Performance Analysis of Hybrid Power Plant (Wind and Solar) in Baron Techno Park Gunung Kidul Yogyakarta

Mychel Gatriser Pae[1], Ridwan Budi Prasetyo[2], Suharyanto[3], T. Haryono[4]
Department of Electrical Engineering and Information Technology, Universitas Gadjah Mada[1,3,4]
Agency Assessment and Application of Technology Yogyakarta[2]
Jl. Grafika No.2, Yogyakarta[1,3,4]
Kanigoro, Sapto Sari, District of Gunung Kidul, Daerah Istimewa Yogyakarta[2]
mychel.pae@mail.ugm.ac.id[1], ridwan.budi@bppt.go.id[2], suharyanto@ugm.ac.id[3],
thr@ugm.ac.id[4]

Abstract

Renewable energy is generated through the conversion process of energy sources which are abundant in the earth such as wind, sun, heat, rain, geothermal, hydro, ocean water and others into an environmentally friendly form of energy. This kind of energy does not cause negative effects to the environment when being used. Therefore, by using renewable energy, the earth is not polluted. This is a major step in controlling global warming, which is one of the elements that leads to environmental degradation. The use of renewable energy sources is indispensable. One great opportunity for future renewable energy is the integration of various sources of energy (hybrid power plant). This paper presents the analysis performance of hybrid power plant (wind and solar) installed in the area of Baron Techno Park. Modeling with HOMER (Hybrid Optimization Model for Electric Renewable) Version 3.8.1 was done with two conditions, first was a grid connected and the second was an off-grid condition. The first system modeling for the installed system capacity NPC and COE had the lowest price for the off-grid condition being $ 62.020 and - $ 0.0213. For the $ 4,910.37 / year was system operating cost. For this capacity, electricity that was connected into grid up to 152.473 kWh / year. The second modeling systems was done with generating capacity in operating. Unknown NPC price was $ 20,887.76 and the COE was - $ 0,021 for grid connected system condition. Operational cost up to $1,685.87 / year, and electricity production being was 63,55 kWh / year. With the grid, the contribution of Baron Techno Park hybrid power plants could lower carbon dioxide gas up to 82.63 kg/year for operating systems and 202.63 kg/year for systems with installed capacity.

Keywords: *Wind; Solar; Hybrid; Homer; On-grid; Off-grid; NPC; COE.*

1. Introduction

Availability of conventional energy sources in the earth is getting decreased day by day. it will bring an impact on the energy crisis if there are no suitable and sustainable solutions [1]. Renewable energy sources are an alternative energy solution to overcome dependence on electrical energy is to convert from conventional power plants such as coal and petroleum in Indonesia [2].

Special Region of Yogyakarta is one of 33 provinces in Indonesia, located in the central part of Java island. The southern part of Yogyakarta is restricted Indonesian seas, while the eastern part of northwest-southeast, west, and northwest bounded by the province of Central Java. The position of Yogyakarta Region, located between 70.33'- 80.12' south latitude and 1100.00 '- 1100.50' East Longitude, has an area of 3185.80 km2 recorded or 0:17% of the area of Indonesia consisting of Kulon Progo district with an area of 586.27 km2 (18:40%), Bantul with an area of 506.85 km2 (15.91%), Gunung Kidul with an area of 1485.36 km2 (46.63%), Sleman district with an area of 574.82 km2 (18.0%), and Yogyakarta city with an area of 32.50 km2 (1:02%) [3].

As counties that have the largest area in Yogyakarta, Gunung Kidul district has a lot of potential the renewable energy includes wind energy potential, solar energy, sea etc. By used optimally, it will greatly impact on the lives of people in the area. This is the reason of the Agency for the Assessment and Application of Technology to develop some of the renewable energy and

one of them is a hybrid power plant which is located in Kanigoro village, District Saptosari Gunung Kidul district Yogyakarta. Since 2010, BPPT has built "Baron Techno Park" as a center for research and development of renewable energy technologies, also used as dissemination of Science and Technology of Renewable Energy [4].

