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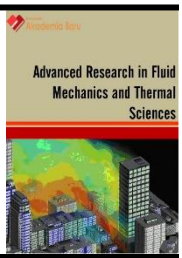

A Review on Kinetic Energy Harvesting Towards Innovative Technological Advances from Sustainable Sources

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ABSTRACT

High energy demand that is indicated by abundant energy use especially fossil fuels, has led to the depletion of fossil fuels, global warming, and air pollution. Consequently, clean sustainable renewable energy was developed to provide safe, clean, secure and affordable energy. Amongst various forms of harvestable energy, the kinetic energy is easily detected, abundant, and widely available. Moreover, the industrial revolutions brought to the mechanical dominant world, increasing the kinetic energy within the ecosystem. It can be harvested more directly compared to other forms of energy. However, there are many systems with significant kinetic energy do not complement with any kinetic energy harvesting technology. Therefore, this paper reviews the fundamentals and applications of the kinetic energy harvesting from clean sustainable renewable sources via three different transduction mechanisms, besides their pros and cons, opportunity, challenges, and environmental impacts. Similarly, this paper briefs about their carbon performance, and existing policies promoting their use or development. Based on the discussions, suggestions were given on the policy to promote the clean sustainable renewable kinetic energy harvesting. This paper provides understanding and information on the kinetic energy harvesting; besides explore its potential applications and impacts, contributing to sustainable energy harvesting and use.

1. Introduction

Along with the rapid population growth and economic growth, global energy demand is predicted to increase by 30% from 575 quadrillion Btu in 2017 to 736 575 quadrillion Btu in 2040 [1]. Electricity is the most concerning secondary source of energy due to its vast demand. According to IEA [2], the total electricity demand by 2016 is up to 1794 Mtoe. Industrial sector (41.6%) is the largest

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contributor, and followed by the sector residential (27.1%), commercial and public services (22.2%), other (7.4%), and transport (1.7%). The abundant energy use especially fossil fuels leads to depleting of fossil fuels. On the other hand, based on the Intergovernmental Panel on Climate Change (IPCC), the increasing global warming in this world impact our environment significantly, causing natural disasters and extreme conditions. Indirectly, many unwanted global issues are emerging, for example, insecure water and energy supply, economic decline, diseases outbreaks and so on. Global warming is contributed by the carbon emissions from the rapid development and natural process in the earth, which is highly difficult to be avoided. In fact, two-third of greenhouse gas (GHG) emissions are from the energy sector. The energy sector carbon emissions achieved up to 33.1 Gigatonnes CO_2 by 2018. Consequently, carbon emissions mitigation and reduction related to energy harvesting and generation are vital [3].

The alarming surge of the energy demand and carbon emissions, with its grave impacts, leads to the development of clean sustainable renewable energy as the complementary energy source, in order to provide safe, clean, secure, and affordable energy supply to the society with huge energy demand. The research of renewable energy was once declined during the surging fossil fuel economy, and now again mushrooming due to the enormous environmental, ecological and economic problems [4]. The clean sustainable renewable energy harvesting and utilization can be observed in most of the developed and developing countries and achieved 8.4 to 25 % of the global power generation by 2017 [5,6]. The research and development of the clean sustainable renewable energy were facilitated by various level policies from international to local, for example, Paris Agreement 2015. With the intention to achieve the objectives of the Paris Agreement, the renewable energy is required to increase to 86 % in 2050, which will occupy at least two-thirds of the total end energy supply on 2050 [6]. In accordance with Paris Agreement, various state and local policies and action plans were implemented by its compliance countries such as UK, US, Malaysia, and Australia. Further examples of the efforts were discussed in section 6.

As shown in Figure 1, there are two main types of energy, which are potential energy and kinetic energy. The energy can be within a natural or artificial system. The kinetic energy can be further divided into mechanical kinetic energy, thermal energy, electrical energy, radiant (electromagnetic radiation) energy, and sound energy. While the potential energy can be divided into chemical energy, mechanical potential energy, nuclear energy, and gravitational energy [7].

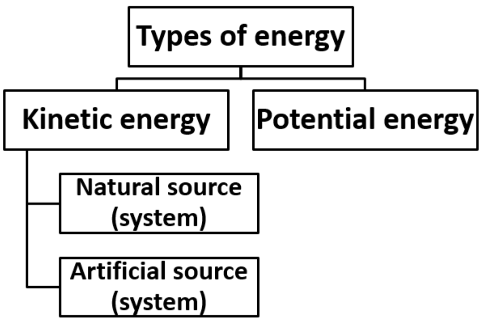

Fig. 1. Main types of energy

Based on the first law of thermodynamics, energy cannot be destroyed, thus, the energy within a system can be harvested and regenerated as the energy supply for the use of the system itself or even other systems. Basically, energy harvesting is the capturing of a specific amount of available energy in an environment into the energy harvesting system on-site, and its conversion from one form (usually non-usable for the case) into another form (usable for the case) via specific system(s) [8–10]. Both kinetic and potential energy can be harvested via the designed energy harvesting system. Notably, the mechanical kinetic energy is more easily detected and widely available even in daily routine processes with a significant amount for energy harvesting. Moreover, the industrial revolutions brought to the mechanical dominant world, increasing the kinetic energy within the ecosystem. It can be harvested more directly compared to other forms of energy. Yet, there are some existing or developing systems with significant kinetic energy does not complement with any kinetic energy harvesting technology.

The fundamental theory that governs the conversion of kinetic energy into the electricity by the displacement of specific moving substance or the mechanical deformation of specific structure within the kinetic energy harvesting system. Generally, the kinetic energy, K.E. (J) is the function of inertia and velocity. It acts either in linear or rotary form, which can be defined as in Eq. (1) and (2) respectively [11-12].

$$K.E._{linear} = 0.5\ Mv^2 \tag{1}$$

$$K.E._{rotational} = 0.5\ I\omega^2 \tag{2}$$

where M is the mass (translational inertia), v is the linear velocity, I is the rotational inertia (moment of inertia), and ω is the angular velocity.

The mechanical-electrical energy conversion works based on three types of transduction mechanisms, namely electromagnetic induction, piezoelectric, and electrostatic [13-14]. Each of these mechanisms has its own advantages and disadvantages, but theoretically, electromagnetic induction is the most effective and established technique despite its dependence on the transducer scale. Each of them has their own preferable application condition. The fundamental principles and mechanisms of transduction (kinetic energy conversion), as well as their pro and cons, were discussed in section 2. Their applications and literature reviews were presented in section 3 and 4.

After all, all energy harvesting approaches including from both renewable and non-renewable energy harvesting produce carbon emissions, and renewable energy sources were reported to produce less than that of the non-renewable energy source especially fossil fuels. Still, the emissions from these renewable energy sources will impact the environment [15-16]. Thus, the renewable energy harvesting should be studied wisely considering its energy performance and environmental impacts especially life cycle carbon emissions, in order to develop the appropriate clean sustainable renewable energy which is safe, secure, and affordable. Working principle and mechanisms of a clean sustainable renewable kinetic energy harvesting technology should be understood to better review the major carbon emissions process (phase) throughout its life cycle, and thus suggest a solution to overcome. Despite, there are limited studies on the working principle and mechanisms, as well as the life cycle emissions of the clean sustainable renewable kinetic energy harvesting technologies. Moreover, these studies did not review other similar studies done in different sites and regions [15,17–20].

Therefore, the present paper reviews and provide an insight into the fundamental, existing applications and past studies on kinetic energy harvesting from different sources (using different technologies) via three different mechanisms of transduction (kinetic energy conversion), namely electromagnetic induction, piezoelectric, and electrostatic energy. Furthermore, the present paper discusses the pros and cons, opportunity and challenges, as well as environmental impacts of each kinetic energy harvesting source (technology). In like manner, this paper briefs about their carbon emissions, role, and performance in carbon emissions mitigation and reduction, as well as existing policy promoting its use or development. Based on the discussions, this paper provides suggestions about the policy to promote the clean sustainable renewable kinetic energy harvesting.

2. Principles and Mechanisms of Transduction (Kinetic Energy Conversion)

Generally, all types of kinetic energy harvesting technologies convert their harvested kinetic energy into electrical energy via three different mechanisms of transduction (kinetic energy conversion), namely electromagnetic induction, piezoelectric, and electrostatic. Table 1 shows the comparisons of these three main mechanisms of transduction.

Table 1
Comparisons of these three main mechanisms of transduction

Mechanisms of transduction	Benefits	Limitations	Reference
Electromagnetic induction	• high output current even without an input of external voltage and mechanical constraints. • suitable for a large-scale system and most of the system except for the microscale system.	• its effectiveness depends on the scale, thus not suitable to integrate with the MEMS. • has a lower ratio of generator size to the output voltage	[21]
Piezoelectric	• simple, no external voltage and mechanical constraints needed but with high voltage output • suitable for Micro-Electro-Mechanical Systems (MEMS) since its effectiveness are independent on the transducer scale.	• its coupling depends on the thickness of the film. • lower output current due to the high impedance. • poorer mechanical properties. • the properties of piezoceramic are easily affected on by its material and construction	[13]
Electrostatic	• suitable for MEMS, since it can have high output voltage even in microscale	• needs mechanical constraints and external voltage source or pre-charged electrode. • maximum power generation needs a very small dielectric gap which have a very high source impedance, leading to poor power delivery	[14]

2.1 Electromagnetic Induction

The electromagnetic induction works based on Faraday's law of induction. It involves the relative motion (rotary or linear) of a magnet to a coil (electromagnet) which causes the change/interruption of the magnetic field (flux) linked with a coil by the magnet, to produce an electromotive force (e.m.f) / current. Figure 2 shows the linear motion of the magnet into and out of the coil. The magnitude of electricity generated depends on the strength of the magnetic field, velocity of the relative motion of a magnet to a coil, as well as the number of turns of coil. The electromagnetic induction within a generator initiates via the rotary or linear movement of its specific part by the kinetic energy within the kinetic energy source (system). The rotary electricity generator is more common and established in kinetic energy harvesting. Fleming's right-hand rule can be used to identify the direction of the induced current. In the case of the rotary electricity generator, the direction of the induced current depends on the orientation of the rotating conductor plate. The magnitude of the induced current depends on the deflection angle of the magnetic field caused by the rotation of the conductor plate. The larger the deflection angle, the larger the magnitude of the current (e.m.f). Eq. (3) shows the formula to determine the magnitude of induced current. Based on Lenz's law, the negative sign indicates the opposing force which counteracts the motion force. Lenz's law works in accordance with Newton's 3rd law and law of energy conservation. Lenz's law states that the polarity of the induced current is such that it produces the direction of induced current whose magnetic field opposed to the magnetic field of the source of flux change, in order to keep the total magnetic flux in the loop constant [22–24]. The electromagnetic generators harvester system works based on the hydraulic/pneumatic system, electrochemical systems, or micro-electromechanical (MEMS) [25].

$$\text{Magnitude of e.m.f, volt} = -N\frac{\Delta\emptyset}{\Delta t} \quad (3)$$

where
N is the number of turns
∅ is the magnetic flux (external magnetic field multiplied by the area of the coil)
t is the time

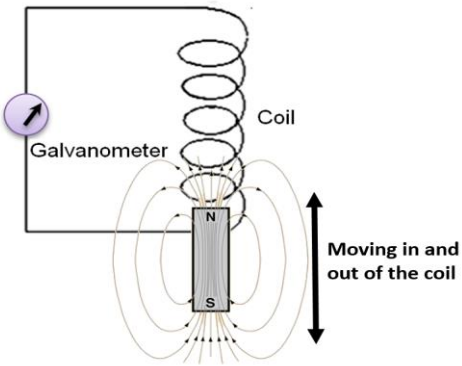

Fig. 2. Electromagnetic induction

2.2 Piezoelectric

As shown in Figure 3, piezoelectric mechanism is a phenomenon when the mechanical strain and (or) stress applied on the electroactive material, there is an electric charge generated within the material. The magnitude of mechanical strain and(or) stress applied to the electroactive material is directly proportional to the magnitude of electrical polarization within the material [26]. The piezoelectric transducer consists of electroactive materials for high electromechanical coupling [13]. For examples, Barium Titanate ($BaTiO_3$), Zinc Oxide (ZnO), and Lead Zirconate Titanate ($Pb[Zr_xTi_{1-x}]O_3$), and polymer-ceramic composite (PVDF-PZT) which then replaces ceramics due to its flexibility, inexpensiveness, and durability. The 31 mode is typically used although has a lower coupling coefficient. Piezoelectric works based on either voltage-constrain or charge-constrain approach. The consecutive equations for a piezoelectric material, calculation formula of the voltage source, piezoelectric damping coefficient, optimum resistance, and maximum power was presented by Kazmierski [14].

