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Analysis of Water Utilization as a Source of Energy

Rudy Laksmono W[*] I Wayan Midhio[**] Yanif Dwi Kuntjoro[***]

[*]Universitas Pertahanan Indonesia
[**]Universitas Pertahanan Indonesia
[***]Universitas Pertahanan Indonesia

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Corresponding Author:
rudy.laksmono@idu.ac.id

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Abstract

Micro-hydro as one form of renewable energy and could be developed, it is important as a new knowledge so that it can know to the public. This study shows how the feasibility of micro hydro system to be built in the communities to provide benefits to the safety and well-being. Feasibility study covering aspects of the social environment, the technology and its benefits. Through the simulation of the application of micro hydro power plant (MHP) in the Indonesian Defence University (IDU), this study intends to find empirical data is about the design of the MHP can be implemented. This research reveals about the type of MHP in accordance with the demographic conditions in the IDU.

Mikrohidro sebagai salah satu bentuk energy baru yang terbarukan terus berkembang di seluruh dunia, hal ini menjadi penting untuk menjadi pengetahuan baru sehingga dapat diketahui masyarakat umum. Penelitian ini menunjukkan bagaimana kelayakan sistem mikro hidro untuk dapat dibangun di lingkungan masyarakat agar dapat memberikan manfaat bagi keamanan dan kesejahteraan. Kelayakan yang dipelajari meliputi aspek lingkungan social, teknologi dan manfaatnya. Melalui simulasi penerapan Pembangkit Listrik Tenaga Mikrohidro (PLTMh) di lingkungan kampus Universitas Pertahanan (Unhan), penelitian ini bermaksud untuk menemukan data empiric tentang rancangan PLTMh yang dapat dilaksanakan. Hasil penelitian mengungkapkan tentang jenis PLTMh yang sesuai dengan kondisi demografi di lingkungan Unhan.

Introduction

Economic progress in the modern era is strongly influenced by the amount of energy possessed by a country (Hossain, 2015), it is evidenced by the demand for fuel increased significantly every year, especially in the developed and developing countries (Carneiro and Ferreira 2012).

Conditions regarding the current energy-dominated oil by 49.7%, then coal and gas amounted to respectively 24.5% and 20.1% (Figure 1) shows that Indonesia is very vulnerable to the use of fossil energy. The amount of use of the waterwheel type of impacting the increased air pollution, global climate change, and security of supply to the increased current consumption (Fuss, 2009; Georgakellos 2009; Longo, 2008; Stigka, 2014) even result in the disruption of productivity ecosystem (Doll and Zhang, 2010). This is what causes the need driven renewable energy to maintain environmental friendliness and sustainability of energy security (Hadian, 2015).

Renewable energy is an energy source that is constantly replenished by nature and are derived directly from the sun, indirectly from the sun (such as wind, hydropower, and energy synthetic images), or from the movement of other natural and mechanisms environment (Ellabban 2014).

The potential and the capacity range of Renewable Energy (EBT) came from hydro, geothermal, biomass, solar, wind, ocean, and uranium (Ellabban, 2014; Johari, 2014; Hossain, 2015). Overall renewable energy potential, that potential energy of water resources is the highest potential with total resources produced 75,000 MW and the installed capacity of 7,572 MW or 10.1%.

This means hydropower potential can still be developed to the maximum of 89.9% to reach about 67,500 MW or more (Table 1). 7572 MW of installed capacity, generating classification is divided into three types as shown in Table 2.

