2009 FAA DESIGN COMPETITION FOR UNIVERSITIES

Lighting Airfields through Harvested Kinetic Energy from Vehicular Traffic

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14th April 2010

KENT STATE
UNIVERSITY

14th April 2010

Ms. Mary L. Sandy, Director
Virginia Space Grant Consortium
600 Butler Farm Road, Ste. 2253
Hampton, Virginia 23666

Dear Ms. Sandy:

Following is a complete proposal report on "Lighting Airfields through Harvested Kinetic Energy from Vehicular Traffic," which is being submitted on behalf of a group of eight Aeronautics students from the College of Technology at Kent State University.

This proposal, which constitutes the second group proposal from the College of Technology at Kent State University, is submitted under the Airport Environmental Interactions Challenge category of the 2009 FAA Design Competition for Universities.

The report on "Lighting Airfields through Harvested Kinetic Energy from Vehicular Traffic" is an important proposal, which merits favorable consideration. As needed, I may be reached at inettey@kent.edu or 330.672.9476. Thanks for the opportunity.

Sincerely,

I. Richmond Nettey

I. Richmond Nettey, Ph.D.
Associate Dean, College of Technology and
Faculty Advisor, FAA Design Competition for Universities

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Executive Summary

Airports across the world are some of the leading users of energy. They join the rest of the world in the energy crisis that has come to light of late, with good reason. Airports are some of the largest consumers of energy imaginable. From terminals that are open twenty-four hours, airplanes burning thousands of pounds of fuel and lighting systems that guide those aircraft in and out of the airport safely.

This proposal, submitted under the Airport Environmental Interaction Challenge of the FAA Design Competition for Universities 2009-2010, proposes and explores the installation of a new renewable energy source in development at airports small and large. The technology is being called *MotionPower* by it's inventors. This new technology harnesses the energy wasted by vehicles everyday and converts it into useful power. This proposal will investigate taking that power and applying it to light airfield components, including taxiways, runways and approach lighting systems.

The student team consisting of eight undergraduate students majoring in Flight Technology and Aviation Management at Kent State University approached the project when presented by the faculty advisor with one goal in mind. Research this new technology being developed and bring it into the eyes of airports across the nation. One member had seen the technology presented in a news article and having been to Chicago O'Hare International Airport over the summer, put the two together. He realized that not only could it produce an extreme amount of energy, but also that it would also improve safety for pedestrians at the airports. When the group was presented the technology, there was a consensus that this new energy harvesting technology could change the way energy is produced all over the world since they realized how big of an issue energy use

is today.

Choosing this design over others such as windmills and solar panels was an easy decision for the group. Windmills are large, take up a lot of space and could be dangerous for aircraft. Solar panels are small and need a lot of room for multiple units to be effective. Another factor is weather. If there is no wind, windmills do not work. If there is no sun, solar panels are not very effective. The system being proposed is small, compact, easy to install on existing facilities and is not airside (aircraft operations side) so it would not effect air traffic. It also works in all weather conditions and really does not have many variables that would or could disable it.

The technology uses a speed bump that compresses as it is rolled over by a vehicle and produces energy that can then be used to power whatever is needed. In our proposal, the technology will solely be used to light airfields and not the facilities located on airport grounds. Included is a case study on Cleveland Hopkins International Airport (KCLE) as well as the much smaller Kent State University Airport. These studies will hopefully show how airports can lead the way in eliminating their carbon footprint.

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Problem Statement

Airports, large and small, use enormous amounts of energy every day and night. Due to the specific use airports serve, it is difficult to develop a new technology that fits in with technology already in place that does not interrupt the daily flows of traffic in and out of the airport. Airports pose a problem because they are nearly always turned on, which creates very large energy consumption and costs. This makes an airport a very good candidate for renewable energy technology.

Background of the Design Challenge

Airfield lighting is a vital part of an airport and a key in aviation safety. When the sun goes down or the weather takes a turn for the worst, pilots turn to airport lighting to make a safe landing and to navigate around the airport property. Federal Aviation Regulations state that lights may not be spaced any closer than 75 feet or more than 200 feet apart and with runways being anywhere from less than a mile long to over 3 miles long, there will be a substantial amount of lights, which in turn will use a lot of energy every single night. Throw in a bad weather day and it could be a full 24 hours of lighting. By researching and implementing a renewable energy source that is self sustaining by the vehicular traffic the airport is practically guaranteed to receive, it is a great and remarkable step to providing a carbon-free energy source that currently relies on expensive, non-renewable fossil fuels.

