Additional Electricity Generator Model from Vehicle Movement within an Industry Area

Suppajee Pornpongmetta, Kasetsart University, Thailand
Monthon Thanuttamavong, Kasetsart University, Thailand
Vipak Jintana, Kasetsart University, Thailand

The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
The purpose of this research was to create a method and design a generator model from vehicle movement in the industry area at a slaughter and food processing plant called CPF PCL., which is located in Bangkok, Thailand. The main concept of the design was sustainable energy harvesting. The design method consisted of 2 primary elements, the designing process and relevant criteria. The new designing process was applied using a logical framework approach and SWOT analysis. The criteria for the design were based on a life cycle assessment, which included raw materials, production, usage and disposal. The result of the new design model was an integration of the pressure between air and water to generate electricity by collecting energy from the movement of the 4 and more wheels on a vehicle.

Keywords: energy harvesting, electricity, generator model, vehicle movement

Introduction

Electricity is important for overall human life because it is one of the essential elements used in the production of consumer products and is critical for propelling the economy of the country. In industry, electricity is associated with a product life cycle, beginning from the extraction of raw material, to production, to use by customers and to the end of the cycle with waste disposal. By 2050, the world population is estimated to have risen to 9 billion and food demand will increase by 70% (United Nation, 2011). Thus, electricity will have a vital role for food production, which is used in most production processes for food high in demand. Base on Thailand's energy consumption, as reported by the Energy Policy and Planning Office (Department of Alternative Energy Development and Efficiency, 2012), the business sector consumes the most electricity in Thailand. The food industry and fossil fuels are the major energy resources that are exhaustible. Therefore, the Thai government is aware of excessive use, resulting in the shortage of electrical power. The government and business sectors are currently interested in alternative energy, which relates to the Ministry of Energy's renewable energy development plan over 10 years (2013-2021), and has established alternative/renewable energy as a goal of 25% for all energy requirements in the country (Department of Alternative Energy Development and Efficiency, 2013).

The food industry has a good opportunity for harvesting energy from vehicle movement through product and raw material transportation as well as the use of personal vehicles, which was recorded at a slaughter and food processing plant for CPF PCL., located in Bangkok, Thailand (study area). An average of 1000 vehicles/day moved in and out of this area (CPF PCL., 2013). Thus, an additional electricity generator model is an innovation that will help harvest and generate supplemental electricity from vehicle movement, which is used in several activities of industrial areas.

Energy harvesting from vehicle movement

Energy harvesting is the process of capturing energy from energy generating sources. Harvesting can be natural or artificial, such as using vibration, heat, light, air flow, water flow, piezoelectric, electromagnetic, mechanical etc. The energy is accumulated and stored using various means for supplying electronic or electrical appliances at a later time (Energy Harvesting, 2014).

Vehicle movement is one of the energy sources readily and abundantly available for energy harvesting. The existing products used to harvest energy from vehicle movement have a similar concept, which is comprised of a platform for embedding on the road to access vehicle movement, the mechanism which connects to a generator, and an electricity storage system. The differences for energy harvesting from vehicle movement machines are the characteristics of the platform and the mechanism for generating electricity. There are many types, such as cog, piezoelectric, water and air pressure, among others. A sample of an existing product currently in use is the cog KineticPower^{TM}, a proposed product of Kinergycarpet^{TM} for roads with high traffic patterns. The efficiency of the generator depends on the overall capture volume and the weight of the vehicle at any particular site (KineticPower, 2013). Moreover, Innowattech Piezo Electric Generator (IPEG^{TM}) of Innowattech Company created an application for road or railway for harvesting the weight of vehicle, movement, vibration and temperature change from grating between the road and vehicle wheels to generate electricity by piezoelectrics (Innowattech Energy Harvesting Systems, 2007). Energy harvesting from pedestrian footsteps is illustrated by Pavegen. It has pioneered a floor tile which translates the energy from pedestrian footsteps into energy that can be used for powering traffic lights and other applications (Pavegen, 2014). Frontier Service Development Laboratory at Research & Development Center of JR East joint researched a "power-generating floor", which is equipment for harvesting energy from footsteps that was installed in Tokyo at the railway station. The generated electricity is used for light bulbs (East Japan Railway Company, 2008). There are existing products in the market for harvesting energy, which is converted to electricity. In this research, the focus was on a new design model for harvesting energy from vehicle movement and specifically for industrial areas or vehicle speed control areas.

Objectives

There are two objectives in this study: 1) To propose an approach for finding an innovative design for sustainable energy harvesting and 2) To design a mechanism and characteristic model of an electricity generator from vehicle movement (EGM model).