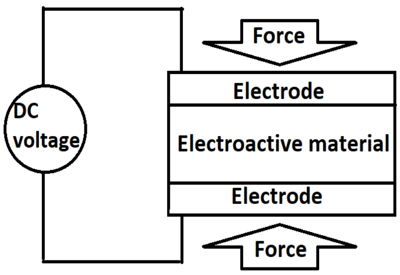

Fig. 3. Piezoelectric

2.3 Electrostatic

As shown in Figure 4, the electrostatic transducer consists of a variable capacitor which has one movable electrode indirectly connected (via beam) to an oscillating mass suspended, and one fixed electrode connected to the conditioning circuit [13]. It is capacitive and electrostatic. When the external oscillation indirectly moves the movable electrode further, the distance between two electrodes will increase, and the capacitance will decrease, the capacitor will be charged to a specific value, and the energy of the electric field stored in the capacitor will increase. This can be related using the formula of the capacitance (C_t) and the energy of the electric field stored (W_t) which are Eq. (4) and (5). Other related formula is presented in the same study as well [27]. Recent technology works based on the electrostatic induction and contact electrification is triboelectric nanogenerator (TENG).

$$C_t = \frac{\varepsilon_0 \epsilon_r A}{d} \tag{4}$$

where ε_0 is the permittivity of the air space, ϵ_r is the permittivity of the medium (air or solid) between 2 plates, A is the area of the plates, and *d* is the distance between two plates.

$$W_t = \frac{Q_t^2}{2\,C_t} \tag{5}$$

where Q_t is the electrical charged where the capacitor charged to

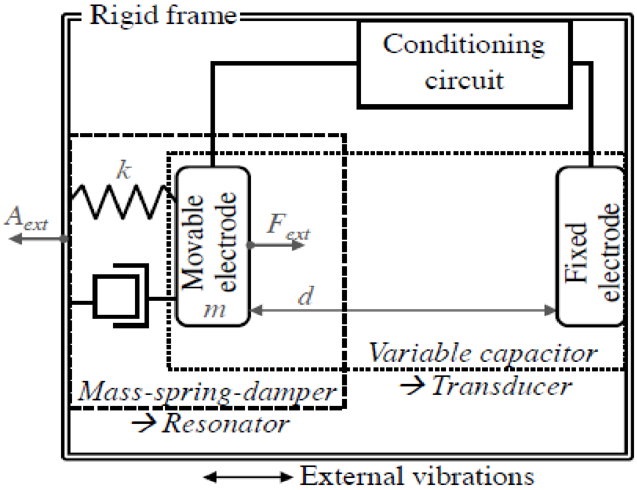

Fig. 4. Electrostatic

2.4 Energy Storage

The induced current can be used directly or kept in a storage system such as flywheel system, rechargeable chemical cell, thermal storage, compressed air, cryogenic system, and superconducting magnetism [28–30]. Chemical cell is the most common electricity storage system. Most batteries are under lithium-ion type [29].

3. Kinetic Energy Harvesting from Natural Energy Sources/Systems

3.1 Wave

Wave energy is the derivative of the hydro kinetic energy. Generally, the fluid wave energy extraction relies on the wave effects of the targeted fluids, especially seawater. The effects are temporal water level alterations, spatial hydrostatic pressure fluctuation, spatial total water pressure fluctuation, the slope of water surface, concentration differential of water energy for different front and depth, as well as the combinations of any of these effects. The wave power device (WPD) only utilize the mechanical kinetic energy and (or) potential energy of the wave for the wave energy harvesting. This study focuses on kinetic energy harvesting. The principle of the mechanical wave energy harvesting is defined by the wave power equation as shown in Eq. (6) for the case of deep water such that water depth is larger than half of the wavelength.

$$P = \frac{\rho g^2}{64\pi} H_{m0}^2 T_e \approx 0.5 \frac{kW}{m^3 s} H_{m0}^2 T_e \qquad (6)$$

where P is the wave power/energy flux per meter of wave-crest length (kW/m), H_{m0}^2 is the significant wave height (m), T_e is the wave energy period (s), ρ is the density of water (kg/m^3), g is the gravitational acceleration (m s^{-2}) [31-32].

Basically, the wave energy harvesting by WPD can be divided into two phases which involve different parts of the WPD. Firstly, the working tool or body (solid, liquid, or gas) contained in it will be moved by the wave which is directly contacted to it, for examples, The wave motion harvesting can be done at sea surface and deep-sea using floating and submerged system respectively. The relative movement of the working tool or working body relative to the fixed frame produces internal energy within the system, which will be converted into usable, storable, or transmittable form to be used on-site, kept, or transmitted respectively. The conversion of kinetic energy to electrical energy can be classified into direct and indirect conversion based on the principle of kinetic energy harvesting (hydro-mechanical conversion) and kinetic energy conversion (mechanical-electrical conversion). For the classifications of the WPD based on the kinetic energy harvesting, the oscillating water column type and overtopping type use indirect kinetic-electrical energy conversion, whereas the oscillating body type can use direct or indirect kinetic-electrical energy conversion. For the classifications of the WPD based on the kinetic energy conversion, electromagnetic WPD uses direct kinetic-electrical energy conversion. The wave motion turns the turbine to change the electromagnetic field thus inducing the current. This usually applied at high wave motion area. Another type that uses direct conversion is piezoelectric WPD. The mechanical strain and (or) stress applied to the electroactive material creates charges to be converted into electricity. This commonly applied at low wave motion area. In contrast, pressurized gas-driven turbine WPD uses indirect kinetic-electrical energy conversion. The wave motion creates internal energy (high pressure of gas/water) to turn the turbine This internal energy is collected until a specific amount and transferred to the power converter for further conversion. This can be only applied at high wave motion area. Although direct-drive wave energy converter produce fluctuating electrical power caused by a fluctuating wave, the energy loss during the conversion from wave to electricity is at the minimum. It is vice versa for the indirect drive wave energy converter [33]. The effectiveness and efficiency of the WPD depend on the transmission of the wave energy from its source to the working tool, and the internal energy collected from the working tool to the power converter, as well as the energy conversion performance of the power converter [34].

Oscillating water column (OWC) is a hollow structure with a low-pressure well turbine inside which is driven by the air pressure created by the moving wave. It has its principal axis perpendicular to the predominant wave direction. It is typically installed onshore or nearshore and partially submerged. The moving waves cause the water column to rise and fall, compressing and decompressing the air column within the hollow space, driving the good turbine to generate electricity. Its power rating depends on the wave and device dimensions [35–37]. For example, the offshore WPD Energetech by Oceanlinx company [33]. Overtopping device has a pair of largely curved reflectors to guide the waves flow along the ramp into its central reservoir. After the water reached a specific level in the reservoir, it will be released back into the sea through a low-head turbine to generate power. Oscillating body can be further divided into attenuator, oscillating wave surge converter (OWSC) and point absorber. For example, the Sea-wave Slot-cone Generator by Norwegian company Wave Energy [33]. Attenuator is a long multi-segment floating or semi-submerged cylindrical structure, with several sections connected by hinged joints. They are located parallel to the wave direction to be driven by the waves, in order to capture energy from the relative motion of the two arms as the wave passes them. Its segments move with the waves to directly be converted into electricity or pressurize the resistive hydraulics, producing the pressure energy to be converted into the electricity. For example, Pelamis system with several series [32]. OWSC comprised of a hinged deflector, positioned perpendicular to the wave direction (a terminator), moves back and forth, exploiting the horizontal velocity of the wave. Its float, flap or membrane oscillates along a given axis at a specific reaction point (fully submerged, partially submerged or floating), to extract the mechanical kinetic energy to be converted into electrical energy. For instance, Oyster 1 which is a fully submerged flap, was commercially developed by Aquamarine Power Ltd in 2005, followed by improvised Oyster 2. The surface-penetrating flaps were developed to harvest the wave energy at different points. This type of OWSC includes waveRoller, bioWave, and Frond [38-39]. Point absorber or cylindrical energy transfer oscillator consists mainly of buoyant actuator, tether, pump, foundation, and connectors. The buoyant actuator that fully submerged harvests the alternating movement of wave for hydraulic compression. Due to its small size, the wave direction is insignificant. The pressurized water will be used to drive the turbine generator and generate desalinated water [33]. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors [40-41]. For example, Powerbuoy that oscillating in the sea was tested in Spain in 2008 [42]. Table 2 shows the improved WPDs with the integration of advanced features or(and) new application, which were studied in recent years.

Table 2
Past studies on improved WPDs

Previous studies (applications)	Pros and cons	References
Electromagnetic induction		
OWSC based on adaptive geometry with more degree-of-freedom was developed to compensate for the hydrodynamic factors. The power take-off system was integrated with the monitoring of time-average power and resulting surge foundation force, to better control the energy harvesting effectiveness.	Pros 1. enable adjustment based on the conditions Cons 1. increase energy harvesting efficiency	[43]
The advancement of OWC by combining multiple harvesting chambers to one electric generator through a hydraulic system.	Pros 1. lower energy loss during conversion to electric Cons 1. faulty of one of the harvesting devices affect the whole system.	[44–46]

Piezoelectric		
Improved point absorber was developed using the novel surface-mounted and interior permanent magnet tubular linear generator which make up a series-parallel hybrid magnetic system. This enables an optimum pole-arc coefficient.	Pros 1. Higher efficiency of electric harvesting and conversion 2. improved sinusoidal characteristic, vibration, and thermal conditions. Cons 1. thermal insulation protection equipment must be considered	[47]
Non-linear multi-stable system was developed with non-linear restoring mechanism and linear damper-like generator, which enables it to have a wider frequency bandwidth of the wave absorber and that of the power take-off damping coefficient.	Pros 1. Better frequency and damping ratio bandwidth even without additional elements compared to the conventional linear point absorbers Cons 1. Optimum operation conditions are required for better performance relative to the conventional system	[48]
Electrostatic		
A spring system was integrated into the triboelectric nanogenerator (TENG) to efficiently harvest low-frequency wave energy. The spring acts as the potential energy storage when the system is receiving the external force, keeping the extra energy for later conversion when there is no external force received. The output power is optimized by the spring rigidity and spring length.	Pros 1. accumulated charge of the system and the generated electrical energy is raised by 113.0 % and 150.3 % respectively. 2. It has high efficiency and output performance for even low-frequency wave energy Cons 1. Lower mechanical strength	[49]

3.1.1 Opportunity

Accounting for the fact that water covers more than 70 % of the earth surface, wave energy has the chance to contribute in annual electrical energy generation of up to 80 000 TWh that is equal to around five times of the current global electricity consumption of 16 000 TWh [50]. Consequently, wave energy harvesting was being widely studied and developed. Moreover, technologies applied in other renewable energy fields can also be applied in wave energy harvesting. Varieties of integration and innovation of the technologies to advance wave energy harvesting, such as piezoelectric and triboelectric nanogenerator [51–54]. In addition, due to its benefits as a highly available with a high capacity renewable energy source, wave energy kinetic energy harvesting industry is now being significantly invested and developed by venture capitalists and utility companies especially in UK, US, Portugal, Australia and China [50,55-56]. Furthermore, it is applicable to many countries with coastal regions. For example, it was reported to have an average potential hydrokinetic energy of 2.8 kW/m to 8.6 kW/m to be generated in water bodies in Malaysia, especially Terengganu and Sarawak which contain the most coastal area [57].

