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Investment Cost Analysis of Renewable Energy Plant Development in Bali Province

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Abstract – Bali Province is one of the areas that has abundant renewable energy potential. Through increasing the role of renewable energy in the national energy mix which is a government program, which aims to reduce the use of non-renewable energy and open community participation in utilizing renewable energy in Bali Province. To overcome these problems, an analysis of the investment costs of developing renewable energy plants in Bali Province in 3 scenario modeling was carried out. In this scenario modeling is carried out to determine the investment cost of developing renewable energy plants in Bali Province in the 2024 - 2045 time span. The results of this study show that renewable energy investment costs in the optimistic scenario require investment costs of 264,12 Million USD in 2024 increasing to 2.078,35 Million USD in 2045 with total investment costs during the modeling period of 46.477,10 Million USD. The moderate scenario requires investment costs of 264,12 Million USD in 2024 increasing to 1.186,30 Million USD in 2045 with total investment costs during the modeling period of 27.362,52 Million USD. The pessimistic scenario requires investment costs of 264,12 Million USD in 2024 increasing to 986,80 Million USD in 2045 with total investment costs for the modeling period of 20.817,04 Million USD.

***Index Terms*-Investment Cost, Renewable Energy, Electric Energy.**

I. INTRODUCTION

Throughout Indonesia in general, the growth of electricity demand is very high, including in Bali Province. The increase in fossil fuel prices over the past few years has encouraged the use of renewable energy to meet the demand for electricity in Bali Province. Based on the abundant potential of renewable energy in Bali Province, it can be utilized in the energy transition from the use of fossil fuels. According to the Regional Energy General Plan (RUED) and the National Energy General Plan (RUEN) of Bali Province for 2020-2050, the potential of renewable energy including hydropower reached 208 MW, mini hydro and micro hydro reached 15 MW, biomass reached 146,9 MW, biogas reached 44,7 MW, solar power reached 1.254 MW, wind power reached 1.019 MW, marine energy reached 320 MW, and geothermal reached 262 MW [1].

The Republic of Indonesia is working to realize greenhouse gas reduction by realizing Net Zero Emission 2060 [2]. Net Zero Emission is a condition where carbon emissions produced by various emission-contributing sectors do not exceed the amount of absorption of emissions released into the atmosphere so that there is no evaporation that can become a greenhouse gas effect. Bali Province has set a target that is 15 years ahead of the national target of 2060, so that Bali Province becomes a pioneer so that other regions can make an example of initiatives in terms of accelerating greenhouse gas reduction. In addition, the dominant source of carbon emissions in Bali Province comes from the energy sector [3]. Through this renewable energy potential in Bali Province can be optimized in the energy transition carried out to achieve Bali Net Zero Emission 2045.

In Bali Province, the provision of electricity is still limited to the addition of small-scale renewable energy plants, so it cannot keep up with the growth in electricity demand. Based on these problems, careful planning is needed to be able to estimate the additional capacity for renewable energy generation in Bali Province in order to meet the needs of electrical energy. Furthermore, from the additional capacity can be sought investment costs that need to be incurred for the development of renewable energy generation in Bali Province. This planning aims to avoid losses in infrastructure development in the future. Renewable energy has a very important role in meeting energy needs. This is because the use of fuel for conventional power plants in the long term will deplete fossil fuel resources and can also cause environmental pollution.

II. LITERATURE REVIEW

A. State off The Art

In this study, five previous studies were used as comparison and reference materials in the process of making research because the theory used in the study was relevant. In the first study conducted by Purnomo et al [4], analyzing forecasting, meeting electrical energy needs, and investment costs in 2020-2030 in Bali Province. The results of the research on investment cost analysis show that in terms of system costs offered in the RUPTL scenario, it has a cheaper value than the Business as Usual scenario, amounting to 107,58 Million USD, which is due to the lower aspects of investment and maintenance or O&M costs in the RUPTL scenario.

In the second study conducted by Liun Edwaren [5], analyzed the comparison of investment costs for the development of electricity systems in Sumatra from each scenario, namely the 8% scenario, 10% scenario and 12% scenario. The results of this study show that the estimated cost requirements for the development of the Sumatra system are 57,465 million USD at Base Scenario DR 8%, 59,349 million USD at Base Scenarion DR 10%, and 57,796 million USD at Base Scenario DR 12%. While the objective function is 15,172 USD at Base Scanario DR 8%, 12,663 million USD at Base Scenario DR 10%, and 11,017 million USD at Base Scenario DR 12%.

