

Electric Mile

Intro:

The first section is an attempt to describe the layout and structure in terms with a minimum use of jargon and formulas. I apologize for my informal language and less than perfect examples.

There is a technical section for those with a background in this field. Feedback would always be welcome. Please send it to curieositytech@blackkomodoinvestments.com

Background

What is energy? The first law of thermodynamics states that energy cannot be created nor destroyed, only transferred from one form to another. There are many kinds of energies, from potential and kinetic, to electrical, mechanical, nuclear, etc. All of these are interchangeable from one form to another. Electricity or electrical energy is another form of energy, it is the flow of electrons or electric charge from one point to another creating a potential difference across a surface, called the voltage. The amount of charge moved over a period of time is the flow of current across a distance. Electricity is used in various activities, from heating water, lighting dark spaces to electric vehicles and allowing the use of technology. Electricity was first seen as a natural phenomena given off from electric eels and lightning strikes. In the mid 1700s, Benjamin Franklin was interested in the capabilities of electricity and how to harvest it from naturally occurring lightning strikes, which lead him to perform his famous kite flying experiment. Fast forward to the late 1800s, Thomas Alva Edison invented the light bulb, which used electricity from a source, passed through a piece of metal, which gave off light and heat, known as the light bulb. Since then, inventions to do with the uses of electricity have come a long way. We are now going back to our roots, laid out by Benjamin Franklin of trying to harvest electricity from natural phenomena around us. For example, the use of renewable energy such as solar, wind, tidal, hydrogen, etc. There is one that was overlooked and we actually waste most of this energy everyday. This energy is mechanical energy and chemical energy from our own bodies. When we eat food, it is converted from chemical energy stored in the food to chemical energy in our bodies, then we use this energy and convert it to mechanical energy as we walk and carry out our other daily activities. I would like to bring your attention to walking. A simple action performed by most at a very young age and we use this mode of transport as our primary mode of transport in our daily lives. What if I told you, you were wasting most of that energy? You would ask, how so? Well the way we walk is by using mechanical energy by lifting our feet off the ground, placing it down in front of us and pushing off the ground via the virtue of friction (rubbing our foot against the ground to move you forward). When one pushes off the ground to continue this motion, they are pushing into the ground and the ground is pushing onto them (Newton's third law of motion). This pushing mechanical energy is degraded (wasted) as heat due to friction. However, it can be converted into electrical energy.

As I would go around walking on the pavements for morning walks or just generally walking around as everyone does to get from place to place, I would look around and see lights and lamps lighting our way forward. I wondered, what if we could produce the electricity required to power these lamps in the day and use them at night? I was very surprised that those around me opted for a more costly, environmentally damaging and wasteful way of producing electricity through the use of power plants (by burning coal and unleashing greenhouse gases into the environment, as if we didn't already have a problem) to power the streets we walk on, drive on, cycle on and skate on. When we are the solution to reducing this use of electricity, produced from non-renewable sources.

The Problem

Energy has always and will always be a hot topic. In my opinion, it is one of the most powerful tools in our environment. There are two kinds, renewable and non-renewable. The problem is, we have an overdependence on non-renewable energy, however, we are in the process of changing that by having a “green-shift” to produce greener energy, from coal to gas to electric, hopefully to green energy like solar, wind, etc. At the moment, all the green energy we produce comes from environmentally dependent sources, those which depend on the weather mainly. How do we reduce the effect weather has on these green methods of harvesting energy?

The Electric Mile in my opinion is the right solution for this. We can use our own degraded energy to power the lamps and lights that light up the way for us to walk, drive, cycle and skate on. This is one instance in where we are the solution to our own problem! We can use the pressure from a person walking, jogging, running, cycling, skating, scootering and driving to create electricity throughout the day and night and then when the night falls, the lamps come on, using this energy produced in the day and throughout the night simultaneously. This will reduce the load on the national grid, reduce the consumption of electricity from the power plants and make our world a greener place.

What is the Electric Mile?