Summary of Literature Review

Renewable energy is not just going to be another trend of the world that just disappears over the next few years. It is a serious problem that the population of the world is going to have to face. People of the world are going to need to design solutions to meet our rising energy demands and cut our dependence on non-renewable energy. Not only is the world going to have to face it, but airports will need to as well. The airports, especially ones of size, use non-renewable resources constantly. Whether it's the airplane using fuel to move about the airfield or keeping the lights on in the terminal continuously, day or night. What other facility uses as much constant power as an airport? It's a challenge to find one. "Going green" is in the spotlight so much now that the American Association of Airport Executives (AAAE) recently held a conference in Chicago titled "Airports Going Green."

According to Cape Cod Today, in March 2008 Boston Logan International Airport installed 20 wind turbines on their administration building. The turbines are said to produce an annual electrical output of approximately 100,000 kilowatt hours and save the authority $13,000 annually (Brooks, 2008). In March of 2007, Community Energy Incorporated announced they had partnered with Philadelphia International Airport to provide the airport with 13,000 megawatt hours per year of renewable energy, making it the largest renewable energy purchase among the nation's airports. Philadelphia International's purchase is equivalent to powering 1,300 homes per year (Community, 2007). The two examples above are from wind energy, but solar panels are going in all across the country at airports including San Francisco International and Denver International. This diversity shows us that there are many ways to produce renewable energy, so depending on your location, climate and other factors; renewable energy can be put practically anywhere.

In August 2009, the Department of Transportation released their monthly study on vehicular traffic. There are over 61 million vehicles registered in the United States that drove 1.9 billion miles. New Energy Technologies of Burtonsville, Maryland is currently researching and developing a technology that harnesses wasted energy from those vehicles to produce power.

Airports across the nation are becoming “green” one-by-one by installing wind turbines and solar panels to help make the transition of using renewable energy. Our proposal team has found a new groundbreaking technology currently in the research stage that has the potential to be installed nearly anywhere. Since the new technology uses vehicles the way a windmill uses wind, airports seem like a logical choice for installation. Cleveland Hopkins International Airport serves 12 million passengers per year, equating to nearly 34,000 per day which shows that there are also thousands of vehicles on airport grounds per day. Our group’s proposal focuses on the installation of traffic devices that capture a vehicle’s energy as it is being driven over. The technology can be installed at any airport where vehicles are traveling at a slow speed and won’t affect daily operations or create traffic backups.

Problem Solving Approach

In 2008, oil prices hit a record high. Those prices really showed the world that there is a need for research of renewable energy and that it needs to be done quickly. Wind farms and solar panel clusters are popping up at airports across the nation to address their needs, and they do provide an attractive alternative that saves energy costs.

However, the group has come to a consensus that the energy produced is simply not enough for the needs of an airport. The group tackled this problem by researching a new technology and conducting a case study of two airports of different sizes to show how the technology could be implemented and the effect it would have.

The technology that has been researched involves installing traffic control devices (speed bumps) that harvest energy from your vehicle as they drive over the device. Not only does the device provide a large amount of power, but also increases safety levels at airports by slowing the traffic down.