3.1.2 Advantages

Among renewable energy sources, wave energy is highly ranked due to its abundant advantages. Firstly, it is persistent and not limited by seasons and weather as the solar and wind do. Based on the study carried out in California, wave energy is more constant compared to solar and wind energy which unstable during winter season or night time [58]. No carbon emissions produced. Most importantly, wave energy is reliable and abundant. In the case of kinetic energy harvesting, wave energy recorded a density of 2 to 3 kW per meter square outreaches the density of 0.1 to 0.2 kW and 0.4 to 0.6 kW per meter square for solar energy and wind energy respectively [59]. There are many ways to capture and harvest wave energy from both surface layer and deep bottom layer of the ocean, for example, hydro turbine, attenuator, submerged vibrator, point absorber and so on. In addition, it is predictable in terms of its magnitude and direction. An appropriate numerical simulation evaluation can produce very accurate baseline data for energy planning use [60,61]. Its high strength also contributes to its low energy loss [44,50,62]. Last but not least, its localized application benefits both domestic and industrial electric use. For example, the generated electricity can be used for residential and commercial shops, as well as the fishery and desalination or other industries near the sea [60].

3.1.3 Challenges and disadvantages

Obviously, the WPD can be applied at a location with coasts [58]. Moreover, large scale, high strength, and maintenance of the wave power plant is needed for most of the high wave energy area, because the force of the wave is larger than that of other natural kinetic energy sources [4]. Moreover, the wave is more complicated and difficult to be estimated due to its rapid changes between linear and non-linear, depending on the wind, weather and other factors [63]. Unstable sea states along with seasons require the flexible designs of WPD which is compatible with the accounted variations [4]. Consequently, its design and operation is theoretical difficult and involve multidisciplinary expertise including structural and mechanical engineering, meteorology, hydrology, geology and so on [50,64]. Wave energy needs more complicated technologies and investment since its location is usually away from the other infrastructure and facilities especially grid facilities. This makes it difficult to transport the generated wave energy to the electricity grid for commercial, residential and industrial utilization [61,65]

3.2 Hydro

The hydropower is derived from falling or running water at significant velocity. The hydrokinetic energy which is the kinetic energy within high-velocity water turns the turbine blades, initiating the electromagnetic induction in the generator, generating the electricity. The hydrokinetic energy is supplied by the natural water cycle which consists of evaporation, condensation, precipitation. Hydro power harvesting can be done with four main types of water movements, namely falling water, flowing water, self-generated water wave and automated water wave. With the same hydrokinetic harvesting system, falling water records the highest energy harvesting [66]. Basically, hydropower plant is made up of a reservoir, receiving valve, penstock, turbine, generator, electricity transmission or(and) storage system [67,68]. The hydropower plant is usually located adjacent to the dam. Storage or impounding dam is used to store water to increase the potential energy within the upstream water which will be released to produce higher kinetic energy to drive the turbine [67].

The theoretical mechanical energy (horsepower) and electrical energy generated (W) from the hydropower plant can be calculated using Eq. (7) and (8) respectively.

$$\text{Theoretical mechanical energy generated} = (Q \times H)/\,8.8 \quad (7)$$

$$\text{Theoretical electricity generated} = (Q \times H)/\,8.8 \times 746\ \text{W} \quad (8)$$

where Q is the flow rate of the water (cfs), H is the head height (ft), and 8.8 is a constant [68].

The conventional hydropower plant only functions for energy generation. Meanwhile, the advance hydropower plant is incorporated with the computer technologies for continuous remote monitoring and controlling. The monitoring of the power plant, dam, and their environmental conditions is important for the system operation, safety, and maintenance while conserving the environment surrounding it [68]. The improvement of turbine efficiency and electricity transmission efficiency are also the main focused aspects. The hydropower plant can directly supply the electricity to the manufacturing work of the dam near to it, and the surplus electricity generated is transmitted to the local power grid for agricultural and domestic consumption. Table 3 shows the improved hydropower plant with the integration of advanced features or(and) new application, which was studied in recent years.

3.2.1 Opportunity

There is a greater opportunity in the countries with high elevation inland, which leads to precipitous rivers availability, for example, Malaysia and Tanzania. In Tanzania, the potential hydropower to be generated is up to 190 000 GWh annually [74]. On the other hand, development of the small and large-scale hydropower plants in several states in Malaysia including Pahang and Sarawak brings light to the hydropower field. Barely Sarawak state is forecasted to have 60 % hydropower as their power generation by 2020 [75]. Furthermore, the decommissioned mining pits are potential to be modified as the water reservoir for hydropower harvesting [76]. Small scale/mini hydropower plant without dam and water storage was being studied and applied to a wide range of location due to its flexibility and less environmental impact [77].

3.2.2 Advantages

Similar to the wave energy, hydropower is persistent, abundant, clean, and predictable with appropriate expertise and technologies. In additions, hydropower can be generated in most of the countries at a wide range of weather and climate, as well as geography conditions, for example, Malaysia, China, high north [78–80]. Moreover, hydropower is highly flexible in terms of its intensity or time to be generated. All scale of hydrokinetic energy can be harvested using different harvesting device and transduction mechanisms. The hydropower generator can be located at different altitude along the same water channel since the hydropower harvesting at upstream has a negligible effect on the downstream hydropower harvesting [67]. Technically, the hydropower plant can be turned on based on the energy demand. Most importantly, the hydropower plant can generate power to grid immediately, reducing energy loss during transportation. The accumulated water will be stored as potential energy to be converted into kinetic energy when the sluice gate of the dam is opened [81]. Positively, most of the hydropower dam has the potential to be a tourist spot due to its aesthetic and functional for water sports such as boating, swimming, and fishing.

Table 3
Past studies on improved hydropower plant

Previous studies (applications)	Pro and cons	Reference
Electromagnetic induction		
Adaptive hydrokinetic energy harvesting system can adapt to the changes in water flow. It consists of the supporting structure that defines a flow-way, with hydrofoil vane on it to capture the fluid	Pros 1. High efficiency regardless of changing flow properties.	[69]

flow kinetic energy to be converted into electricity. Its control module modifies the resistance of the vane and the mechanical-electric conversion based on the vane oscillation, the torque produced and generated current. It is compatible with both electromagnetic and piezoelectric generator.	Cons 1. Faulty control module causes the wrong adjustment in the harvesting setting.	
Vertical Axis Autorotation Current Turbine (VAACT) was developed by addition of optimum mass moment of inertia to the optimum starting moment. This enables the continuous rotation of the turbine to generate a more stable and higher amount of kinetic energy.	Pros 1. Longer effective energy generation period without the need of additional external force Cons 1. Require accurate and precise calculation of the addition mass	[70]
Piezoelectric		
A vortex-induced vibration (VIV) hydrokinetic harvester was developed and simulated using the CFD software. It harvests the vibration induced by turbulent vorticity instead of the water motion. It is a circular cylinder with a pair of fin-shaped strips symmetrically attached to its surface to disturb the flow pass through, creating higher vorticity in slow-moving water for kinetic energy harvesting based on piezoelectric. This system can harvest up to 60 W/m at water flow velocity of 1.5 m/s.	Pros 1. Microscale hydrokinetic energy harvesting 2. Adaptive to various flow properties by changing the bluff body geometry Cons	[71]
The similar study carried out by optimizing the bluff body geometry to produce the most suitable vorticity for a specific frequency range to be harvested. Maximum energy density generated is predictable with known water velocity.	1. Optimum shape, size, location, and angle of the obstacles (eg: fin, bluff body) is required 2. Only can be applied at slow-moving water	[72]
Electrostatic		
Triboelectric nanogenerator (TENG) powered by hydrokinetic energy for water splitting was studied. With only the spin speed of 600 rpm (driven by normal tap water), the hydrogen generation can reach 2.5 X 10^{-2} mL min^{-1}.	Pros 1. Microscale hydrokinetic energy harvesting 2. On-site use of the electricity generated reduce energy loss during transport Cons 1. Not suitable for high water flow	[73]

3.2.3 Challenges and disadvantages

Similar to the wave, hydropower plant has a high structural demand since it must be strong enough to withstand the high magnitude hydrokinetic energy. Compared to wave energy, river hydropower is less predictable due to the seasonal and weather variations that cause the changing river level. There are minimum and an optimum requirement on the water current and water depth based on the hydropower plant. Generally, the flow properties requirements include steady, no serious flood and extreme condition, as well as free of large debris, animals and any substances to cause installation difficulty, blockage or damage. Moreover, the river used should be large enough yet not be the important waterway for transportation. In light of this, the river assessment should be carried out before the installation of the hydropower plant [82].

3.3 Wind

Wind energy is derived from the high velocity moving air, indicating its high kinetic energy. Its movement is initiated by the different heat absorption of solar radiation by the earth surface, which causes the temperature and pressure differential of air, causing the air movement. The moving wind will lift each of the aerodynamically designed rotor blades upwards, leading to the rotor rotation and thus rotation of the magnetic field in the generator. This cause the electromagnetic induction to produce current based on Faraday's law. The wind power, P (W depends on the air volume, velocity, and density. Its formula is derived from the formula of kinetic energy and the fluid mass flow rate, which is shown in Eq. (9) [10,83].

$$P = 0.5C\rho AV^3 \tag{9}$$

where C is the coefficient of wind turbine performance [0.593 for max efficiency (betz limit)]
ρ is the air density [1.2 kg/m^3 [84]]
A is the swept area of the blade (m^2) [A= πr^2]
V is the air velocity

Betz limit is the theoretically maximum possible for all turbine, C which is 0.59. This is because the movement of air particles should not be fully harvested by the rotor since they need a specific minimum quantity to continuously flow. Capacity factor is the percentage of the year the turbine generator is operating at rated power, which is defined as its average output divided by its peak output, with a common value of 30 % or above for a good site. There are two main types of turbine which are horizontal axis and vertical axis. The applications of wind power harvested includes to power the water pumps, stone grinding, sailing ships and so on [10,83].

The future improvement was done to improve its performance in terms of its capacity and capacity factor using a greater height, better design and material of blades, superconducting magnets, advanced control system and site-specific designs [85–89]. Modeling and simulation are incorporated to anticipate the wind harvesting spatial and temporal point to increase wind harvesting reliability and availability [90]. For the downstream phase, the efficiency of output electricity increased from 40% to 70% by significantly reducing its voltage drop from 0.6 to 0.15 V [91]. Later, the high altitude wind energy system (HAWE) or airborne wind energy system (AWES) is emerging as a novel design of the wind energy harvesting system, by turning it into a high mobility and flexibility mobile system [92–95]. Table 4 shows the improved wind power plant with the integration of advanced features or(and) new application, which were studied in recent years.

Table 4
Past studies on improved wind power plant

Previous studies (applications)	Pro and cons	Reference
Electromagnetic induction		
Horizontal axis wind turbine (HAWT) on top of a cubic building was modeled and simulated using CFD. The parameter turbine height from roof level was optimized. Surprisingly, the power coefficient starts to increase with increasing height from building top, even when it was partially located in the separation zone.	Pros 1. Save space for wind turbine facilities 2. Enable wind energy harvesting in urban Cons 1. Results were restricted to the optimal tip speed ratio condition only	[96]
The aerodynamics, control algorithms and power curve designation method of HAWE or AWES were studied. An improved aerodynamic model, mathematical model, and the power curve of this system were developed.	Pros 1. Save land space 2. Harvest higher magnitude and uniformity wind at high altitude Cons 1. More complicated maintenance	[93]
Piezoelectric		

Enhanced piezoelectric wind energy harvester was developed by addition of two thin cylindrical rods on two sides of the circular cylinder at 60°. This effectively increases the aeroelastic unstable range of that circular cylinder, leading to a higher VIV as in the hydrokinetic energy harvesting discussed above. The harvestable wind energy can even be higher than the VIV onset wind speed and long-lasting.	Pros 1. Save space for wind turbine facilities 2. Enable wind energy harvesting in urban Cons 1. Results were restricted to the optimal tip speed ratio condition only	[97]
Electrostatic		
A hybrid nanogenerator working based on the TENGs and electromagnetic generators (EMGs) to harvest the kinetic energy from airflow. It was reported to harvest up to 14.6 kW/m^3 from 18 m/s airflow. The energy generated also used to support the temperature sensors within it.	Pros 1. Wider range of harvestable airflow speed 2. More efficient Cons 1. Generation of the large wake behind the rotor.	[98]
A wind turbine working based on TENG was invented to harvest small scale wind energy. The thin Teflon dielectric membranes on the stator provide large capacitance difference and polarization source for the electrostatic converter. At 20 m/s, it was reported to harvest up to 550 µW.	Pros 1. Able to harvest low wind energy Cons 2. Friction loss needs to be reduced	[99]

3.3.1 Opportunity

The invention of Small-scale Wind Energy Portable Turbine (SWEP) enables the incorporation of wind energy harvesting into daily routine, for example, wind turbine on the vehicles and highway [100,101]. Surprisingly, a small simple vertical axis wind turbine (VAWT) made up of 3-D printed components was introduced and reported to be feasible. This enables the wind energy to be available for personal, families and small communities use [102,103]. Moreover, although the refilled abandoned mining sites with elevated landscape has limited landuse, it can be a beneficial opportunity for wind energy harvesting. Wind turbine should be built on it since it can harvest more wind energy and with less aesthetic impact compared to the case on flat land. Still, the stability and safety of the site must be considered. For example, in UK, some former coal mine sites were evaluated for its potential for wind energy harvesting. The factors taken into accounts are space sufficiency, existing ecosystem, mean wind speed, and accessibility. Surprisingly, 106 sites evaluated recorded a total of 4 GW (10TWh/year) of potential wind energy generation [76].