Methodology

The entire process of this study referred to eco-design ISO/TR 14062 (2002) (International Organization for Standardization, 2002), starting from the planning, site survey and measurement to set the target of the EGM model efficiency. Subsequently, the design the conceptual details were devised, which were comprised of an elaborate innovation process for design criteria and solutions for the EGM model, such as an approach for finding an innovative design for sustainable energy harvesting and design of a mechanism and characteristics for a EGM model. This study only followed three steps of eco-design because it focuses on proposing an approach and design model, it does not deal with a prototype or the actual building of the machine.

The approach for finding an innovative design for sustainable energy harvesting was applied from a combination of 4 main approaches, including SWOT analysis, logical framework, life cycle assessment and sustainable concept. These were employed for setting the elaborate innovation process of design criteria and solution for EGM model.

The SWOT analysis (Humphey, 2005) is a useful technique for identification of strengths, weaknesses, opportunity and threats. The logical framework approach is a management tool mainly used for designing, monitoring, and evaluating international development projects (Gasper, D, 1997). In this research, both approached were applied for finding an innovative design for sustainable energy harvesting. The SWOT analysis was adopted to identify the desirable and undesirable characteristics of energy harvesting equipment from vehicle movement and used the logical framework's technique to develop the equipment for better function, comfort and safety for users.

The life cycle assessment or LCA, referred to ISO 14040 (International Organization for Standardization, 2006), is a technique used to assess environmental impact associated with the various stages of a product's lifecycle, which covers raw material extraction, production, usage, transportation and waste disposal. The LCA is related to the sustainable concept (World Commission on Environment and Development, 1987) concerning three dimensions including environmental, social and economic. The LCA and sustainable concept were applied for the design criteria in the process of finding and developing the EGM model.

A proposed approach for finding an innovative design for sustainable energy harvesting

The proposed design process was applied from SWOT analysis and a technique used in the logical framework approach. The prominent process is a system to find the innovative characteristics of a product and use it for product development. In the first process, research of the information on EGM should be done, as well as which products are available in the market. Afterwards, research should identify the desirable and undesirable characteristics of all the existing EGM in 5 dimensions such as engineering, space, financial, environmental and social, which are related to the sustainable concept. The desirable characteristics were selected for optional characteristics in setting the model. When the researcher considered the existing characteristics, should proposed the new idea that they are different from the existing were been proposed characteristics and assumed that proposed characteristics will have undesirable characteristics for cross checking the innovation.

The existing and proposed desirable and undesirable characteristics which had their opposite meaning were removed. The remaining desirable characteristics were selected to be necessary characteristics. The remaining undesirable characteristics were changed to be desirable ones by improving to create a new model.

From the new approach, design of the specifications for the product was completed, with the detailed design consisting of the size of the machine, volume and pressure in the system, length of pipe, the number of pipe elbows etc. Finally, all processes helped to create a new sustainable energy harvesting product, as shown in Figure 1. The results are discussed in more detail in a later section.

