw down | MW/year | 3 |
| 7 | Steam Field Capacity/Power Plant Capacity | | % | 110 |

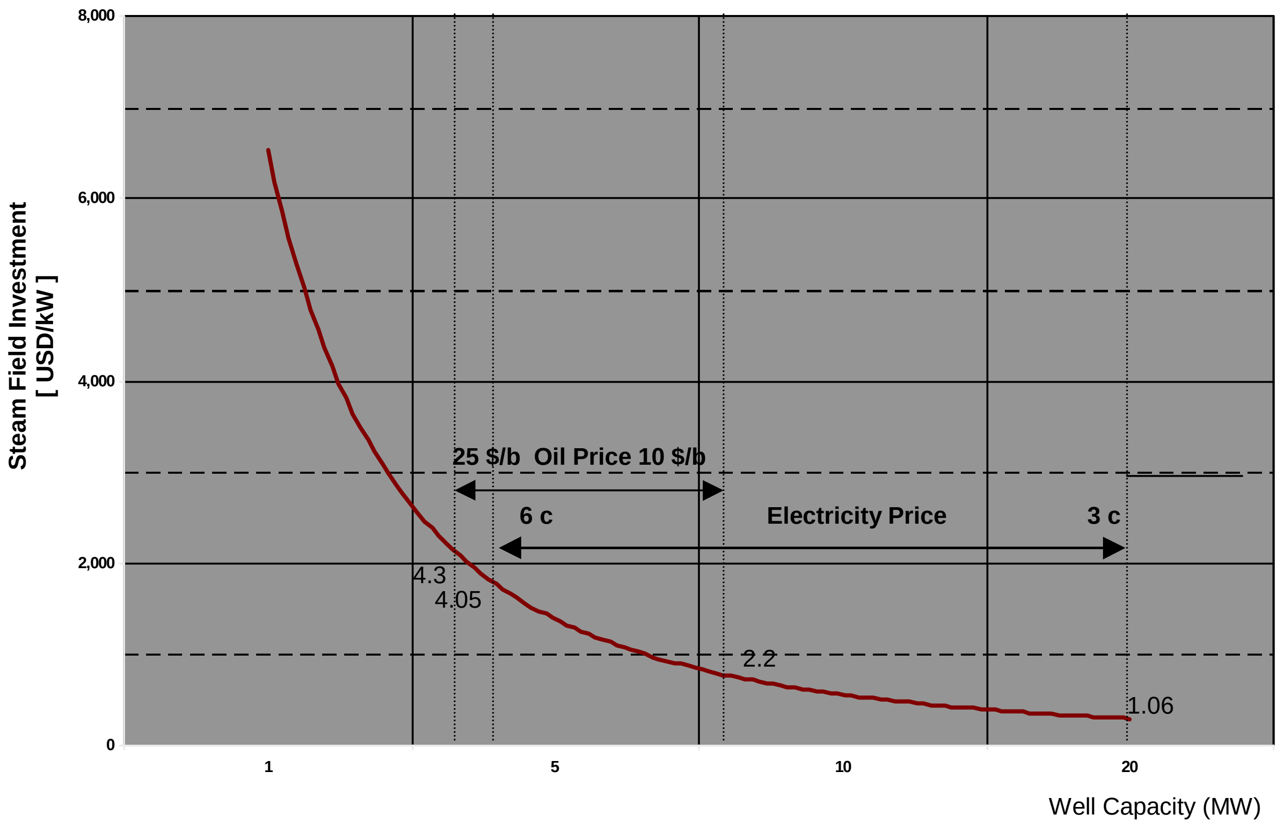



Figure-6
Result Comparison Among Electricity Price, Oil Price and Investment Cost Approaches.