Innovation of Hydro Power Generator from Waste Energy to Green Marketing

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Abstract

This article describes research into an innovation, testing its feasibility by using recovered waste energy to generate electricity. This research consists of three parts. The first part is a technology experiment, using a pump to drive turbines and rotate a generator to study the electricity generated. The second part is testing the innovation idea by applying technology from first part with waste energy from a pond pump. The last part is an economic analysis, determining the cost of electricity generated from waste energy per unit, comparing to the cost of electricity consumption from Metro Electricity Authorized, varied by generator size and operating time. The research result shows a way to use waste energy to generate electricity (green energy), which can be used for "green" marketing.

Keywords: Innovation; Waste Energy; Green Marketing

1. Introduction

Nowadays, the cost of energy is continually increasing(Energy, 2008) while environmental concerns are increasing as well(A.Teschke, 2008). Many businesses are turning to green technology to save long-term costs and take advantage of green marketing. Innovation will be needed to manage the trend of rising energy costs in the future and address environmental concerns. This study tests an idea for green marketing by using a water pump to aerate a pond to generate electricity – enabling waste energy recovering. The electrical power output needed to drive the pump is not high because the pumps used generally in ponds are small. Thus, the question is how much power the pump can generate, and what useful applications exist for the small amount of electricity generated. This work is divided into three parts. The first part is an experimental study to determine how much electrical power can be generated by driving the pump. Two models are designed, injection and vortex, in order to be used in the experiment. From the experiment, it is determined which is the best model for the application. The second part is a proposal for the innovative idea by using the result of the first part to use waste energy from water pump to aerate a pond. The third part is a questionnaire to test the acceptance rate of the innovative idea, and economic analysis by calculating cost per unit of electricity that is generated from waste energy compared with the cost for the same energy from the Metro Electricity Authority (MEA). The objective of this research is to test the feasibility of the Innovation of Hydro Power Generator from Waste Energy to Green Marketing.

2. Literature Review

2.1. Waste Energy and Waste to Energy

Waste to Energy (WtE) is different from Waste Energy. WtE is bringing waste to burn and generate electricity or heat, while Waste Energy is taking leftover energy from the system. For example, ironing produces a lot of heat, and leftover heat from the system is waste energy that could be recovered and used. This process is called a "recovery" system, and is popular in many industries presently (e.g., using heat for the drying process in the textile industry) (Oulata, 2004).

The waste energy studied in this research is a water pump aeration system in a pond. The pump works with electricity by sucking water from the bottom of the pond and injecting it on top of the pond, thereby adding needed air into the water. This research uses the injected water from the pump to generate electricity.

2.2. Innovation research

Past studies have been separated by being either laboratory experimental research or market research (NRCT, 2009). However, for research into innovation, they cannot be separated because the innovation integrates knowledge from research experiments and market demand. The innovation research is therefore multi-level research; there are many forms of research under the same topic. Accordingly, the innovation researcher needs to have multi-disciplinary knowledge and can use many research methods such as experimental, survey, development, and so on. The definition of "innovation" is "the creating something new and useful that is accepted by markets or society." In other words, innovation fills the gap between technology and market demand (Christensen, 1997; Tidd, Bessant, & Pravitt, 2006; Trott, 2003) so the basis of innovation consists of science & technology base, technological developments and market needs (Carayannis, Gonzalez, & Wetter, 2003).

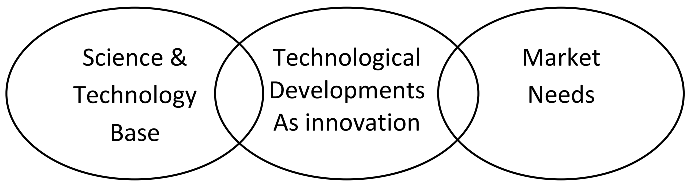


Fig.1: Conceptual Framework of innovation (Carayannis, et al., 2003)

Accordingly, this research covers technology, innovation and marketing. The first part of the study is to conduct experiments with technology to study electricity output. The second part of the study is to find an innovative way to use technology from the first part. And the last part of the study is marketing research to create the marketing concept for the technology and test its rate of acceptance and economic analysis.