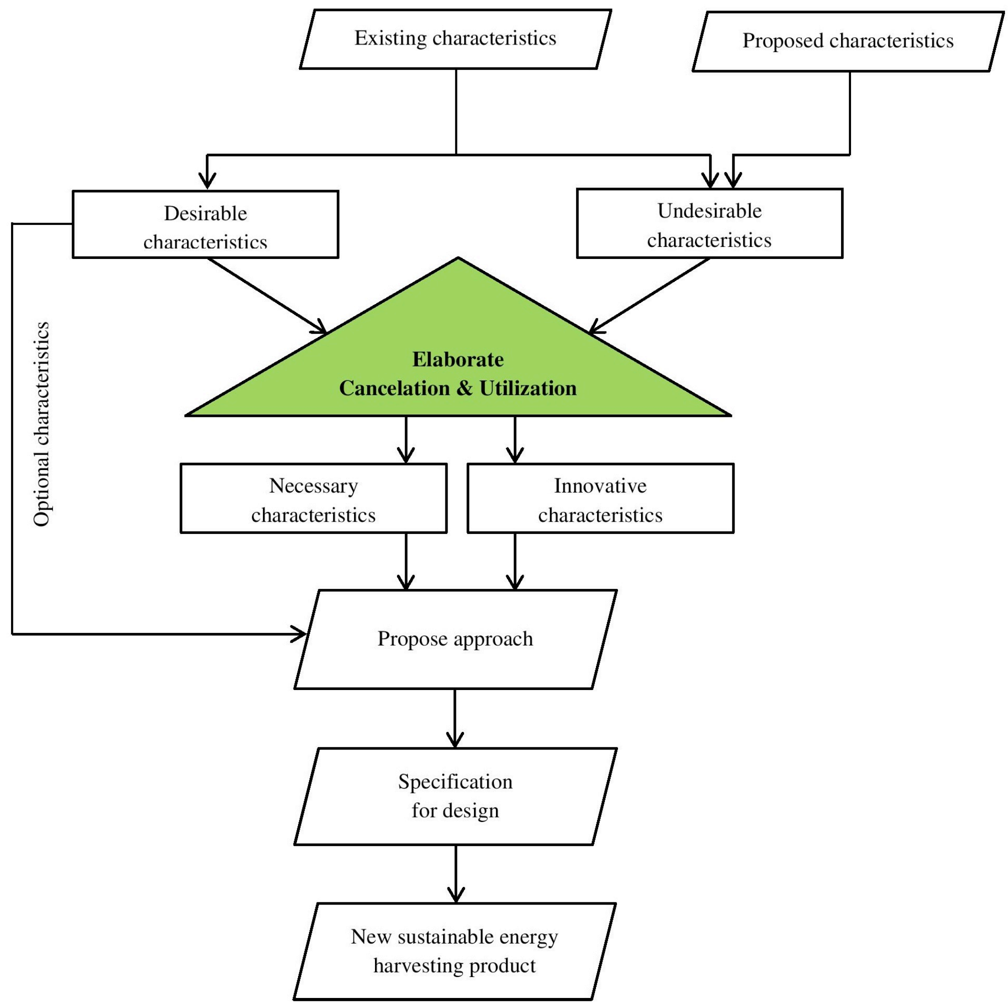

Figure 1: Schematic diagram of the design solution

Results and Discussion

The EGM model was designed with a new proposed approach. It had mechanism characteristics, as shown in Table 1. The EGM model had main parts for the machine, including a platform, one air tank, two water tanks, two generators, as well as water pipes and air pipes. The platform structure was made from metal for installation on the surface of a road. It was durable for 4 or more wheel vehicle movement and the surface platform was covered with rubber for smoother driving. The EGM model was combined between air and water pressure for the generation of electricity from vehicle moment. The prominent system was important input, which included ambient air. It is an inexhaustible resource and available everywhere. The EGM model used water pressure to rotate the generator with a closed loop. The water could circulate between water tanks I and II, so it had resource efficiency and safe water.

Table 1: EGM model mechanism characteristics

LCA	Necessary characteristics	Innovative characteristics	Optional characteristics
Material	- Metal structure for durability	- Water and air combination system: water has high momentum and air is an unlimited resource - Rubber surface platform for smoother driving	- Materials are locally available - Luminous sign in night time - Weather proof - Long-time useful life material
Production	- Slope platform suitable for vehicles	- Length of platform is less than 8 meters for smooth driving	- No dig on a surface road - Uses less time to assemble - Parts of machine can separate: comfortable for installation and movement
Usage	- Driver and vehicle must exercise safety when using machine	- Has two generators: comfortable for maintenance - Has two water tanks with a circulate system: saves water - Has a spare pipe: continues working when a generator breaks down or one water tank leaks - Smooth walk way for pedestrians	- Parts of machine can separate: comfortable for maintenance - Suitable for many types of vehicles
Waste disposal			- Materials can be reused or recycled - Reduction of waste to landfill
Transport			- Parts of machine can separate: comfortable for transport - Suitable package for protection of the parts of machine

The conceptual mechanism design of the EGM model

The electricity generation from the movement of vehicles with four or more wheels vehicle movement model required air pressure and water pressure. Air was generated through the movement of vehicles on the platform. A flexible raw material formed with a plastic bag and metal sheet was capable of creating pressure to activate the valve and turbine of the generator. The mechanism of the EGM model is shown in Figure 2. The working cycle of this model switched between water tanks I and II. When the air pressure in the air tank was released to water tank I, generator I would function to generate electricity. On the other hand, when the air pressure in air tank was released to water tank II, the generator II would function to generate electricity. The electricity was then generated and collected in a battery, directly or indirectly used for electronic appliances.