In the third study conducted by Halim Levin [6], analyzed the technical and investment costs of renewable plants, namely PLTS On Drid and Off Grid in Indonesia. The results of the study are from the cost and technical analysis of the use of Off-Grid systems incurring greater costs than the use of On-Grid per month for On-Grid requires a cost of Rp. 126,116 while Off-Grid Rp. 694,233 for Off-Grid the value is included in the warranty fee, if not including the warranty fee the cost of the Off-Grid system per month is Rp. 347,111.

The fourth study conducted by Larasati et al [7], analyzed the financial feasibility of using bagasse as a substitute for boiler fuel as the main source of fuel for electrical energy generation. The results of the study show that the investment in bagasse-fueled power plants at PT Gunung Madu Plantations is financially feasible to implement. This is evidenced by the results of the financial analysis which shows a positive NPV value of Rp. 1,437,425,146,844.25, Net B/C more than one of 7.00 Gross B/C more than one of 1.81, IRR more than the prevailing interest rate of 34.84 percent, Payback period less than the economic life of the power plant is 1.75.

In the fifth study conducted by Purnama Ady [8], analyzing the feasibility of micro hydro power plant development in Sleman Regency technically and economically. The results showed that the potential power generated from the MHP was 23.54 kilowatts. The construction of this MHP meets the technical feasibility criteria, while financially this development cannot bring profit if it is financed with a bank loan with an interest rate of 18% per year. However, it will be profitable if it is financed with interest-free loans or grants from the government or donors.

Of all the research described above, there are similarities and differences in this study. The difference with the above research is that this research analyzes investment costs for the development of renewable energy plants based on the actual conditions of a region. In addition, this study will analyze investment costs with 3 scenario modeling, namely optimistic scenarios, moderate scenarios, and pessimistic scenarios. This analysis is carried out based on projection data and data on the fulfillment of electrical energy needs in Bali Province from 2024 to 2045.

B. Bali Province Electricity System

Electricity demand in Bali Province is supplied by PLN in two ways, the first by relying on electricity supply from Java via a sea cable, and the second by using plants located in Bali Province. Both combinations provide a total capacity of 1,349.3 MW. Through the sea cable method, 400 MW of electricity from the Paiton power plant, is sent through a 150 kV submarine transmission cable between Banyuwangi and Gilimanuk [9].

Fig 1: Electricity system of Bali Province

Electricity supply from 150 kV plants totaling 944 MW located in Bali Province consists of 372 MW BBM plant, 192 MW LNG/BBM plant, and 380 MW Celukan Bawang PLTU. The combination of the two supplies of electrical energy provides a total capable power of 1,344 MW [10].

C. Renewable Generation Investment Cost Calculation

The development of Energy generation as an alternative to electricity generation that will be built in Bali Province is expected to reduce emissions generated by plants that still use fossil fuels in their work systems. Calculation of the investment cost of renewable plants built can be sought with data on installed capacity (existing capacity), additional capacity needed to meet electrical energy needs, and the capital cost value of each plant developed.

The calculation starts by finding the total capacity required by Bali Province to meet the projected electrical energy demand from 2024 to 2045. Furthermore, the total capacity will be reduced by the previously installed capacity (existing capacity). The result of the reduction will show the total capacity that Bali Province must have to meet the demand for electrical energy until 2045. After that, the capacity growth will be known every year, so that the capacity growth can be used to calculate the cost of electricity investment in Bali Province until 2045. Mathematically, the plant investment cost can be calculated through the following equation:

$$BI = Pk \times Cc \quad (1)$$

In the equation above, BI is the investment cost (Million USD), Pk is the capacity growth of each renewable energy plant, and Cc is the capital cost of each renewable plant to be developed. The capital cost of each plant has a different value according to the economic parameters of the generating unit that will be used in the modeling. The calculation of plant investment costs will be divided into three modeling scenarios, namely optimistic, moderate, and pessimistic. From these calculations, the total investment cost of renewable energy generation for each modeling scenario will be obtained, the investment costs that need to be incurred by the Province of Bali each year, and the costs that need to be incurred for each plant developed from 2024 to 2045.

III. RESEARCH METHOD

There are several research flows that have to be carried out in this study, which are as follows:

1. Collecting data needed in this study, such as installed capacity (existing capacity), the increase in renewable generation capacity, and the capital cost value of each renewable energy plant.
2. Calculating the cost of plant investment in each modeling scenario to determine the total cost incurred during the modeling period.
3. Conduct a review of the modeling results that have been carried out to determine the comparison of investment costs between each modeling scenario.