3. Technology Research

3.1. Experiment generating electricity from pump

The experiment generates electricity by using a submersible pump. There are two models—the first is an injection model (see fig. 2) and the second is a vortex model (see fig. 3). The injection model operates by injecting water from the pump into the Pelton turbine to rotate the generator. The vortex model operates by turning water in a vortex within a tank to drive turbines and rotate the generator.

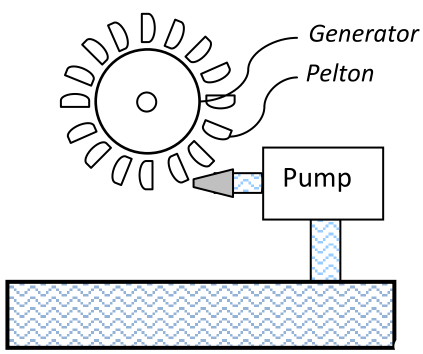


Fig. 2: Injection Model

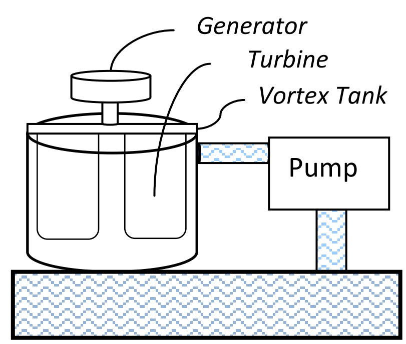


Fig. 3: Vortex Model

3.1.1. Materials for experiments

- Submersible pump with flow rate of 3,000 liters/hour
- 3 Phase AC Generators 100W, 200W
- Pelton Turbines
- Vortex tank with 3 turbine blades

3.1.2. Experiment Method

1. Create models as in Fig. 2 and Fig. 3
2. Turn on submersible pump and adjust nozzle in the best position for injection

3. Measure electrical voltage
4. Observe and record the results
5. Repeat #1 - #4, using 200W instead of 100W generator
6. Repeat #1 - #4, changing the size of the nozzle

3.1.3. Experiment results

Table 1 Experiment results

Pump = 3000l/h	Gen200W	Gen100W
Vortex	Voltage	Voltage
No Nozzle	15.7-16.3	4.7-4.8
Nozzle 13mm	17.8-18.0	5.1-5.2
Nozzle 10mm	16.7-17.0	4.6-4.7
Injection		
No Nozzle	35.0-37.2	5.8-6.0
Nozzle 13mm	47.0-49.0	13.9-14.2
Nozzle 10mm	56.0-57.0	14.8-17.0

3.1.4. Experiment conclusion

The injection model can generate the highest voltage at approximately 57 Vac, while the vortex model can geneate the highest voltage at approximately18 Vac. The reason why the vortex model in this experiment generated lower voltage than the injection model is that the generator used in this experiment was rated to operate at 400 rpm, which is suitable for the rotation of an injection model, while the vortex model has a lower rotation speed.

In the injection model, a smaller nozzle generates higher voltage, while in the vortex model, there is not a linear relationship between the size of the nozzle and voltage. The 200W generator with no nozzle generated 16 Vac, but increased to 18 Vac with a smaller nozzle size of 13mm. However, voltage fell back down to 17 Vac with an even smaller nozzle size of 10mm. The reason for this is that a nozzle that is too small cannot take water to a high rotational speed, but instead injects through the water in the tank and makes bubbles. So the development of the vortex should be optimized to the size of the nozzle. The results from this experiment will be used to develop an innovative generator using waste energy in the innovation phase.