The Electric Mile is an attempt to use pressure to convert mechanical energy to electrical energy. There are a few ways to create renewable energy from our daily activities. For example, Alpha 311 is a company in the UK, which is using the wind generated by traffic on a road to turn wind turbines attached to the street lamps across them. However, when there isn't enough wind (never the case in windy UK) or places around the world where there aren't strong enough winds in land locked cities or countries to turn those turbines effectively, the turbines just sit there and add to the aesthetic of the road.

Additionally, having solar panels on the top of the street lamps or the traffic lights, is a great way to generate electricity and reduce the use of power plants to produce more electricity. However, this leads us to the biggest flaw of solar panels, which is that they need the SUN. In places like England or other such countries, where there are limited number of days where the sunlight is present for long hours throughout the day, due to cloud cover or rain or the geographical location, the solar panels will be virtually ineffective.

This leads us to the Electric Mile. Where there is a civilization or people moving from one place to another, there is an opportunity to produce green energy. The Electric Mile is not dependent on the environment, only dependent on the movement of people or objects across it. Where there is pressure, there is electricity on the Electric Mile. It can be implemented inside speed breakers, walking/jogging/running tracks, cycling tracks, roads, campuses etc. As people and modes of transport move over it, it will produce electricity via virtue of piezoelectricity. Piezo in Latin means pressure and electricity is well, electricity. These materials convert mechanical energy, which is pressure into electric energy.

Limitations and Advantages

Presently speaking, there aren't any formal limitations to these materials, due to the lack of research done on them. However, there is a wear and tear time frame dependent on the duration of their usage and the limited flexibility of the piezoelectric ceramic.

These materials have an extremely low carbon footprint and can work in any temperature if they are put in the right material, they will be able to be implemented in any surface. I would like to add a recent update to solve one of the limitations, to do with the flexibility of the ceramic. PZT piezo

ceramics can be 3D printed into a flexible form to allow for the bending or morphing of the crystal in order for the electricity to be produced.

The Economics

The material used have relatively minor expenses, several hundreds of millions of dollars for multiple miles long producing over 4000kW per day, compared to the several million dollars required to produce one wind turbine for a capacity of producing 100kW, taking the rate of \$8,000 per kilowatt for a commercial street fit wind turbine. Additionally, with the solar street lights, the price is two times that of a normal street light. While, with the Electric Mile, the street lights stay the same, it is placed under the existing roads or walkways, so not many changes to make to take advantages of the natural resource, which is us, humans. The Electric Mile produces around 24-40 times the amount of power produced by the wind turbines, while costing a similar amount. To produce 100kW through solar panels, one would need 300 panels and 656 meter squared of space and 15744 meter quarter of space to produce anything close to the Electric Mile, and of course sunlight all day long!

Electric Mile

Technical Section

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1)Abstract

Existing methods of renewable energy harvesting exist, such as tidal, solar, wind and nuclear. All of these methods, barring nuclear depend on the weather and environment. Nuclear requires a substantial amount of capital and land mass to build a power plant and has major safety concerns, as of today. Additionally all of the above are very costly and if the weather doesn't give, they are inefficient. Electric Mile is a new method of energy harvesting which aims to be the catalyst for a paradigm shift for energy harvesting by being inexpensive and creating energy for the people by the people. Electric Mile is a flexible concept, which is ready to adapt. Feedback is always welcome from the community to help make advancements to the design in order to bring it to reality.

The Electric Mile consists of piezoelectric materials such as Barium Titanate (BaTiO_3), Lead Zirconate Titanate (PbZrTiO_3), quartz crystals or other crystals like Rochelle salt in the form of bricks or a mat made out of two conductive surfaces with the piezoelectric material in between them as the "cement", which can be placed under jogging/walking/running tracks and in the form of a filling to go under the speed breakers on the roads. It will be a multilayer piezoelectric generator, which will have 3 layers stacked on top of each other to receive the maximum output. It will have conductive ends at either side to be able to attach wires and transmit this electricity to a step-up transformer and then to capacitors under the street lights which will be attached to a light dependent resistor and when the sun sets or there is no/less light, the energy will be released from the capacitor to light up the street lights or any other output device it is attached to.

In this paper, the initial route, design depending on the type of application and circuit design have been derived. There will be 3 models to the Electric Mile, the jogging track version which can be used on pavements as well, the road version, which can be used in parking lots as well and the speed breaker version.