Baron Techno Park power plant system consists of two wind power plants with the capacity of 10 kW and 5 kW. Solar power plants with the capacity of 36 kW are divided into three PV arrays with 120 cells of each array, system storage (Bank Battery) are divided into two arrays with 8 strings of each array, the capacity of bank Battery is 288 kVAh, 1200 Ah. Caused by some problems, until now system of a hybrid power plant that operated only a wind power plant with a capacity of 5 kW and solar power generation 24 kW [5]. Baron Techno Park hybrid power plant system configuration is shown in Figure 1.

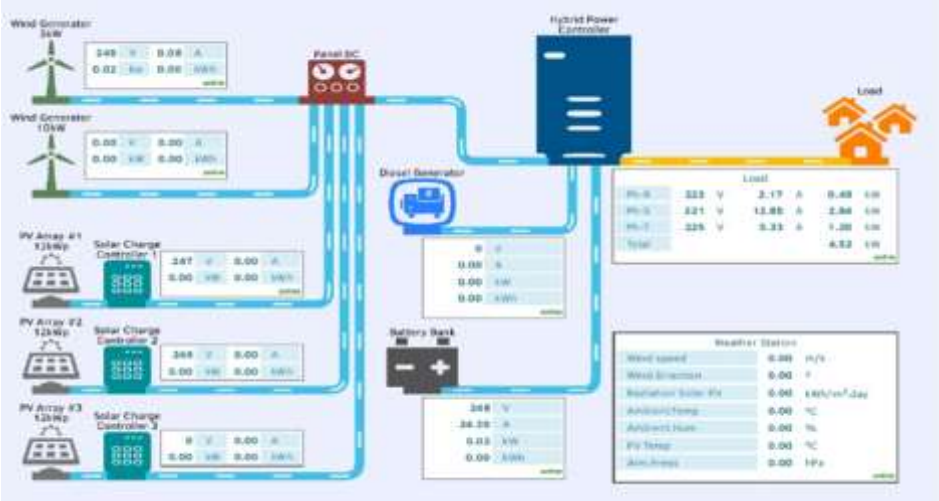

Figure 1. Baron techno park power plant system

2. Research Method

Research on the analysis of hybrid power plants with the help of HOMER software has been widely practiced in several countries including Indonesia. Therefore, HOMER feasibility levels can be used to analyzing stand alone and hybrid power generation systems. In this study, used HOMER software for simulation of PLTH Baron Techno Park with two different conditions. The first simulation an off-grid system condition. That modeling was done to known the performance of PLTH in fulfilling internal load (electric energy consumption for main building, electronic device, and location lighting of Baron Techno Park). With the HOMER software, the NPC and COE values are calculated as system performance parameters in meeting the electrical load. The second modeled are on-grid system. That modeled aims to determine the improvement of PLTH performance in the future with the grid in economic terms.

2.1. Load Profile

The main daily load of Baron Techno Park is divided into three blocks, R, S, and T. From the results of historical data, known that electrical load in each block are: block R 0.78 kW, block S 1,542 kW, and block T 1,241 kW. Average total power load is 3,563 kW. Figure 2 shows the electrical load in each block. For daily load profile can be seen in Figure 3.

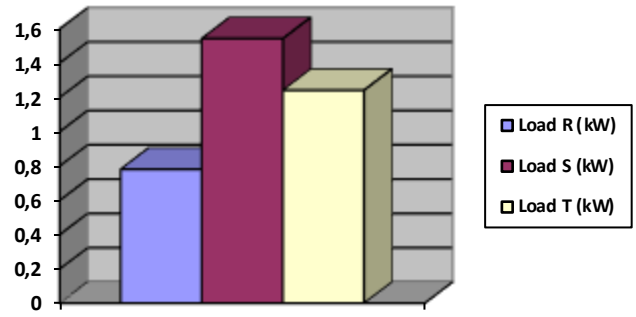

Figure 2. Power loads each Block

Figure 3. Daily load profile

2.2. Potential of Wind Energy

Based on data obtained from NASA, the average speed of wind is 4:42 m/s measured at a height of 50 m. The highest wind speeds are 6:15 m/s in the month of August, while the lowest wind speed is 2.91 m / s. in December. Figures 4 and Figure 5 shown the average wind speed at the location Baron Techno Park for one year.