Water is the resource of energy that is clean, friendly, cheapest and assessed significant to the needs of a sustainable future (Aliakbar, 2009). Hydroelectric energy has benefited for over a hundred years, and has been the source of the most efficient and trust as renewable energy (Brooker, 2014). The energy has been able to address the problem of electricity shortage and financial problems in rural areas and poor (Elbatran 2015). Hydropower generated from moving water in the hydrological cycle, which is driven by solar radiation thereby creating energy that can be captured and converted into electricity using turbines (Ellabban 2014):

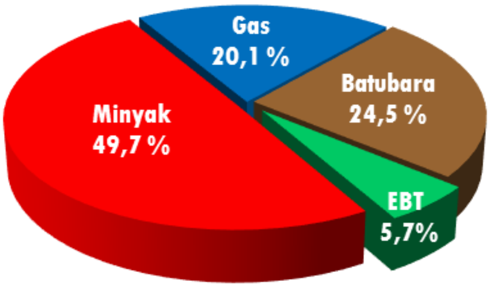

Figure 1. Energy Conditions Currently
(Source: Ditjen EBTKE, Ministry of Energy, 2014)

Table 1. Variety of New and Renewable Energy (EBT)

No	Renewable Energy	Resources	Capacity	Ratio (%)
1	Hydro	75.000 MW	7.572 MW	10,1%
2	Geothermal	28.617 MW	1.343,5 MW	4,7%
3	Biomass	49.810 MW	1.716,5 MW	5,26%
4	Surya	4,80 kWh/m^2/day	42,77 MW	-
5	Wind	3 – 6 m/s	1,87 MW	-
6	Ocean	49 GW***	0,01 MW****	-
7	Uranium	3.000 MW*	30 MW**	-

*Only in Kalan – Kalimantan Barat
**Energy study center
***Source: National Energy Board
****Prototype BPPT

Source: Ditjen EBTKE, Ministry of Energy, 2014, Hydropower Potential

Table 2. Number of Units and Plant capacity based Classification Plants

No	Classification Power	Units	Capacity (MW)
1	PLTA	156	6,997
2	PLT Mini-hydro - PLN	192	442
3	PLT Mini-hydro - IPP	31	62
4	PLT Mini & Micro-hydro-Off Grid	431	70
	Total	910	7,572

Source: Ditjen EBTKE, Ministry of Energy, 2014, Hydropower Potential

While the world needs the energy of water increases, water energy required for extraction, treatment, and distribution (Dennen et al, 2007; Rewards and Madani, 2013). While the water available is more limited, in 2035, global water needs of the energy sector is expected to grow by 37-66% compared with 2012 (Rewards and Madani, 2013). With the water-based renewable energy can create competition on the water (Gerbens-Leeneset al., 2007), especially in the food sector because it can increase food prices and decreasing food security (Gerbens-Leenes and Hoekstra, 2011a). Some renewable energy sources, requires fresh water a high, it need to be managed effectively and efficiently in the future (Hadian 2015). Hydroelectric energy has been used as a form of improvement in the level of the modern world, approximately 16% of hydroelectric power plants capable of generating electrical energy the world in 2010, is expected to increase by 3.1% per year over the next 25 years (Hossain, 2015).

	Sumatera	Jawa-Bali	Kalimantan	Sulawesi	Papua	Nusa Tenggara	Maluku
■ Kapasitas Potensi Hidro (2003)	15,587	4,200	21,581	10,183	22,371	624	430
■ Kapasitas yang Dibutuhkan (2010-2019)	13,666	58,617	3,442	3,140			
■ Kapasitas yang Tersedia	2,940	21,485	620	559			
▨ Lokasi Potensi Hidro (2003)	447	120	160	105	205	120	53

Figure 2. Charts and Tables Potential Hydropower Indonesia (Source: Directorate General of Water Resources, Ministry of Public Works, 2012, the Integrated Water Resources Management to support the Energy Security)

The distribution of water power potential in the Indonesian archipelago which can be utilized most on the island of Papua, but in terms of its location at the most and should be developed there on the island of Sumatra, then potential and distribution of a great location and can be developed in sequence, namely on the island of Borneo, the island of

Sulawesi, Nusa Tenggara islands, Java and Maluku islands (Figure 2). With the depletion of oil resources and the amount of water resources in Indonesia, giving it great potential to explore water-based energy production.

Potential water resources are abundant in Indonesia, makes us must be able to develop this potential for water as a renewable energy source and natural. If this can continue to be explored, conversion of water into electrical energy is very beneficial for the country.

