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Article

Economic Policy of Renewable Energy: Development of Marine Current Energy in Madura Straits, Indonesia

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Abstract: The depletion of fossil resources and environment degradation caused by conventional oil and gas exploitation highlights the urgency for renewable energy adoption to achieve sustainable development. Marine current energy offers a promising alternative, yet its economic feasibility remains insufficiently studied. The study aims to analyze the economic potential of marine currents energy and policy development as a source of renewable energy by developing of power plant in Madura Strait, East Java Province, Indonesia. The analysis methods used in this study were technical feasibility, econometric analysis, cost-benefit analysis, input-output model and policy analysis. Results show that the Madura Strait had sufficient resource potential to produce marine current energy. Consumers' income and KWh usage were significant parameters in using marine current energy. The development of a marine current energy power plant was found to be financially feasible for at least three units (30 kW) or more, with an NPV of USD 57,010, a Net B/C ratio of 1.57, and an IRR of 8% over a 10-year investment period. The development of a 3 MW marine current energy power plant was projected to increase the gross regional domestic product by 0.02%. Policy analysis using the Analytical Hierarchy Process (AHP) identified regional infrastructure development, including coastal spatial planning, as the top policy priority.

Keywords: economic policy; regional economic growth; marine current energy; technical and economic feasibility; sustainable development policy

1. Introduction

The use of new and renewable energy is low and inefficient. Also, the dependence on imported fossil energy is currently one of Indonesia's big energy problems. Population growth and infrastructure development encourage increased electricity consumption. The Per capita electricity consumptions (energy consumption per customer) were 0.88 GWH (2014), 0.91 GWH (2015), 0.96 GWH (2016) and 1.02 GWH (2017) (Directorate General of Electricity, Ministry of Energy and Mineral Resources, 2018). Sufficient supply and energy reserves should support these energy needs which should consider sustainable renewable energy (Firdaus et al., 2014).

The transition from conventional energy sources to renewable energy is expected to meet energy supply and reserves in Indonesia. Kusumastanto (2006) stated that one of the potential renewable energies in Indonesia is ocean/marine energy. The total potential of efficient ocean energy in 2014 was 60,985 MW, with the practical potential of wave energy of 1,995 MW, marine current energy of 17,989 MW and Ocean Thermal Energy Conversion-OTEC of 41,001 MW (Directorate General of New Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources, 2017). The trend of increasing energy consumption and renewable energy potential, especially ocean energy, is not optimal, illustrating that the development of renewable energy sources is essential. Furthermore, fuel energy adequacy in the long run to meet the demand is questionable and it is needed policy toward transition to non-petroleum-based energy system (Field, 2001).

Therefore, the economic study of renewable energy to support policies is very important. Renewable energy policies encouraging the fulfilment of Indonesia's energy supply and reserves are needed. Ocean/marine energy sources become one of the potential renewable energies to be developed and utilized in Indonesia. Marine Current Energy conversion technologies are promising renewable energy with some full scale and semi-commercial turbines constructed and deployed in several countries around the world (Liu and Bahaj, 2021). A study of economic policy analysis was carried out based on a case study of marine current energy potential in the Madura Strait, East Java Province, Indonesia. Madura Strait is a strait connecting Madura Island and Java Island, with the dominant current velocity ranging between 0-7 cm/s and the maximum current speed is in the range of ≥35 cm/s.

Based on the description of the study, the purpose of this study are to: 1) analyze the energy potential of marine currents as a power plant in the Madura Strait, East Java Province; 2) determine technical and financial feasibility study and also regional economic impact of marine current energy; and 3) evaluate economic policy alternatives for the development of marine current energy. This research covers the study of economic policies on renewable energy resources, namely marine currents as energy sources, potential electricity supply for the community, economic potential for the use of marine currents, and policy directions.

2. Methods

2.1. Research Methods

The research used a case study method in the development of potential marine currents in the Madura Strait, East Java Province. This research was carried out in West Sukolilo Village and Suramadu Bridge, East Java Province. The selection of the location of the study was carried out by considering the electricity needs of the coastal community and the designation of the Suramadu Bridge.

The type of data used was primary and secondary data. Primary data were obtained from filling out questionnaires as a result of interviews with respondents. Secondary data were data on technology for marine currents, characteristics of the research area, and socio-economic aspects of the community, as well as other supporting data. Sampling was done purposively based on research criteria

2.2. Data Analysis Methods

2.2.1. Analysis of prospective marine currents

Analysis of the potential of marine currents aims to describe the suitability of marine currents in the development of ocean energy. The data were secondary data including the speed and direction of the current, and the tides characters in the Madura Strait waters. In addition to predicting the suitability of marine currents, this analysis was also an input to estimate the electrical power potential of marine current power generation technology.

2.2.2. Analysis of electrical power potential of marine-current power plants

Analysis of the potential electrical power was carried out to determine the electrical power generated from the conversion of marine currents. According to Fraenkel (1999) in Yuningsih (2008), the electrical power equation generated from the conversion of marine current energy was as follows:

$$P = \frac{1}{2} \rho A |V|^3 \eta \quad (1)$$

where:

P = Produced energy (watts)
A = Cross section of the turbine
ϱ = Mass of water type (1025 kg/m3)
η = Generator efficiency (%)
V = Current velocity (m/s)

2.2.3. Analysis of the willingness to pay

The Analysis of willingness to pay (WTP) is carried out with a direct approach so that economic value is obtained directly from the results of respondents' interviews regarding the willingness of respondents to pay the basic electricity tariff sourced from the Sea Power Plant (MCPT). Respondents were people in West Sukolilo Village and Madura Island. The determination of the WTP value used the regression equation as follows:

$$WTP = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + e_i \quad (2)$$

where:

WTP = WTP value
X1 = Number of family members (people)
X2 = Income of the family (rupiah per month)
X3 = Electricity payment (rupiah per month)
X4 = Availability of electricity from PT. PLN (1 if “not good”, 2 if “not good enough”, 3 if “normal”, and 4 if “good”, and 5 if “very good”
X5 = Respondent’s occupation or livelihood (1 if “entrepreneur/trader”, 2 if “private employee”, 3 if “Civil servant/National police”, and 4 if ‘’fishers “

b0 = Intercept
b1 – b5 = Coefficient of regression
ei = Error term

According to Nababan et al. (2008), the price variable of electricity proxied by WTP can be used because WTP consumers can disclose the actual value or price of an item or service, and WTP can be used as a basis for pricing.