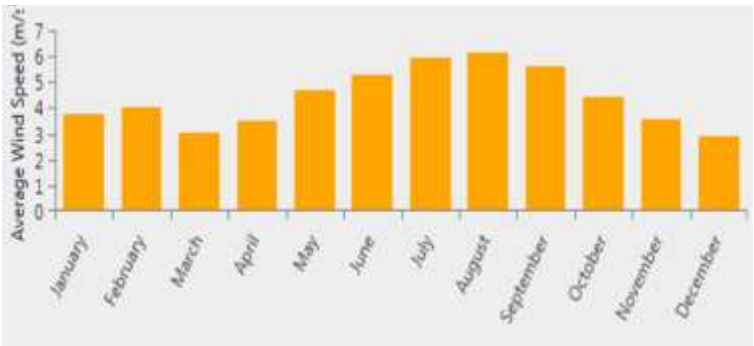

Figure 4. Wind speed (monthly average).

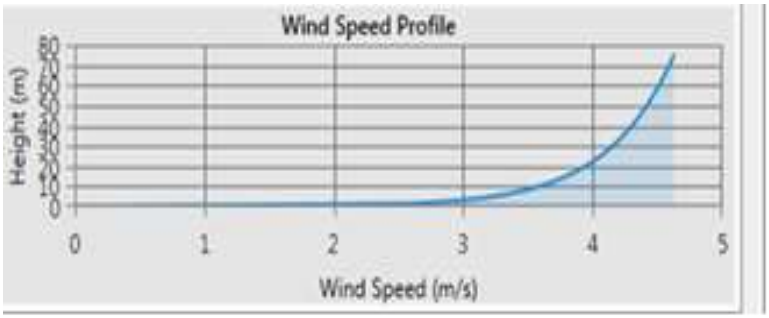

Figure 5. The relation between wind speed and anemometer height.

2.3. Solar Energy

In this study, the monthly solar radiation data were taken from NASA (National Aeronautics and Space Administration). The highest solar radiation obtained in September is 6.56 kWh/m2/day with clearness index of 0.646, while the lowest solar radiation is 5.08 kWh/m2/day in January with clearness index of 0.469. The average solar radiation for one year is 5.66 kWh / m2 / day. Solar radiation for the location of Baron Techno Park was shown in Figure 6.

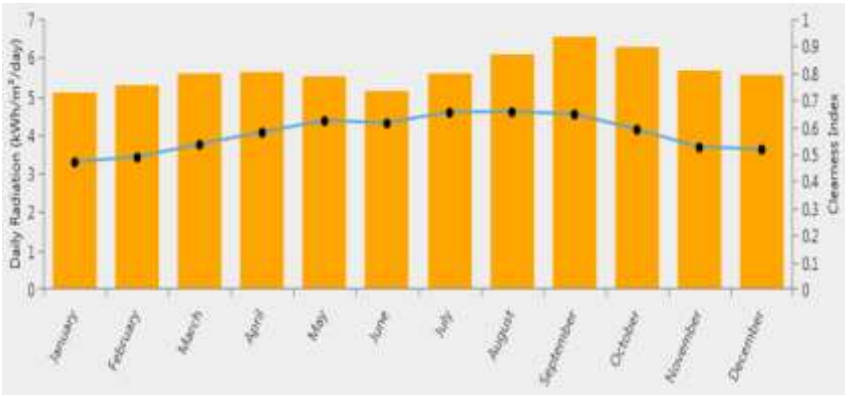

Figure 6. Total solar irradiance and clearness index

Table 1. Solar radiation (SR) and a clearness index (CI)

Month	CI	SR kWh/m^2
January	0.469	5.080
February	0.487	5.280
March	0.534	5.610
April	0.579	5.630
Mei	0.622	5.500
June	0.613	5.120
July	0.653	5.580
August	0.655	6.090
September	0.646	5.650
October	0.590	6.290
November	0.524	5.650
December	0.516	5.650

2.4. Hybrid System Components

A hybrid energy system usually consists of two or more renewable energy sources used at the same time to provide Inserted: and efficiency increased of the system as well as greater balance in energy supply [7]. Capital cost: total cost of the installation of the installed components on the starts of the project. Replacement cost: the cost of replacement component at the end of its useful life, determined by the parameters or specification of component life. Cost of operation and maintenance (O & M): annual fee for operation and maintenance of the system [8].