Fig. 4 Experiment

4. Innovation Phase

4.1. The idea of using waste energy from an aeration system in a pond

The idea of using waste energy recovery to generate electricity is plentiful in many plants. However, there is little use of waste energy recovery to generate electricity in buildings or homes. They are too small and use little energy compared to plants. Nevertheless, analyzing electricity consumption, it is found that a small user group consumes 2,112,092,688 kWh (MEA, 2012), or 54%, while a large user group consumes 1,408,480,334 kWh, or 36%. It shows that small user groups consume significantly more electricity than large user groups. This is an opportunity to develop an innovative technology for small user groups. The aim of the technology is to develop a way to recover waste energy to generate electricity. In considering sources of waste energy, it is found that aeration systems have the potential to generate electricity.

Fig. 5 Examples of locations with aerate system

4.2. Design and application concept

4.2.1. Product design concept of micro hydro generator from a water pump

Singapore has Merlion, an animal statue in which the top half is a lion squirting water and the bottom half is a fish. It is a common spot for tourists to visit and take photos. While many fountains use animals to squirt water, Singapore's Merlion is unique because it is not an existing animal. According to a Google search, the most common animals used in fountains to squirt water are elephants, dolphins and frogs. So the animal in this work is designed to be the hippopotamus. The hippo is a powerful symbol of aquatic animals.

4.2.2. Concept of electricity application

Electricity from waste energy can be applied to provide service for charging mobile phones in restaurants, coffee shops, hotels or resorts that have ponds and water pumps. Providing such services can be considered green marketing as it is recovering waste energy. Besides charging mobile phones, another application may be to power small lights along pathways.

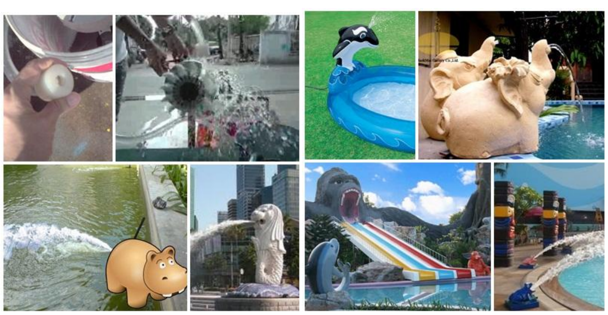


Fig. 6 Examples of squirting water animals

Fig. 7 Examples of applications

5. Market Research

5.1. The result of acceptance rate test

Acceptance rate for a new product

In testing the new product concept, Hippo, the acceptance rate was quite high. The question asked in the questionnaire was, "if you are an entrepreneur and have a pond, would you be interested to buy Hippo?" The acceptance rate was 82%.

Acceptance rate for the product design

In testing the product design as a hippo, the acceptance rate was 68% (acceptance 59% and high acceptance 9%). The acceptance rate of using a plain tank was only 9% (acceptance 9% and high acceptance 0%) and the not acceptance rate of using plain tank was 41%. It shows that the product design as a hippo is better than a plain tank.

Acceptance rate for its use

In testing the use of an electricity generator for 100-200W, it is very challenging to launch this product to the market due to the small electricity generated. However, presenting its application as an electronic equipment charger such as mobile phone or laptop, the acceptance rate was 78% (acceptance 64% and high acceptance 14%). Presenting its application of powering lights along pathways, the acceptance rate was closer to 96% (acceptance 55% and high acceptance 41%).

Acceptance rate as an innovative concept

In testing the innovative idea of recovering waste energy from pond pumps to drive generators to generate electricity, the acceptance rate was a perfect 100% (acceptance 45% and high acceptance 55%). It shows that people see the use of idea of using waste energy. For its use to businesses looking to use the marketing concept as a "green" energy source, the acceptance rate is higher to 95% (fair 5%, acceptance 27% and high acceptance 68%). Both questions about acceptance of the innovative idea received zero "non-acceptance" answers.