3.3.2 Advantages

Similar to most of the renewable energy, wind energy is unlimited and clean. It is abundant at the offshore and high elevation land. Moreover, it can provide domestic energy use since it occupies a smaller base area, thereupon can be built on existing farms and remote residentials. This can save up space and provide extra income for the landowner, triggering remote economics [104].

3.3.3 Challenges and disadvantages

The most obvious drawback is its high initial cost, especially its manufacture and installation. Furthermore, the good site is usually a remote area with less energy demand. Surplus energy still needs to be transported, causing unavoidable energy loss [104]. To reduce the need for converted wind energy transportation, consideration should be taken on the fact that most cities were occupied by built structures, which disturbs the natural wind airflow. Thus, the study on the airflow is more complicated, leading to difficulties in designing and choosing a suitable wind turbine. For an efficient wind energy harvesting, expertise in fluid mechanics and fluid dynamics is needed to understand the flow-structure interactions, which is required to develop the appropriate design and configuration of the wind energy harvesting system based on the site environmental conditions. Study of the airflow can be done using computer simulation as well as wind tunnel and water tunnel experiments [103,105-106].

3.4 Steam (Geothermal, Solar, Nuclear or Biofuel)

Steam energy is the mechanical kinetic energy derived from the thermal energy of the heated water vapour (steam) within the steam generator power plant. However, this paper only covers the clean renewable heat sources such as geothermal, solar, nuclear and biofuels. The steam energy harvesting will be started from the burning of fuel (chemical energy) or use of geothermal or solar heat to boil the water (thermal energy) to produce high temperature and thus high-pressure steam (mechanical kinetic energy). The high pressure is due to the higher collisions of high thermal energy gas particles with each other and the wall. For the steam energy harvesting from geothermal, the high temperature and high-pressure steam or water are transported from the underground to the power plant to directly or indirectly drive the turbine depending on the type of the geothermal power plants, namely, dry steam plants, flash steam plants, binary cycle power plants [107,108]. Typical temperature and pressure needed to rotate the turbine blades are around 578 °C and 6.895 $X10^6$ Pa respectively. The turbine rotation leads to shaft rotation within the magnetic field, producing the induced e.m.f (current) based on the principles of electromagnetic induction. On the other hand, the water cooling system is contributing to the kinetic energy harvesting as well. The used steam loss its energy and converted back into the water in the condenser by the water coolant. Based on the laws of conservation of energy, assuming the inlet mass flow is equal to the outlet mass flow, the output energy (MW), efficiency, and output power (MW) of the steam generator power plant can be defined as in Eq. (10)-(12) respectively [109–112].

$$\text{Energy}_{out} = \Delta q_{steam} * m_{steam} \tag{10}$$

$$E_{power\ plant} = [E_{boiler}][E_{turbine}][E_{generator}] = \left[\frac{Thermal\ energy}{Chemical\ energy}\right]\left[\frac{Mechanical\ kinetic\ energy}{Thermal\ energy}\right]\left[\frac{Electrical\ energy}{Mechanical\ kinetic\ energy}\right] = \left[\frac{Electrical\ energy}{Chemical\ energy}\right] \tag{11}$$

$$\text{Power}_{out} = \text{Energy}_{Out} * E_{power\ plant} \tag{12}$$

where the Energy_{out} is the energy output (MW), Δq_{steam} is the change of specific enthalpy of steam (kJ/kg) , m_{steam} is the mass flow rate of the steam (kg/s), $E_{power\ plant}$ is the efficiency of the steam power plant, and Power_{out} is the output power (MW) [109].

Simultaneously, in the water cooling system, the potential energy of the floating steam is converted into the kinetic energy of the falling water. This kinetic energy will be harvested by the water wheel and converted based on the principles of electromagnetic induction. The steam generator power generation is usually to complement the grid electricity. So far, the geothermal heat source for steam generation is not used in Malaysia. Table 5 shows the improved steam energy/

thermal power plant with the integration of advanced features or(and) new application, which were studied in recent years.

3.4.1 Opportunity

There is a large opportunity in countries located in or near the Sun Belt. They have widely distributed and high magnitude more than world and duration solar radiation and constantly available geothermal heat. The regions with daily solar radiation of more than that of the world average, which is 3.61 KWh/m^2/day, have a high potential to use the solar as a heat source of steam power plan. For example, Pakistan receives 4.45 to 5.83 kWh/m^2/day and with more than 250 sunny hours per month [118]. Underground mine hole acts as the natural reservoir for water heat up to produce steam energy. A former coal mine site was modified into the geothermal steam power plant in Netherlands since 2008. However, the geothermal produces more carbon emissions than other steam energy heating source [76].

3.4.2 Advantages

Steam (thermal) energy derived from clean renewable energy sources that mentioned in section 3.4 is clean and unlimited. The geothermal, nuclear and biofuel heat sources are less affected by external factors and consistent, with minimal fluctuation compared to solar and wind energy, because it is independent of weather. They are also abundantly available in the earth, providing a large energy harvesting. Moreover, it contributes to controlled heating and cooling too [119].

3.4.3 Challenges and disadvantages

Generally, the steam (thermal) power plant can only be built at a selected location with geothermal energy. For example, location near to the heatbelt of the Earth. Moreover, the high-temperature operation poses risk of overheat, meltdown and overpressure of the steams to damage the components of facilities. In this case, it requires effective cooling systems for the post-treatment. Furthermore, there are potential carbon and pollutants emissions for the steam thermal power plant heat source of geothermal and biofuel due to the greenhouse gas deposited underground and the combustion process respectively. The reservoirs underground contain toxic heavy metals, leading to pollutants emissions. The channel extracting heat of the geothermal also causes the earth ground layer to be altered [120].

Table 5
Past studies on improved steam energy/ thermal power plant

Previous studies (applications)	Pro and cons	Reference
Electromagnetic induction		
The solar heat direct steam generator was integrated into the biomass thermal power plant. The solar heat collected from parabolic trough was used to generate the steam that was then superheated by the biomass combustion. This system has solar-to-electric efficiency of 10 % higher than the conventional steam (thermal) power plant.	Pros 1. Double heating source to enhance performance and save cost Cons 1. The detailed study must be done to avoid contradict between two heat sources	[113]

A heat recovery steam generator (HRSG) with the power-tower-based air heater was developed to reuse the biogas or syngas to further heat up the steam. Biogas derived from wastewater records the highest internal rate of return of 11 % among other biofuel sources.	Pros 1. Best biofuel and biogas source was determined Cons 1. Higher manufacture and installation cost	[114]
A study on the steam temperature control of the steam power plant was done by optimizing the inner-loop PI controller parameters, upgrade and integrate mathematical algorithm to the outer-loop PI. The experiment using 300 MW power plant shows a good result.	Pros 1. Reduce temperature deviation and the external factors effect to its operation. Cons 1. Programming expertise needed	[115]
Solar steam generator was improved by integrating heat localization to the thin-film evaporation using inexpensive materials. Its energy efficiency is up to 78 % at 1 kW/m^2.	Pros 1. Lower cost than equivalent efficient power plant. Cons 1. Solar is weather dependent	[116]
The hydrogen-oxygen steam generator with a storage system was developed to increase the efficiency, maneuverability, and reliability of the ordinary geothermal power plant. It enhances the rate of capacity change and the start-up period of power production.	Pros 1. provides backup power for the accident or failure period Cons 1. safety issues on the explosive and reactive hydrogen gas.	[117]

4. Kinetic Energy Harvesting from Artificial Energy Sources/Systems

4.1 Regenerative Drive and Braking

Regenerative drive and braking technology are applied in the regenerative elevator and hybrid car. The most common regenerative drive is a permanent magnet synchronous motor (PMSM) drive, which allows the electrical power to flow in two directions. It applies Faraday's Law of electromagnetic induction. The electric motor acts as a motor during powering phase when the electrical power (volts X amps) provided by the power converter is higher than the counter e.m.f generated by the rotation in mechanical power (torque X speed). The electrical energy is converted into the mechanical kinetic energy which produces accelerating or lifting torque on the motor shaft. In contrast, it acts as a generator during the generating phase when the electrical power source is less than the counter e.m.f generated by the rotation. The mechanical kinetic energy is decreasing and being converted to the electrical energy to be transmitted back to the drive storage to be used during the motoring phase. For the elevator system, the extra electrical energy will be transmitted into utility lines [121,122]. In relation to the vertical transportation in the mid or high-rise building usually have a large usage demand, it can be considered as a sustainable kinetic energy source. The regenerative roped elevator has been applied in many modern high-rise buildings and reported to be effective in energy saving [123-124]. However, the developing rope-less elevator system which is a non-contact system, with the potential harvestable kinetic energy of its moving elevator car which can only be transferred through the airflow induced by its movement [125,126]. Thus, an aerodynamic study of the rope-less elevator system is needed to evaluate the induced high-speed airflow, in order to determine the significant spot and quantity of the kinetic energy harvesting. The energy generated may power the auxiliary system as in the case of the regenerative roped elevator system.

4.2 Piezoelectric Step-On Generator

The heel strike generator using a piezoelectric energy harvesting mechanism was developed [127]. A power electronics circuit extract, store, regulate the electrical energy generated by four Lead Zirconate Titanate (PZT-5A) piezoelectric materials, and then convert their input AC voltage into the DC output voltage of 12 V. The average power produced is much lower than the targeted value, due to the unbalanced mechanical load (weight) application. This was improved by the integration of piezoelectric ceramic in steel holder installed in the shoe sole, which can extract up to 0.4 % of the weight applied into 1.43 mW of electrical power [128]. Another application of piezoelectric energy harvesting is on the building floor [129]. This technology can be used to supply the low power systems such as LED lighting and wireless sensor network (WSN) for data transmitting and internal environmental monitoring. Road energy harvesting can be done using the piezoelectric material to collect the vibration energy from the movement of vehicles on the pavement [130]. Different types of road need different designs of the piezoelectric energy harvesting system, such as its vibration frequency and durability. This system is only suitable to supply electricity to small devices such as traffic light, traffic guiding facilities, and traffic information gathering system. Evaluation of the harvesting point is important to enable effective and efficient piezoelectric energy harvesting. Computational fluid dynamic (CFD) was used to study the analyze the wake region behind the bluff body for piezoelectric energy harvesting [131].

4.3 Wind Turbine Harvesting Vehicle Induced-Air

In earlier, a portable wind power harvesting system for the electric vehicle is invented [132]. This system comprised of a wind turbine on the vehicle and a generator that convert the wind kinetic energy into the electrical energy based on the electromagnetic induction. The electrical energy was used to power instantaneous usage and recharge its battery. After that, a variable speed wind turbine on a vehicle was invented using a novel Turbine Control Unit (TCU) to control the generator torque based on the rotor speed and required turbine output power [133]. This technology enables a constant turbine output power regardless of the inconsistent high-speed winds. Another wind turbine on the train roof with the turbine output power stabilization was developed [134]. This system integrates an auxiliary system to collect and compress the air to be stored in a pressure conduit, in order to maintain the turbine operation during low wind condition. This system has high efficiency and produces a large-scale power. For the fixed wind turbine, a horizontal axis wind turbine on overhead shafts is developed to capture the wind energy induced by the vehicle movement on the highway [135]. Based on the computational fluid dynamics and MATLAB results, the power generated by different vehicles is 0.4 kW to 1.883 kW and 1.167 kW to 2.28 kW respectively. This energy can be used for street light and small auxiliary systems along the highway. Same as the piezoelectric harvesting, modeling, and simulation which was used to simulate the airflow surrounding the car or solid objects enable the determination of the significant spot to place the wind power harvesting system to capture a significant value of wind power [136].

