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Harvesting Human Power as Eternal Renewable Alternative Energy Resource

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Abstract*: This study presents overall review about the green, sustainable, and alternative energy. After comparisons of all energy sources, it concludes that the best of all energy sources is the human power energy source because it is green, clean, sustainable, and renewable with no any negative impact environment, no limitation about the location and weather condition plus the low overall cost. A brief discussion about evolvements, new developments, future challenges, and possible solutions of the human powered machine, tools, and their applications are presented. To better utilize the human power as the eternal renewable alternative energy resource, it concludes that the integrated approaches are needed due to the complexity of challenges.*

Keywords—human power harvest; piezoelectricity, renewable, energy, biomechanical, green, alternative energy, sources, human powered vehicle, kinetic energy, pedaling power, smart fabrics, wearable

1. INTRODUCTION

Human power harvesting is a term used to describe the using of systems that utilizes the human body power as the primary source of energy to generate and store energy.

Green and renewable alternative energy is the mainstays of our future energy. The main green and renewable energy are the solar panel arrays and massive wind turbine systems that span great lengths, collecting energy from the sun and wind and generating megawatts of energy. We are in hope that these behemoths that we point to as bellwethers of a future where the world no longer depends on fossil fuels. However, these solar panel arrays and massive wind turbine systems have some limitations of the large initial capitals and huge land needed with weather condition constrains so that we cannot totally depend on these solar panels and wind turbine farms to support our daily life because the infrastructure for these solar panels and wind turbine systems are so expensive to build, maintain, operate, and dispose during their life-cycle.

On the other hand, human power is one of the most greenest, cleanest, cheapest, sustainable, renewable, and perpetual energy sources. Human power had been used in almost every activities and applications since150 years ago. The products that relied on human energy such as the bicycle, pedal-powered lathe, and sewing machine could be found in most households in every corner of the world before. However, while electrical and electro-mechanical motors have well-developed, human-powered products and their applications gradually diminished.

Today is the time to re-think how to better utilize the human power to protect our environment and save our limited none-renewable natural resource such as fossil fuels because human power is the future of the green and renewable energy and it needs to be appropriately recognized for its potential as an alternative solution to our growing energy needs. Indeed, as we search for more renewable energy sources, human power shouldn't be left behind or to be abandoned because human power could play important role to perform traditional certain tasks instead of using electricity exclusively for our daily life activities.

With help of the modem digital technology and researches, more efficient and cost effective advanced human power harvesting technology and products will save more electricity in our day to day life. Researching and developing high efficiency and easy to use human powered products, such as human powered high efficiency liner-motion driving products, could easily harness human power from our everyday behavior and activities, such as cycling, exercising, and walking.

Therefore, developing and using human-powered products as a countermeasure to our increasingly sedentary lifestyles could create a credible new perspective towards daily routine activities and exercise endeavor as an alternative energy generation source. In some respects, human-power can be seen as the cleanest and eternal renewable energy source available, with great potential for helping people stay healthy and have fun at the same time whenever and where one can.

2. Review Of Green And Sustainable Alternative Energy

2.1 Green, Sustainable, Renewable, Clean, and Alternative Energy

Alternative energy refers to energy sources other than fossil fuels (such as coal, petroleum, and diesel) and Alternative energy may imply to green, renewable, clean, and sustainable energy, and it might include wind, solar, tidal, nuclear, biomass, hydrogen gas, biofuels, geothermal power, hydroelectric, wave, solar thermal energy, and even space solar energy.

There are some degrees of disagreements and ambiguity of the energy classifications. For example, some industry leaders would classify solar energy as sustainable energy because it can never be used up. But others counter that although the sun's energy cannot be diminished, the production of solar panels creates significant negative environmental impacts. These people say that solar energy should not be considered sustainable because its creation is sourced unsustainably. By the same token, a massive huge wind turbine farms not only involve very high upfront capital investment and it has to occupy vast land and filled with ten thousands of wind turbine towers but also create immense negative visual and environment impacts, such as reducing local bird population, endangering local underground habitats, and causing noise disturbances, not to mention cost of millions to dispose abandoned wind turbine towers at their end of life-cycle.

Similarly, many scientists may consider nuclear energy as clean energy because it does not produce harmful pollutants, except that if something goes wrong with nuclear plants could potentially produce staggering amounts of hazardous radiation. Moreover, disposal of nuclear waste is a major concern of environment and national security.