Given the importance of the MHP as a form of renewable energy and the potential that exists in Indonesian Defence University (IDU), this study intends to obtain data on the applicability of the MHP empirical that can be used to facilitate the needs of society in the campus and surrounding areas. The formulation of this research is how the strategy and program utilization of hydropower is right for the conditions in the area around campus IDU?

Literature Review

Micro Hydro Power (MHP)

Micro-hydro Power (MHP) is an alternative source of electrical energy for the community (Omar and Hussain, 2015) and provides many advantages, especially for rural communities throughout the world (Nouni et al., 2009; North, 2010). When other energy sources thinning and negatively impacted, then the water becomes a source of energy which is very important because it can be used as a source of cheap energy power plants and does not cause pollution (Ellabban, 2014; Johari, 2014).

Micro-hydro is a small-scale power plants that use hydropower as its driving force such as irrigation canals, rivers or waterfalls nature by utilizing the high waterfall (head) and the amount of water discharge (Bahtiar et al, 2015). Micro-hydro get energy from the flow of water that has a certain height difference with three main components: water (as a source of energy), turbine and generator (Das et al, 2016). Basically, micro-hydro harness the potential energy of water falling (Rehman et al, 2015). The higher the dropping water, the greater the potential energy of water that can be converted into electrical energy (Su et al, 2014).

Besides the factor of the layout of the river, the high water falling can also be obtained by stemming the flow of water so that the water level is high. Air flowed through a pipe rapidly into the house plants that are built on the edge of the river to drive turbines or micro-hydro waterwheel. Mechanical energy derived from the rotation of the turbine shaft is converted into electrical energy by a generator (Elbatran, 2015).

Micro-hydro can utilize the water level is not too large, for example, with a height of 2.5 meters of water can produce 400 watts of electricity. The relatively small amount of energy produced micro-hydro compared with large-scale hydropower, has implications for the relatively simple equipment as well as small areas that needed to installation and operation of micro hydro.

Social Dimensions of Environmental

Micro-hydro is an appropriate choice as the most environmentally friendly energy conversion because it does not significantly interfere with the flow of the river (Mishra et al, 2011). However, the technology applied can change the conditions of the river and its ecosystem, especially changes in river flows and habitats (Renofalt et al., 2010).

Changes in the environment of the river due to the manufacture of micro-hydro in addition to impacts on soil sediments also have problems of social environment, especially the potential risk of flooding due to the installation of micro-hydro may block the river system (Lane et al, 2007; Maynard, 2014), potentially increasing the local flood (Lane et al. 2007). Pinho et al. (2007) considers that there is a negative impact on the environmental quality of the construction of small hydropower plants in Portugal.

Main Structure and Components

Micro-hydro power plants are usually considered a clean technology for generating electricity that can be of two types: run-of-river and storage type (Pinho, 2007). The power plant run of river type obtained by diverting the river water flow to one side of the river further subjecting it again to the river at a place that has a different height. According to Porter (2006) run-of-river system does not depend on the reservoir with a generating capacity can vary significantly depending on seasonal river flows.

These systems often utilize technology dams that are not connected to the network. While the storage-type, can create a reservoir to be used continuously. This type of storage can also be referred to as: (i) pondage, allows the transfer of water which produces energy during low flow or increase demand, or (ii) the reservoir, allowing the transfer of the volume of rain water into the dry season (Pinho, 2007). Classification is based on the magnitude of Hydroelectric power as defined in the European Union (Porter, 2006), as shown in the following table:

Table 3. Classification and Capacity of Hydro Power

Classification	Power Output
Large	> 100 MW
Medium	10 – 100 MW
Small	1 – 10 MW
Mini	100 kW – 1 MW
Micro	5 – 100 kW
Pico	< 5 kW

MHP is generally a water supplied to the plant house (Power House), which are usually built on the river bank. The water will turn a turbine, then the water is returned to the river of origin. Mechanical energy from the turbine shaft rotation is converted into electrical energy by a generator. Hydroelectric power plants under 100 kW are classified as MHP. The main components of micro-hydro run-of-the-river does not require storage of water but divert some water from the river is channeled along the sides of the valley before the 'fall' into the turbine through a penstock (Munster, 1999).