Draw conclusions based on the results of the research

The research location was conducted in a hybrid manner, namely online at the place of residence of each house and offline in the Smartgrid and Electric Vehicles Research Group Room, 4th floor, Advance Research Laboratory Building, Faculty of Engineering, Udayana University. The implementation of the research took place from January to June 2024. In preparing the report, it is necessary to collect data to obtain the information needed to achieve the research objectives. From the data collection, managed to obtain data on the total installed capacity of renewable plants from 2024 to 2045 obtained from the RUPTL data released by PLN in 2021.Dalam dokumen RUPTL [10], kapasitas dari pembangkit listrik terbarukan in the electricity system of Bali Province, namely PLTA and PLTS. Muara Panji Hydroelectric Power Plant has a capacity of 1.4 MW and PLTS which has a capacity of 2 MW consisting of PLTS Kubu and PLTS Banglet, each of which has a capacity of 1 MW as shown in Table I.

TABLE I
INSTALLED CAPACITY OF RENEWABLE GENERATION

Power Plant	Capacity (MW)
PLTA Muara Panji	1,4
PLTS Kubu	1
PLTS Banglet	1
Total	**3,4**

After knowing the installed capacity, proceed with finding additional capacity data to meet the needs of electrical energy in Bali Province. For additional capacity obtained in the journal Widianto, A. G. I, et al, 2024 [11] as shown in table II.

TABLE II
TOTAL ADDITIONAL RENEWABLE GENERATION CAPACITY

Power Plant	Total Additional Capacity (MW)		
	Optimistic	Moderate	Pessimistic
PLTA	24,10	24,10	24,10
PLTAL	320,00	320,00	320,00
PLTSa	57,60	57,00	39,00
PLTBm	615,00	615,00	615,00
PLTP	225,00	225,00	225,00
PLTB	60,00	60,00	60,00
PLTS	11.150,00	8.150,00	6.150,00
PHES	5.000,00	3.000,00	1.350,00
BESS	989,87	-	-
PLTS *Charging*	3.728,97	-	-
Total	**22.170,55**	**12.451,70**	**8.783,10**

In the moderate scenario and pessimistic scenario, Battery Energy Storage System (BESS) and PLTS Charging did not experience development, this is because the eight renewable plants that have been developed are able to meet the needs of electrical energy in Bali Province until the end of the modeling period. Other data required are the economic parameters of renewable energy generation units obtained from KESDEM, 2021 [12]. The data is needed to determine the capital cost value of each renewable energy plant that will be developed in Bali Province as in table III.

TABLE III
ECONOMIC PARAMETERS OF RENEWABLE ENERGY GENERATION UNITS

Power Plant	***Capital Cost*** **(Mil. USD/MW)**	***Variable OM Cost*** **(USD/MWh)**
PLTA	2,4	1
PLTAL	5,3	12
PLTB	2,2	0,8
PLTBm	2	3
PLTP	4	0,25
PLTS	2,5	0,4
PLTSa	6,8	24,1
PHES	0,86	1
BESS	0,58	0,4

These economic parameter data are used to find the investment cost of each renewable energy plant in Bali Province. In this modeling, non-renewable power plants or domestic plants that supply electrical energy in Bali Province will be assumed to be always available and should not be interrupted to supply electrical energy during the modeling period, unless domestic plants in Bali Province have reached their operating life..

IV. RESULT AND DISCUSSION

A. *Investment Cost of Bali Province Electricity System According to 3 Modeling Scenarios*

In the optimistic scenario, the total investment cost required for renewable energy generation in the Bali Province electricity system from 2024 to 2045 is 46,477.10 Million USD with a total additional capacity of 22,170.55 MW. From the investment cost, solar power plant requires the largest investment cost during the modeling period which is 59.98% of the total investment cost of all plants. In addition, PLTS will be used as a charger in BESS with an investment cost of PLTS Charging of 20.06%, so that the total investment cost required for PLTS is 80.03% or 37,197.43 Million USD.

For Pumped Hydro Energy Storage (PHES) and Battery Energy Storage System (BESS) plants require investment costs of 9.25% or around 4,300.00 Million USD and 1.23% of the total investment costs of all plants or 572.15 Million USD. Furthermore, the investment costs of other plants such as hydropower, PLTAL, PLTSa, PLTBm, PLTP, and PLTB require investment costs of 0.12%, 3.65%, 0.84%, 2.65%, 1.94%, and 0.28% of the total investment costs for the development of renewable energy plants as in table IV.