There is also some confusion about how to classify hydropower. Because hydropower is using water to power machinery or make electricity and the water cycle is an endless constantly recharging system. Hydropower is often classified as renewable and sustainable energy because we cannot use up the earth's water supply. Conversely, some experts argue that hydropower presents too many social and environmental costs to be considered a sustainable and/or renewable resource. Dams can cause permanent destruction to local ecology, dramatic change in water flow, lead to drought and substantial deforestation and loss of biodiversity, disrupt local ecosystems as well as loss of livelihood for fishers and farmers.

With so many different types of energy appearing in the news and on the websites as if interchangeable, but in reality, they have distinct meanings. The following below are explanations about some of the differences between these terms with some examples.

Green energy refers to the energy that emits relatively small amounts of pollution in the form of greenhouse gases, radiation, or chemical contaminants. Though green energy can affect the environment, the impact is typically localized and occurs on a small scale. Normally, it should not threaten plant or animal species with habitat loss, population reduction, or extinction. In general, the green energy comes from natural sources such as sunlight, wind, rain, tides, plants, algae and geothermal heat. These energy resources are renewable, meaning they're naturally replenished. In contrast, fossil fuels are with a finite resource that take millions of years to develop and will continue to diminish eventually with use.

Sustainable energy is a form of energy without putting them in danger of getting expired or depleted and it can be used over and over again without causing any harm to the environment, Sustainable energy is available widely free of cost, and it can be renewed by itself automatically. In this way, it can remain a viable energy source across many generations to come. Renewable energy like wind, solar, geothermal, hydropower, and ocean energy are examples of sustainable energy as they are stable and available in plenty. Humans cannot deplete stores of solar energy or wind energy. The sun will keep producing light energy until it dies, and the rotation of our planet will keep generating wind for as long as the planet exists.

A renewable energy source means energy that is sustainable. The renewable energy is endless of energy and it can't run out, like the sun energy. In some general sense, renewable energy is theoretically exhaustible. However, in practice, it consumes such minimal amounts of resources that it will be viable as an energy source over the long term. For example, ethanol is a renewable energy source because it comes from sugarcane or corn, and we can grow more of those crops to replenish our stores. At their current level of usage, logs and wood chips could also be considered renewable energy because the tree regrowth can replace the wood burned for fuel. This situation could easily change, though increased deforestation and widespread wood burning could make wood fuel unsustainable in short term. The most popular renewable energy sources currently available in use are solar energy, wind energy, hydro energy, tidal energy, geothermal energy and biomass energy.

In general, clean energy is energy that it normally comes from renewable with zero or very low emission sources without polluting the atmosphere when it is used. Therefore, the clean energy is energy that emits negligible amounts of pollution in the form of carbon dioxide, radiation, or chemical contaminants. Zero-carbon energy sources are forms of clean energy. The minuscule emissions from clean energy should have minimal to no impact on the surrounding environment. Wind and solar energy are good examples of clean energy because their production emits no pollution into the environment. The energy that comes from burning fossil fuels, on the other hand, is not clean energy because it releases harmful contaminants into the air. Though wind turbines can cause problems for bats and birds, they still have minimal negative overall effects on the environment.

2.2 Comparison of Energy Sources

As discussions above, each of individual alternative energy has its own set of advantages and disadvantages, as well as impact variables that should be taken into account, such as limitations about location, weather condition, climate, upfront cost versus financial benefits, overall cost, and most importantly the reduction of damage done to the environment.

Green energy has a small negative impact on the earth's atmosphere and environment. If we use the green energy as one umbrella term to encompass all types of alternative energy we've described above. The differences between clean and green energy are differences of degree for cleanness. Clean energy takes the idea of green energy a step further with no negative impact on the earth's atmosphere and environment at all.

The difference between green and renewable energy involves the possibility of replenishment. Renewable energy comes from sources that the earth can naturally replenish, such as crops and biomass. Sustainable energy comes from sources that don't need to be replenished because they can never be depleted, such as sunlight and wind energy.

As you can see, renewable and sustainable energy are more or less subsets of clean energy. Wind and solar power are examples of sustainable energy because they cannot be depleted. But they are also examples of clean energy because they do not pollute the atmosphere or damage the environment.

