·AN ECONOMIC COMPARISON BETWEEN CONVENTIONAL AND MODULAR GEOTHERMAL DEVELOPMENT MODELS

A. DANAR

Pertamina EP, Divisi Panasbumi, Jakarta, Indonesia

.SUMMARY - The priaary concern of the governaent's energy policy for geotheraal developaent is to deteraine the optiaua steaa price, The stean price should enable the geothernal producer to recover the pre-production investaent, operating expenses, governaent taxes and also to achieve an attractive rate of return, The steaa price should also enable the geotheraal user to ainiaize the generating cost of the geotheraal power plant,

This paper describes the conparison study of the econonics of two hypothetical 110 Megawatts geothernal developaent nodels: conventional and nodular, The conventional aodel is designed to deliver geothernal stear into two centrally located power plants, while the modular aodel is designed to deliver the steaa into six portable power plants located separately.

The nodular aodel requires a higher pre-production investnent, but due to a shorter pre-production period, the aodel is nore attractive econoaically,

1. INTRODUCTION

One of the aain objectives of the geothernal producers in developing the resources is to achieve an attractive internal rate of return (BOB), The level of the BOB is influenced by the scale of developlent and investaent, the expected life of the project, the type of the project, the stean price, the operating and aaintenance cost, the tax payment and sone other financial regulations, as well as the tiaing of the cash flow,

There ere several types of geothernal developnent project: one of then is the conventional project that has been applied in Indonesia. The other type is the nodular project that will be applied in Indonesia in the future. The conventional project is a geothernal developaent project by using large sized geotheraal power plants (nore than 30 HY each), while the aodular project is a geotheraal developnent project by using saall sited geotheraal power plants (less than 30 MW each).

The capital cost of a conventional project is less than a nodular one, but the construction tine is longer.' Large sized power plants have to be constructed in the field,' while sone saall sized power plants could be nade portable.

The geotheraal field that was used for this study is one of the fields located in West Java, Indonesia. The size of this field is about 15 square kns with an estimated electrical potential of 420 MW. in this study, it is assuaed that the field will be developed with a capacity of 110 MW.

if a conventional project was chosen, it is planned to install two power plants of 55 KY each, On the other hand, if a nodular project was chosen, it is planned to install five portable power plants of 20 MW each plus one portable power plant of 10 HW.

This study is based on the following assuaptions :

a, The excess supply of steaa to each power plant is 10% of the power plant capacity,
b. The success ratio of exploration wells is 50% and the success ratio of development wells is 80%.
c. The water fraction of the geotheraal fluid fron the well is 40% and the water condensation in the power plant is 20%.
d. The average production rate of a successful well is about 161,000 lbs per hour per well, consisting of 100,000 lbs of steaa and 67,000 lbs of brine water.
e. The average brine injection rate is 400,000 lbs per bour per well.
f. The steaa required to generate 1 kWh of electricity is equal to 20 lbs of steaa per hour.
g. The naxioun nunber of wells in one location is seven.
h. The aaxiaua number of rigs available for exploration drilling is two.
i. The aaxiaua number of rigs availzble for developaent drilling is five.
j. The base values are : 80% for the capacity factor of the power plant, 3.5% of the cuaulative capital cost for the operating and oaintenance cost, and 100% of the cost nodel for the capital cost.

k. · The production rate during the life tire of the project is forecasted by using an increasing erponential decline as follows :
- 0 % decline rate for the first five years
- 1 % decline rate for the second five years
- 2 % decline rate for the third five years
- 3 % decline rate for the fourth five years
- 4 % decline rate for the fifth five years
- 5 % decline rate for the sixth five years.

The cost aodel estiaation is based on tbe project planning by using the above nentioned assuaptions while the cash flow of the geothernal project is based on the cost rodel including the financial regulations in Indonesia.

