Make-up wells drilling cost in financial model for a geothermal project

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Abstract. After commissioning of a power plant, geothermal reservoir will encounter pressure decline, which will affect wells productivity. Therefore, further drilling is carried out to enhance steam production. Make-up wells are production wells drilled inside an already confirmed reservoir to maintain steam production in a certain level. Based on Sanyal (2004), geothermal power cost consists of three components, those are capital cost, O&M cost and make-up drilling cost. The make-up drilling cost component is a major part of power cost which will give big influence in a whole economical value of the project.

The objective of this paper it to analyse the make-up wells drilling cost component in financial model of a geothermal power project. The research will calculate make-up wells requirements, drilling costs as a function of time and how they influence the financial model and affect the power cost. The best scenario in determining make-up wells strategy in relation with the project financial model would be the result of this research.

1. Life cycle of a geothermal field
A geothermal field has a life cycle that is different with other energy resource. It consists of four periods: (1) Developing, (2) Sustaining, (3) Declining and (4) Renewable [2]. In developing period, the increments of a plant capacity come in line in steps. In sustaining period, the output of the field remains steady over an extended period of time. The declining period begins when the underlying declines in the capacity of individual wells become evident in the actual output of the entire facility. The renewable period would achieved when the field reach a state in which net mass withdrawals in production stage and the operations are still profitable at this level.

A geothermal power plant is built to generate a specific capacity that requires a certain supply of geothermal steam. One of the consequence in a continuing operation of a geothermal field is decreasing in production of steam. A lowering production to below the limit would cause a reduction in plant output. A continued reduced output would reducing the economic value of the project along with inability to meet previous contract with the electricity buyer.

Typically, a developer will drill enough wells at the early period of the project to be able to meet plant capacity requirement, even set a limit of minimal surplus capacity at the wellhead to anticipate declines in well productivity. Later, when previous production wells have decreasing production, constant output is sustained by drilling make-up wells [2].
2. **Flowchart of this paper**

The objective of this paper is to analyze make-up well cost component in a financial model of a geothermal power project. In this research, synthetic data is used to calculate make-up wells requirement to maintain sustainability electricity production of 55 MW plant with project lifetime 30 years. The data is obtained from sample case in a geothermal field in Indonesia. The project is assumed to starts in 2017 with four years allocation time for exploration, feasibility study stage and plant development. The field is estimated to start producing electricity by 2021. The complete flow chart of this research is in figure 1.

![Flowchart](image_url)

**Figure 1.** Working flowchart of the research
Data collection is the first step done from this research. The required data is:

1. Well data retrieved from exploration and production wells
2. Surface facilities data, that include separator pressure, turbine characteristics and other surface facilities components

Those data is required to determine required minimum steam supply to generate total capacity of 55 MW and accommodate 10% of excess steam supply to calculate required number of production wells. Then the data is used to calculate required number of make-up wells. The number of make-up wells and its drilling cost then put into a geothermal financial model.

The financial model will calculate make-up well cost together with other parameters, including exploration, well drilling, O&M and other costs, as well as revenue, tax, interest and all parameters that built the model. The model then will be used to evaluate value of the project using some financial parameters as NPV (Net Present Value), IRR (Internal Rate of Return) and PBP (Payback Period).

This research will study make-up wells cost as one of component in a financial model. Evaluation of the project with NPV, IRR and PI calculation would be done only to describe variation of those financial indicators related with different strategy in make-up wells drilling. Calculation will be done using basic financial model with expected result NPV > 0 and IRR > 16%. The IRR number is retrieved from Abadi Purnomo (2007) stated that ideal IRR of a geothermal project is 16%.

3. Required parameters to calculate make-up wells
Miller stated that the term ‘make-up’ wells are applied to all wells drilled after plant start-up [3]. The timing of the drilling of make-up wells and the number of those wells can make the difference between project economic success and failure. The required number for make-up wells and the timing of drilling those wells is directly dependent on some aspects as: plant capacity, life time of the project, capacity of production wells, decline rates of the field and the minimum steam allowance.

Make-up wells are drilled to accommodate steam required by the geothermal plant to be able to produce certain capacity. There are some parameters that need to be determined to calculate the number of make-up wells required in a geothermal field for a specific lifetime project. The most important parameters are plant capacity, lifetime of a project, average flow rate of geothermal well and steam consumption rate to produce electricity. All calculation in this research use data from a synthetic field of a steam dominated geothermal plant in Indonesia.