All those costs required for system modeling. Modeling will be done in two capacities of different hybrid power plant based on a system with an installed capacity of wind power plant with capacity of 15 kW and solar power with capacity of 36 kW, while the second modeling for systems that currently operating is wind power with a capacity of 5 kW and solar power with a capacity of 24 kW. Data modeling of hybrid power plant Baron Techno Park consists of solar panels (PV), wind turbines (WG), Battery (BAT), and inverter (INV). Economically data from hybrid power plant Baron Techno Park consists of the initial cost /capital (M), replacement cost (R), the cost of operation and maintenance (O & M). Technical and economic data are shown in Table 2.

Table 2. Technical and Economic Data

Componets			Cost		
Name	Capacity (kW)	L (yr)	M ($)	R ($)	O & M ($)/years
PV	36	25	135.338	2.706	436
WG	5	10	6.015	120	150
	10	10	9.210	184	150
BATT	-	20	120.000	2.400	270
INV	25	8	3.945	120	79

1 $ = Rp. 13.300,00

Grid and Emission: Grid is an electricity network provider of PT PLN (Persero), for an interconnection system with the grid, the amount of electrical energy that can be produced by the system or excess of electric power by hybrid power plant system will be purchased by the grid. The mechanism to do will contracts kWh. The price of electricity that must be purchased by the grid of hybrid power plant amounted to the US $ 0.091. The purchase price of electricity from the grid by customers was the US $ 0.122, according to the tariffs applied by the Government [9]. Limits of carbon dioxide were allowed to the grid is 0.714 tons / MWh [10].

2.5. Modeling and Simulation

Because the damage on some equipment of Baron Techno Park hybrid power plant like solar panels and wind turbines, the operated system until now is different from the real system plan at the beginning. Initial design system was solar power with power 36 kW and wind turbines with 15 kW of power, while the system that operating now are shown in table 2. Therefore, the modeling and simulation need to be done in the initial design of the real system and operating system. This modeling is done for off grid condition of the system and on-grid conditions.

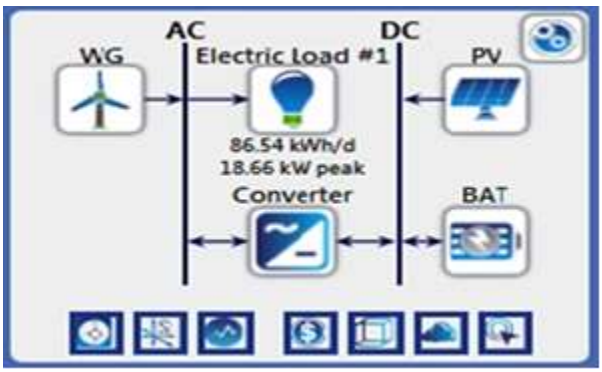

Figure 7. Off-grid Systems

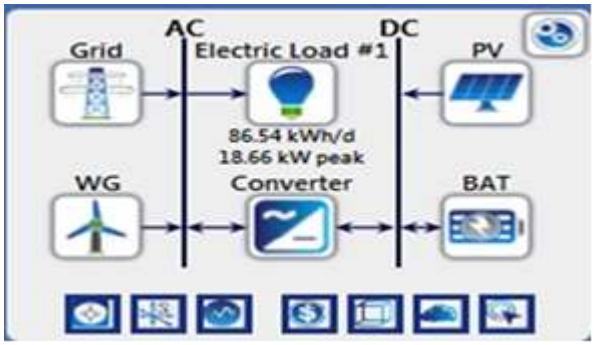

Figure 8. On-grid system

3. Results and Analysis

Based on the results of the modeling and analysis that was done by the HOMER program, known:

3.1. Hybrid Power Plant System Installed Capacity Off-grid Conditions

HOMER modeling results and analysis for hybrid power plant system with an installed capacity of NPC obtained for $ 196.399 and COE of $ 1.24, with operating costs of $ 15.038 / year. The production of electric energy amounted to 167.482 kWh / year with a contribution of solar panels at 60.165 kWh / year (35.92%) and wind turbines amounted to 107.317 kWh / year (64.08%). The power consumption of 12.212 kWh / year (7.6%). Energy Excess generated of hybrid power plant Baron Techno Park is 154.831 kWh / year (92.4%). Baron Techno Park hybrid power plant modeling results are shown in Table 3.