1)a) The piezoelectric effect

The piezoelectric effect is the ability for a material to convert an applied mechanical stress or pressure to electrical energy as a potential difference. Piezoelectric is derived from the word piezo, the latin word for pressure and elektron, the Latin word for the particles responsible for producing an electric charge. The effect was discovered and invented by Jacques and Pierre Curie, two French Physicists in the late 1800s.

This phenomenon explains the relationship between the pressure applied and the potential difference (electrical voltage) produced from certain materials with a specific crystalline lattice structure. When a force/pressure is applied on this lattice, a charge is produced because the negative and positive charges which are previously evenly distributed now have a difference between them, hence producing a potential difference (voltage). When no force is applied, the lattice structure is preserved, hence no potential is produced since the positive and negative charged are balanced out and distributed evenly. This electric charge, which is spread out across the surface can be extracted by virtue of wires.

The piezoelectric effect is divided into two types, direct and converse. The direct piezoelectric effect is as described above, where the application of pressure produces a flow of electric charge. The latter effect is the opposite, where when a potential difference is applied to the piezoelectric crystal, the lattice structure is deformed. This effect is used in quartz watches.

2)Background

The beach jogging tracks around kite beach, which is one of the most used beaches in Dubai. The current method of harvesting energy is with solar panels on top of the lights around the track, however, no solar or any other harvesting is taking place for the lights leading up to the beach or once you leave the beach from any of its many exits. Additionally, the parking meters have solar panels on top of them, around the beach. All of the solar panels are environmentally dependent. Given Dubai has sunlight for most of the year, they are able to gain enough charge to sustain the devices, however, the days where there is excessive cloud cover or it rains, the solar panels aren't able to absorb enough sunlight to convert it to electricity. Additionally, there is no energy being harvested from the tens of thousands of people coming to the beach on a daily basis and the thousands of people who use this as their daily activity.

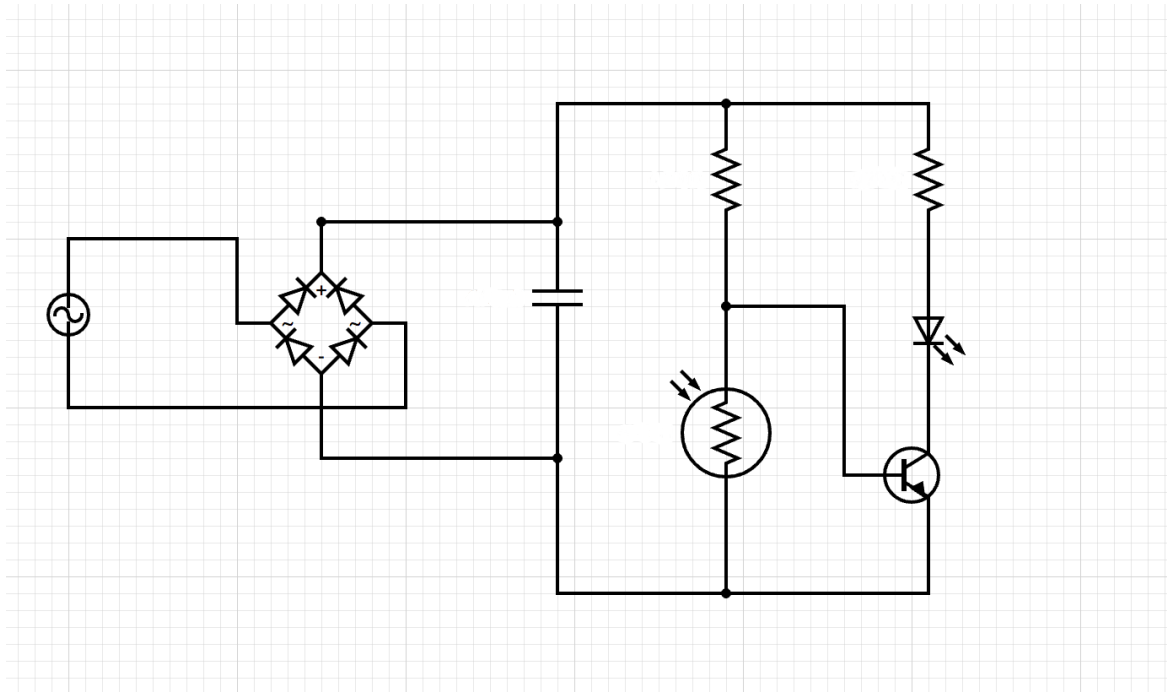
A new method is required, which provides more benefits without having the environmental dependence and doesn't disrupt the current harvesting methods or surrounding. One which allows for solar power to still be in use, for people to still be able to jog on the beach track or cycle or walk without being disturbed or their route being disrupted and to work throughout every weather, and if needed in conjunction with solar, wind and /or other renewable energy harvesting methods, so as to generate the maximum amount of green energy as possible.