### Table 1. Parameters of the field and calculation of number of wells required as production wells in the beginning of the project.

| No. | Parameter                                | Value       | Symbol  |
|-----|-----------------------------------------|-------------|---------|
| 1   | Plant Capacity                          | 55          | MWe     |
| 2   | Lifetime project                        | 30          | year    |
| 3   | Turbin Input Pressure                   | 6.5         | bar     |
| 4   | Turbin Efficiency                       | 85%         | Ƞt     |
| 5   | Steam flow rate                         | 371         | ton/h   |
| 6   | Specific steam consumption              | 6.7         | ton/h/MW|
| 7   | Average well production rate            | 20          | kg/s    |
| 8   | Steam fraction in well                  | 90%         |         |
| 9   | Steam flow rate from a well             | 18          | kg/s    |
| 10  | Total mass flow rate (required)         | 114.6       | kg/s    |
| 11  | Well drilling success ratio             | 80%         |         |
| 12  | Average well capacity                   | 9.6         | MW      |
| 13  | Required production wells               | 8           | unit    |

Make-up wells calculation parameters
Some parameters in table 1 determined based on data on synthetic field in a steam dominated geothermal field in Indonesia. Some others are calculated based on previous data. Calculation in this paper use specific steam consumption 6.7 ton/hour/MW and plant capacity 55 MW. Based on the calculation, the requirement of productions wells that have to be drilled in the beginning of the project is 8 wells with each well have flow rate 20 kg/s or able to produce 9.6 MW in average. It means that the geothermal plant need steam supply similar to 114.6 kg/s to be able to produce 55 MW in electricity. The requirement is fulfilled by drilling 8 production wells with flow rate 18 kg/s and turbine efficiency 85%, or capacity 9.6 MW/well.

At initial production, there are 8 production wells that produce steam to fulfil plant requirements. Concomitant with time, the field will have production decline due to lowering pressure, scaling or other factor and the production will decline. Then the make-up wells need to be drilled to fulfil steam production requirement.

4. Calculating make-up wells

To be able to calculate the number of make-up wells, there are some other parameters required. Those are: excess steam, minimum steam supply and decline rate. Excess steam is a level of surplus in steam production to maintain supply to geothermal plant above minimum requirement. In this research the calculation for make-up wells will use excess steam 10%. Minimum steam supply is a number of minimum steam production supplies to geothermal power plant. With excess steam 10% then the minimum supplies value is 110% of plant requirement. Decline rate is directly related to wells capacity to supply steam to geothermal power plant. Well productivity decline rates may vary widely in different geothermal fields. In this paper decline value is determined in 3% per year as stated in Adiprana (2015). Those parameters are calculated in order to determine the required time to drill make-up wells and number of wells to be drilled. Specific values of each parameter are in table 1.

Based on table 1, minimum flow rate to be applied to supply a 55 MW geothermal plant is 114.6 kg/s or equal to 55 MW. But ideal requirement is about 60.5 MW considering 10% excess steam requirement. Thus, when production rate almost reach 60.5 MW or below, the field needs addition supply, which can be accommodated by drilling make-up wells.

However, there are some limitations that need to be considered in make-up wells drilling procedure as:

1. The real decline rate is vary through the year and wells, but in this research we use similar decline rate for the field to forecast the production decline in whole period of plant (30 years)
2. The minimum number of wells drilled in a drilling campaign period is 2 or 3, considering the high rig mobilization cost. This research will use different number of minimum wells drilled in a drilling campaign period as part of determining make-up wells strategy.
3. Success rate of well make-up well drilling will affect the number of required well drilling in each drilling campaign period. Calculation in this paper will use success rate 80%.
Figure 2 contains make-up wells strategy for the whole 30 years of project. The field needs 8 make-up wells to maintain production level. Those wells need to be drilled in two drilling campaigns, four wells each, considering the 80% success ratio. The drilling time would be in year 8 (2029) and year 25 (2046) with assumption that the project start in 2017 (for exploration and feasibility stage) and electricity production start in 2021.

5. Make-up well cost in financial model
Make-up well drilling is treated as an occasional operating cost allocated to the years in which is anticipated that additional drilling will be required [1]. Inserting the make-up wells drilling into financial model must consider some important parameters, as inflation and depreciation.