The ROE of the resource project is calculated by using a Discounted Cash Plow Bate of Return (DCP-BOB), while the capital cost of póver plant is calculated by using a Capital Recovery Factor (annuity paynent)

An econoaic conparison of conventional and iodular geothernal developnent aodels and the sensitivity analyses of the project BOR upon the steaa price, the capacity factors, the operating and maintenance costs, and the capital costs, are described in this paper,

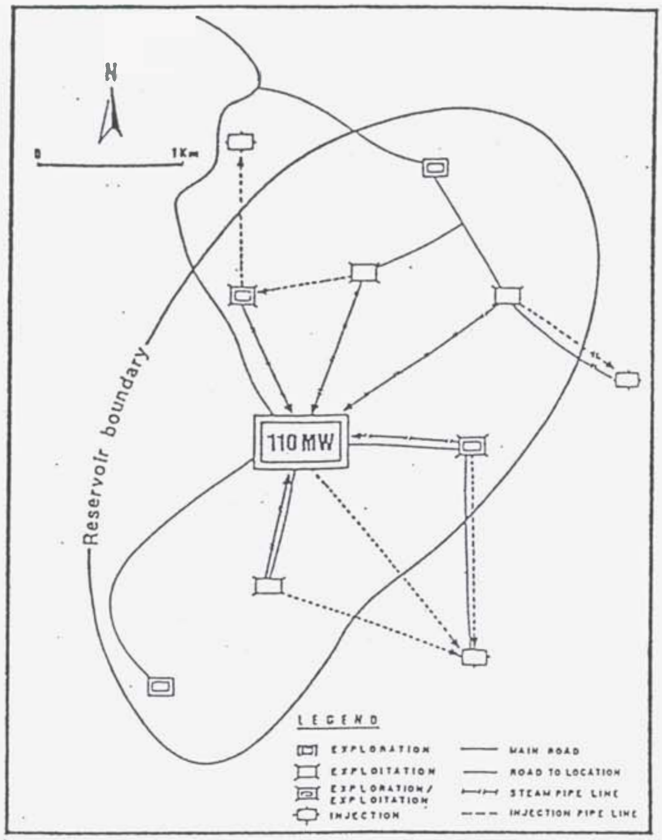

Figure 1- Conventional Geotheraal Developaent Hodel

2. PBOJXCF PLAKXIWG

2.1 Project Specification8

Conventional aodel

To develop geothermal recource by using the conventional aodel, the producer should build 11 Kas of roads and prepare 10 well locations as shown in Figure 1.

The nunber of wells to be drilled during the developoent (pre production) period is 39, consisting of 4 exploration wells, 28 exploitation wells and 7 injection wells, Assuaing 2 exploration wells and 6 exploitation wells are not successful, so 22 wells will be used as production wells and 2 others will be used as standby wells,

The stean pipe length is about 5.25 Kas with a diaaeter in the range of 28' to 32", while the length of the injection pipe is approxiaately 8.75 Kas with a diaaeter of about 12" to 16",

To eaintain the level of stean delivery during the production period (30 years) as aany as 46 additional aake up wells have to be drilled.

Hodular node1

The producer will build 11 Kas of roads and prepare 11 well locations as shown in Figure 2.

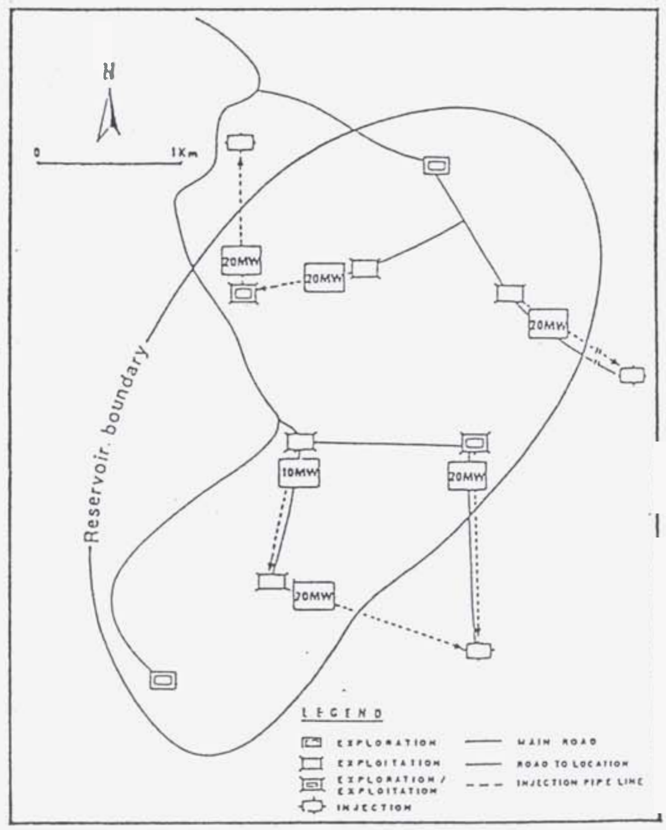

Figure 2- Hodular Ceothernal Developaent Hodel

The nuaber of wells to be drilled during the pre production period is 45 wells; consisting of 4 exploration wells,' 35 exploitation wells, and 6 injection wells.