Table 1: Energy Sources Comparison

Energy Sources	Green	Clean	Sustainable	Renewable	Negative impact environment	Weather/location limitations	Overall Cost
Fossil Fuel	×	×	×	×	Severe	Yes	High
Hydropower	✓	✓	✓	✓	Severe if happen	Yes	High
Nuclear Power	✓	✓	✓	✓	Severe if happen	Yes	High
Geothermal	✓	✓	✓	✓	Minimum	Yes	High
Biomass	✓	✓	✓	✓	Moderate	Yes	Moderate
Solar	✓	✓	✓	✓	Moderate	Yes	High
Wind	✓	✓	✓	✓	Moderate	Yes	High
Wave and tidal	✓	✓	✓	✓	Moderate	Yes	High
Human Power	✓	✓	✓	✓	No	No	Low

From the Table 1: Energy Sources Comparison, the hydropower and nuclear power energy sources are better than fossil fuel as the energy source. Among green, clean, sustainable, and renewable energy sources, the solar and wind energy provide more environment friendly option as alternative energy source. But, the best of all is the human power energy source because it is green, clean, sustainable, and renewable with no any negative impact environment, no limitation about the location and weather condition plus the low overall cost.

3. ALTERNATIVE ENERGY FUTURE: HUMAN POWERED MACHINE AND PRODUCTS

In history, humans well understand the ways in which they are a part of an energy cycle. Their bodies virtually function as energy converters but instead of converting solar energy into electric energy for instance, they are converting energy from food into kinetic energy. The kinetic energy can be harnessed; much like some hydropower technologies harness water movement. Ever since the arrival of fossil fuels and electricity, human powered tools and machines have been viewed as an obsolete technology. This makes it easy to forget that there has been a great deal of progress in their design, engineering and technological advancement, largely improving their productivity and efficiency.

Human kinetic energy can be transferred into many ways. The most commonly using of human energy is to propel bicycles and exercise, but human energy can also be used to generate electricity and power hand-crank or pedal tools, machine and products. Some developing countries are implementing human power energy to generate electricity to power computers and other appliances.

The most efficient mechanism to harvest human energy appeared in the late 19th century: stationary pedal powered machines and hand-powered tools went through a boom at the 20th century, but the arrival of cheap electricity and fossil fuels abruptly stopped all further development. Hand cranks, capstans and treadwheel with rotary motion have been the fundamental mechanism of most machines throughout human history. There have been several important innovations in applying human power to rotary motion, many of which already appeared in antiquity with improved mechanical advantage by which the mechanism multiplied the human input force into a higher output force. The following are good examples of human powered drilling tools.

Fig.1: Hand-Powered Bench Drill and Hand Drill [1]

The historical importance of pedal powered machines can be easily overlooked by people, who grew accustomed to fossil fuels, electricity, and modern technologies. The treadwheel had advantage over the hand crank because it replaced the use of the arm muscles by the use of the much stronger leg muscles, and same using leg power for riding a bicycle.

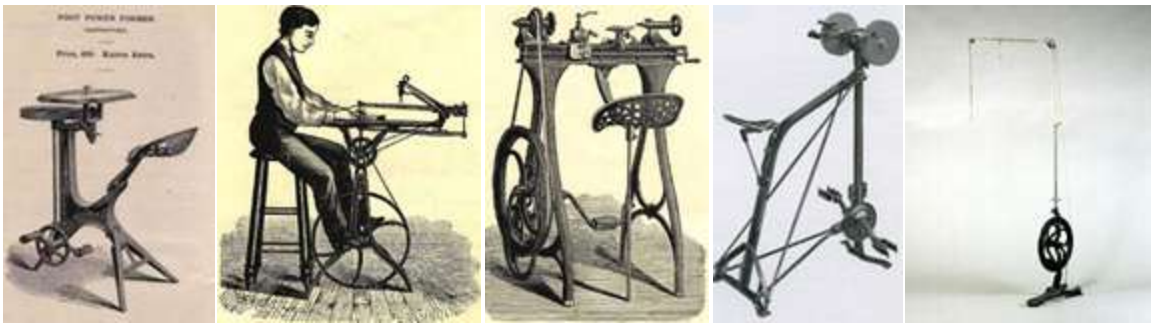

Fig. 2: From Left to Right: Pedal Powered Former, Saw, Lathe, Grinder, and Dentist Drill [2]

The Fig. 2 shows the human pedal powered former, saw, lathe, grinder and dentist drill, which we used to use in our daily life.