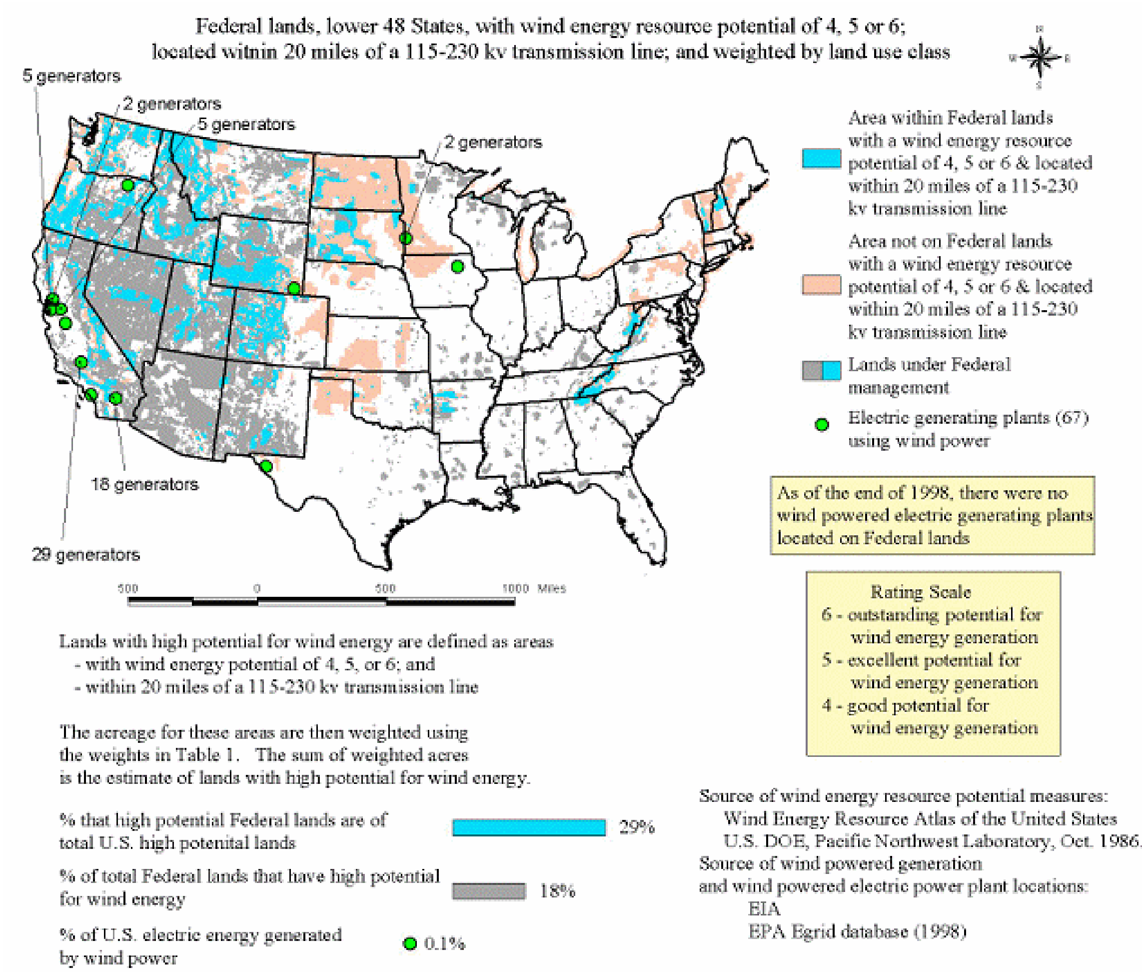
The group has decided to only focus it's efforts on providing airfield lighting as a starting point to provide an understanding of the extent of the power that is able to be produced. The proposal will feature runway, taxiway and approach lighting systems at airports and a way to power them through this new technology.

The team's goal is to provide an understanding of this new system and how it works, to bring it into the spotlight at airports across the country to take advantage of a huge resource they already have; while providing an added benefit of safety for it's customers.

Alternative Energy - Wind Power, Solar Power and Kinetic Energy

Wind Energy

When people think of “going green” for energy, they think of windmills and solar panels. Wind farms have been installed all over the country and smaller versions are also being used to power smaller needs, such as at Boston Logan International Airport in Boston, Massachusetts. According to Siemens, the largest developer and management corporation for wind farms, they have 7,793 operating turbines across the globe that produce 8,813 Megawatts, which is equivalent to 8,813,000,000 watts of power (Siemens, 2009). Taking your standard 60-watt household light bulb, that power is enough to generate light to 146,883,333 bulbs for 1 hour each. No one doubts that the number sounds like large; however, there are a lot of downfalls to wind turbines that limit their power production. One problem is that not all areas are windy. Energy production would depend on the weather making wind turbines not suitable for many areas. The following figure from the United States Department of Energy demonstrates suitable land areas in the 48 contiguous states that have the potential for producing wind energy on a constant basis.