Assuming 2 exploration wells and 9 exploitation wells are not successful, so 22 wells will be used as producing wells and 6 others will be used as standby wells.

The attar pipe line length in about 3.4 Kms with a diareter in the range of 16' to 28", while the length of the injection pipe is approximately 9.8 Kms with a diaaeter about 6' to 16".

Po maintain the level of steam delivery during the production period as many as 56 additional rake up wells will be drilled.

2.2 Schedule of the Project

Conventional model

The project period is divided into two phases, the pre production period and the production period. The pre production period will be conpleted in 6 years and the production period is estinated to last for at least 30 years after the pre production period,

As shown in Figure 3, the activities to be carried out in tbe pre production period consist of :

- Roads and locations, from the first year to the third year (27 aonths)
- Bxploration drilling, froa the first year to the second year (9 aonths) .
- Exploitation drilling, froa the second year to the fourth year (27 aonths)
- Reservoir study, for the first year to the second year (12 aonths)
- Bnvironnent study, froo the first year to the second year (12 aonths)
- Bngineering design of pipe line, in the fourth year (6 aonths)
- Construction of pipe line and production facilities, froa the fourth year to the fifth year (30 ronths)
- Office and housing, in the fifth year (12 months)
- Coaaercial operation, to be started at the beginning of the seventh year,

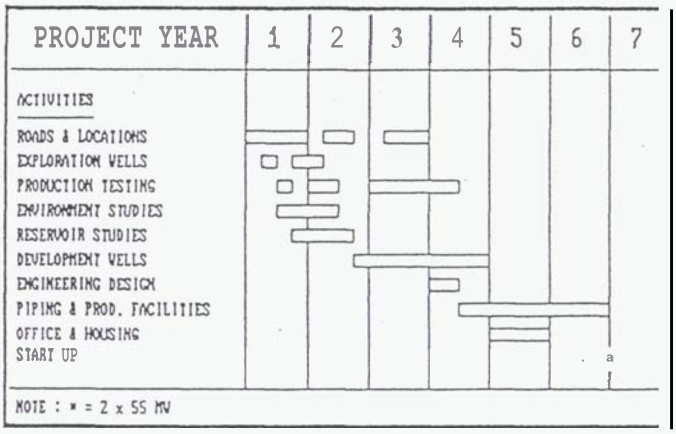

Figure 3- 110 MW Geothermal Project Planning (Conventional Hodel)

Hodular model

As shown in Figure 4, the activities to be carried out in the pre production period consist of :

- Roads on locations, from from the first year to the fourth year (30 ronths)
- Bxploration drilling, froi the first year to the second year (9 ronths)
- Bxploitation drilling, froi fror the second year to the fifth year (33 Months)
- Reservoir study, from the first year to the second year (12 ronths)
- Bnvironnent study, fror the first year to the second year (12 months)
- Engineering design of pipe line, from the third year to the fifth year (24 ronths)
- Construction of pipe line and prodaction facilities, froa the fourth year to the sixth year (30 rontbs)
- 'Office and housing, in the fourth year (12 months)
- Commercial operation to be started at the beginning of the fifth year.