Table 2 Result for acceptance new product, HIPPO™

Acceptance question	No comment	Not accept	Neutral	Accept	High Accept
Product Design					
• Design of a hippopotamus	0%	0%	32%	59%	9%
• Plain tank no design	5%	41%	36%	9%	0%
Application					
• Electronic devices charging service	0%	0%	23%	64%	14%
• Lighting	0%	0%	0%	55%	41%
Innovative Idea					
• Product using waste energy	0%	0%	0%	45%	55%
• Use as "green" marketing	0%	0%	5%	27%	68%

*n=22

Table 3 HIPPO™ interested to buy survey results

	No answer	No Interest	Interest
Suppose that you are an employer and your business has a fish pond pump or a working fountain, Would you be interested to buy a HIPPO™?	14%	5%	82%

*n=22

6. Economic analysis

6.1. Key assumption

This section analyzes the electricity generating cost of the injection model. There are seven generators for consideration. They are 100W, 200W, 300W, 500W, 1000W, 2000W and 3000W. The baht per kilowatt (cost per unit) can be calculated by taking the power of generating for 10 years divided by the investment cost of equipment. The key assumption is as follows:

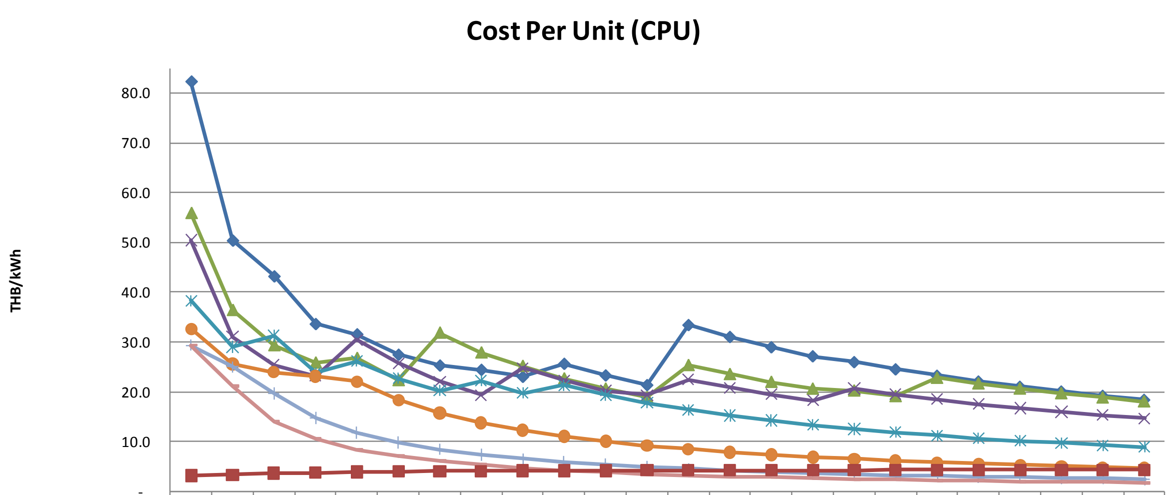
1. Generated power depends on generator specification and operating hours.
2. Investment cost depends on equipment price and lifelong maintenance.

- Investment in equipment
  - Inverter, life span 3years
  - Battery 12V, life span 3years
- Assumption of system life span of 10 years
- The equipment with a life span less than 10 years has to be replaced and investment cost is not prorated in the additional year. For example, a battery with life span of 3 years costs 1,000 THB. To use 10 years for the system's life span, the investment cost is 1,000 x roundup ((10/3),0) = 4,000 THB. This calculation implies investing 3 times and each cost is 1,000 THB. The investment cost within 9 years is 3,000 THB but will require another 1,000 THB in the 10th year although it is only a year (not 1/3). So the total investment cost of the battery for 10 years will be 4,000 THB (not 3333.33 THB).