Inflation is defined as a sustained increase in the general level of prices and usually measured as an annual percentage increase (Investopedia). In make-up wells cost component, the cost is increasing with a certain degree of inflation. The escalation cost is influenced by initial drilling cost in the start of the project, inflation rate and year, the longer drilling time from year start of the project and the higher inflation rate, the more costly the drilling price would be.

The calculation of make-up well cost is using initial cost of make-up well drilling as USD 8 million per well in start year of the project (2017), and inflation rate based on US PPI (United States Producer Price Index) 2.5% in January 2017.

The more detailed calculation of present make-up well cost is in APPENDIX A. Based on previous calculation, the additional make-up wells are required in year 8 (2029) and year 25 (2046) of the project. Considering inflation, the required cost to fund 4 make-up wells drilling in 2029 is USD 38.98 million and USD 59.33 million in 2046. The total cost to drill make-up wells for the whole project is USD 98.3 million.

6. Geothermal financial model
Every geothermal project is different with others because each of them has their own resource characteristics with different risks and opportunity. The cost driver also behaves differently under different conditions. Sanyal stated that geothermal power cost consists of three components, those are capital cost, O&M cost and make-up drilling cost [5]. The make-up drilling cost component is a major part of power cost because it requires big amount of money that must be spent during the plant project.
A financial model is anything that is used to calculate, forecast or estimate financial numbers. A valuable financial model integrates accurately all the costs throughout all phases of development and presents the resulting information in a manner to help various users make the appropriate decision (Ngugi, 2014). One of the objectives of this paper is to provide analysis on technical aspect of a geothermal project, focusing on make-up wells cost to apply in a proper financial model of the project.

The research will not focus on detailed data on specific process and determined cost in a financial model, yet it will explain about how to put the make-up well cost properly in the structure of general geothermal financial model.

6.1. Make-up well cost in geothermal financial model

A financial model in general is designed to meet the information need of investor and decision maker with objective to consider whether the investment for the project is viable. The model is consists of four financial statements that prepared annually in most cases, present the result and financial position of a project (or a company) by a certain date (Ngugi, 2014). Those are:

1. **Income statements**
   The objective of income statement is to establish the profitability of the project. The main elements in this statement are revenue, expenses, depreciation, interest and tax.

2. **Balance sheets**
   This statement detailed financial position and consists of two major grouping, the assets and the equity and liability.

3. **Cash flow statement**
   This statement mainly account for the cash availability to the company or project owner. Amount of the cash accounted will define how much it can meet its financial obligation. The statement is divided into three major segments: cash flow from operation, cash flow from investment activities and cash flow from financing activities.

4. **Statement of owner’s equity**

The make-well costs are included in a geothermal financial model in some statements as:

- Operating expenses in Cash Flow Statements, that encompass all cost directly and indirectly associated with the generation of the sold energy
- Depreciation expenses, because the make-up well cost is applied depreciation with a straight line or fixed percentage deduction or other depreciation method applied

6.2. Make-Up Well Cost in Cash Flow Statement

Make-up wells cost is occasional operating cost which allocation years and amount is retrieved from previous calculation in table 2. Forecasting the year of required drilling time needs technical calculation while the amount of required cost would be affected by inflation rate. If there is more than one power plant unit in the project, calculating the requirement of make-up well and forecasting their cost must be done for each unit.

6.3. Make-up Well Cost in Depreciation Expense

Depreciation is an accounting method of allocating the cost of tangible asset over its useful life. A business financial model will depreciate long-term asset for both tax and accounting purposes. For tax purpose, businesses can deduct the cost of the tangible assets as business expense. For accounting purpose, depreciation expense does not represent a cash transaction but it indicates how much of an asset’s value has been used up over time.

Calculation depreciation of make-up well cost will provide better basis for investment decision. The life of a make-up well would be calculated based on the time it was drilled. There are some methods to calculate depreciation: the Straight Line and the Double Declining method. Besides choosing the method, calculating depreciation also must consider the depreciation period time.
6.4. Make-Up Well Cost in Balance Sheet
Make-up Wells are considered as fix asset with book value calculated by taking the cost minus the accumulated depreciation. Book values of make-up wells cost are carried in the balance sheet with other fix assets as exploration book value and power plant.

7. Make-up well cost in determining investment feasibility of a project
Make-Up well cost will determine the feasibility of a geothermal project. Make-up wells drilling cost is varying with range USD 3.2 Million (SKM, 2009) to 6 Million (Sudarman, 2012). The cost will increase along the time and will be allocated as operating cost for the whole project. The huge cost of make-up wells drilling along the project would affect the investment feasibility.