There is no current contender, apart from the wind turbines that can be installed around the beach, however, they are extremely expensive per wind turbine, obstruct the view and disrupt the beautiful structure of the beach.

2)a) Methodology

In today's world, there are more and more people growing up and turning the age of 16-18, which means they are eligible to drive. In most of the western world, as soon as a person turns 16-18 (depending on the country you are living in) receives a car as their birthday gift or gets their license and is allowed to drive from that day onwards. This means that there are more cars and/or drivers in the world than ever before and this number will keep increasing as people get older. Therefore, there is bound to be more traffic on the road and with the production of electric vehicles, there will be even more cars, since they are more environmentally friendly and some are cheaper than the usual cars. This would require the nations to have more speed and traffic regulations put in place, such as speed breakers, traffic lights, radar systems, etc. Why not use these increased safety measures to harvest energy from these cars and use the increases number of cars to produce energy while they are on the road? The Electric Mile can use the piezoelectric effect, in the form of piezoelectric generators, which will convert the pressure applied by these vehicles on the road and sped breakers to produce electricity, which can be used to power a variety of outlets, such as the street lights, traffic lights etc. The pressure applied by the vehicles on a speed breaker will bend the piezoelectric generator with a larger difference due to the height of the speed breaker versus the normal road, this larger push will generate a higher voltage as the lattice structure of the crystal is being deformed at a larger difference. This coupled with the piezoelectric generators on the road will produce electricity. This potential difference will then go through a step up transformer, a rectifier to convert the high AC voltage to DC voltage and then to a capacitor in the electrical outlet box connected to the various outlets (eg. Street lights), there will be a light dependent resistor attached to the lights and when the sun sets, it will pass on the DC voltage to the lights and light up the road as normal.

Proposed Circuit Diagram:



A similar approach will be taken for the jogging paths, walking paths, cycling tracks and campuses and shopping centers. This will be in the form of a mat with the piezoelectric generators that will be placed underneath the existing jogging tracks, so as to keep the foam layer available to run on.

The Electric Mile Gen Z:

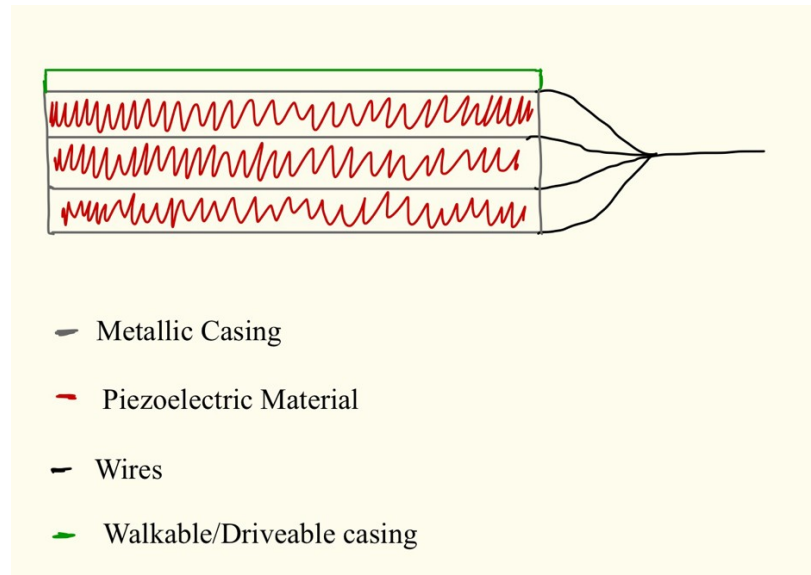


Fig. 1

3) Electric mile Road Application

The Electric Mile is a proposed energy harvesting method for roads, walking tracks and speed breaks around Kite Beach to generate power to use to light up the streets around Kite Beach and make Dubai a greener city. The Electric Mile consists of the following:

1. Piezoelectric crystals
2. External circuit
 - a. Step up transformer
 - b. Capacitors
 - c. LDR- Light dependent resistor
3. Type of application
4. Route

Additionally, the cost for the Electric mile will be addressed in this paper.

The Electric Mile is able to expand as its use becomes increasingly demanded. It can be created for most areas and surfaces to be applied to the roads or tracks around cities. As the areas that it is used in increases, the energy generated from it will greatly increase.

3)a) Speed Breakers

This is the first version of the Electric Mile application that is being considered. The speed breakers will be fitted with the piezoelectric generator (Gen Z Fig 1) allowing a large enough surface area to take into account the complete pressure from the cars going over the speed breaker. Assuming the

average weight of a car to cross the speed breaker is 1 ton = 1000kg, this would equal around 25870 Pa of pressure on the ground with an average tyre contact area of 147 square inches. This would produce around 600 V approximately due to 0.6V/press (voltage production by kg). For example, if we take the scenario that 100 cars pass on this speed breaker in an hour that would be around 10kWh. Which would mean, in a day this would produce 240kW. Each existing speed breaker on the road, lets take 10 speed breakers in an area, which is 1/4th the number of speed breakers in the Al Safa 1 residential area, this would be producing 2400kW/day. Al Safa 1 residential area has 41 speed bumps, which would mean a potential energy generation of 9840kW per day. This would suffice the energy required for the street lights and the traffic lights and can be routed to the national grid in the future. This is only one residential area, the Greens Community, Meadows, Arabian Ranches and many more. This would mean an average of at least 9840kW per day per area. Dubai has many more areas just like these with around the similar number of speed breakers. If this piezoelectric technology of the Electric Mile can be implemented, it would reduce the electrical load on the city to produce and would made Dubai a greener city.

Installation:

The piezoelectric generator will be installed under the top dome of the speed breaker. The top dome will be removed of the existing speed breakers and the piezoelectric generator will be placed underneath and the dome of the speed breaker will be refitted as the surface of the generator, where the cars will apply the pressure by traveling over it like a normal speed breaker. This would be placed on the angle at which cars apply the most pressure, as shown below in Fig 2.