2.2.4. Cost-Benefit Analysis

The cost-benefit analysis was conducted to determine the financial feasibility of MCPT investments, using three criteria in determining the feasibility or non-feasibility of a program to be run or invested in, namely Net Present Value (NPV), Net Benefit-Cost (net B/C), and Internal Rate of Return (IRR).

The basic electricity tariff used in the calculation of electricity sales, based on the group rate of government offices and street lighting in 2013, was Rp. 997.00 per kWh. The determination of basic tariffs based on consideration of MCPT development was carried out by the government and is still in the stage of technology testing. The determination of the value of the Break Even Point (BEP) was also done to determine the break-even point of MCPT investment on the stipulated electricity tariff.

Assumptions used include a decrease in electricity production by 30% due to uncertain environmental conditions (unstable current velocities) or electrical energy conversion mechanisms that do not operate optimally; and an increase in costs (input prices) by 20 % due to the effect of increasing prices of parts or materials of the MCPT technology.

2.2.5. Input-Output (I-O) Analysis

The Input-output (I-O) analysis was used to examine the role of the energy sector in the economy. The analysis was carried out to evaluate the power dispersion index and sensitivity degree using the RAS method or updating data based on transactions from producer prices. The updates were carried out at I-O in 2000 and 2006 to I-O in 2012. The I-O analysis approach was also carried out to obtain an overview of the contribution of the energy sector.

2.2.6. Policy analysis

The Analytical Hierarchy Process (AHP) was used to organize information and make decisions in choosing the right alternative decisions. Alternative policy arrangements are made through the combination of expert judgment. The results of the expert assessment are then processed with AHP to determine policy alternatives.

Criteria and alternative assessments were carried out by several multidisciplinary experts related to the development of marine current energy. Consequently, the assessment of some of these experts needs to be checked for consistency one by one. Consistent assessments are then combined using geometric averages. The geometric average was as follows:

$$\overline{X_G} = \sqrt[n]{\prod_{i=1}^{n} X_i} \quad (3)$$

where:

$\overline{X_G}$ = Geometric average
n = Number of respondents
Xi = Assessment by expert i

$\prod$ = Multiplication

3. Results and Discussion

3.1. Prospective marine currents in Madura strait waters

Tidal are the phenomenon of rising and falling of the surface water (sea) as a result of the attraction of celestial bodies (especially the moon and sun) on the mass of water on earth. Based on the Formzahl equation, the tides in the Madura Strait waters were tidal mix leaning to double daily, as shown in Figure 1.

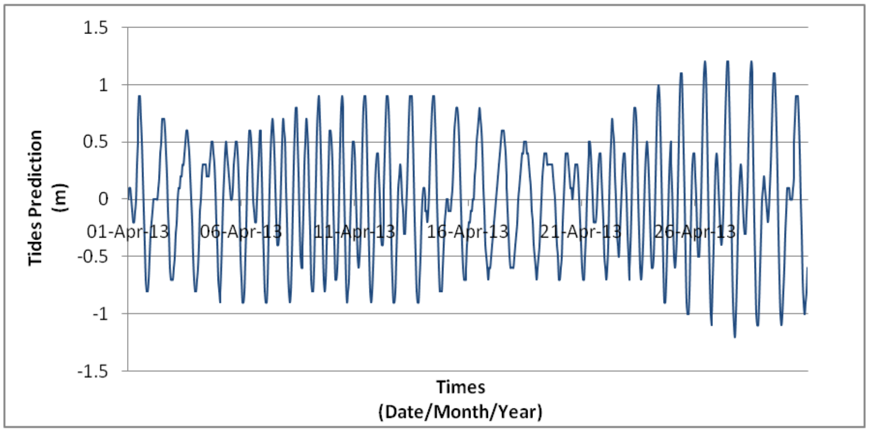

Figure 1. Tidal Predictions in the Madura Strait (April 2013)

The tidal patterns affect the movement of waters such as marine currents so that tides are one of the factors determining the amount of current energy. Water current is a horizontal or vertical movement of water masses continuously until the balance of forces acting is achieved. The movement of the water mass occurs due to generating forces, such as wind, tides, thermohaline, and geostrophic.

The Madura Strait has the characteristics of straits that are protected from direct exposure to marine waters. These characteristics cause the potential for the current generation to be dominated by tides. Thus, tidal patterns determine the movement of currents in the Madura Strait. In addition to the tidal currents, the movement of the Madura Strait waters is certainly influenced by other current generation factors such as wind. The pattern of current velocity distribution ($^{cm}/_{s}$) based on zonal (u) and meridional (v) current components are presented in Figure 2. Components of u and v currents presented were the current velocity data ($^{cm}/_{s}$) for 5 years in the Madura Strait waters. The visualization of components u and v illustrated the prevailing currents during 2008-2012 heading east or northeast and west or southwest. The direction of the current moving towards East or Northeast and West or Southwest was suspected because of the geographical conditions of the Suramadu region. The pattern of distribution of direction and speed of currents in Suramadu waters is shown in Figure 2.