Some financial indicators as Nett Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PBP) determine investment feasibility of a geothermal project.

7.1. Nett Present Value (NPV)
NPV is equal to present value of cash flow substract with initial investment, which represented by following formula:

\[ NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 \]  

(1)

With \( r \) is internal rate of return (IRR), \( C_0 \) is initial investment, \( C_t \) is cash flow in Year \( t \) and \( n \) is period of investment in year. Positive NPV indicate that the present value of cash flow is more than initial investment. Investor would need positive NPV that represent they have benefit from their investment.

7.2. Internal Rate of Return (IRR)
IRR is the discount rate that makes the present value of investment’s income stream total to zero. Following formula represents the IRR:

\[ \sum_{t=0}^{N} \frac{(CF_t)}{(1+IRR)^t} = 0 \]  

(2)

With \( CF_t \) is cash flow at year \( t \). The IRR is expected rate of return of the project that can be used to forecast margin. When the IRR is larger than the cost of capital, the project will generate a positive margin for the shareholder. Therefore a project with IRR greater than the cost of capital will increase the project worth.

7.3. Payback Period (PBP)
The payback period is the length of time required to recover the cost of an investment. This indicator is important to determine whether to undertake the position or project, as longer payback periods are usually not desirable for investment position. The amount of make-up wells cost along the whole time of the project will affect those financial feasibility projects. The huge cost that allocated for some periods of the project will influence NPV, IRR and Payback Period.

Calculation of those financial indicators would not be done in this research. That calculation would need further research and more complex parameters and project strategy that would not cover in this paper.

However, there are some factors that influence make-up wells calculation in cash flow that will generate different value of IRR, NPV and Payback Period. Those are:
1. Amount of initial well drilling cost
2. Inflation rate
3. Minimum well drilled in a drilling campaign period
4. Make-up well drilling success ratio
5. Allocated drilling time
Considering the time value of money, the bigger cost in the beginning of the project will generate smaller NPV and IRR and longer PBP. Further research must be done to find out how different strategy of make-up wells drilling strategy influences those indicators. The sensitivity analysis also needs to be done to determine how different strategy of make-up well drilling impact NPV, IRR and PBP.

8. Make-up well cost affect project financial
Determining when and how much make-up wells need to be drilled is one of production strategy. In technical view, the make-up wells should be drilled soon after production rate decreasing to the minimum requirement. In financial consideration make-up wells should be drilled in cost efficient strategy.

In this paper, we only present four scenarios. Actually, in the real world there are many possible scenarios regarding the number of required make-up wells to be drilled and when they are drilled. The research choose only four possible scenarios only based on minimum steam requirement and minimum wells drilled at one drilling period. In this research the limitation of minimum wells drilled in one drilling period is 3 wells, based on economical reason and experience in real case in geothermal field.

To be able to know how big make-up well cost affects the feasibility of a geothermal project, this paper will compare financial indicators from four different make-up wells strategy. Both are in the same field and use similar data as previously calculated. The differences between those scenarios are drilling time and the number of wells drilled in a drilling campaign period.

All the scenarios were analysed using basic geothermal financial model with constant cost and general assumption. The objective of this analysis is to compare the result of NPV, IRR and PBP indicator for different make-up wells strategies

8.1. Scenario 1
Based on figure 2, total make-up wells = 8 wells (4 wells in 2029 and 4 wells in 2046), total make-up well cost = USD 98.3 Million (APPENDIX A).

8.2. Scenario 2
Based on scenario 2 in figure 3, total make-up wells = 8 wells, all drilled in 2029, total make-up well cost = USD 77.97 Million (APPENDIX B).
8.3. **Strategy 3**

Based on scenario 3 in figure 4, total make-up wells = 8 wells (4 wells in 2029 and 4 wells in 2038), total make-up well cost = USD 87.68 Million (APPENDIX C).

![Steam Production](image)

*Figure 4. Make-up calculation of Scenario 3*

8.4. **Strategy 4**

Based on scenario 4 in figure 5, total make-up wells = 6 wells (3 wells in 2029 and 4 wells in 2042), total make-up well cost = USD 69.55 Million (APPENDIX D).