- The equipment with a life span of more than 10 years is calculated by its full investment cost. For example, a generator with a life span of 15 years and price of 20,000 THB, has an investment cost of 20,000 THB (not 20,000 x (10/15) = 13,333.33).
- Total generated power per day is calculated by generator specification multiplied by operating hours per day. For instance, a 100W generator with five operating hours per day has a total generated power of 500Wh per day.
- Inverter specification depends on load, and it is assumed to comprise 3/5 of the power generation per day. However, the maximum power of the inverter is 3,000 W. For example, a 100W generator with five operating hours per day has a total generated power of 500Wh per day. The inverter power calculation is thus 500 x (3/5) = 300. From this calculation, the inverter power equal or more than 300W will be selected, but the maximum is 3000W.
- In case batteries are used in the system, the calculation of battery capacity is Ah = generated power per day / [battery voltage x 0.6 (% of current use) x 0.85 (efficiency of the inverter)]
- In case the calculation of battery capacity is more than 200Ah per day, add 200Ah more into the battery bank.
- The maximum battery bank is 1000Ah per day, referring to average MEA usage of 11.6kWh per day or 12000Wh/12V=1000Ah approximately.
- The MEA electricity cost is calculated by formula type1.2 Residence (Progressive Rate) power over 150kWh per month (see more details from www.mea.or.th).

6.2. Result from calculation

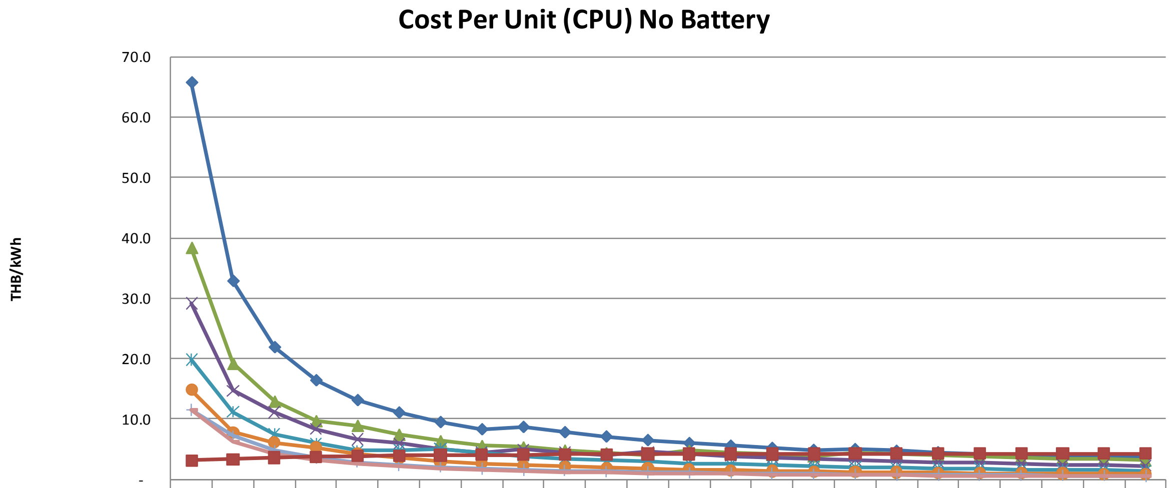
From the above assumption, there are two scenarios of the calculation: system with and without battery. The findings show that the cost per unit decreases when the operating hours increase.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CPU 100W	82.3	50.3	43.2	33.6	31.6	27.5	25.3	24.4	23.0	25.6	23.3	21.4	33.4	31.0	28.9	27.1	26.0	24.5	23.2	22.1	21.0	20.1	19.2	18.4
CPU 200W	55.8	36.3	29.3	25.8	26.7	22.3	31.8	27.8	25.1	22.6	20.6	18.8	25.3	23.5	21.9	20.6	20.2	19.1	22.7	21.6	20.6	19.6	18.8	18.0
CPU 300W	50.4	31.1	25.4	23.2	30.4	25.7	22.1	19.3	24.8	22.3	20.3	19.4	22.4	20.8	19.4	18.2	20.6	19.5	18.5	17.5	16.7	16.0	15.3	14.6
CPU 500W	38.3	29.0	31.2	23.7	26.1	22.7	20.3	22.2	19.7	21.3	19.4	17.7	16.4	15.2	14.2	13.3	12.5	11.8	11.2	10.6	10.1	9.7	9.3	8.9
CPU 1000W	32.6	25.6	23.9	23.1	22.0	18.4	15.7	13.8	12.2	11.0	10.0	9.2	8.5	7.9	7.3	6.9	6.5	6.1	5.8	5.5	5.2	5.0	4.8	4.6
CPU 2000W	29.3	25.0	19.6	14.7	11.8	9.8	8.4	7.4	6.5	5.9	5.3	4.9	4.5	4.2	3.9	3.7	3.5	3.3	3.1	2.9	2.8	2.7	2.6	2.5
CPU 3000W	29.4	21.1	14.1	10.5	8.4	7.0	6.0	5.3	4.7	4.2	3.8	3.5	3.2	3.0	2.8	2.6	2.5	2.3	2.2	2.1	2.0	1.9	1.8	1.8
MEA CPU 3000W	3.2	3.3	3.6	3.8	3.9	4.0	4.0	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3