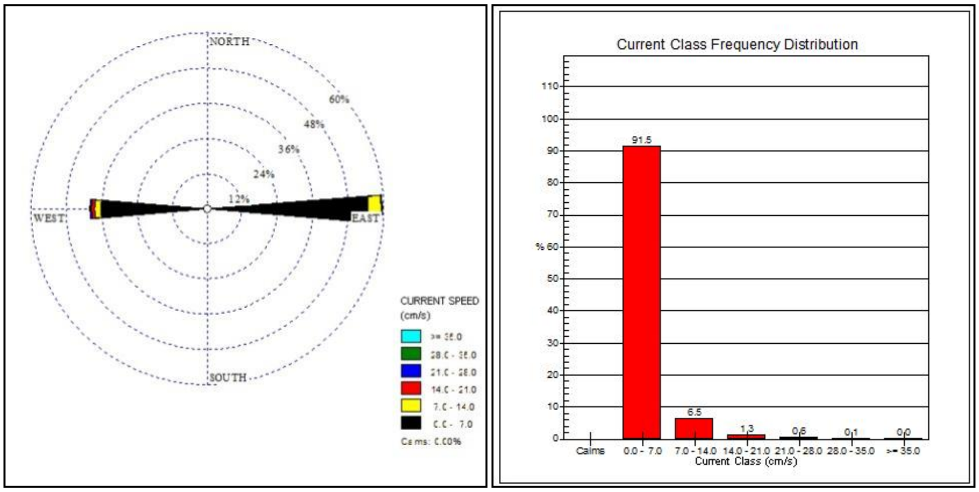

Figure 2. Diagram and histogram of the frequency distribution of direction and velocity for 5 years (2008-2012) in the Madura Strait waters

The pattern of water currents (Figure 2) moved the domain to the East and West. The movement of water masses was influenced by wind and topography. The displacement of the Suramadu water mass was thought to be predominantly influenced by topography. The dominant current velocity of 91.5 percent is in the range of speed frequencies of 0-7 $^{cm}/_{s}$. The slow current velocity was thought to be due to the influence of wind and tides moving insignificantly. The potential for current velocity is the basis for predicting the electrical power potential.

3.2. Potential Electrical Power of Marine Current Power Plants Technology (MCPT)

The potential marine currents in the Madura Strait waters were thought to be dominantly generated by tidal waters (tidal currents). This tidal current determines the electrical power potential produced by electricity generation technology. The higher the current speed, the higher the potential for electric power is to be produced, and conversely. But on a technical basis, modification of the tool can be done to adjust the current velocity. Modifications to these tools can be done by adjusting the suitability of mechanical components such as bevel gear or increasing the number of plants (increase in the number of turbines) and generator settings and other mechanical systems. Tidal prediction pattern in April 2013 and internal velocity (in situ data is the power data produced by the Marine Current Power Plant (MCPT) for 4 days of trial at the Suramadu Bridge waters area.

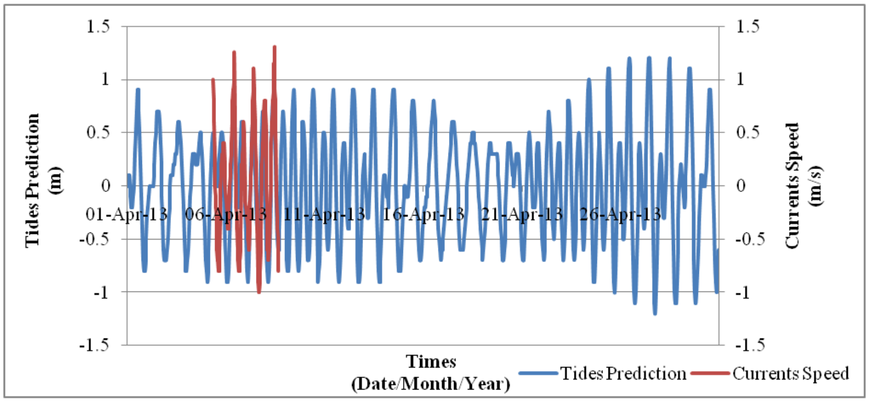

Figure 3. Comparison between the April 2013 tidal prediction patterns and the speed of the currents

The results of the data plots (Figure 3) illustrated that the data collection was carried out at high tide and has not reached the highest and lowest tides, so the electricity produced was not optimal. The energy potential at highs and lows was greater because the displacement of the water mass will be greater so that the generated currents will be faster. Visualization of the data on the current velocity and predictions of tides during in-situ data retrieval is shown in Figure 4.

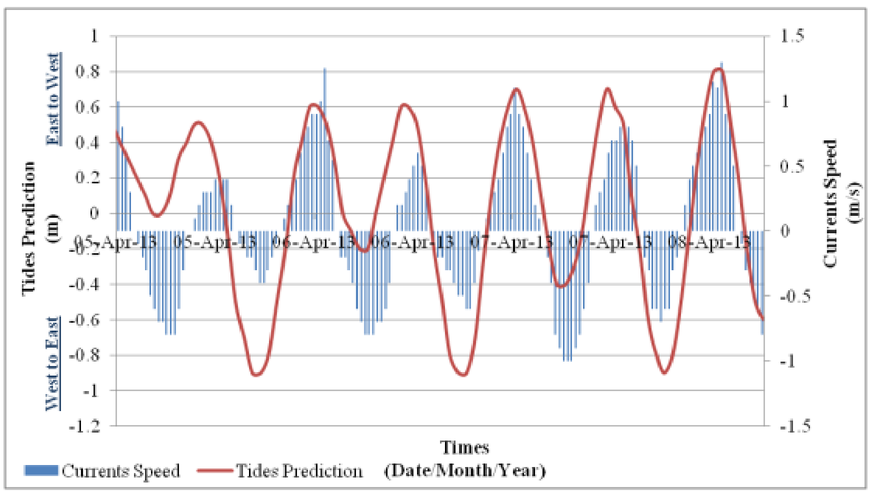

Figure 4. Visualization of current velocity and tidal predictions (in situ)