![Steam Production](image)

*Figure 5. Make-up calculation of Scenario 4*

Using scenario 1, 2, 3 and 4, financial indicators of the project are description in table 2.
Table 2: NPV and IRR and Payback.

| Scenario | NPV     | IRR   | Payback Period |
|----------|---------|-------|----------------|
| 1        | 74 Million | 17.5% | 11 years       |
| 2        | 66 Million | 16.5% | 11 years       |
| 3        | 72 Million | 17.4% | 11 years       |
| 4        | 77 Million | 17.8% | 11 years       |

9. Resume of 4 make-up wells strategies
Resume of analyses from previous make-up wells drilling strategies are as in Table below:

Table 3. Resume of financial model for all scenario

| Scenario  | Drilling Time | Total Make-Up Wells Cost (USD Million) | NPV (USD Million) | IRR (%) | Payback Period (Year) |
|-----------|---------------|---------------------------------------|-------------------|---------|-----------------------|
| Strategy 1 | 4 Wells 2029  | 98.32                                 | 74                | 17.5    | 11                    |
|           | 4 Wells 2046  |                                       |                   |         |                       |
| Strategy 2 | 8 Wells 2029  | 77.98                                 | 66                | 16.5    | 11                    |
| Strategy 3 | 4 Wells 2029  | 87.68                                 | 72                | 17.4    | 11                    |
|           | 4 Wells 2038  |                                       |                   |         |                       |
| Strategy 4 | 3 Wells 2029  | 69.55                                 | 77                | 17.8    | 11                    |

Based on calculation that had been done using financial model for 4 different make-up wells drilling strategies, there are some conclusions as:
- Different strategies in drilling make-up wells will require different cost
- Different time of drilling and number of make-up wells drilled will affect NPV and IRR of the project, but not significant
- Degree of IRR difference is between 0.1 to 6% or 0.16 to 1.2 point for average IRR Project 17.3%
- Amount of NPV difference is between 2.7 to 6% or USD 2 to 5 Million for average NPV project USD 73.75 Million
- The Payback Period is similar for all strategies

10. Conclusion
From this study, there are some points that need to be considered in calculating make-up wells requirement in a geothermal project and development. Calculations make-up well was not only based on required power plant and decline rate, but also financial factors of the developer and drilling vendor into the calculations that the optimum strategy. All calculation in those scenarios using electricity price USD 12 ¢/kWh
- The best IRR (17.76%) is obtained with make-up wells strategy that used fewest make-up wells
- The best NPV USD 98.32 Million is obtained with make-up wells strategy that used 8 wells in 2 drilling

Based on technical requirement, the make-up wells strategy could vary as long as the steam production not below the minimal production level. Then applying a make-up wells strategy should consider not only technical requirement, but also the financial consideration.

Suggestion for further work is to develop more accurate model to find the most optimum strategy of make-up wells scenario in a geothermal field.
11. References
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APPENDIX A. Calculation of required time, which is anticipated that additional make-up wells drilling is required and make-up well (Scenario 1)