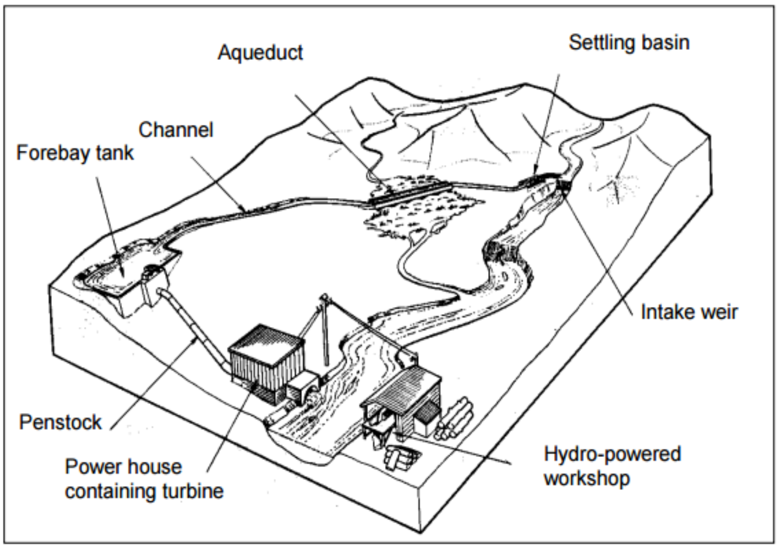

Figure 3. Schematic Layout Micro-hydro (Munster, 1999)

In Figure 3, the turbine drives a generator to produce electricity that can be used for lighting a specific place such as in a campus environment or rural communities. To build the MHP requires several stages and components that must be met are as follows: is a hydrological survey and site, the head measurement, flow measurement, components of civil works (weir and intake, channels, settling basins, spillways, fore-bay tank, penstock); election turbines (impulse turbine, turbines reaction); propulsion systems; and power (Mohibullah et al, 2004).

The main components of micro-hydropower systems use waste disposal system with sewage tank, penstock, turbine, and generator induction for reliable system operation (Saket, 2008). Penstock is the most expensive item in the micro hydro projects up to 40% of the total project cost (Saket, 2008).

In determining the penstock need to consider some important things such as surface roughness of the pipe interior, merging method, weight, ease of installation, access to the site, the design life, maintenance, weather conditions, availability, cost and the possibility of structural damage (Saket, 2006; 2008). Penstock pressure level is influenced by the high head and is very important because it serves to hold the maximum water pressure so it is spared the risk of explosion (Saket, 2008).

Turbines can be selected based on the design of head and flow and speed of plant classification as Impulse (Pelton, Turgo and flow Cross), Reaction (Francis, Propeller, and Kaplan) and water wheels. The range of efficiency of the turbine ranges from 80-95% and for water wheels' ranges from 25-75% (Saket, 2008).

The turbine serves to convert the energy in falling water into electrical power source, are generally divided into three groups; high, medium and low head, and in two categories: impulse and reaction (Munster, 1999). Classification high group has a high dropping water> 50 m, were between 10-50 m, and a low of less than 10 m (Paish, 2002).

Table 4. Classification of Turbines

Turbin Runner	Head Pressure		
	High	Medium	Low
Impuls	Pelton Turgo Multi-Jet Pelton	Crossflow Turgo Multi-Jet Pelton	Crossflow
Reaction		Francis Pumps-as-turbine (PAT)	Propeller Kaplan

Source: Micro-hydro Design Manual, IT Publications, 1992

Selection of the type of turbine can be determined based on the advantages and disadvantages of the types of turbines, especially for a very specific design. High factor dropping water effective (Net Head) and a discharge that will be used for turbine operation is a major factor that affects the choice of turbine (Damastuti, 1997; Lius, 2009; Hendarto, 2012), for example: turbine pelton effective for operations on the high fall-out water (head) high, while highly effective propeller turbines operate on the high fall-out of water (head) is low. Power factor (power) is desired about the high fall-water (head) and discharge available. The Characteristic each turbine as appears in Table 5 below:

Table 5. Characteristics of Hydro Turbine Energy

Turbin	Tinggi Terjun	Debit Air	Kecepatan	Efisiensi
Pelton	≥ 200 m	< 1,5 m^3/det	10 - 62 rpm	80 – 87 %
Propeller dan Kaplan	10 – 100 m	0,1 – 30 m^3/det	55 – 500 rpm	80 – 90 %
Francis	≤ 10 m	5 – 100 m^3/det	300 – 3200 rpm	80 – 90 %
Crossflow	≤ 200 m	0,02 – 10 m^3/det	250 – 700 rpm	80 – 85 %

The principles of MHP

MHP in principle take advantage of the height difference and the amount of water flow per second that of the flow of water irrigation channels, river or waterfall. The water flow will rotate the turbine shaft to produce mechanical energy. This energy then move generator and generator to produce electricity.

A micro-hydro scheme requires two things, namely, the flow of water and height of fall (head) to produce energy that can be harnessed. It is an energy conversion system of the form and the height of the flow (potential energy) into the form of mechanical energy and electrical energy (Dwiyanto, 2016).

Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electric generator, or other machine. Available power is proportional to the product of head pressure and volume flow rate. The general formula for the power output of each hydro system are:

$P = \eta \rho g Q H$ (Paish, 2002)

Where P is the mechanical force generated on the turbine shaft (Watts), η is the hydraulic efficiency of the turbine, ρ is the density of water (kg/m^3), g is the acceleration due to gravity (m/s^2), Q is the volume flow rate through the turbine (M^3/s), and H is the effective pressure head of water in the turbine (m).

According Paish (2002) best turbines can have hydraulic efficiencies in the range of 80 to over 90%. Micro-hydro systems tend to be efficient in the range of 60 to 80%. Each turbine has a certain velocity associated with the turbine output power and characterize its performance (Paish, 2002a). Associated with the turbine speed power turbine output and pressure head, generally calculated by the following formula (Paish, 2002a).

$$\boldsymbol{N_s = \frac{nP^{1/2}}{H^{5/4}}}$$

Where n = the turbine speed (r / min), P = shaft power (kW), and H = head pressure in the turbine (m).

Research Method

To explore the development of micro-hydro in the IDU to conduct studies on the feasibility analysis of the project. The study was conducted in two stages. First, do a survey of the geographical environment around Defense University to obtain data that are significant in the formation of micro-hydro projects. Further analyzing the feasibility of concepts and literature appropriate for micro-hydro projects in the IDU.

Result and Discussion

The research location is Defense University campus area with the object waterway that lies between Language Service Center and the University of Defense. Location waterways analyzed is the point with the highest elevation before it flows into the lower channels.

Differences in altitude / elevation can be utilized as a source of energy to turn turbines that will drive electric generators. Location waterways were the lowest observed in the retention pond, with entrance point output adjusting pool water (Figure 4).

Figure 4. Location of the waterways with the lowest elevation

Table 6. Coordinates and elevation of the location of activities

No	Location	Coordinate	Elevation (m)
1	Waterways on top	6° 31' 32.24" S 106° 52' 51.59" E	261
2	Waterways on middle	6° 31' 31.44" S 106° 52' 51.00" E	255
3	Waterways on Bottom	6° 31' 28.61" S 106° 52' 45.95" E	243

Data: Processed

Debit Moment Analysis

Momentary debit analysis was performed using a current meter (Figure 5). Measurements were made at two different locations with each of the four repetitions. Results instantaneous water discharge measurements is shown in Table 7.

Figure 5 Measurement of instantaneous water discharge

Table 7. Results of Measurement of Water Discharge Waterways.

