# Chapter 4
# Applications of Vibration-Based Energy Harvesting (VEH) Devices

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## ABSTRACT

*This chapter reviews present usage of vibration-based energy harvesting (VEH) devices and their applications. The evolution of energy resources and advancement in electronic technologies has resulted in the need for a self-sustainable wireless/portable electronic device in current modern society. Batteries are non-beneficial in the miniaturization process of electronic designing, and alternative power supplies are desperately needed to drive the advance of the wireless/portable development further. VEH has emerged as one of the most promising alternatives to replace conventional batteries and as the solution for the bottleneck. Consideration of creating an optimal vibration energy harvester is suggested through an analytical model of a mechanical transducer, including a relatively new method defined as triboelectricity. Useful applications and usages of VEH are presented, and some suggestions for improvement are also given. Lastly, the trend of energy harvesting is annotated and commented in-line with the demand of electronic sensors market.*

## ENERGY HARVESTING FOR WIRELESS SENSOR NETWORKS (WSN)

Due to the advancement in electronic technology, the size and power consumption of CMOS technology has led to wide research activities on wireless/portable devices. By removing the wires from the devices, there is a potential for embedding sensors in previously inaccessible locations, such as roof

DOI: 10.4018/978-1-7998-6709-8.ch004

tops, underneath the raised-access floor panel, implant into the concrete wall and etc. Presently, most of the remote electronic devices are still powered by batteries with finite lifespan (Wang et al., 2016). This not only limits the miniaturization process of the device size, but also creates environmental pollution caused by the improper disposal of used batteries (NHDES, 2017). Not to mention the cost of labors and parts involved during the batteries replacement process, especially in an enormous electronic device system. Energy harvesting can be used as an alternative long-lasting energy sources for the sensor devices, particularly in applications where the replacement of batteries is practically unfeasible or costly.

Energy harvesting is generally defined as the process of extracting available energy from the ambient surrounding (otherwise known as ambient energy) and converting it into useful electrical power. Ambient energies can come in the form of light, wind, kinetic, heat and many others form of waves. Hence, this makes energy harvesting a promising alternative as the replacement for the batteries. Applications of energy harvesting tend to focus on this aspect (battery replacement in low-powered electronics) because energy that is harvested from the ambient surroundings are usually in the order of micro- or milliwatts, hence limiting its practical usage. However, in the past decade, research have shown that it is possible to harvest energy to the order of Watts, allowing broader applications usages for larger-powered components such as railway signal lights (Dotti and Sosa, 2019). The main advantage of energy harvesting is that ambient energy resources are redundant and have ideally an infinite lifetime. Besides, they are also considered as a green energy resources, with very little to no environmental pollution impact.

The idea of providing a sustainable source of power for wireless sensor nodes (WSN) through energy harvesting has been actively discussed by Roundy (2003) in the past decade. WSN plays an important role in realizing the concept of Internet-of Things (IoT). This concept envisions a stage where humans and machines can transfer data over a wireless network without the need of physical interactions. IoT is a crucial component towards digitalizing the manufacturing industry, creating a cyber-physical environment where human and machines can communicate and exchange data in real- time globally. This sort of environment is commonly known as a ‘smart factory’ and it represents the main goal of the fourth industrial revolution (Industry 4.0).

Figure 1 shows the schematic of an IoT system powered by a sustainable energy harvesting source. IoT is generally a platform which transmits the collected data from the sensors to a central control station via the cloud computing system. The processes of data collection and transmission are executed using sensors, which explains the main purpose of WSN in an IoT system. Ideally, these sensors are required to be powered by a sustainable energy source to reduce maintenance cost and machine downtime. However, till date many WSN are still powered by batteries which lead to an issue in energy sustainability as these batteries have finite lifespan. Different techniques have been imposed to reduce the energy dissipation effect and prolong the battery life. One of the methods is called the duty-cycle operation. This method periodically places the sensor nodes in ‘sleep’ mode to save the energy, or in other words, the cycle of operation of the sensor’s nodes operate intermittently rather than continuously. However, this comes with the trade-off on the data latency, since during the ‘sleep’ mode, no data can be transmitted or received by either ends. On top of that, batteries are also prone to leakage, as it will continuously deplete over time due to energy leakage even if the devices are periodically placed in the ‘sleep’ mode.

Another technique to prolong battery life was demonstrated by Chamanian et al. (2014) as depicted in Figure 2. In this design, a WSN device (MicaZ Mote) is integrated with an energy harvesting circuit and two rechargeable batteries. The energy harvester (which produces 169.0 μW of power) was used to charge the two rechargeable batteries, which then channeled to power the MicaZ Mote device that required 186μW in operation mode. With that, theoretically only net amount of 17μW will be directly