| Production Year | Well Capacity (MW) | Required (MW) | Available before make up (MW) | Additional Make-up Wells | Available After Make-up (MW) | Make Up Well Cost (USD) |
|-----------------|--------------------|---------------|------------------------------|--------------------------|-----------------------------|-------------------------|
| 2021            | 55                 | 60.5          | 76.82                        | 0                        | 76.82                       | 0                       |
| 2022            | 55                 | 60.5          | 74.51                        | 0                        | 74.51                       | 0                       |
| 2023            | 55                 | 60.5          | 72.28                        | 0                        | 72.28                       | 0                       |
| 2024            | 55                 | 60.5          | 70.11                        | 0                        | 70.11                       | 0                       |
| 2025            | 55                 | 60.5          | 68.01                        | 0                        | 68.01                       | 0                       |
| 2026            | 55                 | 60.5          | 65.97                        | 0                        | 65.97                       | 0                       |
| 2027            | 55                 | 60.5          | 63.99                        | 0                        | 63.99                       | 0                       |
| 2028            | 55                 | 60.5          | 62.07                        | 0                        | 62.07                       | 0                       |
| 2029            | 55                 | 60.5          | 60.21                        | 4                        | 98.62                       | 38,988,893              |
| 2030            | 55                 | 60.5          | 95.66                        | 0                        | 95.66                       | 0                       |
| 2031            | 55                 | 60.5          | 92.79                        | 0                        | 92.79                       | 0                       |
| 2032            | 55                 | 60.5          | 90.00                        | 0                        | 90.00                       | 0                       |
| 2033            | 55                 | 60.5          | 87.30                        | 0                        | 87.30                       | 0                       |
| 2034            | 55                 | 60.5          | 84.68                        | 0                        | 84.68                       | 0                       |
| 2035            | 55                 | 60.5          | 82.14                        | 0                        | 82.14                       | 0                       |
| 2036            | 55                 | 60.5          | 79.68                        | 0                        | 79.68                       | 0                       |
| 2037            | 55                 | 60.5          | 77.29                        | 0                        | 77.29                       | 0                       |
| 2038            | 55                 | 60.5          | 74.97                        | 0                        | 74.97                       | 0                       |
| 2039            | 55                 | 60.5          | 72.72                        | 0                        | 72.72                       | 0                       |
| 2040            | 55                 | 60.5          | 70.54                        | 0                        | 70.54                       | 0                       |
| 2041            | 55                 | 60.5          | 68.42                        | 0                        | 68.42                       | 0                       |
| 2042            | 55                 | 60.5          | 66.37                        | 0                        | 66.37                       | 0                       |
| 2043            | 55                 | 60.5          | 64.38                        | 0                        | 64.38                       | 0                       |
| 2044            | 55                 | 60.5          | 62.45                        | 0                        | 62.45                       | 0                       |
| 2045            | 55                 | 60.5          | 60.57                        | 0                        | 60.57                       | 0                       |
| 2046            | 55                 | 60.5          | 58.76                        | 4                        | 97.17                       | 59,326,211              |
| 2047            | 55                 | 60.5          | 94.25                        | 0                        | 94.25                       | 0                       |
| 2048            | 55                 | 60.5          | 91.42                        | 0                        | 91.42                       | 0                       |
| 2049            | 55                 | 60.5          | 88.68                        | 0                        | 88.68                       | 0                       |
| 2050            | 55                 | 60.5          | 86.02                        | 0                        | 86.02                       | 0                       |
| 2051            | 55                 | 60.5          | 83.44                        | 0                        | 83.44                       | 0                       |
| Total           |                    |               | 8                            |                          |                             | 98,315,104              |
APPENDIX B. Calculation of required time, which is anticipated that additional make-up wells drilling is required and make-up well (Scenario 2)

| Production Year | Well Capacity (MW) | Required (MW) | Available before make up (MW) | Additional Make-up Wells | Available After Make-up (MW) | Make Up Well Cost (USD) |
|-----------------|--------------------|---------------|-------------------------------|-------------------------|----------------------------|-------------------------|
| 2021            | 55                 | 60.5          | 76.82                         | 0                       | 76.82                      | 0                       |
| 2022            | 55                 | 60.5          | 74.51                         | 0                       | 74.51                      | 0                       |
| 2023            | 55                 | 60.5          | 72.28                         | 0                       | 72.28                      | 0                       |
| 2024            | 55                 | 60.5          | 70.11                         | 0                       | 70.11                      | 0                       |
| 2025            | 55                 | 60.5          | 68.01                         | 0                       | 68.01                      | 0                       |
| 2026            | 55                 | 60.5          | 65.97                         | 0                       | 65.97                      | 0                       |
| 2027            | 55                 | 60.5          | 63.99                         | 0                       | 63.99                      | 0                       |
| 2028            | 55                 | 60.5          | 62.07                         | 0                       | 62.07                      | 0                       |
| 2029            | 55                 | 60.5          | 60.21                         | 8                       | 137.02                     | 77,977,785              |
| 2030            | 55                 | 60.5          | 132.91                        | 0                       | 132.91                     | 0                       |
| 2031            | 55                 | 60.5          | 128.93                        | 0                       | 128.93                     | 0                       |
| 2032            | 55                 | 60.5          | 125.06                        | 0                       | 125.06                     | 0                       |
| 2033            | 55                 | 60.5          | 121.31                        | 0                       | 121.31                     | 0                       |
| 2034            | 55                 | 60.5          | 117.67                        | 0                       | 117.67                     | 0                       |
| 2035            | 55                 | 60.5          | 114.14                        | 0                       | 114.14                     | 0                       |
| 2036            | 55                 | 60.5          | 110.71                        | 0                       | 110.71                     | 0                       |
| 2037            | 55                 | 60.5          | 107.39                        | 0                       | 107.39                     | 0                       |
| 2038            | 55                 | 60.5          | 104.17                        | 0                       | 104.17                     | 0                       |
| 2039            | 55                 | 60.5          | 101.05                        | 0                       | 101.05                     | 0                       |
| 2040            | 55                 | 60.5          | 98.01                         | 0                       | 98.01                      | 0                       |
| 2041            | 55                 | 60.5          | 95.07                         | 0                       | 95.07                      | 0                       |
| 2042            | 55                 | 60.5          | 92.22                         | 0                       | 92.22                      | 0                       |
| 2043            | 55                 | 60.5          | 89.45                         | 0                       | 89.45                      | 0                       |
| 2044            | 55                 | 60.5          | 86.77                         | 0                       | 86.77                      | 0                       |
| 2045            | 55                 | 60.5          | 84.17                         | 0                       | 84.17                      | 0                       |
| 2046            | 55                 | 60.5          | 81.64                         | 0                       | 81.64                      | 0                       |
| 2047            | 55                 | 60.5          | 79.19                         | 0                       | 79.19                      | 0                       |
| 2048            | 55                 | 60.5          | 76.82                         | 0                       | 76.82                      | 0                       |
| 2049            | 55                 | 60.5          | 74.51                         | 0                       | 74.51                      | 0                       |
| 2050            | 55                 | 60.5          | 72.28                         | 0                       | 72.28                      | 0                       |
| 2051            | 55                 | 60.5          | 70.11                         | 0                       | 70.11                      | 0                       |
| **Total**       |                    |               | **8**                         |                         | **77,977,785**             |                         |
**APPENDIX C.** Calculation of required time, which is anticipated that additional make-up wells drilling is required and make-up well (Scenario 3)