Measuring Point	Time (Snd)	r	n (rps)	V (m/det)	Q (m^3/det)
1a	30	66	2.2	0.546	0.025
1b	30	64	2.1	0.530	0.024
1c	30	69	2.3	0.571	0.026
1d	30	70	2.3	0.579	0.026
Average					**0.0252**
2a	30	87	2.9	0.718	0.018
2b	30	96	3.2	0.792	0.020
2c	30	105	3.5	0.865	0.022
2d	30	102	3.4	0.841	0.021
Average					**0.020**

The conditions to capture instantaneous water discharge made at locations with different channel dimensions, namely: a channel depth of 50 cm and width of 90 cm and depth of 50 cm channel and the channel width of 50 cm. From the results of measurements of water discharge channel for a moment, obtained an average discharge measurements of 0.0252 m3/sec or 25.2 liters per second.

High gross (gross-head) between sedative bath (water channel top) and the water level in the canal discharge/tailrace (underground sewer) on the drains at the Indonesian Defence University is 18 m. Based on the analysis of instantaneous water discharge and elevation difference of altitude on the location of the research, it can be concluded that the electricity generation potential is shown in the table below:

Table 8. Results of Measurement

Description	Measurement Results
Location Power House	S 7^{o} 56’20” E 110^{o} 44’50”
Gross Head	18 m
net Head	14 m
debit Plan	20 liters / sec
power Plans	1.7 kW
The electric power proposed	1 kW (60% of the power plan)
Distance power house to the electricity grid	<20 m

The power of power-Spout is harnessed from water sources along the cable sizes for connections shown in Table 9 below.

Table 9. Calculation Power-Spout

Power-Spout Description		Electrical Description	
Available Water flow	20 lps	PowerSpout Output Voltage	84 V
Used Water flow	20 lps	Target Cable Efficiency	95%
Available Head	18 m	Length of Cable	20 m
Pipe Length	300 m	Design Load Voltage	80 V
Target Pipe Efficiency	80%	Actual Load Voltage	80 V
Pipe Diameter	134 mm	Cable Material	Copper
Number of PowerSpouts	4	Cable cross section	3.17 mm
1 or 2 Jets Per PLT	2	Next size up cable	12 AWG
Jet diameter	14.7	Cable Current	18.7 A

Power-Spout Description		Electrical Description	
Actual Pipe Efficiency	79%	Actual Cable Efficiency	95%
Rotor Speed	661	Power at Your Shed	1499 W
Output per PowerSpout	394 W		
Total PowerSpout output	1576 W		

Source: Data Processed

From the calculation of the efficiency of the entire system is obtained that the conversion efficiency of mechanical-electrical covering turbine efficiency (50-70%), mechanical transmission between the turbine-generator (98%) and a generator (90%). While the loss of press (head-loss) due to friction pipes and bends by 70%. With these assumptions, the theoretical potential of electrical power can be generated 1.73 kW or 1730 Watt.

Conclusion

Micro-hydro strength is the power that is continuous unlike solar or wind, by utilizing the existing drainage channel will provide domestic water gravity, so it can be used as penstocks to generate electricity (Davis et al, 2003).

Aside from high rainfall, the object of research has a drainage area with a high steepness (18 m) that has the potential to be utilized as a source of micro-hydro.

Altitude head the research object to be in modest scale is between 10-50 m (Paish, 2002), so the impulse turbine suitable is because the amount of water discharge Cross-flow <0.4 m3 / sec (Penche, 1998). While the reaction may use Francis turbines and Pumps-as-turbine (Munster, 1999). MHP in the Indonesian Defense University, should be established to provide benefits such as cost savings and electric lighting for the village community.

Reference

A Harvey & A Brown. (1992). Micro-hydro Design Manual. ITDG Publishing.

Abhijit Date, Aliakbar, AZ. (2009). Design and cost analysis of low head simple reaction hydro turbine for remote area power supply. *Renew Energy*, Vol. 34, p: 409 – 415.