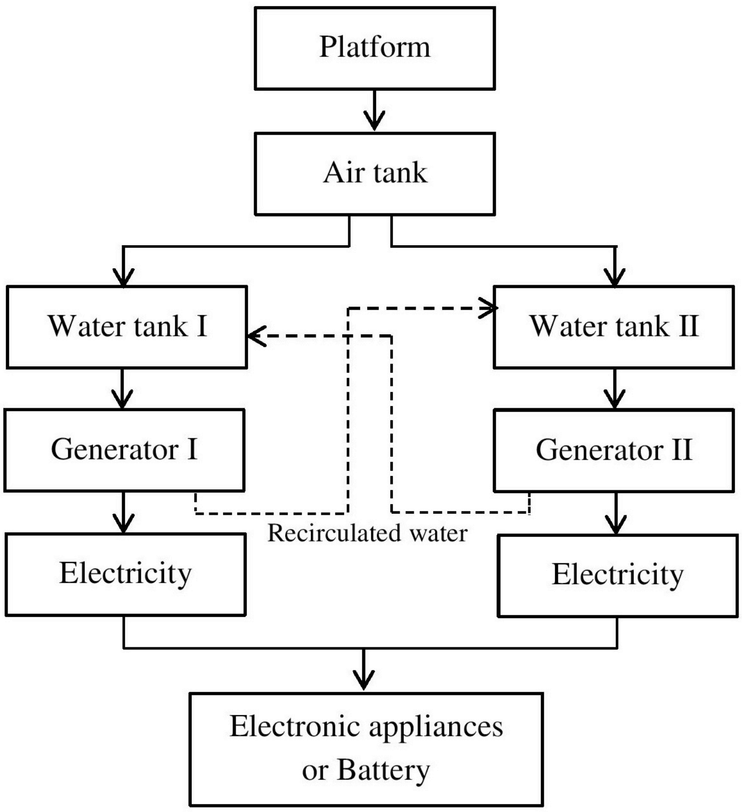

Figure 2: Schematic diagram of the conceptual mechanism design

Based on the condition of the study area, efficiency scenario of the EGM model's generator could generate as high as 60 kWh/day by installing of 3 sets of EGM model. The total length of platform was 240 meters with requirement of 60 pairs-wheel movements. Each set of EGM model generated 1 kWh as per one meter platform with 1,880 pairs-wheel movements.

This research focused on the design concept of the mechanism and conceptual characteristics of the EGM model. If the EGM model's prototype is established in the future, it should concern the specification of equipment and the conditions of each area. The efficiency of the model depends on the specification of equipment such as length platform, size of air tank, size of water tank, capacity of generator etc. Thus, choosing the equipment specification to suit electricity target is recommended. Construction and installation of the model needs to be adjusted properly in order to avoid energy loss. The example uses many elbow joints of air pipe and long pipe. It will lose air pressure, so there must be a valve in the pipe system. Future research must improve the hotspot of lost energy in the EGM model as a step to release surplus air pressure for water movement from one water tank to another. This will help to increase the efficiency of the generator and support resource consumption for high efficiency.

Conclusion

The approach proposed criteria and a solution, which can be used to design a new and more elaborate sustainable energy harvesting mechanism from vehicle movement. Innovation for an EGM model should be designed using an intentional combination of air pressures and water pressures.

Acknowledgments

The authors acknowledge the support received from the ECON fund of the Energy Policy and Planning Office, Ministry of Energy for research scholarship funding. We are also grateful for the study area support received from CPF PCL. Thank is extended to MR. Suphachai Aungsupakorn, for inspiration and encouragement provided. Finally, appreciation is extended to MS. Kularb Kimsri for teaching basic concept of LCA and for valuable suggestions.

References

Department of Alternative Energy Development and Efficiency. (2012), *Energy in Thailand: Fact&Figures Q1-Q3/2013*, Available at :http://www.dede.go.th

Department of Alternative Energy Development and Efficiency. (2013), *Renewable energy development plan in 10 years (2013-2021)*, Available at: http://webkc.dede.go.th

East Japan Railway Company. (2008). Demonstration Experiment of the "Power-Generating Floor" at Tokyo. Available at: www.jreast.co.jp

Energy Harvesting. (2014), *What is Energy Harvesting*, Available at: http://www.energyharvesting.net

Gasper, D. (1997), *Logical Frameworks: A Critical Assessment Managerial Theory, Pluralistic Practice*, The Hague, Institute of Social Studies, Netherlands

Humphrey, A. S. (2005). *SWOT analysis for Management Consuting In A.S.SRI Internation*, United Kingdom.

Innowattech energy harvesting systems.(2007), *Technology: Technical Information*, Available at: http://www.innowattech.co.il

International Organization for Standardization. (2006), *ISO14040 Environmental management-Life cycle assessment-Principles and framework*.

International Organization for Standardization. (2002), *ISO/TR 14062 Environmental management-integrating environmental aspects into product design and development*.

KinergyPower. (2013), *KinergyPower™ product*, Available at: http://kinergypower.com/products/

Pavegen website. (2014), *technology section*, Available at: http://www.pavegen.com/technology

United Nation. (2011), *Water and agricultural in the green economy*, Available at: http://www.un.org/waterforlifedecade/green_economy_2011/pdf/info_brief_water_and_agriculture_eng.pdf

World Commission on Environment and Development.(1987), *Our common Future*, Oxford university press

Contact email: suppajee.jam@gmail.com, monthon.t@ku.ac.th, fforvij@ku.ac.th