Operating (Hours/day)

Fig.8 The chart shows cost per unit of the system with battery



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CPU 100W	65.7	32.8	21.9	16.4	13.1	11.1	9.5	8.3	8.7	7.8	7.1	6.5	6.0	5.6	5.2	4.9	5.0	4.7	4.5	4.3	4.1	3.9	3.7	3.6
CPU 200W	38.3	19.2	12.9	9.7	8.9	7.4	6.4	5.6	5.4	4.8	4.4	4.0	4.8	4.4	4.1	3.9	4.5	4.2	4.0	3.8	3.6	3.5	3.3	3.2
CPU 300W	29.1	14.7	11.1	8.3	6.7	6.0	5.1	4.5	5.0	4.5	4.1	4.5	4.2	3.9	3.6	3.4	3.2	3.0	2.9	2.7	2.6	2.5	2.4	2.3
CPU 500W	19.8	11.2	7.5	5.9	4.8	4.9	5.0	4.4	3.9	3.5	3.2	2.9	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.7	1.6	1.5	1.5
CPU 1000W	14.8	7.8	6.1	5.3	4.2	3.5	3.0	2.6	2.3	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9
CPU 2000W	11.5	7.2	4.8	3.6	2.9	2.4	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6
CPU 3000W	11.6	6.3	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5
MEA CPU 3000W	3.2	3.3	3.6	3.8	3.9	4.0	4.0	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3

Operating (Hours/day)

Fig.9 The chart shows cost per unit of the system without battery

6.3. Cost Analysis

- The cost from MEA increases when consumption increases because the MEA calculation uses progressive rate, while the cost of the injection model decreases when operating hours increase. Thus, an establishment with a pump operating for many hours per day may have cheaper electricity costs than the cost from MEA.
- In case of the system with battery, only a 2000W generator with operating hours of more than 15 hours and a 3000W generator with operating hours of more than 11 hours can generate electricity with costs per unit being less than MEA cost.
- In case of the system without battery, a generator with a specification below 200W cannot generate electricity with costs per unit less than MEA cost. Only 300W, 500W, 1000W, 2000W and 3000W with operating hours over 18, 11, 7, 5 and 4 hours respectively can generate electricity with costs per unit less than MEA cost.

7. Conclusion

The innovation of hydroelectricity generation by using an aeration pump in a pond, and its application for mobile phone charging service in resorts, hotels or coffee shops is feasible in technique and marketable. The experiment has shown that an injection model pump can generate electricity. The marketing survey has shown that the acceptance rate of this innovation is high. Finally, from the economic analysis has shown that for places with long operating hours, the cost per unit is cheaper than places with short operating hours. Accordingly then, the innovation of hydroelectricity production from waste energy is feasible for "green" marketing.

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