4.4 Electrostatic Harvesting Vehicle Induced-Air

A Polydimethylsiloxane single-electrode TENG (S-TENG) was developed to harvest the friction energy of rolling tyre. It contains only one back electrode to collect the induced charge, while its front surface is directly contacted with the ground. More than one S-TENGs can be installed in the tyre surface to harvest higher induced chargees and increase the generated power. It was reported to output up to 1.79 mW instantaneously at a load resistance of 10MΩ, resulting in 10.4 % energy conversion efficiency. This enables the power support for 6 normal light-emitting diodes (LEDs) [137]. The triboelectric nanogenerator tree in train tunnel was studied for wind energy harvesting based on the coupling of contact electrification and electrostatic mechanism. The wind speed of 11 ms^{-1} was reported to produce 330 V of open-circuit voltage and 3.6 mW output power which is able to support 145 light-emitting diodes. Thus, it can be used for the small scale lighting system in the train tunnel [138].

5. Environmental Impact of The Kinetic Energy Harvesting System

Generally, clean sustainable renewable energy sources can reduce fossil fuel use. Their applications preserve the natural resource, reduce carbon emissions, climate change, and pollution. Since they are renewable and sustainable, continuous and inexhaustible, they lower the long-term cost compared to conventional energy sources. Other than the general environmental impacts, each of the energy sources has their own impacts on the environment, which were discussed as follows.

5.1 Wave

Wave energy harvesting system has less social impact disruption compared to other kinetic energy harvesting system because it mostly submerges at the surface layer of ocean and shore, which has less human populations and activities held on compared to the facilities on land. Its operation also has a less environmental impact since no risky chemical or additives needed [50]. Importantly, on-site wave energy harvesting reduce the fuel and oil transport to the area near to the sea, preventing water pollution [60]. Despite, wave energy harvesting system facilities may affect the habitat and balance of the ocean ecosystem, but not in a significant level [50]. The harvesting of wave energy causes the decreasing of natural wave energy, leading to the disruption of longshore sediment transport. Consequently, uneven deposition and erosion will happen [139].

5.2 Hydro

Similar to wave, hydro energy harvesting has less visual aesthetic impact since most of the mechanical components are located underwater. Moreover, the dam storage provides a secure water supply. Most of the hydropower plant also offer an aesthetic value to be a leisure area. In contrast, hydro energy harvesting may affect water body ecosystem, especially that of rivers. The risk of water pollution is caused by the installation, maintenance and dismantle of the facilities. Large scale hydropower plant has impacts on freshwater animals by changing their habitat, blocking migration and create turbulence [140]. It also affects natural water flow thus affecting sediments transport.

5.3 Wind

Wind energy harvesting facilities have less land space occupancy. Positively, wind energy enables the reduction of water use by complementing the other renewable and non-renewable energy which require a large amount of water such as geothermal, nuclear and fossil fuel [141]. On the contrary, new roads are needed to access the new wind turbine, leading to the grassland clearance. The transportation and installation of the wind turbine on offshore, which is the best spot to harvest wind energy, may cause water pollution and is of high cost [142]. Since it is an open structure, a tall wind turbine poses risk to the flying wildlife to be killed by the rotating components. Its height also brings to its aesthetic impacts, especially the large scale wind turbine. During its operation, the noise and vibration lead to the public nuisance. Moreover, there is a risk of land pollution and water pollution due to the leakage of lubricating fluids or fire of the wind turbine onshore and offshore respectively. In addition, the wind farm may affect the natural weather of its surrounding area due to the induced turbulence, which increases the vertical mixing of heat and water vapour [143,144].

5.4 Steam

The steam (thermal) plant is a closed structure, so it can avoid animals from entering and being killed. It also can provide direct heating of water or air for domestic use, reducing the energy loss during transportation [119]. Even so, the steam (thermal) plant produces heat, contributing to global warming. Likewise, it requires abundant water supply for cooling, depleting water resource and increasing the temperature of the water body where the coolant water is expelled. Moreover, its carbon emissions are higher than wind, wave and hydro energy.

6. Current Energy Policies in Light of Carbon Emission Reduction

Along with the rising high energy demand and environmental impacts of the fossil fuels use, various policies on the promotion of renewable energy were established and being developed. Since the 1970s, the renewable energy targets were implemented via various renewable energy action plans, government announcements, and renewable portfolio standards, at different levels [145]. Some examples of international and national policies from different countries, which cover the general renewable energy or focus on the specific type of renewable energy, were discussed in this section.

6.1 International

The most established international agreement on climate change is Paris agreement that was established in 2015, in order to limit the global temperature rise within 1.5 °C. This international effort in fighting the carbon emissions was supported by many countries, which can be indicated by the 197 signatories. This agreement provides flexibility to the signatories in their effort of cutting their carbon emissions via National Determined Contributions (NDCs). Despite, these signatories need to show their commitments such as a regular report on emissions and efforts [146]. Each of the signatories implements their own NDC-based renewable energy efforts in accordance with this agreement, with many of them lagging behind the rapid actual development of the renewable energy [147]. However, Paris agreement still in active and receiving new members along with its implementation. Positively, with the NDCs implementation by its signatories, a minimum increment of 1.3 TW of global renewable power capacity can be achieved by 2030. This means that it can achieve up to 76 % and 90 % increment by 2030 and 2050 relative to 2014 [148].

6.2 National

In 2018, China's National Energy Administration proposed a draft of national policy entitled Renewable Portfolio Standard and Assessment Method [149]. Moreover, the 13th Renewable Energy Development Five Year Plan 2016 to 2020 was introduced to achieve the non-fossil energy of 15 % and 20 % by 2020 and 2030 respectively [150].

Portugal's Industrial Strategy for Ocean Renewable Energy (EI-ERO) was introduced by the Ministry of sea in Portugal in 2017. This policy aims to trigger the export and value-added investment, as well as facilitate the ocean energy industry risk reduction. This action was focused on the financial and facilities for research and development (R&D) to attract more investment in it [151]. Another national effort by Portugal is the blue fund established by the Sea Policy General Directorate and managed by the Ministry of the sea in 2017. This fund aims to financially support the R&D projects of wave energy systems and/or components [151].

Since hydropower is a conventional renewable energy source, early before the Paris Agreement 2015, Government of India Policy on Hydro Power Development 2008 was introduced in India to fasten the hydropower development [152]. It works based on several objectives as followings

i. Targeted capacity addition of up to 9815MW via hydropower generation during 9th Plant
ii. Swiftly explore hydroelectric potential
iii. Encourage small and mini hydel projects
iv. Strengthen the role of power supply unit and state electric board in new hydel projects
v. Increase private investment
vi. Policy instruments to promote hydropower generation, such as funding, R&D, capacity addition, survey and investigation, inter-state projects, small hydrel projects and so on.

By the same token, thermal power generation development policy 2008 was established by government of Uttar Pradesh. It aims to promote the private investments, define the power-sharing agreement between State Distribution Utilities and private power developer in order to enhance power availability in the state via incentive for investment, as well as aiding in hydro project development [153]. Similarly, national wind-solar hybrid policy was adopted since 2018 in accordance with the Paris agreement. This policy aims to promote the large grid-connected wind-solar PV hybrid system for more efficient and effective energy generation, transmission and grid stability [154-155].

In Australia, Renewable Energy Target (RET) was implemented at national level in 2011. It set a target of 23.5 % renewable energy supply in 2020 [156].

6.3 Recommendations on Global Energy Policy

There are some recommendations based on the current global situations, policies and the challenges discussed. Firstly, the policies and legislation must be coordinated vertically among all levels (local, national, international) and horizontally within each of the levels. Furthermore, the policies should also be coordinated with cross-disciplinary manner. For example, policies on building and construction should incorporate the requirement to use renewable kinetic energy in the manufacturing and end-use stages of the buildings and infrastructures. Financial is one of the most crucial factors to be innovated. The financial schemes should be reviewed regularly by different fields professionals including environmental, economic, and social. This can ensure the appropriateness of fund allocation and fund sources. The financial source can be expanded unlimitedly from the local to the global level, for example, local government should provide low-interest loans for the residents or small business owners to invest in renewable energy applications. This not only can encourage the use of renewable kinetic energy but the local government also earn some income via the interest payment. Resources and capacity building of facilities and infrastructure, as well as human involved, must be adequate. Power plant employees must be well knowledged for the most efficient and effective renewable kinetic energy harvesting. Moreover, all companies' employees and staffs should be provided with basic environmental knowledge training to enable them to incorporate this knowledge into their works innovatively. For example, the new suitable kinetic energy source may be realized by anyone during their routine work. Last but not least, research and development for innovation of current technology should be given priority to overcome current challenges. For example, wave energy faces the transport problem of generated electrical energy, so study on the efficient and effective transport of electrical energy, or even some better uses of this electrical energy on-site. More funding and experts should be allocated to the research university in the renewable energy field to nurture future researchers.

7. Carbon Emissions Performance (Production and Reduction) of the Kinetic Energy Harvesting Systems

Generally, all types of clean renewable energy are able to mitigate or reduce carbon emissions since they replace some of the non-renewable energy generation [157]. Despite, each of them has significantly different amount of net carbon emissions reduction, taking into accounts its total carbon emissions throughout their life cycle, from the extraction, transport, processing, construction, operation, maintenance until decommissioning [17]. However, the net carbon emissions reduction was significantly affected by the approaches of life cycle analysis and some affecting factors, namely their installation and deployment rate, the efficiency of technology and manufacturing process, as well as the main energy the site, state, or country relies on. For example, Great Britain recorded the most carbon emissions reduction since it replaces most of the fossil fuels, which are its main energy generation source. Conversely, in Denmark, the energy generation using fossil fuels is not of the big portion. Hydropower imports from Sweeden subsidize the energy demand too. Thus, renewable and clean energy use do not contribute more to the reduction of fossil fuels, instead, to the import hydropower [158]. In this study, the total carbon emissions throughout the life cycle were chose to be focused instead of the total net carbon reduction. This is because total life cycle carbon emissions are the root factor that indicates its carbon emissions efficiency. The total net carbon reduction experience inconsistency caused by the affecting factors mentioned above. Table 6 to 10 shows the total life cycle carbon emissions of each kinetic energy source (harvesting technology).

7.1 Total Life Cycle Carbon Emissions Reduction of Kinetic Energy Harvesting from The Natural Source

All the clean sustainable kinetic energy sources indirectly contribute to the carbon emissions reduction by complementing the fossil fuels for the energy supply as mentioned above. Surprisingly, some studies lead to direct carbon emissions reduction while harvesting the kinetic energy from a specific source. For example, a study proposed the use of wave energy to power carbon sequestration. The wave energy was used to generate high gas pressure in order to condense out atmospheric carbon dioxide (CO_2) that is the densest molecules of atmospheric air, for further sequestration or industrial use. Simultaneously, it also can generate electricity using this high-pressure gas to drive a turbine system, achieving indirect carbon emission reduction as mentioned above [159].

7.2 Total Life Cycle Carbon Emissions Production of Kinetic Energy Harvesting from The Natural Source

Based on the published results of the past studies, the carbon emissions per kWh (gCO^2eq/kWh) is increasing from steam energy (derived from nuclear) technology, wind energy technology, hydro energy technology, to wave and tidal energy technology [17]. These results in terms of the value range and sequential order can be different for different sites and regions, depending on the other factors as mentioned above.

Table 6
Total life cycle carbon emissions of each kinetic energy source

Kinetic energy source		Total life cycle carbon emissions (gCO_2eq/kWh)	Phase/ stage with the highest carbon emissions	Reference
Wave and tidal		25 – 50	Materials manufacturing (steels)	[17]
Hydro	Storage (dam) type	10 – 30	Manufacturing (steels, concrete)	
	Run-of-river type	< 5		
Wind	Onshore	4.64	Manufacturing (steels, concrete, epoxy)	
	Offshore	5.52		
Nuclear (steam)		5	Manufacturing (Uranium extraction), decommissioning	

On the other hand, another past study reported that the carbon emissions per kWh is increasing from hydroelectric technology, wind, to steam energy (nuclear) technology [15].