| Production Year | Well Capacity (MW) | Required (MW) | Available before make up (MW) | Additional Make-up Wells | Available After Make-up (MW) | Make Up Well Cost (USD) |
|-----------------|--------------------|---------------|-------------------------------|--------------------------|----------------------------|-------------------------|
| 2021            | 55                 | 60.5          | 76.82                         | 0                        | 76.82                      | 0                       |
| 2022            | 55                 | 60.5          | 74.51                         | 0                        | 74.51                      | 0                       |
| 2023            | 55                 | 60.5          | 72.28                         | 0                        | 72.28                      | 0                       |
| 2024            | 55                 | 60.5          | 70.11                         | 0                        | 70.11                      | 0                       |
| 2025            | 55                 | 60.5          | 68.01                         | 0                        | 68.01                      | 0                       |
| 2026            | 55                 | 60.5          | 65.97                         | 0                        | 65.97                      | 0                       |
| 2027            | 55                 | 60.5          | 63.99                         | 0                        | 63.99                      | 0                       |
| 2028            | 55                 | 60.5          | 62.07                         | 0                        | 62.07                      | 0                       |
| 2029            | 55                 | 60.5          | 60.21                         | 4                        | 98.62                      | 38,988,893              |
| 2030            | 55                 | 60.5          | 95.66                         | 0                        | 95.66                      | 0                       |
| 2031            | 55                 | 60.5          | 92.79                         | 0                        | 92.79                      | 0                       |
| 2032            | 55                 | 60.5          | 90.00                         | 0                        | 90.00                      | 0                       |
| 2033            | 55                 | 60.5          | 87.30                         | 0                        | 87.30                      | 0                       |
| 2034            | 55                 | 60.5          | 84.68                         | 0                        | 84.68                      | 0                       |
| 2035            | 55                 | 60.5          | 82.14                         | 0                        | 82.14                      | 0                       |
| 2036            | 55                 | 60.5          | 79.68                         | 0                        | 79.68                      | 0                       |
| 2037            | 55                 | 60.5          | 77.29                         | 0                        | 77.29                      | 0                       |
| 2038            | 55                 | 60.5          | 74.97                         | 4                        | 113.38                     | 48,691,784              |
| 2039            | 55                 | 60.5          | 109.98                        | 0                        | 109.98                     | 0                       |
| 2040            | 55                 | 60.5          | 106.68                        | 0                        | 106.68                     | 0                       |
| 2041            | 55                 | 60.5          | 103.48                        | 0                        | 103.48                     | 0                       |
| 2042            | 55                 | 60.5          | 100.37                        | 0                        | 100.37                     | 0                       |
| 2043            | 55                 | 60.5          | 97.36                         | 0                        | 97.36                      | 0                       |
| 2044            | 55                 | 60.5          | 94.44                         | 0                        | 94.44                      | 0                       |
| 2045            | 55                 | 60.5          | 91.61                         | 0                        | 91.61                      | 0                       |
| 2046            | 55                 | 60.5          | 88.86                         | 0                        | 88.86                      | 0                       |
| 2047            | 55                 | 60.5          | 86.19                         | 0                        | 86.19                      | 0                       |
| 2048            | 55                 | 60.5          | 83.61                         | 0                        | 83.61                      | 0                       |
| 2049            | 55                 | 60.5          | 81.10                         | 0                        | 81.10                      | 0                       |
| 2050            | 55                 | 60.5          | 78.67                         | 0                        | 78.67                      | 0                       |
| 2051            | 55                 | 60.5          | 76.31                         | 0                        | 76.31                      | 0                       |
| **Total**       |                    |               | **8**                         |                          | **87,680,677**             |                         |
**APPENDIX D.** Calculation of required time, which is anticipated that additional make-up wells drilling is required and make-up well (Scenario 4)