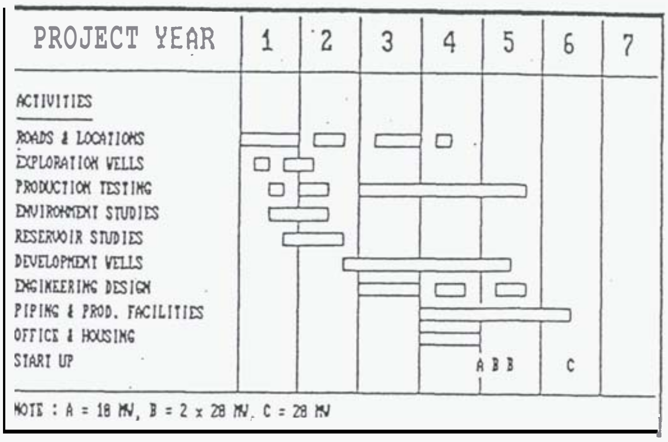

Figure 4- 110 MW Geothermal Project Planning (Hodular Hodel)

3. COST MODELS

3.1 Conventional Hodel

The total pre production investaent expenditures of the project is estiaated to be about US$ 87,700,000, distributed to roads and locations (4.3%), wells (74.8%), piping and production facilities (19.4%), office and housing (1.1%) and otber expenses (0.4%).

As shown in fable 1, the largest part of the cost (39.93) will be spent in the third year and the least (7.5%) will be spent in the sixth year,

In the production period, the tot21 expenditures for make up wells is estinated to be about US$ 78,200,000 and the annual operating and maintenance cost is estinated to be about 3.5% of the cuaulative capital cost,

The capital cost of a geothernal power plant of 55 MW size is about US $ 950 / KW (excluding interest during construction).

The capital cost disbursesent of this power plant is about 25% in the first year, ?0X in the second jear and 5% in the third year,

3.2 Nodular Model

The total pre production investment expenditures of the project is estinated to be about US$ 93,400,000, distributed to roads and locations (4,4%), wells (81.3%), piping and production facilities (12.9%), office and housing (1.1%), and other expenses (0.3%).

As shown in Table 1, the largest part of the cost (38.0%) will be spent in the third year and the least (1.8%) will be spent in the sixth year,

In the production period, the total expendituree of make up wells is estimated to be about US$ 95,200,000, and the annual operating and maintenance cost is estimated to be about 3.5% of the curulative capital cost.

The capital cost of a geotheraal power plant of 10 MW or 20 MW size is about US$ 1,375 / KW (excluding interest during construction), The capital cost disbursenent of this power plant is about 65% in tbe first year and 35% in the second year,

Table 1- Pre Production Cost Estimation

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR b	TOTAL
ROADS & LOCATIONS							
CONVENTIONAL	1,675	1,175	950	-		-	3,000
MODULAR	1,675	1,175	1,150	100	-	-	4,100
WELLS							
CONVENTIONAL	4,900	9,900	34,000	16,000	-	-	65,600
MODULAR	4,900	9,900	34,000	23,600	3,500	-	75,900
STUDIES							
CONVENTIONAL	125	175	-				300
MODULAR	125	175	-				300
PIPING & PROD. FACILITIES							
CONVENTIONAL			-	3,000	6,600	6,698	17,000
MODULAR			300	8,100	2,000	1,700	12,100
OFFICE & HOUSING							
CONVENTIONAL			-	-	1,000	-	1,000
MODULAR		- .	-	1,000		-	1,000
TOTAL							
CONVENTIONAL	6,700	11,250	34,950	28,600	7,600	6,688	87,700
MODULAR	6,700	11,250	35,450	32,000	5,500	1,700	93,400

4. METHODOLOGY

4.1 Steam Price Calculation

There are two kinds of steae price; an econonic price and a financial price,

The econonic price is the price which is deterained without considering the financial distortion (such as tax, subsidies, etc.), while the financial price is the price which is calculated by taking the financial distortion into consideration,

This study is focussed to the financial price, because this price can recover the total investaent expenditures, the operating and maintenance costs, and the taxes, and fulfill the required rate of return for the project,

a. The ROR of the project is calculated by using this forrula :

$$\sum_{t=1}^{n} \frac{CF_t}{(1 + ROR)^t} = I_0$$

where :
CF_t = Cash flow in year t, US$
I_0 = Initial investment expenditures in year 0, US$
n = Expected life of the project, years
ROR = Internal Rate of Return, %.

b. While the cash flow is formulated as follows :

$$CF_t = R_t - O_t - T_t - I_t$$

where :
R_t = Revenue in year t, US$
O_t = Operating & eaintenance cost in year t, US$
T_t = Taxes in gear t, US$
I_t = Investment expenditures in year t, US$.