Table 7
Total life cycle carbon emissions of each kinetic energy source

Kinetic energy source	Total life cycle carbon emissions (gCO_2eq/kWh)	Phase/ stage with the highest carbon emissions	Reference
Nuclear (steam)	13 - 39	Manufacturing (Uranium extraction), decommissioning	[15]
Wind	10 - 36	Manufacturing (steels, concrete, epoxy), decommissioning	
Hydroelectric	5 - 29	Manufacturing (steels, concrete)	

Another study in Romania reported that the carbon emissions per kWh is increasing from steam energy (nuclear) technology, wind energy technology, hydro energy technology, to wave and tidal energy technology [18].

Table 8
Total life cycle carbon emissions of each kinetic energy source

Kinetic energy source	Total life cycle carbon emissions (gCO_2eq/kWh)	Phase/ stage with the highest carbon emissions	Reference
Hydroelectric	400	Manufacturing (steels, concrete)	[18]
Wind	70	Manufacturing (steels, concrete, epoxy), decommissioning	
Nuclear (steam)	30	Manufacturing (Uranium extraction), decommissioning	

In like manner, a study in US reported that the carbon emissions per kWh is increasing from wind energy technology, hydroelectric technology, to steam energy (nuclear) technology [20].

Table 9
Total life cycle carbon emissions of each kinetic energy source

Kinetic energy source	Total life cycle carbon emissions (gCO_2eq/kWh)	Phase/ stage with the highest carbon emissions	Reference
Hydroelectric	45.36 -- 226.80	Manufacturing (steels, concrete)	[20]
Nuclear (steam)	45.36 -- 90.72	Manufacturing (Uranium extraction), decommissioning	
Wind	9.07 -- 18.14	Manufacturing (steels, concrete, epoxy), decommissioning	

A study on the global warming potential of different selected electricity sources reported that the carbon emissions per kWh is increasing from wind energy technology, steam energy (nuclear) technology, to hydroelectric technology [19].

Table 10
Total life cycle carbon emissions of each kinetic energy source

Kinetic energy source	Total life cycle carbon emissions (gCO_2eq/kWh)	Phase/ stage with the highest carbon emissions	Reference
Geothermal (steam)	38	Manufacturing (steels, concrete), earth heat extracting	[19]
Hydroelectric	24	Manufacturing (steels, concrete)	
Wind offshore	12	Manufacturing (steels, concrete, epoxy), decommissioning	
Nuclear (steam)	12	Manufacturing (Uranium extraction), decommissioning	
Wind onshore	11	Manufacturing (steels, concrete, epoxy), decommissioning	

Based on the literature reviews, the total life cycle carbon emissions of hydropower and wave energy is relatively high due to its large scale metal and concrete structure. This is because these two kinetic energy harvesting technologies need a higher structural strength. Another fact is that both wind and hydro energy were observed to has very low direct carbon emissions during their operating phase. Yet, the total life cycle emissions of hydro energy can reach up to six times higher than that of wind energy, depending on the site, power plant type and factors mentioned above [18]. This is because wind energy harvesting has a lower structural strength requirement since it involves a lower force than that of the hydro energy and wave energy. Thus, the components of the wind energy harvesting system are smaller and have a cleaner manufacturing process. The same goes to the steam energy from nuclear, which has relatively lower total life cycle carbon emissions since this technology does not involve the huge force to harvest the kinetic energy. In fact, safety and stability are more important. Yet, the steam energy from geothermal has the highest carbon emissions among the kinetic energy harvesting from natural source discussed in this paper. This is because the transfer of heat from Earth's deeper part unintentionally transfer the greenhouse gas with it, for example, sulphur dioxide and silica emissions [119].

8. Conclusions

In conclusion, the kinetic energy harvesting should be studied extensively and not limited to the large scale movement, but also include the medium and microscale movement. The magnitude, frequency, and consistency of the energy source are the main factors, but the limitations on these factors can be solved by the auxiliary system to magnify or continuously supply the stored energy to the kinetic energy harvesting device. Moreover, it should focus on the sustainable kinetic source (system) regardless it is natural or artificial. The efficiency and effectiveness of each kinetic energy source and its harvesting approach depend greatly on the environmental conditions of the site and other factors. Thus, appropriate renewable kinetic energy source and its harvesting approach should be evaluated wisely, considering the environmental conditions, current policies, current main energy generation approaches, as well as the affordability. In light of the carbon emissions reduction efforts, the decision-making should also take into account its life cycle analysis results. To sum up, the renewable kinetic energy harvesting source and approach chose should perform well technically, environmentally and promote sustainability.

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References

[1] IEA. "World Energy Outlook 2017." *International Energy Agency: Paris, France*, 2017, 1–19.
[2] IEA. "Key World Energy Statistics 2018." 2018.
[3] IPCC. "Global Warming of 1.5 °C." Special report on global warming, 2018.
[4] Shami, Elie Al, Ran Zhang, and Xu Wang. "Point Absorber Wave Energy Harvesters: A Review of Recent Developments." *Energies* 12, no. 1 (2019).
[5] BP p.l.c. "BP Statistical Review of World Energy 2018." Vol. 67, 2018.
[6] IRENA. *Global Energy Transformation: A Roadmap to 2050 (2019 Edition)*. *International Renewable Energy Agency*. IRENA, 2019.
[7] U.S. EIA. "Forms of Energy." Energy Explained, Your Guide To Understanding Energy, 2019.
[8] Richard, Merritt. "Harvesting Energy from Natural Motion : Magnets , Cantilever Capture Wide Range of Frequencies." Phys.org 2003 - 2019, Science X network, 2009.
[9] Bizon, N., N. Mahdavi-Tabatabaei, F. Blaabjerg, and E. Kurt. *Energy Harvesting and Energy Efficiency: Technology, Methods, and Applications*, 2017.
[10] Khaligh, Alireza, Omer C. Onar, and Omer C. Onar. *Energy Harvesting*. CRC Press, 2017.
[11] Royal Academy of Engineering. "Wind Turbine Power Calculations." *RWE Npower Renewables*, 2008, 1–4.
[12] R Nave. "Rotational Kinetic Energy." *HyperPhysics*, 2018.
[13] Helios, Vocca, and Cottone Francesco. *Kinetic Energy Harvesting*. *ICT - Energy - Concepts Towards Zero - Power Information and Communication Technology*. Vol. 12. IntechOpen, 2017.
[14] Beeby, S.P., R.N. Torah, and M.J. Tudor. "Kinetic Energy Harvesting." *Acta Futura* 4 (2008): 44–51.
[15] World Nuclear Association. "Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources." *WNNA Report*, 2011.
[16] Owusu, Phebe Asantewaa, and Samuel Asumadu-Sarkodie. "A Review of Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation." *Cogent Engineering* 3, no. 1 (2016): 1–14.
[17] Parliamentary Office of Science and Technology. "Carbon Footprint of Electricity Generation." *Postnote*. London, 2006.
[18] Ciupageanu, Dana-alexandra, and Gheorghe Lazaroiu. "Carbon Dioxide Emissions Reduction by Renewable Energy Employment in Romania." In *2017 International Conference on Electromechanical and Power Systems (SIELMEN) Carbon*, pp. 281–85, 2017.
[19] Wikipedia. "Life-Cycle Greenhouse-Gas Emissions of Energy Sources." *Wikipedia*, 2017.
[20] UCS. "Benefits of Renewable Energy Use." Cambridge: Union of Concerned Scientists (UCS), 2019.
[21] Kiziroglou, M. E., and E. M. Yeatman. "Materials and techniques for energy harvesting." In *Functional Materials for Sustainable Energy Applications*, pp. 541-572. Woodhead Publishing, 2012.
[22] U.S Energy Information Administration. "How Electricity Is Generated." Energy Explained, Your Guide To Understanding Energy, 2018.
[23] Patana. "Topic 12 : Electromagnetic Induction." anrophysics, 2007.
[24] Galili, Igal, Dov Kaplan, and Yaron Lehavi. "Teaching Faraday's law of electromagnetic induction in an introductory physics course." *American journal of physics* 74, no. 4 (2006): 337-343.

[25] Wang, Hao, Abbas Jasim, and Xiaodan Chen. "Energy harvesting technologies in roadway and bridge for different applications–A comprehensive review." *Applied energy* 212 (2018): 1083-1094.
[26] Mateu, Loreto, and Francesc Moll. "Review of Energy Harvesting Techniques and Applications for Microelectronics." In *Proceedings of the SPIE Microtechnologies for the New Millenium, 2005*, 359–73. Society of Photo-Optical Instrumentation Engineers, 2005.
[27] Philippe, Basset, Blokhina Elena, and Galayko Dimitri. *Electrostatic Kinetic Energy Harvesting*. *Nanoscience and Nanotechnology Series*. 3rd ed. Vol. 91. ISTE Ltd and John Wiley & Sons, Inc, 2016.
[28] Genta, G. (Giancarlo). *Kinetic Energy Storage: Theory and Practice of Advanced Flywheel Systems*. 1st ed. Butterworth-Heinemann, 1985.
[29] Cabral, Lisa, and Energy Information Administration. "Energy Storage: A U.S. Overview." In *EIA Energy Conference*. Washington, DC: Energy Information Administration, 2018.
[30] Mohamad, Ahmad Tajuddin, Nor Azwadi, Che Sidik, and Mohammed Raad Abdulwahab. "The Significant Effect of Graphene on Inorganic Salt Hydrated Phase Change Material Thermal Physical Enhancement." *Journal of Advanced Research Design* 59, no. 1 (2019): 1–10.
[31] Tucker, M. J. (Malcolm John), and E. G. Pitt. *Waves in Ocean Engineering*. Elsevier, 2001.
[32] Gobato, Ricardo, Gobato Alekssander, and Francine Gobato Fedrigo Desire. "Study Pelamis System to Capture Energy of Ocean Wave." *Atmospheric and Oceanic Physics*, no. 8 (2015).
[33] Multon, Bernard. *Marine Renewable Energy Handbook*. ISTE, 2012.
[34] V. Volshanik, V. "Principles of Wind Wave Energy Extraction." *Renewable Energy Sources Charged with Energy from the Sun and Originated from Earth-Moon Interaction* II (2008).
[35] Evans, D. V., and R. Porter. "Hydrodynamic characteristics of an oscillating water column device." *Applied Ocean Research* 17, no. 3 (1995): 155-164.
[36] Evans, D. V. "The Oscillating Water Column Wave-Energy Device." *IMA Journal of Applied Mathematics* 22, no. 4 (1978): 423–33.
[37] Zhang, Dahai, Wei Li, and Yonggang Lin. "Wave Energy in China: Current Status and Perspectives." *Renewable Energy* 34, no. 10 (2009): 2089–92.
[38] Whittaker, Trevor, and Matt Folley. "Nearshore Oscillating Wave Surge Converters and the Development of Oyster." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 370, no. 1959 (2012): 345–64.
[39] ENERGY, EB FROND WAVE. "CONVERTER–PHASE 2."
[40] Ocean Power Technologies Inc. "Powerbuoy® Technology." Products of Ocean Power Technologies Inc, 2018.
[41] Budal, K., and J. Falnes. "Wave Power Conversion by Point Absorbers: A Norwegian Project." *International Journal of Ambient Energy* 3, no. 2 (1982): 59–67.
[42] Falcão, António F.de O. "Wave Energy Utilization: A Review of the Technologies." *Renewable and Sustainable Energy Reviews* 14, no. 3 (2010): 899–918.
[43] Tom, N, Y H Yu, M Lawson, and A D Wright. "Pseudospectral Control of a Novel Oscillating Surge Wave Energy Converter in Regular Waves, Part I: Power Optimization Including Load Shedding." *Ocean Engineering* 137, (2017): 352–366.
[44] Muetze, Annette, and J. G. Vining. "Ocean wave energy conversion-a survey." In *Conference record of the 2006 IEEE industry applications conference forty-first IAS annual meeting*, vol. 3, pp. 1410-1417. IEEE, 2006.
[45] Shalby, Mohammad, David G. Dorrell, and Paul Walker. "Multi-Chamber Oscillating Water Column Wave Energy Converters and Air Turbines: A Review." *International Journal of Energy Research* 43, no. 2 (2019): 681–696.
[46] Joao, Cruz. *Ocean Wave Energy -- Current Status and Future Perspectives*. Edited by Cruz Joao. *Green Energy and Technology*. Springer-Verlag Berlin Heidelberg, 2008.
[47] Kim, Jeong Man, Min Mo Koo, Jae Hoon Jeong, Keyyong Hong, Il Hyoung Cho, and Jang Young Choi. "Design and Analysis of Tubular Permanent Magnet Linear Generator for Small-Scale Wave Energy Converter." *AIP Advances* 7, no. 5 (2017): 056630.
[48] Younesian, Davood, and Mohammad Reza Alam. "Multi-Stable Mechanisms for High-Efficiency and Broadband Ocean Wave Energy Harvesting." *Applied Energy* 197 (2017): 292–302.
[49] Jiang, Tao, Yanyan Yao, Liang Xu, Limin Zhang, Tianxiao Xiao, and Zhong Lin. "Spring-Assisted Triboelectric Nanogenerator for e Ffi Ciently Harvesting Water Wave Energy." *Nano Energy* 31(2017): 560–67.
[50] Asid Zullah, Mohammed, Lee Jae Ung, and Young Ho Lee. "Easing Climate Change with Recent Wave Energy Technologies." *Journal of Fundamentals of Renewable Energy and Applications* 06, no. 06 (2016).
[51] Xie, X.D. D., and Q. Wang. "A Study on an Ocean Wave Energy Harvester Made of a Composite Piezoelectric Buoy Structure." *Composite Structures* 178 (2017): 447–454.
[52] Nan, Wu, Wang Quan, and Xie XiangDong. "Ocean Wave Energy Harvesting with a Piezoelectric Coupled Buoy Structure." *Applied Ocean Research* 50 (2015): 110–118.