TABLE IV
ADDITIONAL CAPACITY AND TOTAL INVESTMENT COST IN OPTIMISTIC SCENARIO

Power Plant	**Total Capacity (MW)**	**Total Investment Cost (Million USD)**
PLTA	24,10	57,84
PLTAL	320,00	1.696,00
PLTSa	57,60	391,68
PLTBm	615,00	1.230,00
PLTP	225,00	900,00
PLTB	60,00	132,00
PLTS	11.150,00	27.875,00
PHES	5.000,00	4.300,00
BESS	989,87	572,15
PLTS *Charging*	3.728,97	9.322,43
Total	**22.170,55**	**46.477,10**

In the moderate scenario, the total investment cost that needs to be incurred for the development of the electricity system to support the Net Zero Emissions program is 27,362.52 Million USD from 2024 to 2045 with an additional capacity of 12,451.70 MW. Of the total investment cost, PLTS is in the first position with the largest investment cost during the modeling period which amounted to 20,375.00 Million USD or 74.46% of the total investment cost of all plants. Followed by the second position, PHES with an investment cost of 2,580.00 Million USD or 9.43% as shown in table V.

TABLE V
ADDITIONAL CAPACITY AND TOTAL INVESTMENT COST IN THE MODERATE SCENARIO

Power Plant	**Total Capacity (MW)**	**Total Investment Cost (Juta USD)**
PLTA	24,10	57,84
PLTAL	320,00	1.696,00
PLTSa	57,00	391,68
PLTBm	615,00	1.230,00
PLTP	225,00	900,00
PLTB	60,00	132,00
PLTS	8.150,00	20.375,00
PHES	3.000,00	2.580,00
Total	**12.451,70**	**27.362,52**

Furthermore, the third position is PLTAL with a total investment cost of 1,696.00 Million USD or 6.20%. In the fourth position is PLTBm with a total investment cost of 1,230.00 Million USD or 4.50%, and the fifth position is PLTP with a total investment cost of 900.00 Million USD or 3.29%. Furthermore, the sixth and seventh positions are

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PLTSa with investment costs of 391.68 Million USD or 1.43% and PLTB of 132.00 Million USD or 0.48%. For the smallest total investment cost during the modeling period is hydropower with a total investment cost of 57.84 Million USD or 0.21% of the total investment cost of all plants

In the pessimistic scenario, the total investment cost that needs to be incurred for the development of the electricity system is 20,817.04 Million USD with a capacity obtained from the cost of 8,783.10 MW. From the investment cost, solar power plant is in the first position with the largest investment cost during the modeling period which is 15,375.00 Million USD or 73.86% of the total investment cost of all plants. Followed by the second position, PLTAL with a total investment cost during the modeling period of 1,696.00 Million USD or 8.15% of the total investment cost of all plants.
Selanjutnya, posisi ke tiga adalah PLTBm dengan total investment costs amounted to 1,230.00 Million USD or 5.91% of the total plant investment costs. Then, in the fourth position is PHES with a total investment cost of 1,161.00 Million USD or 5.58%, and the fifth position is PLTP amounting to 900.00 Million USD or 4.32% of the total plant investment cost. Furthermore, the sixth and seventh positions are PLTSa with an investment cost of 265.20 Million USD or 1.27% and PLTB of 132.00 Million USD or 0.63%. For the smallest total investment cost during the modeling period is hydropower with a total investment cost of 57.84 Million USD or 0.28% of the total investment cost of all plants as shown in Table VI.

TABLE VI
ADDITIONAL CAPACITY AND TOTAL INVESTMENT COST IN THE PESSIMISTIC SCENARIO

Power Plant	Total Capacity (MW)	Total Investment Cost (Juta USD)
PLTA	24,10	57,84
PLTAL	320,00	1.696,00
PLTSa	39,00	265,20
PLTBm	615,00	1.230,00
PLTP	225,00	900,00
PLTB	60,00	132,00
PLTS	6.150,00	15,375,00
PHES	1.350,00	1.161,00
Total	**8.783,10**	**20.817,04**

B. Comparison of Investment Cost of Electricity System According to 3 Modeling Scenarios

Based on Figure 2, displays a comparison of the total investment cost of each renewable energy plant in Bali Province during the modeling period based on 3 modeling scenarios..