c, The aaount of the tares should be paid by the producer depends on the tax rate and other financial regulation (such as depreciation, investaent allowance, arortization, etc.) determined by the government. The applicable' tax rate for the geotheraal business in Indonesia is 46% of tbe taxable iocoae (the revenue deducted by operating and aaintenance cost, depreciation cost and investaent allowance), If the cuaulative taxable income is less than tero, then the tax payable by the geotheraal producer is also tero,

d, Annual depreciation cost is calculated by using this foraula :
year 1 : 1/8 x (Capital - intangible well cost)
year 2 : 1/8 x (Capital - intangible well cost)
year 3 : 3/8 x (Capital - intangible well cost)
year 4 : 1/8 x (Capital - intangible well cost)
year 5 : 1/8 x (Capital - intangible well cost)
year 6 : 1/8 x (Capital - intangible well cost)

?he intangible well costs applied in this paper is 70% of the well costs.

e. Investment allowance which can be charged to taxable income is 20 % of the capital cost after deduction of the intangible well costs,

4.2 Generation Cost

The generation cost of geothermal power plant consists of the capital costs, the operating and naintenance costs and the steae price.

a. The capital cost of the power plant per KWh is calculated by using this forrula :

$$Ck = (CRF \times TC) / (CPP \times H)$$

where :
Ck = Capital cost per KWh, $/KWh
CRF = Capital recovery factor, %
TC = Total capital cost per KW, $/KW
CPF = Capacity factor, %
H = Nuaber of hours in one year = 8,760 hours.

b. The capital recovery factor is calculated by using this forzula :

$$CRF = ((1 + i)^n \times i) / ((1 + i)^n - 1)$$

where : i = interest rate, %.

5. DISCUSSION

5.1 Resource Economics

a, As shown in Figure 5, it can be seen that :

a.1 The ROR of the project will vary fron 9.17 to 17.66% (for the Conventional aodel), and fron 10.31 to 20,831 (for the aodular nodel); both within the range of steaa price between 25 and 50 mills/KWh.

a.2 The steaa price of the project will vary from 40.24 to 59.81 mills/KWh (for the conventional model), and froa 34.62 to 47.58 mills/KWh (for the aodular rodel); both within tbe range of ROR between 15 and 20%.

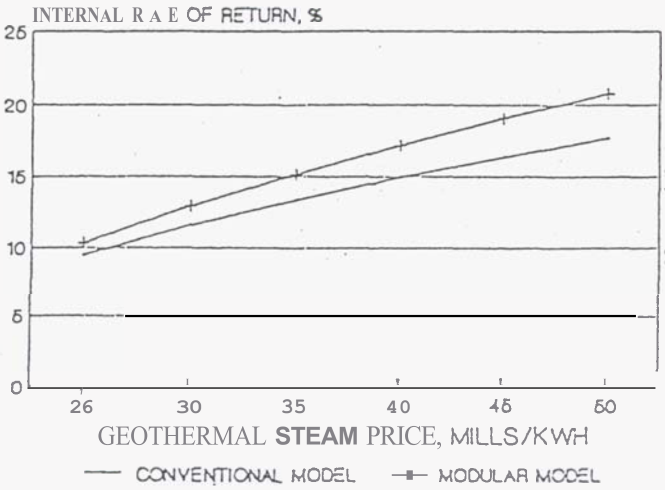

Figure 5- ROR versus Steam Price (Base Case)

b. As shown in Figure 6, it can be seen that changes of the capacity factor will have some effects as explained below :

b.1 If the capacity factor is equal to 75% then the ROR will vary from 8.73 to 16.85% (for the conventional nodel),' and fror 9.39 to 19.37% (for the nodular nodel); both within the range of stear price between 25 and 50 mills/KWh.

b.2 If the capacity factor is equal to 85% then the ROR will vary from 10.15 to 18.43% (for the conventional rodel), and fron 11.19 to 21.871: (for the modular rodel); both within the range of stear price between 25 and 50 mills/KWh.