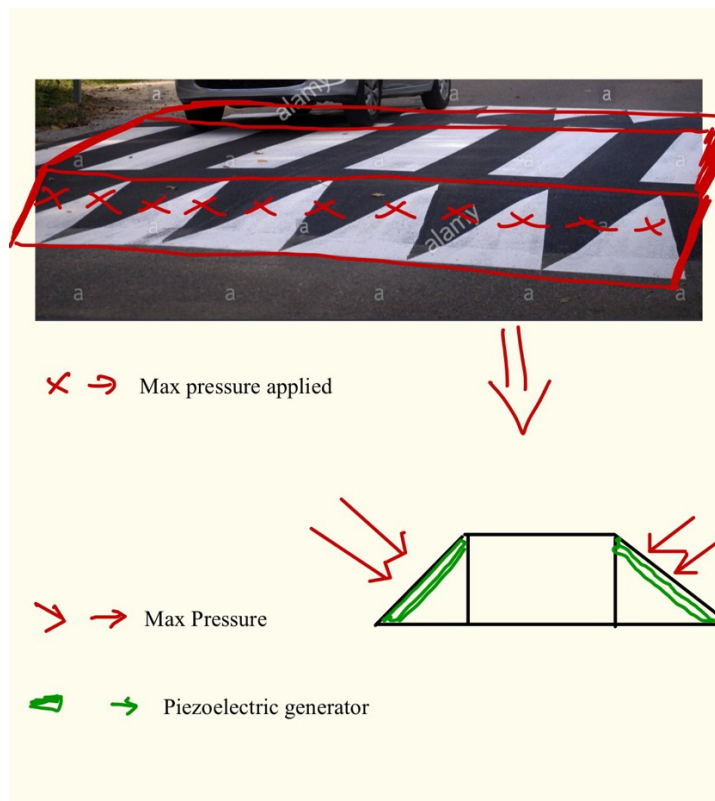


Fig 2

Since speed breakers are traditionally trapezoidal in nature, as seen above in Fig 2, the maximum pressure applied on the speed breaker by the car is on the angle fronts. Therefore the piezoelectric generator will be placed underneath the angles areas to make maximum use of the pressure and obtain the maximum amount of power.

3)b) Walking/Jogging/Cycling Tracks

The second version of the Electric Mile application being considered is for pedestrians. Dubai has wonderful spots to walk around on and have your daily walk or jog and there are new cycling towns that are coming up with specific cycling lanes. Additionally, the normal pavements are now being converted into cycling/walking tracks with specific foam/padded walking tracks to improve the quality of the activity. This technology (Gen Z Fig 1) will be applied underneath the existing padded tracks which will then produce electricity from this daily activity or for some, a mode of transport. Assuming an average person exerts 35000 Pa of pressure, while stationary and taking into account motion, they would produce around 50-70kPa this would mean a moving, adult human would produce 35V approximately. For example, if we take 100 people passing on the beach walking track for 1 hour, every meter on Jumeirah Beach, this would mean 1.92kWh per meter and 1920kWh per kilometer. Dubai has many more walking and jogging tracks just like this around its various beaches and areas such as Jumeirah 3.

Regarding cycling tracks, they would also use the same technology as the walking tracks (Gen Z Fig 1), a normal cycle would produce 310kPa of pressure on the ground, a road racing cycle would produce 620kPa of pressure on the ground. Taking this into consideration, they would produce, 50V – 60V. For example if we take 50 cycles passing on this road for 1 hour, every meter on the cycling track, they would produce 1.37kWh per meter and 1370kWh per kilometer. Dubai has many cycling tracks and areas around where this can be implemented, such as Al Quadra.

Installation:

The piezoelectric generator will be installed underneath the existing tracks. Regarding the walking tracks, the padded surface will be lifted, the generator will be placed underneath and the padded surface will be reapplied on top. This will allow those who use the track to use it as they do normally. Regarding the cycling tracks, the generators will be placed under the areas with the highest traffic volumes in strips to make the best use of the concentrated pressure on the generators. This will be done by digging up the strip or area where it will be placed, then the generator will be placed in the dug up area and the tarmac or previously used material for the track will be placed on top of the generator.

3)c) Roads and Parking Lots

The third version of the Electric Mile is the road and parking lots version. These two will use the same technology (Gen Z Fig 1) since they are trying to tackle the same problem, which is harvesting the power generated by the pressure of cars on the road. Since there will be more cars on the road, as suggested above, the piezoelectric technology can be implemented to make use of this extra pressure on the ground. There will be piezoelectric generators placed under the tarmac, around 5-10 cm below to optimize the production and they will be placed around 1 m away from each other. These piezoelectric generators will not be placed throughout the road, they will be placed in areas of the road where there is a maximum amount of pressure, which we will come to in route optimization. Assuming an average car weights around 1000kg = 1 ton. It will be producing around 400V. Taking the scenario that 100 cars pass on a road which is 1 km long for an hour, this would produce 40kW per kilometer. This same methodology can be used in a car parking lot, which can be used to power all of the parking meters and the lights used to light it up.

Installation:

The similar approach to the cycling tracks will be used to install the piezoelectric generators. The areas and strips where there is a maximum amount of pressure will be dug up and the generators will be placed in the void, then the previously used material for the surface will be reapplied on top.

3)d) Estimated Cost

The estimated cost of the piezoelectric material is around USD\$ 20,000 per kilometer

The estimated cost of the metal sheet both sides is around USD\$ 12,000 per kilometer

The estimate cost of the plastic casing is around USD\$ 10,000 per kilometer

The estimated installation cost is around USD\$ 3000 per kilometer

Therefore, the total estimated cost per kilometer is. USD\$ 45,000 for the piezoelectric generator.