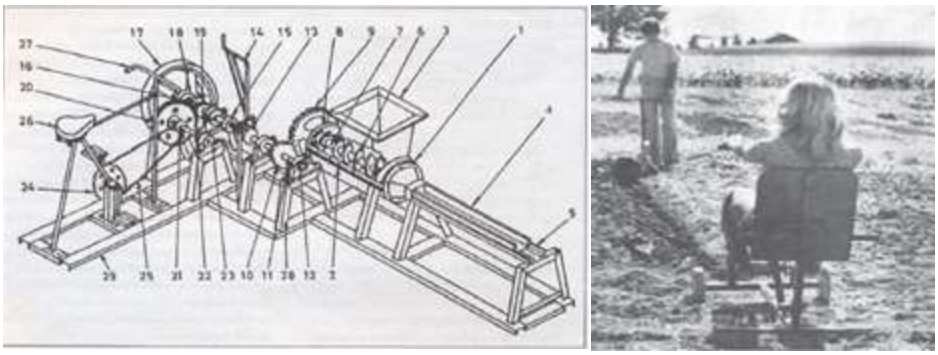

Fig. 3: Pedal Powered Brick Machine and Farm Tractor [3]

The Fig. 3 displays the human pedal powered brick machine and farm horse winch.

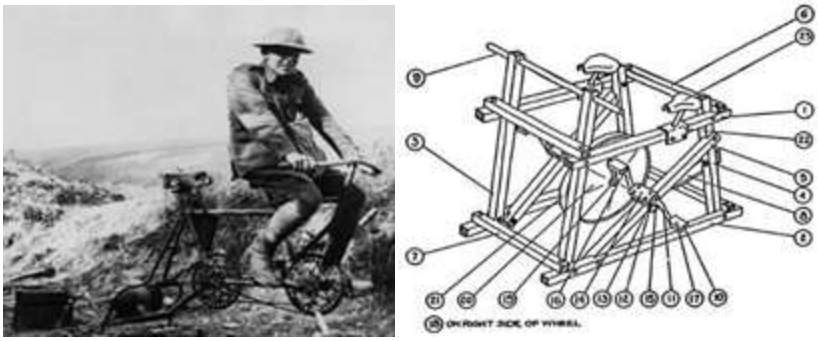

Fig. 4: Left: A Solder during WWI Powering a field Radio with a Bike Generator and Right: Dynapod [3]

The Fig. 4 demonstrates how the human pedal powered a multi-purpose Dynapod looks like. A Dynapod is a stationary pedal-powered device that can be attached to any kind of device or tool and used to generate power for a multitude of activities. Also, the Dynapod could drive pumps, corn grinders, winnowing machines, and forge blowers, grinding machines, drilling machines, potter's wheels, paint sprayers, crop dusting equipment, cassave graters, coffee pulpers, grain hullers, fiber decorticators, threshers, balers, band saws, tire pumps and sewing machines. It could also be used to generate electricity [3].

As shown from Fig. 1, 2, 3 and 4, pedals and cranks were attached to tools like lathe, saws, grinder, shaper, tool sharpener and to boring, drilling and cutting machines. These machines became very popular and were intended for small workshops and households without electricity or steam power. They were made with heavy cast-iron bodies that could be collapsed for shipping. Pedals and cranks tools were developed more sophisticated (made of steel instead of wood, for example, or using gears inspired by bicycles) and became increasingly popular for low or brief power applications. Steel treadles were applied to industrial machines like hat, broom, cigar and hook making machines, printing presses, punch machines and riveting machines. The farm saw the appearance of foot powered harvesters, treshers, milking machines and vegetable bundlers. The historical importance of pedal powered machines can be easily overlooked. Therefore, it cannot be stressed enough how much of an improvement pedal power was in the light of thousands of years of human drudgery. Pedals and cranks make good use of human power in a near-optimum way with endless applications in most of industrial machine, tools, and various products.

3.1 Endless Applications of Human Powered Machine and Products

Human kinetic energy can be transferred in a number of ways. One of use of human energy is most commonly used to propel bicycles. The bicycle has a history that goes back about 600 years and is quite different than the bike as we know today. Many major innovations have dramatically transformed the bicycle's form and features over the years leading up to the modern bicycle.