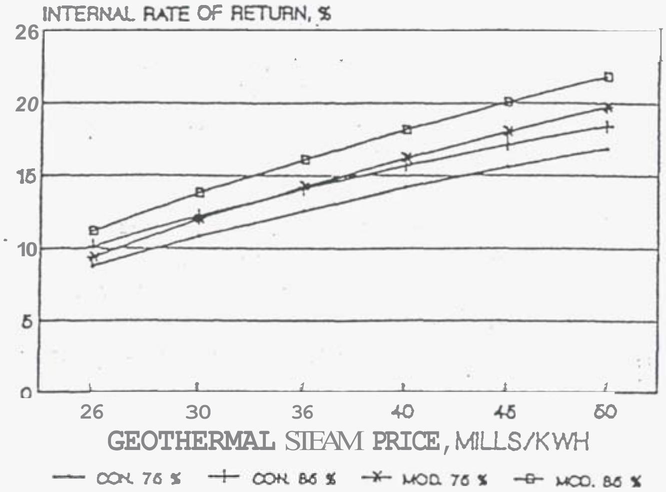

Figure 6- ROR versus Steam Price
(based on Capacity Factor Changes)

c. As shown in Figure 7, it can be seen that changes of the operating cost will have some effects as explained below :

c,1 If the operating cost is equal to 3% of the cuaulative capital cost then the ROR will vary from 9.74 to 17.811 (for the conventional nodel), and fron 10.64 to 20.99% (for the nodular nodel); both within the range of stean price between 25 and 50 mills/KWh.

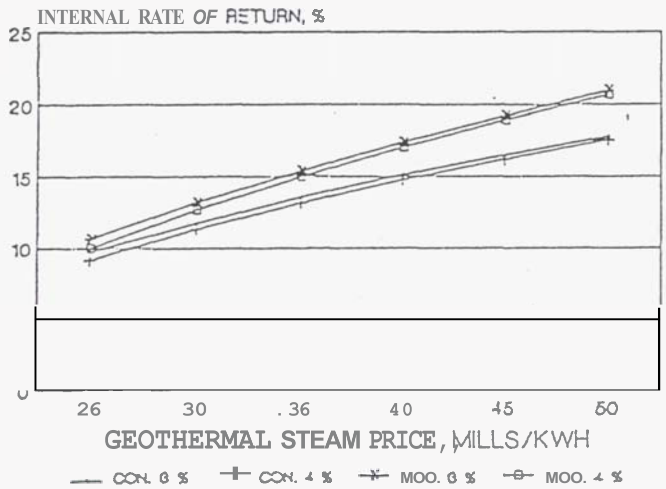

Figure 7- ROR versus Steam Price
[based on Operating Cost Changes)

c.2 If the operating cost is equal to 4% of the curulative capital cost then the ROE will vary fror 9.18 to 17.51% (for the conventional model), and froh 9.97 to 20.67% (for the modular rodel); both within the range of stear price betueen 25 and 50 mills/KWh.

d. As shown in Figure 8, it can be seen that changes of the capital cost will have some effects as explained. below : .

d.1 If the capital cost is 10% lower than the base capital cost then the BOB will vary froa 10.54 to 18.92% (for the conventional nodel), and froi 11.76 to 22.54% (for the modular rodel); both within the range of stear price between 25 and 50 mills/KWh.

d.2 If the capital cost is 10% higher than the base capital cost then the ROR will vary froa 8.50 to 16.55% (for the conventional rodel), and fron 9.10 to 19.34% (for the aodular nodel); both within the range of steam price between 25 and 50 mills/KWh.

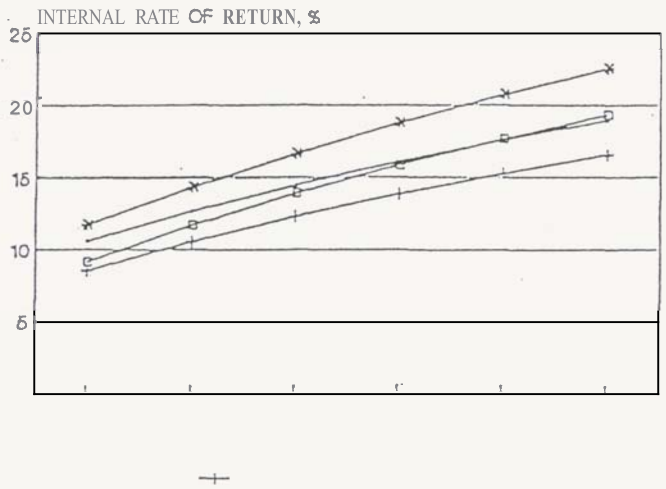

Figure 8- ROR versus Steaa Price
(based on Capital Cost Changes)