Table 3. Results HOMER modeling for a system installed capacity by off-grid conditions.

PV (kW)	WG (kW)	BAT	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating Cost ($)
36.0	15	24	25.0	CC	1.24	196.399	15.038
36.0	15	24	25.0	CC	1.24	196.399	15.038
36.0	15	24	25.0	CC	1.24	196.399	15.038
36.0	15	24	25.0	CC	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	196.399	15.038
36.0	15	24	25.0	CC	1.24	196.399	15.038
36.0	15	24	25.0	CC	1.24	196.399	15.038
36.0	15	24	25.0	LF	1.24	203.096	15.542

3.2. Hybrid Power Plant System that Operats at Off-grid Condition

Baron Techno Park hybrid power plant system that operated, with off-grid conditions, needs NPC obtained of $ 88.493 and COE of $ 0561 to the operational cost of $ 6.760 / year. Whereas the result of electricity production amounted to 75.882 kWh / year with contributions of solar panels at 40.110 kWh / year (52.86%) and wind turbines amounted to 35.772 kWh / year (47.14). Electricity Consumption of Baron Techno Park hybrid power plant system only 17% of the total energy produced or 12.209 kWh / year. The excess of electrical energy produced by Baron Techno Park hybrid power plant of 63.072 kWh / year (83.1%). Modeling results of Baron Techno Park hybrid power plant shown in Table 4.

Table 4. HOMER modeling results for the system operating with off-grid conditions

PV (kW)	WG (kW)	BAT	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating Cost ($)
36.0	5	24	25.0	CC	0.561	88.493	6.670
36.0	5	24	25.0	CC	0.561	88.493	6.670
36.0	5	24	25.0	CC	0.561	88.493	6.670
36.0	5	24	25.0	CC	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670

36.0	5	24	25.0	CC	0.561	88.493	6.670
36.0	5	24	25.0	CC	0.561	88.493	6.670
36.0	5	24	25.0	LF	0.561	88.493	6.670

3.3. Hybrid Power Plant System Installed Capacity with On-grid Conditions

Based on the HOMER simulation results for on-grid conditions system with an installed capacity of NPC obtained to $ 62.020 and COE is - $ 0.02913 with operating costs of $ 4,910.37. With an installed grid for the capacity of the system, the excess of energy that was generated by the system can be distributed amounts to 154.831 kWh / year of the total produced energy by the system amounted to 168.842 kWh / year. From the result of the HOMER simulation for on-grid condition known solar power generated energy its production was 60.165 kWh / year (35.63%), the contribution of wind turbines amounted to 107.317 kWh / year (63.56%), while the production of the grid (grid purchases) is 1,360 kWh / year (0.81%). For energy consumption to the conditions known on-grid system is 12.213 kWh / year (7:42%). Sales of electricity to the grid network amounted to 152.473 kWh / year.

Table 5. HOMER modeling results for a system with the installed capacity on-grid conditions.