The development of the Marine Current Power Plant Technology (MCPT) of the Hydrodynamic Study and Research Centers (BPPH-BPPT) has been successfully carried out and produced electricity. The MCPT has proven technically feasible but still requires developments to produce optimal electrical power. The maximum current speed during in situ measurements on 5-8 April 2013 was 1.3 meters/second. The average rate of in situ current was 0.48 meters/second. The current speed would certainly affect the electrical power produced by the MCPT. The electrical power produced by MCPT technology based on average data is presented in Figure 5.

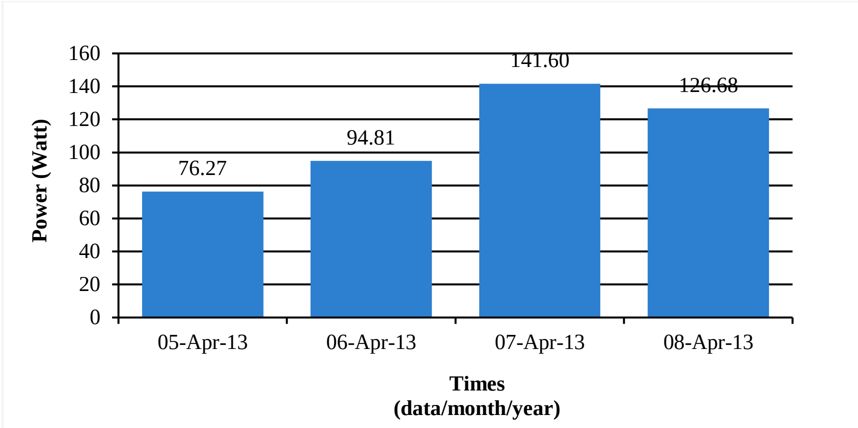

Figure 5. Daily average electric power from the MCPT

The total daily MCPT power were 2,888 watts (April 5); 2,933 watts (April 6); 1,780 watts (April 7); and 3,863 watts (April 8). Thus, the potential electrical power that can be stored for 4 days was 10,864 watts. The electrical power produced by MCPT depends on the speed of the current, and the condition of the equipment, when both of these factors function the resulting power will be optimal.

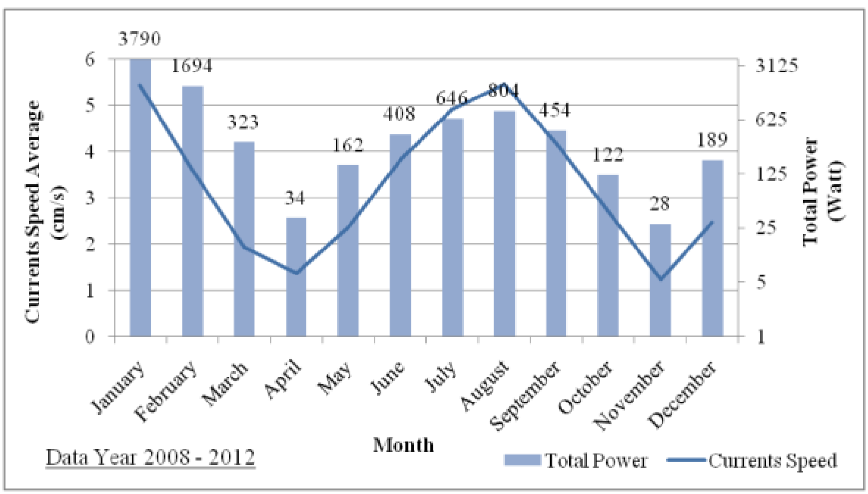

Figure 6. Potential electrical power for 5 years (2008 - 2012) in the Madura Strait

The pattern of potential electrical power and current velocity, presented in Figure 6, was a calculation of the electrical power based on current velocity using electrical power equation Fraenkel (1999). The biggest potential electrical power was in January with a power of 3,790 watts, while the lowest was in November with a power of 28 watts. The highest average velocity occurred in August and was 5.4 cm/second, and the lowest in November was 1.2 cm/second. However, the highest current velocity (without averaging data) occurs in January at 35 cm/second and the lowest in April at 6.15 cm/second.

3.3. Willingness to Pay for MCPT Utilization

The willingness of the respondents to use marine current energy as a source of electricity was an important decision. Indeed, when all respondents are unwilling to use marine current energy, the development of MCPT will also be difficult in the area. The willingness of respondents to use Marine current energy as a source of electricity from 50 respondents was as follows: 86% of respondents were willing, and 14% of respondents were not willing to use or pay.

The willingness of respondents to use the MCPT was allegedly due to the willingness of the respondents to have a safe energy source without interference. The respondents were not willing to use this renewable energy considered the MCPT to be new (it has never been tested) so that if it is used then, electricity disruptions will occur more often. The estimation of the opportunity of willingness to pay of the respondents was done using the logit regression model.

The logit regression model was used to evaluate the chance of occurrence of respondents willing to use MCPT. The model was built on the dependent variable, namely the opportunity of respondents willing or unwilling to pay; and independent variables, namely the number of family members (X_1), family income (X_2), electricity payments (X_3), and electricity availability (X_4), and respondent's livelihood (X_5).