[53] Xie, X D, Q Wang, and N Wu. "Energy Harvesting from Transverse Ocean Waves by a Piezoelectric Plate." *International Journal of Engineering Science* 81 (2014): 41–48.
[54] Xi, Yi, Jie Wang, Yunlong Zi, Xiaogan Li, Changbao Han, Xia Cao, Chenguo Hu, and Zhonglin Wang. "High efficient harvesting of underwater ultrasonic wave energy by triboelectric nanogenerator." *Nano Energy* 38 (2017): 101-108.
[55] Hemer, Mark A., Richard Manasseh, Kathleen L. McInnes, Irene Penesis, and Tracey Pitman. "Perspectives on a Way Forward for Ocean Renewable Energy in Australia." *Renewable Energy* 127 (2018): 733–45.
[56] Wikipedia. "Largest Wave Power Stations." Wave Energy, 2019.
[57] Nasir, Nor Asmida Mohd, and Khairul Nizam Abdul Maulud. "Wave power potential in Malaysian territorial waters." In *IOP Conference Series: Earth and Environmental Science*, vol. 37, no. 1, p. 012018. IOP Publishing, 2016.
[58] AW Energy Oy. "How Wave Energy Can Help Reduce Carbon Emissions Aroud the World." Reducing carbon emissions with wave energy infographic, 2018.
[59] Smith, Helen C.M., Charles Pearce, and Dean L. Millar. "Further Analysis of Change in Nearshore Wave Climate Due to an Offshore Wave Farm: An Enhanced Case Study for the Wave Hub Site." *Renewable Energy* 40, no. 1 (2012): 51–64.
[60] Lavidas, George, Vengatesan Venugopal, and Daniel Friedrich. "Investigating the opportunities for wave energy in the Aegean Sea." In *Proceedings of the 7th International Science Conference Energy Climate Change, Athens, Greece*, pp. 8-10. 2014.
[61] Aderinto, Tunde, and Hua Li. "Ocean Wave Energy Converters: Status and Challenges." *Energies* 11, no. 5 (2018): 1–26.
[62] Thrust, Carbon. "Accelerating Marine Energy: The Potential for Cost Reduction—Insights from the Carbon Trust Marine Energy Accelerator." *Carbon Thrust: London, UK* (2011).
[63] Alternative Energy Tutorials. "Environmental Impact of Wave Energy." Energy articles, 2019.
[64] Arena, Felice, Valentina Laface, Giovanni Malara, Alessandra Romolo, Antonino Viviano, Vincenzo Fiamma, Gianmaria Sannino, and Adriana Carillo. "Wave Climate Analysis for the Design of Wave Energy Harvesters in the Mediterranean Sea." *Renewable Energy* 77 (2015): 125–41.
[65] Zheng, Chong Wei, Lin Zhou, Ben Kai Jia, Jing Pan, and Xin Li. "Wave Characteristic Analysis and Wave Energy Resource Evaluation in the China Sea. " *Journal of Renewable and Sustainable Energy* 6, no. 4 (2014). 043101.
[66] Zakaria, Hidayatul Aini, and Chan Men Loon. "The Application of Piezoelectric Sensor as Energy Harvester from Small-scale Hydropower." In *E3S Web of Conferences*, vol. 65, p. 05024. EDP Sciences, 2018.
[67] USGS. "Hydroelectric Power: How It Works, USGS Water-Science School. " The USGS Water Science Schoo, 2018.
[68] US Department of the Interior Bureau of Reclamation. "Hydroelectric Power. " 2005.
[69] Lynch, Gerard J., Bridgewater, and NJ (US). Adaptive hydrokinetic energy harvesting system. US009006919B2, issued 2015.
[70] Fernandes, Antonio Carlos, and Ali Bakhshandeh Rostami. "Hydrokinetic energy harvesting by an innovative vertical axis current turbine." *Renewable Energy* 81 (2015): 694-706.
[71] Zhu, Hongjun, and Yue Gao. "Hydrokinetic Energy Harvesting from Flow-Induced Vibration of a Circular Cylinder with Two Symmetrical Fin-Shaped Strips." *Energy* 165 (2018): 1259–81.
[72] Kong, Haonan, Vesselina Roussinova, and Vesselin Stoilov. "Renewable Energy Harvesting from Water Flow." *International Journal of Environmental Studies* 76, no. 1 (2019): 84–101.
[73] Tang, Wei, Yu Han, Chang Bao Han, Cai Zhen Gao, Xia Cao, and Zhong Lin Wang. "Self-Powered Water Splitting Using Flowing Kinetic Energy." *Advanced Materials* 27, no. 2 (2015): 272–76.
[74] Kichonge, Baraka. "The Status and Future Prospects of Hydropower for Sustainable Water and Energy Development in Tanzania." *Journal of Renewable Energy* 2018 (2018): 1–12.
[75] International Hydropower Association. "Hydropower in Malaysia." Hydropower profiles, 2016.
[76] Renewable Energy World. "Renewables Revive Abandoned Mines." Renewable energy news, 2019.
[77] Australian Renewable Energy Agency (ARENA). "Hydropower and Pumped Hydro Energy Storage - Australian Renewable Energy Agency (ARENA)." Renewable energy, 2016.
[78] Harby, Atle, Anund Killingtveit, Eivind Solvang, and Magnus Korpas. "Opportunities and Challenges for Hydropower Development in the High North." 2018.
[79] Faizal, M., L. J. Fong, J. Chiam, and A. Amirah. "Energy, Economic and Environmental Impact of Hydropower in Malaysia." *International Journal of Advanced Scientific Research and Management* 2, no. 4 (2017): 33-42.
[80] Liu, Xinghong, and Xiaolin Chang. "Opportunities and Challenges of Hydropower as Sustainable Energy in China." *Asia-Pacific Power and Energy Engineering Conference, APPEEC*, 2011.
[81] Canadian Electricity Association. "Benefits of Hydropower." Water power technologies office, 2006.
[82] Alternative Energy Tutorials. "Hydrokinetic Energy." Energy articles, 2019.
[83] Kalmikov, Alex, and Katherine Dykes. "Wind Power Fundamentals." MIT Wind Energy Group, 2015.
[84] Department of standards malaysia. Malaysian Standard -Code of practice on wind loading for building structure, 1

§ (2013).
[85] Korobenko, Artem, Yuri Bazilevs, Kenji Takizawa, and Tayfun E. Tezduyar. "Recent advances in ALE-VMS and ST-VMS computational aerodynamic and FSI analysis of wind turbines." In *Frontiers in Computational Fluid-Structure Interaction and Flow Simulation*, pp. 253-336. Birkhäuser, Cham, 2018.
[86] Sahu, Abhishek, Sanjeev Gupta, Vinod Kumar Singh, Akash Kumar Bhoi, Amik Garg, and Karma Sonam Sherpa. "Design of permanent magnet synchronous generator for wind energy conversion system." In *Advances in Smart Grid and Renewable Energy*, pp. 23-32. Springer, Singapore, 2018.
[87] Tiwari, Ramji, N. Ramesh Babu, R. Arunkrishna, and P. Sanjeevikumar. "Comparison between pi controller and fuzzy logic-based control strategies for harmonic reduction in grid-integrated wind energy conversion system." In *Advances in Smart Grid and Renewable Energy*, pp. 297-306. Springer, Singapore, 2018.
[88] Novaes Menezes, Eduardo José, Alex Maurício Araújo, and Nadège Sophie Bouchonneau da Silva. "A Review on Wind Turbine Control and Its Associated Methods." *Journal of Cleaner Production* 174 (2018): 945–53.
[89] Brondsted, Povl., Rogier P. L. Nijssen, and Woodhead Publishing Online. *Advances in Wind Turbine Blade Design and Materials*. Woodhead Publishing, 2013.
[90] Cammarano, Alessandro, Chiara Petrioli, and Dora Spenza. "Pro-Energy: A Novel Energy Prediction Model for Solar and Wind Energy-Harvesting Wireless Sensor Networks." In *2012 IEEE 9th International Conference on Mobile Ad-Hoc and Sensor Systems (MASS 2012)*, pp 75–83. IEEE, 2012.
[91] Tan, Yen Kheng, and Sanjib Kumar Panda. "Optimized wind energy harvesting system using resistance emulator and active rectifier for wireless sensor nodes." *IEEE transactions on power electronics* 26, no. 1 (2010): 38-50.
[92] Wijnja, Jelle, Roland Schmehl, Roeland De Breuker, Kenneth Jensen, and Damon Vander Lind. "Aeroelastic analysis of a large airborne wind turbine." *Journal of Guidance, Control, and Dynamics* 41, no. 11 (2018): 2374-2385.
[93] Gupta, Yashank. "Magnus Based Airborne Wind Energy Systems." PhD diss., Univeersite Grenoble Alpes, 2018.
[94] Safaraz, Khan Mhd, Mansuri Mohd Madn, Khan As, and Haji Altamas. "High Altitude Wind Turbine," 2019.
[95] Saleem, Arslan, and Man-hoe Kim. "Aerodynamic Analysis of an Airborne Wind Turbine with Three Different Aerofoil-Based Buoyant Shells Using Steady RANS Simulations." *Energy Conversion and Management* 177, no. 9 (2018): 233–48.
[96] Micallef, Daniel, Tonio Sant, and Carlos Ferreira. "The influence of a cubic building on a roof mounted wind turbine." In *Journal of Physics: Conference Series*, vol. 753, no. 2, p. 022044. IOP Publishing, 2016.
[97] Hu, Gang, K. T. Tse, Minghai Wei, R. Naseer, A. Abdelkefi, and K. C. S. Kwok. "Experimental investigation on the efficiency of circular cylinder-based wind energy harvester with different rod-shaped attachments." *Applied energy* 226 (2018): 682-689.
[98] Wang, Xue, Shuhua Wang, Ya Yang, and Zhong Lin Wang. "Hybridized electromagnetic–triboelectric nanogenerator for scavenging air-flow energy to sustainably power temperature sensors." *ACS nano* 9, no. 4 (2015): 4553-4562.
[99] Perez, Matthias, Sebastien Boisseau, Matthias Geisler, Ghislain Despesse, and Jean Luc Reboud. "A triboelectric wind turbine for small-scale energy harvesting." In *Journal of Physics: Conference Series*, vol. 773, no. 1, p. 012118. IOP Publishing, 2016.
[100] Amit, P., and D. Rita. "Study and development of hybrid wind turbine for highway side application." *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering* 6, no. 9 (2017): 6763-6767.
[101] Quartey, Gideon, and Stephen Kwasi Adzimah. "Generation of Electrical Power by a Wind Turbine for Charging Moving Electric Cars." *Journal of Energy Technologies and Policy* 4, no. 3 (2014): 19–29.
[102] Kishore, Ravi Anant, Thibaud Coudron, and Shashank Priya. "Small-scale wind energy portable turbine (SWEPT)." *Journal of wind engineering and industrial aerodynamics* 116 (2013): 21-31.
[103] Dabiri, John O., Julia R. Greer, Jeffrey R. Koseff, Parviz Moin, and Jifeng Peng. "A new approach to wind energy: opportunities and challenges." In *AIP Conference Proceedings*, vol. 1652, no. 1, pp. 51-57. American Institute of Physics, 2015.
[104] Wind energy technologies office. "Advantages and Challenges of Wind Power." Energy basics, 2019.
[105] Mohammad, Ahmad Faiz, Sheikh Ahmad Zaki, Mohamed Sukri Mat Ali, Hagishima Aya, Azli Abdul Razak, Masataka Shirakashi, and Norio Arai. "Large eddy simulation of wind pressure distribution on heterogeneous buildings in idealised urban models." *Energy Procedia* 78 (2015): 3055-3060.
[106] Irwin, Peter, Roy Denoon, and David Scott. *Wind Tunnel Testing of High-Rise Buildings*. Routledge, 2013.
[107] EIA. "Geothermal Power Plants - Energy Explained, Your Guide To Understanding Energy." Renewable energy source, 2019.
[108] Renewable Energy World. "Geothermal Energy Technology." The power and energy series, 2019.
[109] Ramakrishna, Kolluru, Y. Dhanasekhar, and M. V. H. Satish Kumar. "Performance Analysis of a Heat Recovery Steam Generator." *International Journal of Engineering Research & Technology (IJERT)* 3, no. 12 (2014): 561–568.
[110] Wills, Matthew A. "Chapter 4 Efficiency of Energy Conversion." In *Energy Harvesting*, Vol. 19. Penn State College of Earth andd Mineral Science, 2001.