Human powered vehicle includes all vehicles that are powered only by human muscular-strength. The human powered vehicle can be divided into many categories. The largest category is the bicycle. Other categories comprise the human powered land vehicles such as recumbent bicycles, wheelchair, and velomobiles as shown at Fig. 5 below; human powered water vehicles such as sea cycle, canoe, rowing boat, pedal boat, and human powered submarines as shown at Fig. 6 below; human powered rail vehicles primarily used in the tourism industry as shown at Fig. 7 below; and human powered air vehicles as shown at Fig. 8 below. A real human powered vehicle can be powered by an electric engine, but the energy must come from a human powered generator. The overview does not claim to be exhaustive [4].

Fig. 5: Human Powered Land Vehicles [4]

Fig. 6: Human Powered Water Vehicles [4]

Fig. 7: Human Powered Rail Vehicles [4]

Fig. 8: Human Powered Air Vehicles [4]

There are two ways to better summarize the human power applications. First one is human powered vehicles for mobile applications and the second one is the human powered various machine, equipment, devices, and tools for stationary applications. The followings Fig. 9 and Fig 10 present this point view of classifications.

Fig. 9: Endless Human Powered Vehicle Mobile and Stationary Applications [5]

As shown at Fig. 9 above, the human powered vehicle mobile applications can include variety of human powered vehicles while it is on moving or as an exercising tool to power various electrical and electronic apparatus/devices or charge a battery and a solar panel to harness human energy wherever people go.

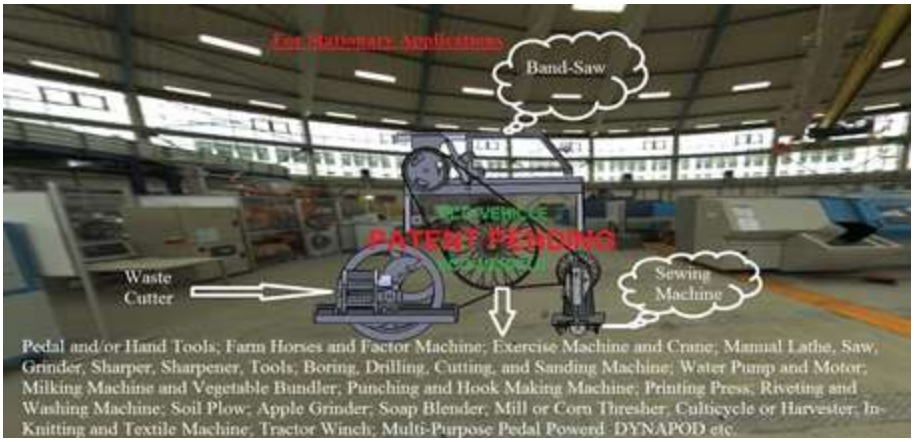

Fig. 10: Endless Human Powered Stationary Applications [5]

As shown at Fig. 10 above, the human powered stationary applications can embrace from powering a factory, generator, devices, tools, lathes, saw, grinder, sharper, tool sharpener, fan, mixer, agitator, water pumps and water motor, textile machinery, sewing machines, and wood saws, crane, lifting device, flywheel motor, home and kitchen appliances, meat grinder and cutter, juice extractor, and food/flour mixer, solar-electric hybrid tools, apparatuses, devices, and any hybrid machines, tools, apparatuses, and devices [5].

In additional to traditional human power applications as illustrated above, there are numbers of innovative ways to harness human power. According to research, adults of average physical fitness can produce between 50 and 150 watts of mechanical power pedaling a bicycle. Therefore, utilizing the exercise workout power electronics, appliances and other machines are cost effective and environmentally friendly way to reduce our dependence of fossil fueled electricity.

Fig. 11: Left to Right 1, 2- Pedal Powered Electricity Generator and 3, 4- Pedal to Power TV and Laptop [6]

At shown on Fig. 11, the first pedal powered generator photo on the left is from Windstream for emergencies, power failures, remote locations, and off-grid applications with typical average continuous about 80 watts power. The next photo is the Pedal-A-Watt Stationary Bicycle Generator by using a bicycle along to create from 100 to 300 watts. The next two photos show the two applications of using human power to power a TV and a laptop respectively [6].