Based on the results of the analysis, the model built was a good model because its Omnibus Test of the P-value Coefficients Model was 0.010 smaller than the real level α = 5 %, with Log-likelihood -2 value of 20.511, Cox & Snell R Square of 0.329, and Nagelkerke R Square of 0.594. The calculation of the Goodness-of-Fits test: Hosmer and Lemeshow Test were 0.286, the Sig value was greater than the real level α = 5% and Overall Percentage was 92%. The logit regression opportunity of respondents willing or unwilling to pay is presented in Table 15. The logit regression results of the respondents' willingness to pay are presented in Table 1.

Table 1. Results of Logit Regression Opportunities for Respondents Willing or Unwilling to Pay Basic Electricity tariffs

Opportunities	Coefficient	*Sig*	*Exp* (β)	Description
Constant	-6,915	0,610	0,001	
X_1	2,195**	0,040	8,983	Significant
X_2	0,000	0,503	1,000	Insignificant
X_3	0,000	0,799	1,000	Insignificant
X_4				
X_4(1)	-1,422	0,469	0,241	Insignificant
X_4(2)	1,334	0,380	3,795	Insignificant
X_5				
X_5(1)	23,230	0,999	1,226E10	Insignificant
X_5(2)	4,899**	0,034	134,116	Significant
X_5(3)	22,625	0,999	6,695E9	Insignificant

Source: Results of data analysis (2014) Description: ** at a level of significant of 5%

The model that can be built based on variables significantly influencing the willingness of respondents to pay was:

L_i = - 6,915 + 2,195 X_1 + 4,899 X_5(2) + e_i .... (4)

Based on the model, independent variables had significant effects on the willingness of the respondents to pay, namely the number of family members and respondents' livelihoods. The variable of the number of family members (X_1) had a Sig value of 0.040, meaning that the variable had a significant effect on the chances of respondents willing to pay the basic electricity tariff to utilize MCPT at a real level of α = 5%. Exp (β) or odds ratio was 8.983, signifying that the respondents with more family members had the opportunity of paying 8.983 times compared to respondents with fewer family members. The coefficient value of the variable was positive (+), meaning that the higher the number of family members, the greater the tendency of respondents to be willing to pay MCPT basic electricity rates (Fidaus et al 2015)

The respondent's livelihood variable (X_5) was a dummy variable stating that respondents such as entrepreneurs or traders had a value of 1, while the private sector had a value of 2, civil servant or national police workers had a value of 3, and the Fishers had a value of 4. The variable X_5 (2) or private had a Sig value of 0.034, meaning that the variable had a significant effect on the chances of respondents willing to pay the basic electricity tariff to utilize the MCPT at a real level of α = 5%. Exp (β) or odds ratio was 134,116, meaning that respondents had the opportunity to pay 134,116 times compared to respondents with other livelihoods. The coefficient value of the variable was positive (+) signifying that the livelihood variable had a positive influence on the chances of respondents to pay the basic electricity tariff to utilize MCPT. The estimation of respondents 'WTP (EWTP) value was calculated based on the data of respondents' WTP distribution. Data on the distribution of willingness of respondent to pay in the West Sukolilo Village are presented in Table 2.

Table 2. The distribution of WTP respondents in West Sukolilo Village

WTP class (Rupiah/kWh)	**Frequency (Respondent)**	**Relative Frequency (P*fi*)**	**Total (Rupiah/kWh)**
(a)	**(b)**	**(d = b/c)**	**(a x d)**
420	30	0,60	252,00
430	5	0,10	43,00
610	11	0,22	134,20
620	2	0,04	24,80
635	1	0,02	12,70
984	1	0,02	19,68
	50 **(c)**	1,00	486,38

Source: Results of data analysis (2014)

The WTP class was obtained by first determining the smallest value to the greatest value of the WTP offered to the respondent. The results obtained the EWTP value of Rp. 486.38 per kWh. The willingness of the respondent to pay can also be seen based on the WTP demand curve for MCPT electricity tariffs. The demand curve of the respondent's WTP is shown in Figure 7.

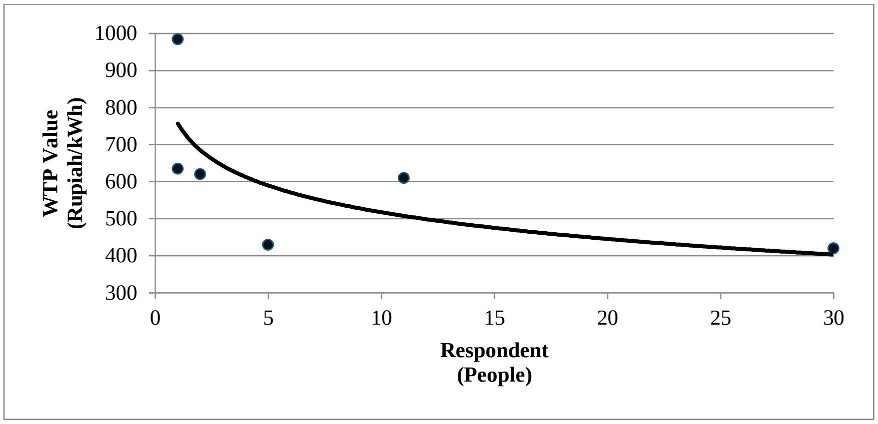

Figure 7. WTP Demand Curve for basic MCPT Electricity Tariff Payments

The WTP multiple regression model of the willingness of respondents to pay the MCPT electricity basic rates is as follows:

$$WTP = 320{,}915 - 15{,}048\ X_1 + 4{,}181E\text{-}5\ X_2 + 0{,}001\ X_3 + 19{,}387\ X_4 - 9{,}798\ X_5 + e_i \ ......\ (5)$$

The variables showing a real effect on the model were income (X_2) and electricity payments (X_3). The income variable had a Sig value of 0.048, meaning that the variable had a significant effect on the WTP value at a real level of $\alpha = 5\%$. The coefficient value was positive (+), allegedly increasing the income of respondents by one rupiah which will increase the value of the WTP of Rp. 4,181E-5 per kWh. This is presumably due to higher income affecting the respondents' willingness to pay higher tariffs.