Adly Havendri Dan Hendro Lius, (2009). Teknika 1 Perancangan Dan Realisasi Model Prototipe Turbin Air Type Screw (Archimedean Turbine) Untuk

Pembangkit Listrik Tenaga Mikrohidro Dengan Head Rendah Di Indonesia. *Teknik* A, Vol.2, No. 31

Anya P. Damastuti. (1997). Pembangkit Listrik Tenaga Mikrohidro. *WACANA*, No. 8 / Mei – Juni.

Ashnani, Mohammad Hossein Mohammadi, Anwar Johari, Haslenda Hashim, Elham Hasani. (2014). A source of renewable energy in Malaysia, why biodiesel?. *Renewable and Sustainable Energy Reviews*, Vol. 35, p: 244–257

Bahtiar, A., Hidayat, D., Mindara, J.M., Syakir, N and Wibawa, B.M. (2015). Aplikasi Pembangkit Listrik Mikrohidro Untuk Penerangan Lingkungan Masyarakat Di Kecamatan Ciwidey Kabupaten Bandung. *Jurnal Aplikasi Ipteks untuk Masyarakat*, Vol. 4, No. 1, p: 15 – 17.

Batley SL, Colbourne D, Fleming PD, Urwin P. (2001). Citizen versus consumer: challenges in the UK green power market. *Energy Policy* 29:479–87

Davis S. (2003). *Microhydro Clean Power from Water*. Canada: New Society Publisher.

Dennen, B., Larson, D., Lee, C., Lee, J., Tellinghuisen, S. (2007). *California's Energy–Water Nexus: Water Use in Electricity Generation*. Santa Barbara: Bren School of Environmental Management and Science, University of California.

Doll, P., Zhang, J. (2010). Impact of climate change on freshwater ecosystems: a globalscale analysis of ecologically relevant river flow alterations. *Hydrol. Earth Syst. Sci. Discuss*. 14 (5), 783–799.

Dwiyanto, V. (2016). *Analisis Pembangkit Listrik Tenaga Mikro Hidro: Studi Kasus Sungai Air Anak (Hulu Sungai Way Besai)*. Fakultas Teknik: Unila

Ellabban, Omar, Haitham Abu-Rub, Frede Blaabjerg. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*, Vol. 39, p: 748–764

Farhad M. Hossain, M. Hasanuzzaman, N. A. Rahim, H. W. Ping. (2015). Impact of renewable energy on rural electrification in Malaysia: a review. *Clean Techn Environ Policy*, Vol. 17, p: 859–871

Fuss S, Johasson JA, Szolgayova J, Obersteiner M. (2009). Impact of climate policy uncertainty on the adoption of electricity generating technologies. *Energy Policy*, 37:733–43

Georgakellos D. (2009). Impact of a possible environmental externalities internalization on energy prices: the case of the greenhouse gases from the Greek electricity sector. *Energy Econ*, 32:202–9.

Gerbens-Leenes, P.W., Hoekstra, A.Y. (2011). The water footprint of biofuel-based transport. *Energy Environ. Sci*. 4, 2658–

2668.

Gerbens-Leenes, W., Hoekstra, A., Meer, T. (2007). The water footprint of energy consumption: an assessment of water requirements of primary energy carriers. *ISESCO Sci. Techno* l, Vol. 4, No. 5, p: 38–42.

Hadian, S., Madani, K. (2013). The water demand of energy: implications for sustain-able energy policy development. *Sustainability* 5 (11), 4674–4687.

Hendarto Aryo P. (2012). Pemanfaatan Pemandian Umum Untuk Pembangkit Tenaga Listrik Mikrohidro (Pltmh) Menggunakan Kincir Tipe Overshot. *Makalah Publikasi*, Fakultas Teknik Jurusan Teknik Elektro Universitas Muhammadiyah Surakarta.

Himadry Shekhar Das, A.H.M. Yatim, Chee Wei Tan n , Kwan Yiew Lau. (2016). Proposition of a PV/tidal powered micro-hydro and diesel hybrid system: A southern Bangladesh focus. *Renewable and Sustainable Energy Reviews*, Vol. 53, p: 1137–1148

Lane, S.N. et al. (2007). Interactions between sediment delivery, channel change and flood risk in a temperate upland environment. *Earth Surface Processes and Landforms*, Vol. 32, p: 155-162

Longo A, Markandya A, Petrucci M. (2008). The internalization of externalities in the production of electricity: willingness to pay for the attributes of a policy for renewable energy. *Ecol Econ*, 67:140–52.