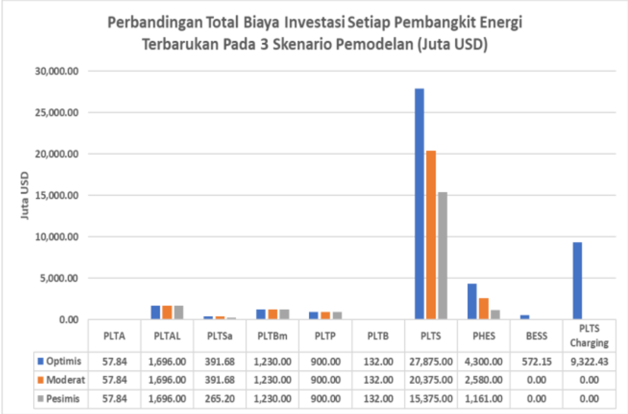

Fig 2. Comparison of Renewable Energy Plant Investment Costs According to 3 Modeling Scenarios

In the optimistic scenario, PLTS requires the largest total investment cost compared to other scenarios during the modeling period, which is 27,875.00 Million USD, followed by investment costs for PHES of 4,300.00 Million USD, BESS investment costs of 572.15 Million USD, and PLTS Charging investment costs of 9,322.43 Million USD. Furthermore, in the moderate scenario, the investment cost of PLTS is 20,375.00 Million USD, followed by the investment cost of PHES development of 2,580.00 Million USD. In the pessimistic scenario, the investment costs of PLTS and PHES are 15,375.00 Million USD and 1,161.00 Million USD, respectively. For the moderate and pessimistic scenarios, the construction of BESS and PLTS Charging was not carried out, this is because during the modeling period without BESS and PLTS Charging, other plants have been able to meet the electrical energy needs in Bali Province until 2045.

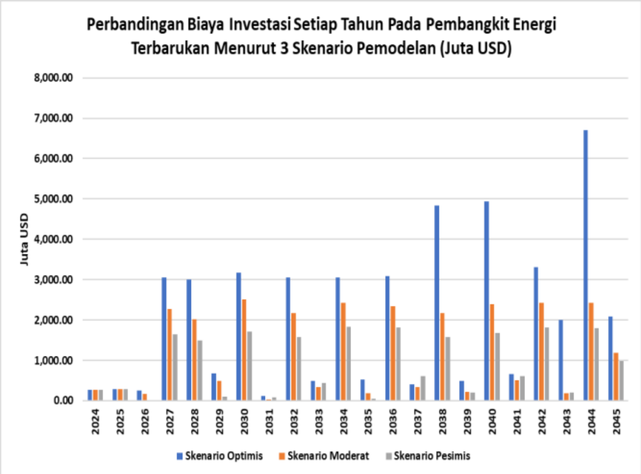

Fig 3. Perbandingan Biaya Investasi Pembangkit Energi Terbarukan Menurut 3 Skenario Pemodelan

Based on Figure 3, shows the comparison of total investment costs in each year of the three modeling scenarios, namely optimistic, moderate, and pessimistic during the modeling period. In 2027, Bali Province provided investment costs of 3,055.49 Million USD in the optimistic scenario, 2,269.72 Million USD in the moderate scenario and 1,643.24 Million USD in the pessimistic scenario. At the end of modeling, investment costs for the optimistic scenario amounted to 2,078.35 Million USD, investment costs in the moderate scenario amounted to 1,186.30 Million USD, and investment costs in the pessimistic scenario amounted to 986.80 Million USD. When viewed from the total investment cost of the entire plant from 2024 to 2045, the optimistic scenario shows the largest investment cost compared to the other 2 scenarios, which amounted to 46,477.10 Million USD. The moderate and pessimistic scenarios have a comparison of investment costs of 27,362.52 Million USD for the moderate scenario and 20,817.04 Million USD for the pessimistic scenario.

V. CONCLUSION

Based on the research that has been done, it can be concluded that in the optimistic scenario there is an increase in capable power capacity of 1,420.50 MW in 2024 to 19,410.77 MW in 2045 with investment costs in the Bali Province electricity system of 264.12 Million USD in 2024 increasing to 2,078.35 Million USD in 2045 with a total investment cost required during the modeling period of 46,477.10 Million USD. In the moderate scenario, there is an increase in capable power capacity of 1,420.50 MW in 2024 to 13,420.90 MW in 2045 with an investment cost of 264.12 Million USD in 2024 increasing to 1,186.30 Million USD in 2045 with a total investment cost required during the modeling period of 27,362.52 Million USD. In the pessimistic scenario, there is an increase in capable power capacity of 1,420.50 MW in 2024 to 9,752.30 MW in 2045 with an investment cost of 264.12 Million USD in 2024 increasing to 986.80 Million USD in 2045 with a total investment cost required during the modeling period of 20817.04 Million USD.

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