The variable of payment for electricity also significantly affected the value of WTP. This variable had a Sig value of 0.066, meaning that the variable had a significant effect on the value of WTP at a real level of $\alpha = 10\%$. The coefficient value of the electricity payment variable was positive (+) and estimated to increase the number of electricity payments affecting the value of WTP.

The average overall WTP value was Rp. 486,38 per kWh with a minimum interval of Rp. 381,73 per kWh and a maximum of Rp. 593,83 per kWh. The WTP value based on the results of the analysis was indeed higher than the price of electricity from PT. PLN (State Company) which was Rp. 415 per kWh. This was presumably because the assessment of respondents' ability was based on variables that significantly affected WTP, namely income (X_2) and electricity payments (X_3).

3.4. Financial Feasibility of MCPT Development

The financial analysis or the feasibility of MCPT investments was done by compiling an investment scenario, assumptions in MCPT development, and using an interest rate of 7.5%. The MCPT investment scenarios carried out included scenario 1 constituting of 1 MCPT unit with a capacity of 10 kW; scenario 2 with 2 MCPT units with a capacity of 20 kW; and scenario 3 with 3 MCPT units with a capacity of 30 kW, and scenario 4 with a MCPT unit with a capacity of 3 MW (MCPT development plan for the Government).

Based on the results of the analysis, the total cost of MCPT investment in scenario 1 was Rp. 587,810,000.00; Rp. 994,020,000.00 in scenario 2; Rp. 1,400,230,000.00 in scenario 3, and Rp.

119,532,300,000.00 in scenario 4. The results of the analysis of the costs of the financial benefits of MCPT are presented in Table 3.

Table 3. Results of MCPT Financial Benefit Analysis

Feasibility Indicators	**Scenario 1 (1 unit)**	**Scenario 2 (2 units)**	**Scenario 3 (3 units)**	**Scenario 4 (3 MW)**
NPV (Rp.)	(70.178.766,86)	345.013.804,96	798.149.031,51	156.618.998.680,08
Net B/C	0,88	1,35	1,57	2,31
IRR	< 0	5%	8%	16%
Tariff of electricity (Rupiah/kWh)	1.320,08	1.254,05	1.188,05	924,04

Source: Results of data analysis (2014)

MCPT development was considered financially feasible to be developed for scenario 3 and scenario 4. The investment scenario 1 and 2 were not feasible (IRR < DR) to be developed presumably because the electric power produced by turbine was too small. So, it did not provide financial benefits. Therefore, MCPT technology needs to be developed so that it is more efficient, and can generate financial benefits.

Modification of MCPT technology needs to be done to produce optimal electrical technology and power. The results of the technical calculation of MCPT basic electricity rates tended to be still higher (Rp. 924 per kWh) than the electricity base rate of PT. PLN which was Rp. 415.00 per kWh (household group rate). The results of this calculation were based on the assumption of the investment feasibility scenario for MCPT development.

Based on data from PT. PLN, the use of MCPT technology to meet the electricity needs of Suramadu Bridge is at 234,620 watts; and East Java Province with an average peak load of electricity needed in 2010-2013 of 4,381.25 MW. The large electricity demand was not fulfilled with the current MCPT technology.

However, the electricity needs can be fulfilled if 25 units of the MCPT technology are built for the Suramadu Bridge area and 300 units for the electricity needs of East Java Province, assuming 1 unit produces 10 kWh of electricity. The Break Even Point (BEP) also needs to be known to estimate MCPT development. BEP MCPT investments are presented in Table 4.

Table 4. Value of MCPT Investment Break-even Points

Indicators	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
BEP (Unit)	143	15	11	6
BEP (Rupiah/kWh)	142.461	14.806	10.884	5.856

Source: Results of data analysis (2014)

Based on the results of the analysis (Table 4), the MCPT investment value needs to exceed the BEP value to obtain a balance condition between the costs incurred with profits. In addition to consideration of the BEP value, the results of a sensitivity analysis of MCPT investments also need to be carried out to assess changes in investments based on an analysis of the cost of financial benefits to changing circumstances or uncertainty.

The results of the sensitivity analysis of MCPT of the assumption of a reduction in the amount of electricity production by 30% due to uncertain environmental conditions or the optimal mechanism for the conversion of electricity not operating are presented in Table 5.

Table 5. Sensitivity analysis results of a decrease of electricity production by 30 %

Feasibility Indicators	Scenario 1 (1 unit)	Scenario 2 (2 units)	Scenario 3 (3 units)	Scenario 4 (3 MW)
NPV	(368.495.035,92)	(251.618.733,14)	(96.799.775,64)	35.469.635.035,85
Net B/C	0,22	0,75	0,93	1,30
IRR	< 0	< 0	< 0	5%

Source: Results of data analysis (2014)

Based on the results of the analysis (Table 5), the reduction in the amount of MCPT electricity production by 30% had an impact on the decline in investment benefits (losses). The investment losses occurred in scenarios 1, 2, and 3, although scenario 4 was still feasible with a decrease in benefits. This decrease in benefits is thought to be due to the sensitive electrical power factor affecting the return-on-investment benefits.