There are additional costs depending on the material used as the surface of the generator, as explained above.

4)a) Route Optimization

The route will be chosen by means of traffic volume. The higher the number of cars, the higher the probability of producing more power. Additionally, the placement of the piezoelectric generator will be positioned due to the area with maximum pressure. This is the line followed by the cars, so as to not waste the materials and unnecessarily produce more generators and add up more costs, they will be carefully positioned to take maximum use of the pressure by the tires of the cars, in rows of size of the width of the tires, as shown in Fig 3 below.

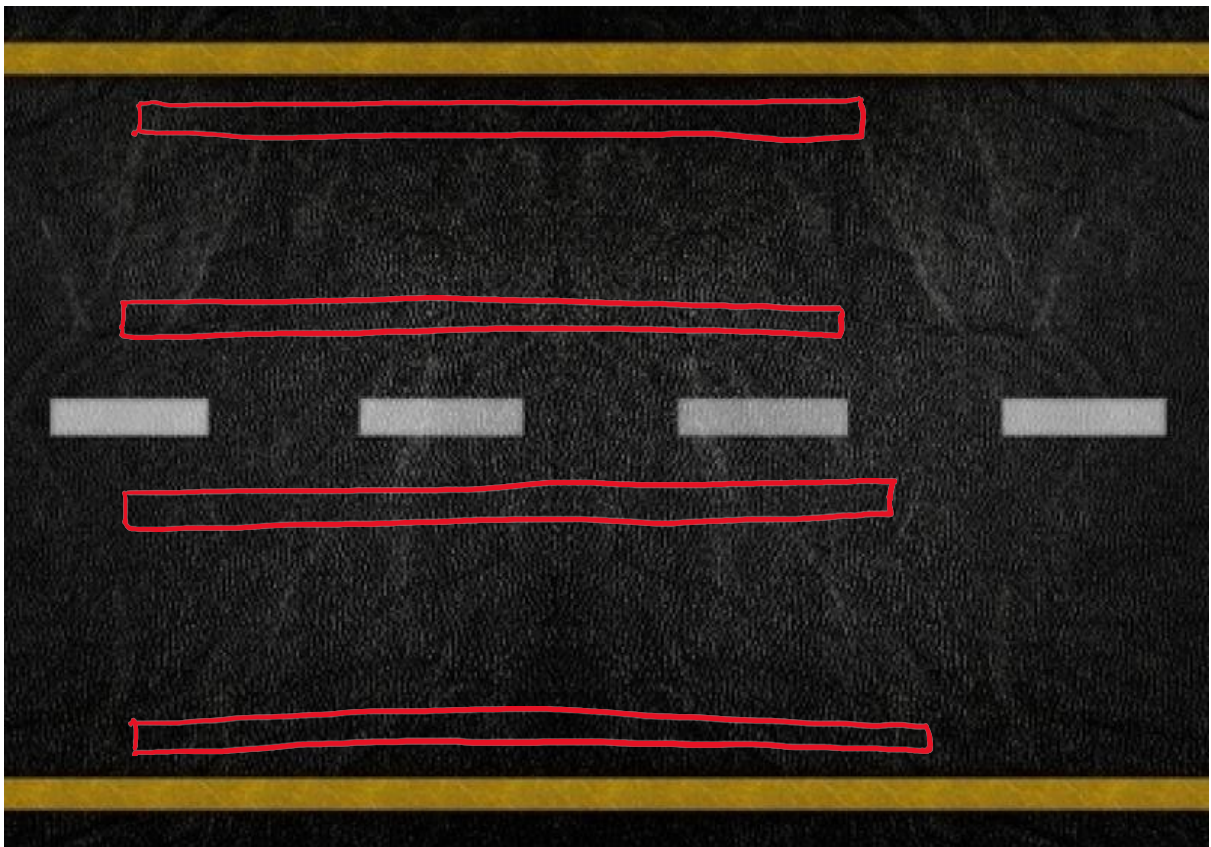


Fig 3

The above figure, Fig 3, depicts the rows of piezoelectric generators. These will be placed like so to maximize the power generation by being placed a car apart and the width of the generators will be the width of the tires of the cars. Therefore on a dual carriageway there will be 4 rows of piezoelectric generators as shown above. One for the right side of the car, one for the left side and a repeat on the other side of the carriageway.