[111] TNEP. "Electricity – Innovative Technologies towards Sustainable Development." The Natural Edge Project (TNEP), 2008.
[112] Dandina N. Rao. Direct combustion steam generator, issued January 9, 2007.
[113] Peterseim, Juergen H., Amir Tadros, Udo Hellwig, and Stuart White. "Increasing the Efficiency of Parabolic Trough Plants Using Thermal Oil through External Superheating with Biomass." *Energy Conversion and Management* 77 (2014): 784–793.
[114] Coelho, Bruno, Armando Oliveira, Peter Schwarzbözl, and Adélio Mendes. "Biomass and Central Receiver System (CRS) Hybridization: Integration of Syngas/Biogas on the Atmospheric Air Volumetric CRS Heat Recovery Steam Generator Duct Burner." *Renewable Energy* 75 (2015): 665–674.
[115] Sun, Li, Qingsong Hua, Jiong Shen, Yali Xue, Donghai Li, and Kwang Y. Lee. "Multi-objective optimization for advanced superheater steam temperature control in a 300 MW power plant." *Applied energy* 208 (2017): 592-606.
[116] Peng, Guilong, Hongru Ding, Swellam Wafa Sharshir, Xiaojia Li, Hanchen Liu, Dengke Ma, Lirong Wu, et al. "Low-Cost High-Efficiency Solar Steam Generator by Combining Thin Film Evaporation and Heat Localization: Both Experimental and Theoretical Study." *Applied Thermal Engineering* 143 (2018): 1079–84.
[117] Schastlivtsev, A. I., and V. I. Borzenko. "Hydrogen-Oxygen Steam Generator Applications for Increasing the Efficiency, Maneuverability and Reliability of Power Production." *Journal of Physics: Conference Series* 891, no. 1 (2017): 012213.
[118] Rasul, Mohammad. "Feasibility of a Solar Thermal Power Plant in Pakistan." In *Thermal Power Advanced Application*, edited by Mohammad Rasul. Croatia: InTech, 2013.
[119] Meyers, Glenn. "Geothermal Energy : Advantages And Disadvantages." *Rewable Energy*. Planetsave, 2016.
[120] Lotfabadi, Pooya. "Analyzing Passive Solar Strategies in the Case of High-Rise Building." *Renewable and Sustainable Energy Reviews* 52 (2015): 1340–53.
[121] Vollrath, Donald. "Regenerative Elevator Drives: What, How and Why." *Elevator World* (2010): 95–99.
[122] Nobile, G., A. G. Sciacca, M. Cacciato, C. Cavallaro, A. Raciti, G. Scarcella, and G. Scelba. "Energy harvesting in roped elevators." In *2014 International Symposium on Power Electronics, Electrical Drives, Automation and Motion*, pp. 533-540. IEEE, 2014.
[123] Plangklang, Boonyang, Sittichai Kantawong, Sirichai Dangeam, and Yuttana Kumsuwan. "Elevator Energy Regenerative Unit (EERU) for Energy Saving in a Permanent Magnet Motor Elevator System." In *2014 17th International Conference on Electrical Machines and Systems (ICEMS)*, pp. 2120-2124. IEEE, 2014.
[124] Yang, Hauyong Huayong, Wei Sun, and Bing Xu. "New Investigation in Energy Regeneration of Hydraulic Elevators." *IEEE/ASME Transactions on Mechatronics* 12, no. 5 (2007): 519–26.
[125] Hongwei, Zhang, Wang Xinhuan, and Yu Fashan. "Research on the operation control for rope-less hoist system driven by Permanent Magnet Linear Synchronous Motor." In *Proceedings of the 31st Chinese control conference*, pp. 5619-5624. IEEE, 2012.
[126] Miley, By Jessica. "The World's First Ropeless Multi-Directional Elevator Will Be Installed in Berlin." Interesting Engineering, 2018.
[127] Christopher, A. Howells. "Piezoelectric Energy Harvesting." *Enery Conversion and Management* 50, no. 7 (2009): 1847–1850.
[128] Turkmen, Anil Can, and Cenk Celik. "Energy Harvesting with the Piezoelectric Material Integrated Shoe." *Energy* 150 (2018): 556–564.
[129] Elhalwagy, Adnan Mohamed, Mahmoud Yousef M. Ghoneem, and Mohamed Elhadidi. "Feasibility Study for Using Piezoelectric Energy Harvesting Floor in Buildings' Interior Spaces." *Energy Procedia* 115 (2017): 114–126.
[130] Xiaochen, Xu, Gao Dongwei, Yang Hailu, and He Ming. "Application of Piezoelectric Transducer in Energy Harvesting in Pavement." *International Journal of Pavement Research and Technology* 11 (2018): 389–395.
[131] Nor, Mohd, Fakhzan Mohd, Rasidi Rasani, Mohd Zaki Nuawi, Zamri Harun, and Yap Khang. "Analysis of Wake Region Behind Bluff Body for Piezoelectric Energy Harvester." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 2, no. 2 (2019): 249–263.
[132] Xiaoying, Yu, Heatherm Heights, Saratoga, and CA (US). Portable wind power apparatus for electric vehicles, issued 2006.
[133] Mikhali, Amir S., Barbara Santa, CA, and Kevin L. Cousineau. Variable speed distributed drive train wind turbine. US 7042110 B2, issued 2006..
[134] Sindhuja, B. "A proposal for implementation of wind energy harvesting system in trains." In *Proceedings of the 2014 International Conference on Control, Instrumentation, Energy and Communication (CIEC)*, pp. 696-702. IEEE, 2014.
[135] Hegde, Shreyas S., Anand Thamban, Shah Palash Manish Bhai, Arham Ahmed, Meet Upadhyay, Ashish Joishy, and Arun Mahalingam. "Highway mounted horizontal axial flow turbines for wind energy harvesting from cruising vehicles." In *ASME 2016 International Mechanical Engineering Congress and Exposition*. American Society of Mechanical Engineers Digital Collection, 2016.

[136] Shaharuddin, Nur Haziqah, Mohamed Sukri Mat Ali, Shuhaimi Mansor, Sallehuddin Muhamad, Sheikh Ahmad Zaki Shaikh Salim, and Muhammad Usman. "Flow Simulations of Generic Vehicle Model SAE Type 4 and DrivAer Fastback Using OpenFOAM." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 37, no. 1 (2017): 18–31.
[137] Mao, Yanchao, Dalong Geng, Erjun Liang, and Xudong Wang. "Single-electrode triboelectric nanogenerator for scavenging friction energy from rolling tires." *Nano Energy* 15 (2015): 227-234.
[138] Bian, Yaoxing, Tao Jiang, Tianxiao Xiao, Wenping Gong, Xia Cao, Zhaona Wang, and Zhong Lin Wang. "Triboelectric Nanogenerator Tree for Harvesting Wind Energy and Illuminating in Subway Tunnel." *Advanced Materials Technologies* 3, no. 3 (2018): 1–7.
[139] Rajagopalan, Krishnakumar, and Gérard C. Nihous. "Estimates of global Ocean Thermal Energy Conversion (OTEC) resources using an ocean general circulation model." *Renewable Energy* 50 (2013): 532-540.
[140] Union of Concerned Scientists. "How Hydroelectric Energy Works." Hydropower, 2019.
[141] Saidur, R., N.A. Rahim, M.R. Islam, and K.H. Solangi. "Environmental Impact of Wind Energy." *Renewable and Sustainable Energy Reviews* 15, no. 5 (2011): 2423–2430.
[142] Lloyd, Dallas. "Wind Energy: Advantages and Disadvantages." 2014.
[143] U.S. EIA. "Wind Energy and the Environment." Wind, 2019.
[144] Wang, Shifeng, and Sicong Wang. "Impacts of Wind Energy on Environment: A Review." *Renewable and Sustainable Energy Reviews* 49 (2015): 437–443.
[145] Heeter, Jenny S., Bethany K. Speer, and Mark B. Glick. *International Best Practices for Implementing and Designing Renewable Portfolio Standard (RPS) Policies*. No. NREL/TP-6A20-72798. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2019.
[146] UNFCCC. Paris Agreement, Adoption of the Paris Agreement § (2015). https://doi.org/FCCC/CP/2015/L.9/Rev.1.
[147] IRENA. "Renewable Energy in National Climate Action." International Renwable Energy Agency (IRENA), 2017.
[148] IRENA. "Global Energy Transformation: A Roadmap to 2050." Abu Dhabi, 2018. www.irena.org/publications.
[149] NEA (National Energy Administration). "National Energy Administration Comprehensive Division on the Solicitation of Renewable Energy Power Quotas and Comments on the Assessment Method: Draft for Comments." National Energy Administration, 2018.
[150] IEA. "China 13th Renewable Energy Development Five Year Plan (2016-2020)." IEA/IRENA Joint Policies and Measures Database, 2018.
[151] Ocean energy system (OES). "Supporting Policies for Ocean Energy." Portugal Country Reports, 2019.
[152] water for welfare secretariat IIT Roorkee. "Hydro Power Policies and Guidelines: Government of India Policy on Hydro Power Development." India, 2008
[153] Government of Uttar Pradesh. "Thermal Power Generation Development Policy 2008." Uttar Pradesh: Government of Uttar Pradesh, 2012.
[154] Ministry of New & Renewable Energy. "National Wind-Solar Hybrid Policy." 2018.
[155] Energy, Ministry of New & Renewable. "Amendment in National Wind-Solar Hybrid Policy." 2018.
[156] IEA. "Australia: Renewable Energy Target 2001." Policies and Measures, 2019.
[157] UN. "Renewable Energy Sources Cut Carbon Emissions, Efficiently Increase Electricity Output Worldwide, Delegates Say in Second Committee." *Meeting Coverage of 14th Meeting*. United Nations, 2018.
[158] Corradi, Olivier. "Do Renewables Always Reduce Carbon Emissions ?" Electricity map, 2018.
[159] J.Z. Dalgaard. "Method for Use of Wave Energy for Capture of Atmospheric Co2 Coupled with Electricity Production." *Journal of Industrial Pollution Control* 33, no. 1 (2017): 686–688.