Another factor in the analysis of MCPT investment sensitivity was the increase in costs (cost over run) of MCPT materials or technological materials. The results of the sensitivity analysis of cost increases are presented in Table 6.

Table 6. The results of a 20% increase in cost sensitivity analysis

Feasibility Indicators	Scenario 1 (1 unit)	Scenario 2 (2 units)	Scenario 3 (3 units)	Scenario 4 (3 MW)
NPV	(581.408.301,99)	146.209.804,96	361.146.299,71	128.279.544.605,72
Net B/C	0,25	1,12	1,21	1,89
IRR	< 0	2%	3%	12%

Source: Data analysis results (2014)

Based on the results of the analysis (Table 6), a 20% increase in costs had an impact on decreasing investment benefits (losses). The scenario of MCPT development had decreased investment benefits, although it was still feasible only for scenario 4 (IRR>DR). This decrease in benefits was allegedly due to the investment that was greater than the electricity produced by MCPT. Thus, the profit from selling electricity was unable to cover the investment costs.

The results of the sensitivity analysis of the decrease in the amount of production and the increase in costs indicated that both of these factors had effects on the decline in the benefits of investment. However, the MCPT investment in scenario 4 was still feasible because the NPV, net B/C, and IRR values under normal or changing conditions remained positive. The sensitivity assessment of MCPT investment was suspected of being sensitive to production changes and increasing input prices. Therefore, the MCPT investment is financially feasible based on scenario 4 or the MCPT development with a capacity of 3 MW.

3.5. The development of the energy sector and regional economic growth

The development of the energy sector is very important in regional economic growth. The Output-Input (I-O) analysis was conducted to describe the role of the energy sector in the economy in East Java Province. The economic sector classification in the I-O analysis was based on the classification of the East Java Province's GRDP and the energy sector assumptions. The I-O analysis used the power distribution index approach and the degree of sensitivity. A sector that has more than one distribution power index value was considered to play a considerable role in encouraging the growth of other sectors, whereas a sector that has a sensitivity degree index greater than one means having a high level of dependence on other sectors. The power distribution index and the sensitivity level of East Java Province are presented in Table 7.

Table 7. Power Distribution Index and Degree of Sensitivity in East Java Province in 2012

	Sectors	Power index distribution	Sensitivity index
1	Agriculture, Animal Husbandry, Forestry, and Fisheries	0,80	0,89
2	**Mining for oil and Natural gas**	**1,34**	**2,30**
3	Non-oil and gas mining	0,76	1,20
4	Processing industry	1,29	0,77
5	**City electricity and gas**	**1,13**	**0,86**
6	Clean water	1,00	0,97
7	Construction, Trade, Hotels, and Restaurants	1,04	0,58
8	Transportation and Telecommunication	0,97	1,17
9	Finance, leasing and company services	0,86	0,73
10	Services	0,82	0,52

Source: Data analysis results (2014)

The power index value of the spread of the oil and natural gas mining sector, and the city electricity and gas sector was known to be greater than one. So, it was assumed that the sector provided a strong driving force to the economy in East Java Province. The sensitivity index of the city electricity and gas sector had a value of smaller than one, meaning that the sector had a low level of dependence on other sectors in the economy of East Java Province.

The feasibility of investment in the economic sector can be seen from the value of the spread index and the degree of sensitivity. The determination of the sector is carried out when the government has limited funding to develop each sector of the economy. Thus, it is necessary to determine the strategic economic sector. According to Daryanto and Hafizrianda (2010), if the government has substantial funds, the development of the economic sector that has a greater power distribution index and sensitivity than one, then it is a strategic choice because it has an impact on economic growth both through increasing aggregate demand and aggregate supply.

Limited funds make the government determine the strategic sector, so the economic sector that has the highest potential includes the oil and gas mining sector. Therefore, the development of the energy sector has strategic potential in driving the economy of East Java Province.

The contribution of the oil and natural gas sector and the city's electricity and gas sector was lower than those other economic sectors. The power index value of the spread and the degree of sensitivity of the sector was known to be greater than 1 (except the index value of the sensitivity of the city electricity and gas sector). This situation was presumably because other economic sectors had a dominant role in the economy. The contribution of economic sectors and MCPT investment to GRDP in 2008-2012 is presented in Table 8.

Table 8. Economic Sector Contributions to the GRDP of East Java Province

No.	Sector/Sub-sector	Years (%)					
		2008	2009	2010	2011	2012	2012 (3 MW)
1	Agriculture, Animal Husbandry, Forestry and Fisheries	16,55	16,34	15,75	15,38	15,42	15,40
2	**Oil and Gas mining**	**0,30**	**0,34**	**0,42**	**0,46**	**0,38**	**0,41**
3	Non-oil and Gas mining	1,92	1,88	1,77	1,78	1,69	1,70
4	Processing industry	28,47	28,14	27,49	27,12	27,11	27,08
5	**City electricity and gas**	**1,49**	**1,46**	**1,42**	**1,34**	**1,26**	**1,28**
6	Clean water	0,09	0,09	0,09	0,09	0,09	0,11
7	Construction, Trade, Hotels and Restaurants	32,37	32,43	33,96	34,66	34,94	34,89
8	Transportation and communication	5,25	5,50	5,52	5,66	5,70	5,71
9	Finance, Leasing and company services	4,79	4,83	4,90	4,97	5,05	5,05
10	Services	8,77	9,00	8,68	8,55	8,35	8,35
Total		100,00	100,00	100,00	100,00	100,00	100,00

Source: Fidaus et al (2014)

Based on the power index value, the spread and degree of sensitivity of the energy sector had the potential to drive the economy if the government opened investment opportunities. The energy sector, especially the electricity sector, played an important role in the economy of a region. The development of an MCPT of 3 MW was estimated to contribute 0.07% to the average peak load of electricity needs in 2010–2013 in East Java Province (4,381.25 MW).