Regarding the walkways, the entire walkway will have the generators below the walking mat.

Regarding speed breakers it will be applied to roads, internal, external and service lanes which have the highest traffic volume since the more cars equals a higher energy production.

4)b) New residential areas (using Al Safa 1 as a base case)

The Al Safa 1 area is the residential zone opposite Jumeirah College where there are 41 speed breakers in the area and since it is a school zone with multiple Emirates airlines pilots and other members of the faculty living there as well, hence there is a very high traffic volume on a daily basis. Therefore, I am proposing the first speed breaker installations to be made in this area to gain the maximum energy production from the Gen Z piezoelectric generators.

4)c) New and upcoming Walking tracks (using Jumeriah beach as a base case)

The Jumeirah, Kite Beach is one of the most used beaches in Dubai and there are several hundreds of people walking/jogging and running on the beach every single day. Hence to maximize production from the walking mat Electric Mile application, I would propose the first installation to be made there.

4)d) New and upcoming Cycling Tracks (using Al Quadra as a base case)

The Al Quadra cycling track is one of the most regularly used cycling tracks in Dubai and there are hundred of people cycling on the track every single day as a routine activity. Therefore to gain the maximum amount of energy from the Electric Mile cycling track application, I would propose the first installation to be made there.

4)e) Estimated Cost

The estimated installation costs for the above areas would be as follows:

4)b) USD\$ 12,000 (piezoelectric material per speed breaker) + USD\$ 7,000 (metal sheets) + USD\$ 5000 (plastic casing) + USD\$ 1750 (installation of the generator) + Additional costs to refill the top dome. Therefore a total estimated cost of USD\$ 25,750 + Additional costs for the top dome per speed breaker. Hence since there are 41 speed breakers in the area is would be a total cost of USD\$ 1,230,000.

4)c) USD\$ 20,000 (piezoelectric material per kilometer) + USD\$ 12,000 (metal sheets) + USD\$ 10,000 (plastic casing) + USD\$ 3000 (installation of the generator) + Additional costs to reapply the walking padded surface. Therefore the total cost of USD\$ 45,000 + Additional costs for re-application per kilometer. Hence since it is 12 kilometers long, the total estimated cost will be for USD\$ 540,000.

4)d) USD\$ 20,000 (piezoelectric material per kilometer) + USD\$ 12,000 (metal sheets) + USD\$ 10,000 (plastic casing) + USD\$ 3000 (installation of the generator) + Additional costs to reapply the walking

padded surface. Therefore the total cost of USD\$ 45,000 + Additional costs for re-application per kilometer. Hence since it is an 85 kilometer long loop, the total estimated cost will be for USD\$ 3,825,000.

Therefore the total approximate costs for all three together will be for USD\$ 5,595,000.

The total approximate amount of electricity that will be generated every year will equal 0.4TW/year. This would save USD\$ 46,800,000. (Taking the cost to be USD\$ 0.117/kWh)

5) Conclusion

A renewable energy solution has been detailed and developed in this paper, the current stage of The Electric Mile is that of research, development and prototyping. Costing around 11% of the amount that will be saved due to it and producing 1.81% of the country's electrical consumption sustainably.

The intention of this paper is to inform and open the world to a new revolutionary way to harvest power and energy from ourselves. The author encourages feedback to improve the model and incorporate them into future versions of the Electric Mile.

6) Future Works

I would propose the future works to be new areas that are being constructed, buildings and parking lots to be fitted with the Gen Z piezoelectric generator and other new build residential areas around Dubai such as Al Barari, The Pearl Jumeirah, the new Palm, to be fitted with the Gen Z generator on the speed breakers and the roads as well.

The author recognizes the need for a deeper analysis and more work regarding detailed designs for the installation and the lifetime of the generator before a refill or replacement is required.

Please feel free to send feedback to the below email.

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