Fig. 12: Left- Human Power Plant and Right- Prototype of a Human Power Plant [7]

As shown at the Fig. 12 above, the left-side photo demonstrates Utrecht University in the Netherlands is designing plans to convert a 22 floor vacant tower building on the campus into an entirely human powered student community for 750 people. The University is also in process to construct a working prototype of the human power plant that supplies the community with all energy needed. The right-side photo depicts the human power plant with a working prototype of a muscular power generator, manned by a group of people. It is an all-round off-the-grid solution, which can supply energy in the form of electricity, water under pressure, and compressed air to restores the connection between human power of physical exercise and energy needed to use on our daily life [7].

3.2 Review of New Developments of Human Powered Machine and Products

With help of new piezoelectric and biomechanical technologies, the following reviews provide some of the new developments on innovative ways to harvest human power and how these researches have played an important role to bring more sustainable energy solutions and new human powered machine and products into our life.

Most mobile phone users must never stray too far from a power supply or suffer from the anxiety of their cell phone or iPads battery draining. There is the Wind-up phone charger, called the “Reactor” is an iPhone case embedded with an ultra-thin generator that enables you to manually charge the battery by turning a handle plugged into the back of it. This method of energy generation is not a novel idea but the concept sheds light on how human-power can be a viable solution during emergencies and how effectively it is available on demand [8] as shown at the Fig.13 center photo below.

Fig. 13: Left- Human Energy Parasitic Harvesting, Center- Wind-up Phone Charger, Right- Gravity Light [8]

As shown at the Fig.13 photo on the left-side above, generating power from people's normal activities such as walking is known as parasitic harvesting. One example of this kind of human energy parasitic harvesting is the nPowerPEG, a handheld tube-shaped device that clips to your belt and backpack and generates electricity as you move around, using a magnet weight, spring, and inductive coil. This doesn't produce enough power for high wattage electronics such as laptops and tablet computers, but better energy efficiency and battery technologies mean the concept has great potential [?]

As shown at the Fig.13 right-side photo above, one of the challenges in designing a human-powered product is in reducing the amount of work it takes to generate power, such as by cranking or winding. The Gravity Light harnesses the power of gravity to resolve this issue. The device only requires a single burst of human power to lift up the sand bag weight. The weight then gradually descends to rotate a spur gear system that powers the LED light for 20 minutes [9].

Fig. 14: Left- Running for the Light, Center- Pedal Power Charging, Right- Powerful Footwear [9]

As shown at the Fig.14 left-side photo above, this motion-powered light is the dreams come true for runners, or anyone else interested in being active after dark. Battery-powered headlamps and body lights can flicker out without warning, leaving you visible after the sun goes down. The Million Mile Light is a small, clip-on LED lamp that draws power from a runner's movement, and emits a continuously flashing light bright enough to ensure that motorists will be able to spot a pedestrian over 200 yards away. The lamp promises a 100,000-hour lifespan, making it a long-term sustainable lighting option for all people [9].

As shown at the Fig.14 center photo above, this bike made from bamboo is green. Mexico-based consortium Bambootec created a clever bicycle that harvests pedal power and turns it into renewable energy. Small gadgets like smartphones and MP3 players can be recharged via a connected power adapter on the go. The bike also sports a navigation dashboard in the handlebars that measures distance and time [9].

As shown at the Fig.14 right-side photo above, the powerful footwear with simple action of walking could power your small electronic devices. University of Wisconsin-Madison researchers created a pair of insoles capable of generating 20 watts of energy from footsteps. The invention prompted the founding of InStep NanoPower, a startup working to produce shoes with the energy-generating insole built right in. Footwear that doubles as a power source would be a boon to busy urban dwellers, college students, long-distance backpackers and anyone else who puts in a lot of steps over the course of a given day [9].

Fig. 15: Left- Human Energy Harvesting Shopping Mall and Right Dancing to Power the LEDs [9]

A photo on the left-side as shown at the Fig.15 above illustrates a human energy harvesting shopping mall. A suburban shopping mall seems like an unlikely place for renewable energy generation, and yet it makes a lot of sense because there are so many people walking around there. Pavegen, a clean tech firm, installed 68 kinetic floor tiles in a Johannesburg mall last year to raise awareness about the problems rural villages face with unreliable power grids. The tiles power an interactive data screen that displays real-time footfall data while harvesting electricity to power struggling communities elsewhere in South Africa. The Sandton City shopping mall sees over two million footsteps each month, which translates into a substantial amount of energy and a major impact in the lives of people who simply want light, heat and other basic amenities [9].