The development of the 3 MW MCPT used the Hydrodynamic Study and Research Centers (BPPH-BPPT) technology with a capacity of 10 kW. Thus, it required 300 technological units to meet the capacity of 3 MW. The MCPT technology needed to be technically, financially, and spatially structured. The city electricity and gas sector was estimated to gain an additional contribution of 0.02% to the GRDP if the development of a 3 MW MCPT had been carried out in East Java Province. Policy impetus was needed for the development of MCPT. Policy studies on ocean/marine energy were identified as some of the drivers of renewable energy development and economic growth that needed to be developed.

3.6. The policy of the Marine current energy development

Policy analysis of renewable energy (marine current energy) should be designed with the framework of energy for sustainable development with the aim to develop sustainable environmental practice, renewable energy, energy security, energy diversification, energy conservation, and economic growth. Renewable energy is an alternative source of energy which can reduce CO_2 and climate change mitigation (Bhattacharyya, 2011). Strategic Enviromental Assesment should be considered in the development program which encourage decision makers to become aware of environment issues in their own region so that sustainable development can be implemented (Daulay et al, 2024). The results of the analysis based on expert perspectives (Hydrodynamic Study and Research Centers (BPPH-BPPT), East Java Provincial Energy and Mineral Resources Office, Regional Development Planning Board of East Java Province and Ministry of Energy and Mineral Resources) with hierarchical analysis method (AHP) are presented in Figure 8.

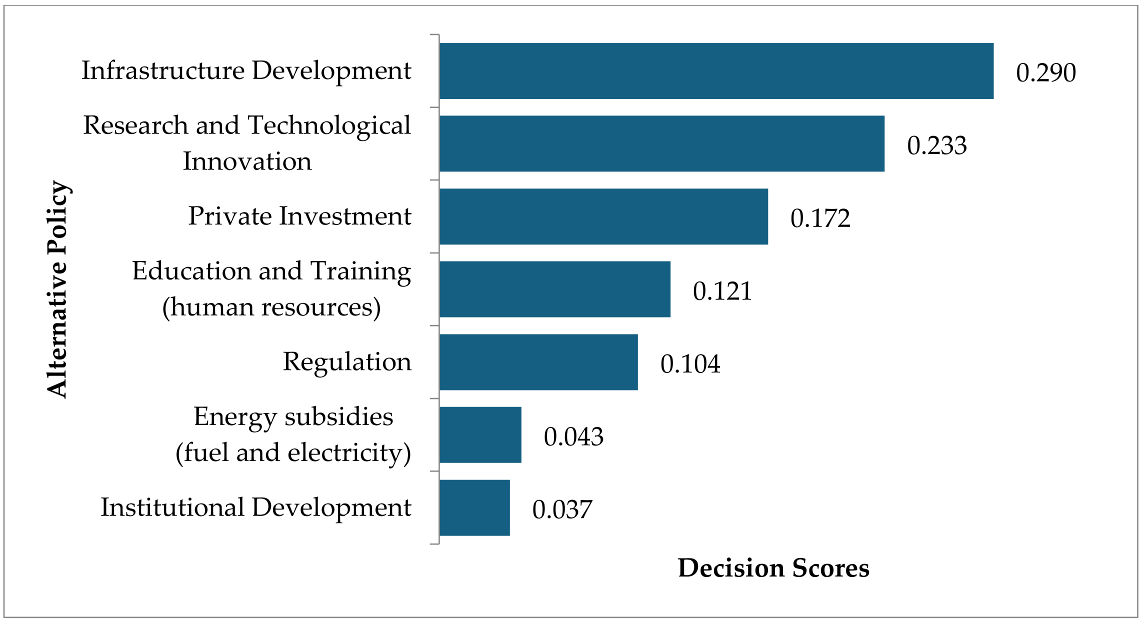

Figure 8. Priority Assessment of Marine current Energy Policy

An alternative policy priority was infrastructure development; this policy was related to the construction of MCPT, which included coastal spatial planning. An alternative policy related to research and technological innovation also ranked as the second-highest decision score, making it an important policy alternative. The right policy was expected to encourage the development of marine current energy.

Other considerations in formulating alternative policies included determining potential energy areas (mapping of energy sources), using appropriate technology, securing government support for research funding, involving and educating the public, and increasing the role of the private sector. Strong support for renewable energy policies, especially marine current energy, was expected to encourage sustainable regional and national development.

4. Conclusions

The development of marine current energy is the implementation of the blue economy concept in the energy sector and sustainable development. Based on the results of the research analysis, can be concluded:

1. The Madura Strait has a potential resource to produce renewable energy from marine current. However, it requires MCPT technology that is more technically efficient and financially feasible.
2. Respondents rated the PLTS development positively and were willing to pay basic electricity tariffs sourced from MCPT, under the condition of having a stable electricity supply.
3. The energy sector can drive economic growth in East Java Province. The electricity and gas sector contributed 1.28% in 2012 to the GRDP of East Java Province with the addition of the development of 3 MW MCPT.
4. The policy priority for developing marine current energy based on the results of research is infrastructure development. Infrastructure development which includes MCPT development and spatial planning.

Recommendation

It is necessary to adjust MCPT technology based on the potential energy sources. Technological adjustments can be made by increasing MCPT capacity. Based on the analysis of financial cost benefits, the greater the MCPT capacity, the more the MCPT investment becomes feasible.

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