5.2 Generation Cost

a, By using an interest rate of 12X and an expected power plant life of 30 years, the capital cost of the power plant is found to be 21.63 mills/KWh for the conventional type, and 29.41 mills/KWh for the modular type.

b. As shown in Figure 9, it can be seen that the generation cost (excluding the power plant operating cost] for the conventional type will vary froa 61.87 to 81.44 mills/KWh, and for the nodular type fron 64.03 to 76.99 mills/KWh; both within the geothernal resource project's ROE fron 15 to 20%.

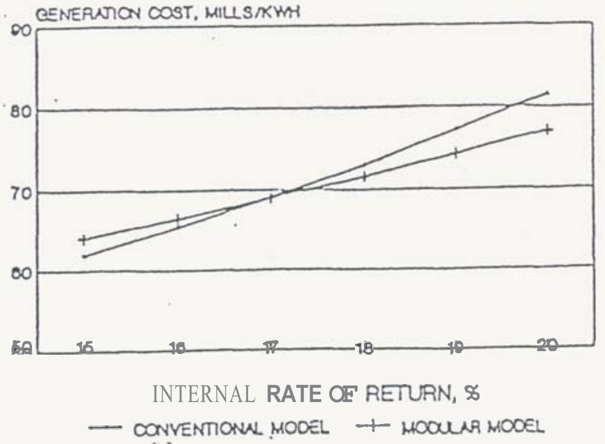

Figure 9- Generation Cost versus ROB
(Base Case, excl. O&M Cost]

6. CONCLUSIONS

a. Although the pre production cost for the nodular model is nore expensive 'than the conventional nodel, its steaa price is cheaper. This is due to the faster start up of the rodular project.

b. Coaparing the capacity factors of 75, 80 and 85%; the ROR of the project is the most sensitive on tbe steaa price changes if the capacity factor is equal to 85%.

c. Coaparing the annual operating costs of 3, 3.5 and 4% of the cumulative capital cost; the ROR of the project is the aost sensitive on the steam price changes if the annual operating cost is equal to 4% of the cuaulative capital cost,

d. Comparing tbe capital costs of 90, 100 and 110% of the base capital cost; the ROR of the project is the most sensitive on the steaa price changes if the capital cost is equal to 90% of the base capital cost.

e. If the ROR of the geotberaal resource project is equal to 17% or greater, then the electricity generation cost for the aodular type is cheaper than the conventional type, assuming the geothernal power plant operating costs are the saw for both types,

f. If the ROR of the geothernal resource project is between 17 and 20%, then the electricity generation cost for the modular type is cheaper than the conventional type, as long as the difference of the geotberaal power plant operating cost between the nodular type and the conventional type is less than 0.16 (at 808 of 17%) and 4.45 mills/KWh (at ROR of 20%).

g. The econooics of the project could be improved by increasing the capacity factor, reducing the annual operating cost, reducing the capital cost and shortening the pre production period,

7. ACKNOWLEDGEMENTS

The author would like to thank the Management of PERTAMINA for' pernission to publish this paper. thanks also due to Mr. Ian Butcheson, Mrs. futi Danar, Mr. Alex Hanif, and others for preparing this paper.

8. REFERENCX3

Danar A. (1989). Project Proposal Evaluation : Basic Concepts And Geothernal Development Project Case Studies. Jakarta.

Danar A.,C.S. (1990). Economic Aspects of Geothermal Development in Indonesia, The 12 th New Zealand Geothermal Workshop, Auckland.

Haim Levy & Marshall Sarnat (1915). Capital Investment and Financial Decisions. Prentice Hall International Inc., New York, Fourth Edition.

PERTAMINA (1990). Technical And Economic Aspect Studies of Geothernal Developxent. Indonesia Institute For Energy Economics Seminar, Jakarta.

Sosrokoesoeno A.S.S. (1984). legal Aspect of- Geothermal Energy Source Undertakings in Indonesia. The ASEAN Geothernal Energy Seminar, Bandung.

Stone & Webster Engineering Corporation (1989). Geothermal Power Plant Study. Denver, Colorado.