PV (kw)	WG (kW)	BAT	Grid (Kw)	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating Cost ($)
36.0	15	8	999,999	25.0	CC	-0.0260	-55.032	-4.384
36.0	15	8	999.999	25.0	LF	-0.0243	-51.470	-4.108
36.0	15	16	999.999	25.0	CC	-0.0229	-48.269	-3.874
36.0	15	24	999.999	25.0	CC	-0.0197	-41.566	-3.370
36.0	15	16	999.999	25.0	LF	-0.0195	-41.216	-3.329
36.0	15	24	999.999	25.0	LF	-0.0148	-31.174	-2.566
36.0	15	48	999.999	25.0	CC	-0.0102	-21.464	-1.856
36.0	15	48	999.999	25.0	LF	-0.0004	-839.18	-260.8
36.0	15	96	999.999	25.0	CC	0.00864	18.393	1.144
36.0	15	96	999.999	25.0	LF	0.282	57.111	4.139
36.0	15	192	999.999	25.0	CC	0.0464	98.829	7.200
36.0	15	192	999.999	25.0	LF	0.0839	152.039	11.316
36.0	15	392	999.999	25.0	CC	0.127	267.296	19.886

3.4. Hybrid Power Plant System that Operates With On-grid Conditions

Modeling and analysis for Power Hybrid system with operating capacity for on-grid conditions NPC obtained to $ 20,887.76 and COE - $ 0.02132 with operating costs of $ 1,658.87. For the systems with a capacity of operating of on-grid conditions obtained total energy production amounted to 77.768 kWh / year. The electricity that generated from Solar Power System is 40.110 kWh / year (51.58%), on-grid.

Modeling and analysis of hybrid for the power generation system with a capacity of operating conditions for on-grid conditions NPC obtained for $ 20,887.76 and COE - $ 0.02132 with operating costs of $ 1,658.87. Total energy production amounted to 77.768 kWh / year. Electrical energy that's generated by solar panels was being 40.110 kWh / year (51.58%), while wind turbines generate electricity at 35.772 kWh / year (46%), and production of a grid of 1,886 kWh / year (2:42%). The power consumption of this system amounted to 12.213 kWh / year (16:12%). Therefore, electricity that was sold out from the total excess electrical energy is 63.55 kWh / year.

Table 6. Results HOMER modeling of a system that operates with on-grid conditions

PV (kw)	WG (kW)	BAT	Grid (Kw)	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating Cost ($)
24	5	8	999,999	25.0	CC	-0.141	-13.513	-1.103
24	5	8	999.999	25.0	LF	-0.0109	-10.252	-871.86

24	5	16	999.999	25.0	CC	-0.0076	-7.487	-649.98
24	5	16	999.999	25.0	LF	-0.0006	-647.09	-121.61
24	5	24	999.999	25.0	CC	-0.0002	-225.28	-102.82
24	5	24	999.999	25.0	LF	0.00918	8.710	588.38
24	5	48	999.999	25.0	CC	0.0209	19.879	1.411
24	5	48	999.999	25.0	LF	0.0382	35.586	2.626
24	5	96	999.999	25.0	CC	0.0607	59.526	4.395
24	5	96	999.999	25.0	LF	0.0862	76.918	5740
24	5	192	999.999	25.0	CC	0.143	139.931	10.448
24	5	192	999.999	25.0	LF	0.178	152.930	11454
24	5	392	999.999	25.0	CC	0.326	308.268	23.124

4. Conclusion

Based on the modeling and performance of analysis conducted by HOMER can be concluded that:

1. The Baron Techno Park average electrical load is 12.213 kW / year consisting of three blocks.
2. For systems with an installed capacity or operating system capable of meeting the electricity needs of Baron Techno Park proved the presence of excess electrical energy generated by the system.
3. Production of energy to the system with the installed capacity is good for both off-grid conditions and on-grid condition, namely 167.482 kWh / year. With an average load consumption of 12.212 kWh / year, the excess electrical energy for this system is 154.831 kWh / year.
4. For off-grid conditions with the system installed capacity NPC and COE value is higher compared to the capacity of the operating system. NPC for the installed system capacity is $ 196.33 and the COE is $ 1.24. while NPC operating system with the capacity now is $ 62.020 and COE - $ 0.0213.
5. Improved performance of Baron Techno Park hybrid power generation systems to do with the grid. This is due to distribute electric energy in production, extend the life of the system components, maintain the stability of the electricity needs, and reduce operating costs and maintenance.
6. With the grid, the contribution of Baron Techno Park hybrid power plants can lower carbon dioxide gas amounted to 82.63 kg/year for operating systems and 202.63 kg/year for systems with installed capacity.

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