A photo on the right-side as shown at the Fig.15 above indicates people are dancing to power the LEDs. It's not a far-fetched idea thanks to the Energy Floors' kinetic energy-generating dance floor. To demonstrate the technology, the company created a translucent floor with a dynamic LED display powered by motion from each shimmy and shake. Motion is transferred through the floor to a small generator, and each 30-inch square floor tile can produce up to 35 watts of sustained output [9].

Biomechanical energy harvesting from human motion presents a promising clean alternative to electrical power supplied by batteries for portable electronic devices and for computerized and motorized prosthetics [10]. There is some state of the arts of human energy-harvesting devices. Currently available center-of-mass devices use the motion of the center of mass relative to the ground during walking to generate energy. For example, when carrying a backpack, the body applies forces on the backpack or any other mass in order to change the direction of its motion. Rome and colleagues used these forces in a spring-loaded backpack that harnesses vertical oscillations to harvest energy [11]. A suspended-load backpack for generating energy is shown on the left-side photo at Fig. 16 below. The pack frame is fixed to the body, but the load is mounted on a load plate and is suspended by springs (red) from the frame (blue) (A). During walking, the load is free to ride up and down on bushings constrained to vertical rods (B). Electricity generation is accomplished by attaching a toothed rack to the load plate, which (when moving up and down during walking) meshes with a pinion gear mounted on a geared dc motor, functioning as a generator. The motor is rigidly attached to the backpack frame [12] [10].

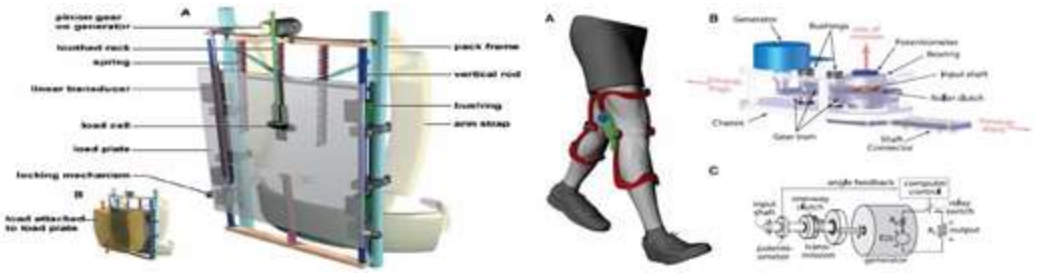

Fig. 16: Left- Suspended-Load Backpack for generating energy and Right- Biomechanical knee energy harvester [10]

A biomechanical knee energy harvester is shown on the right-side photo at Fig. 16 above. The device has an aluminum chassis and generator (blue) mounted on a customized orthopedic knee brace, totaling 1.6 kg; one such brace is worn on each leg. (B) The chassis contains a gear train that converts the low velocity and high torque of the knee motion into the high velocity and low torque required for the generator operation, with a one-way clutch that allows for selective engagement of the gear train only during knee extension and no engagement during knee flexion. (C) The schematic diagram shows how a computer-controlled feedback system determines when to generate power using knee-angle feedback, measured with a potentiometer mounted on the input shaft. Generated power is dissipated in resistors. *Rg*, generator internal resistance; $R_{L;}$ output load resistance; E (t), generated voltage [10].

Recently, there are many comprehensive human motion-based energy harvesting application and products for smart wearable electronics such as smart textiles, smart wrist wearables, smart footwear, smart skin, etc. The piezoelectric energy harvesting technology from human motion exhibits excellent potential for powering low powered electronics and wearable devices. However, All new developments mentioned above are still faced with many challenges and issues that need to overcome in the future.

4. Challenges and Solutions of Human Powered Harvesting Machine and Products

In general, the human power harvesting is still facing both technical and social challenges. The technical challenges are due to lack of scientific and technological research into human power effective and scale-up production. The social challenges are to motivate more and more people to harvest their energy anyway they can in their daily life while walking, running, exercising, dancing, and pedaling to produce and use the green, clean, renewable, and sustainable energy. To meet these challenges, we need to boost our scientific and technological research and encourage all people to harness the human power energy from their everyday activities.