| Production Year | Well Capacity (MW) | Required (MW) | Available before make up (MW) | Additional Make-up Wells | Available After Make-up (MW) | Make Up Well Cost (USD) |
|-----------------|-------------------|--------------|-------------------------------|--------------------------|-----------------------------|-------------------------|
| 2021            | 55                | 60.5         | 76.82                         | 0                        | 76.82                       | 0                       |
| 2022            | 55                | 60.5         | 74.51                         | 0                        | 74.51                       | 0                       |
| 2023            | 55                | 60.5         | 72.28                         | 0                        | 72.28                       | 0                       |
| 2024            | 55                | 60.5         | 70.11                         | 0                        | 70.11                       | 0                       |
| 2025            | 55                | 60.5         | 68.01                         | 0                        | 68.01                       | 0                       |
| 2026            | 55                | 60.5         | 65.97                         | 0                        | 65.97                       | 0                       |
| 2027            | 55                | 60.5         | 63.99                         | 0                        | 63.99                       | 0                       |
| 2028            | 55                | 60.5         | 62.07                         | 0                        | 62.07                       | 0                       |
| 2029            | 55                | 60.5         | 60.21                         | 3                        | 89.01                       | 29,241,670              |
| 2030            | 55                | 60.5         | 86.34                         | 0                        | 86.34                       | 0                       |
| 2031            | 55                | 60.5         | 83.75                         | 0                        | 83.75                       | 0                       |
| 2032            | 55                | 60.5         | 81.24                         | 0                        | 81.24                       | 0                       |
| 2033            | 55                | 60.5         | 78.80                         | 0                        | 78.80                       | 0                       |
| 2034            | 55                | 60.5         | 76.44                         | 0                        | 76.44                       | 0                       |
| 2035            | 55                | 60.5         | 74.15                         | 0                        | 74.15                       | 0                       |
| 2036            | 55                | 60.5         | 71.92                         | 0                        | 71.92                       | 0                       |
| 2037            | 55                | 60.5         | 69.76                         | 0                        | 69.76                       | 0                       |
| 2038            | 55                | 60.5         | 67.67                         | 0                        | 67.67                       | 0                       |
| 2039            | 55                | 60.5         | 65.64                         | 0                        | 65.64                       | 0                       |
| 2040            | 55                | 60.5         | 63.67                         | 0                        | 63.67                       | 0                       |
| 2041            | 55                | 60.5         | 61.76                         | 0                        | 61.76                       | 0                       |
| 2042            | 55                | 60.5         | 59.91                         | 3                        | 88.72                       | 40,309,964              |
| 2043            | 55                | 60.5         | 86.05                         | 0                        | 86.05                       | 0                       |
| 2044            | 55                | 60.5         | 83.47                         | 0                        | 83.47                       | 0                       |
| 2045            | 55                | 60.5         | 80.97                         | 0                        | 80.97                       | 0                       |
| 2046            | 55                | 60.5         | 78.54                         | 0                        | 78.54                       | 0                       |
| 2047            | 55                | 60.5         | 76.18                         | 0                        | 76.18                       | 0                       |
| 2048            | 55                | 60.5         | 73.90                         | 0                        | 73.90                       | 0                       |
| 2049            | 55                | 60.5         | 71.68                         | 0                        | 71.68                       | 0                       |
| 2050            | 55                | 60.5         | 69.53                         | 0                        | 69.53                       | 0                       |
| 2051            | 55                | 60.5         | 67.44                         | 0                        | 67.44                       | 0                       |
| **Total**       | **6**             | **6**        | **6**                         | **6**                     | **6**                       | **69,551,634**          |