Mishra, S., Singal, S. K., & Khatod, D. K. (2011). Optimal installation of small hydropower plant-A review. *Renewable and Sustainable Energy Reviews*, Vol. 15, No. 8, p: 3862-3869

Munster, Frederick J. (1999). *Micro-hydro Power*. Intermediate Technology Development Group

North, P. (2010). Eco-localisation as a progressive response to peak oil and climate change – A sympathetic critique. (Geoforum), Vol. 41, pp: 585-594.

Nouni, M.R., Mullick, S.C. and Kandpal, T.C. (2009). Providing electricity access to remote areas in India: Niche areas for decentralized electricity supply. *Renewable Energy*, Vol. 34, No. 2, p: 430- 434.

Paish, O. (2002). Small hydro power: technology and current status. *Renewable and Sustainable Energy Reviews*, Vol. 6, p: 537–556

Paish, O. (2002a). Micro-hydropower: status and prospects. *Proc Instn Mech Engrs*, Vol 216, Part A: J Power and Energy

Penche, Celso. (1998). *Guidebook on How to Develop a Small Hydro Site*. Belgia: ESHA (European Small Hydropower Association).

Pinho P, Maia R, Monterroso A. (2007). The quality of Portuguese Environmental Impact Studies: the case of small hydropower projects. *Environmental Impact Assessment Review*, Vol. 27, No. 3, p:189–205.

PowerSpout. (2016). *Advanced PLT and TRG Series Calculator*. http://www. powerspout. com/ advanced-calculator/

Renofalt, B., Jansson, R., & Nilsson, C. (2010). Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshwater Biology*, Vol. *55*, No. 1, p: 49-67

Saeed Hadian, Kaveh Madani. (2015). A system of systems approach to energy sustainability assessment: Are all renewables really green?, *Ecological Indicators*, Vol. 52, p: 194–206

Saket, R.K. and Anand Kumar, K.S. (2006). Hybrid Micro Hydro Power Generation using Municipal Waster Water and its Reliability Evaluation. In proceeding of the *Greater Mekong Sub region Academic and Research Network (GMSARN) International Conference-6-7 December 2006 on Sustainable Development: Issues and Prospects for the Greater Mekong Sub region, Asian Institute of Technology*. Bangkok. Thailand, pp: 13-20, http://www.gmsarn.ait.ac.th

Saket, R.K., (2008). Design, Development and Reliability Evaluation of Micro Hydro Power Generation System Based on Municipal Waste Water. *IEEE Electrical Power and Energy Conference*; IEEE Canada / Vancouver Section: October 6 - 7, 2008

Sentanu, H. (2011). *Pembangkit Listrik Tenaga Mikrohidro*. Asosiasi Hidro Bandung

Umar M and Hussain A. (2015). Micro Hydro Power: A Source of Sustainable Energy in Rural Communities: Economic and Environmental Perspectives. *Pakistan Development Review*, Vol. 54, No. 4, (Winter 2015) pp. 487–505

Walker, G. and Devine-Wright, P. (2008). Community renewable energy: What should it mean?. *Energy Policy*, 36(2), 497-500

Williams A, Porter S. (2006). Comparison of hydropower options for developing countries with regard to the environmental, social and economic aspects, *Proceedings of the International Conference on Renewable Energy for Developing Countries*.

Williamson SJ, Stark BH, Booker JD. (2014). Low head pico hydro turbine selection using a multi-criteria analysis. *Renew Energy*, Vo. 61, p: 43–50.

Y. Su, et al. (2014). Hybrid triboelectric nanogenerator for harvesting water wave energy and as a self-powered distress signal emitter. *Nano Energy*. http://dx.doi.org/10.1016/j.nanoen.2014.07.006