The application scope of the human energy harvesting can extend to both powering of devices on or near the human body. Human power energy harvesting outside the body is tapping directly into the biological processes that turn fat into energy is beyond currently available technology. However, human energy might be harvested indirectly from everyday human actions or might be intentionally generated by a human. Indeed, products such as mechanical watches have been on the market for years. Recently, there has been a significant researched on human generated power which can find potential applications particularly in low power biomedical applications such as products for smart wearable electronics such as smart textiles, smart wrist wearables, smart footwear. The challenges are the related systems to be wearable and comfortable with sensors, signal conditioning electronics and wireless transmission technology to support additional features. Moreover, researchers acknowledge that one of the challenges they face is the relatively low voltage that their wearable device produces. It's in the millivolt range. Extracting usable energy from such low frequency human motion has proven to be extremely challenging [13].

The presence of ubiquitous electronics in wearable devices carried by the user is rapidly growing. However, one of the most important challenges is to ensure the human power supply beyond the constraints associated with batteries. A solution to this problem is the development of devices capable of harvesting energy from a user's body motion to allow unlimited operating and standby times because human kinetic or thermal energy can be easily transformed into electrical energy.

The considerable amounts of human energy released from the body in the forms of heat and motion open the way for the development of technologies that can harvest this energy for powering electronic devices. The main challenge in developing such a technology lies in constructing a device that will harvest as much energy as possible while interfering only minimally with the natural functions of the human body. Furthermore, such a device should ideally not increase the metabolic cost, i.e., the amount of energy required by a person to perform his/her activities.

Another challenge in designing a human-powered product is in reducing the amount of work it takes to generate power, such as by cranking or winding. Also human energy harvested may require considerable conditioning (storage, voltage/current or impedance conversion, etc.) before it can be used for an application. The conversion efficiency still remains a key challenge for scientists and technologies at present to resolve.

Human power can be recovered passively from body heat, breathing, blood pressure, arm motion, typing, running, and walking or actively through actions such as winding, exercising or pedaling. The riding a bicycle is a great way of using human power in a way that allows us to exercise, transport ourselves and save on the consumption of conventional energy at same time. The challenges are to produce better human powered vehicles and encourage more people to adopt using human power in their daily life. For example, if we can design and engineering the human powered vehicles such as bicycles to become efficient and more entertaining, the more people would encourage riding bicycles and becoming more physically active and healthier.

Therefore, the continuous advancing our scientific and applied technologies along with novel materials and fabrication techniques would offer boundless possibilities for the benefit of human health and well-being via various types of human energy harvesting machine and products.

5. CONCLUSION

There are a number of drivers that will influence the likely development and take up of human energy harvesting technology. These stem from environmental, economic, social, technical, funding, and stimulus policy factors and are all interrelated. Therefore, the integrated approaches are needed to better and fully utilize the human power as the eternal renewable alternative energy resource.

Highly effective miniaturization and developments in nanotechnology will play a significant role in wearable devices to make possible the good use of human power harvested energy sources that are not currently viable. Moreover, human power and battery management techniques combined with new fabrication and device technologies are steadily decreasing the energy needed for electronics to perform useful functions, providing an increasingly relevant niche for human energy harvesting in wearable systems

Flexible electronics, smart fabrics and interactive textiles may also drive the development of human energy harvesting technologies. These technology and textiles are able to sense stimuli from the environment and react or adapt to them in a predetermined way by mounting electronic devices on flexible plastic substrates along with power-generating rubber films. We can take advantage of natural body movements such as breathing and walking to generate electricity to power electronic devices.

The design of mechanical energy harvesters will be depending upon the location on the body. A research challenge is therefore to develop unobtrusive mechanical energy harvesters designed specifically for key locations such as the foot, lower leg, knee, chest and arm. Therefore, high efficiency flexible thermoelectric structures are needed that can provide useful levels of electrical power from temperature differentials in the range 1 to 10 degree of Celsius. To achieve all mentioned above, financial support researches into new materials with ultrahigh energy density and new biocompatible materials will also be needed on a similar timescale. Nano and micro-scale structures and composites will be researched for applicability to human energy harvesting. In the longer term, polymer materials with high dielectric constants will need to be examined for potential applications [13].

Due to such a wide multidisciplinary area with regarding to human power harvesting, there are some clear needs for new skills and the involvement and supports from various organisations and governments beyond the existing human energy harvesting community. Development of new technology, high efficiency human powered vehicles, and improved devices will still require the involvement of the mechanical and electrical engineers who have for so long driven advances in energy harvesting technology.

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