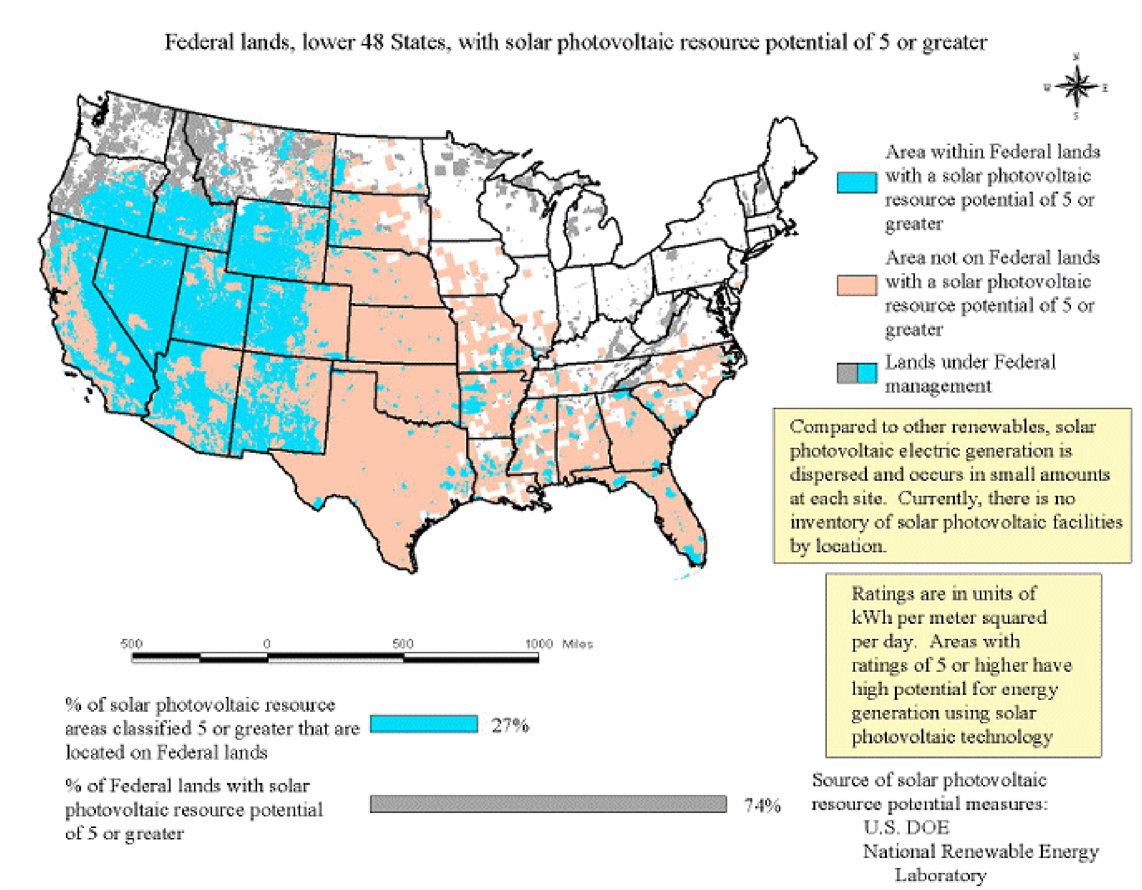
Source: U.S. Department of Energy, 2009

Of course there are several more downfalls to wind turbines, but one is very important and why they cannot be placed on or near airports effectively. The shear size of turbines play a large role in their placement. If placed on airport grounds, they would create a serious hazard for aircraft. Another type of turbine sits in a low profile to the ground and is considered a vertical-axis turbine. However, while it may not stand high in the air like horizontal-axis turbines, they cover much more ground. This is not effective for airports across the nation that have land constraints.

Solar Energy

Solar panels are also a leading technology for renewable energy across the globe. Solar panels are small, and can be installed nearly anywhere sun will hit them. This is a positive for airports as they can be placed practically anywhere and not cause hazards for aircraft. For example, San Francisco International Airport unveiled more than 2,800 solar panels atop their Terminal 3 rooftop for energy production at the airport. The system provides enough power to provide daytime lighting for the airport and save 628,000 kilowatt hours of energy throughout the year. This is the second such solar panel installation at the airport, with the first being installed on the engineering building and saving nearly 150,000 kilowatt hours of energy per year since 2001 (San Francisco, 2007). As one can see, it takes a large number of panels to provide lighting just for the daytime at the terminal. At a total cost of $5.5 million for the system and a national average of 10.8 cents per kilowatt hour (August 2009) it would take just under a year for San Francisco to pay for the system (Energy information administration, 2009). Once again, just like wind power there are downsides to the system. The system requires heat from the sun to operate. If the weather is overcast skies for a period of time, that system output will be greatly reduced. In San Francisco's case, they needed over 2,800 solar panels for the system to be effective and the average cost of each panel comes to nearly $2,000 each.

In the following figure, the Department of Energy has laid out areas across the United States that can utilize solar panels to their full potential. As seen in the figure above concerning wind energy, there are also large amounts of land in the United States that could not use solar energy to their full potential.



Source: U.S. Department of Energy, 2009

Kinetic Energy

Kinetic Energy has been used to power homes in the Western Half of the United States for decades. Kinetic Energy is defined as the "energy associated with motion" (Webster, 1870). The Hoover Dam has been harnessing the water's kinetic energy since 1935 and providing power for 1.3 million people in Nevada, Arizona and California. The Hoover Dam forces water through pipes down the long face of the dam into and through turbines that spin from the force of the water. If the water can provide power for the population in three states just from traveling down the dam, that technology can be transferred over to another form of energy production and all on a much smaller scale (Reclamation, 1999). That is exactly what Maryland based New Energy Technologies Incorporated is currently researching.

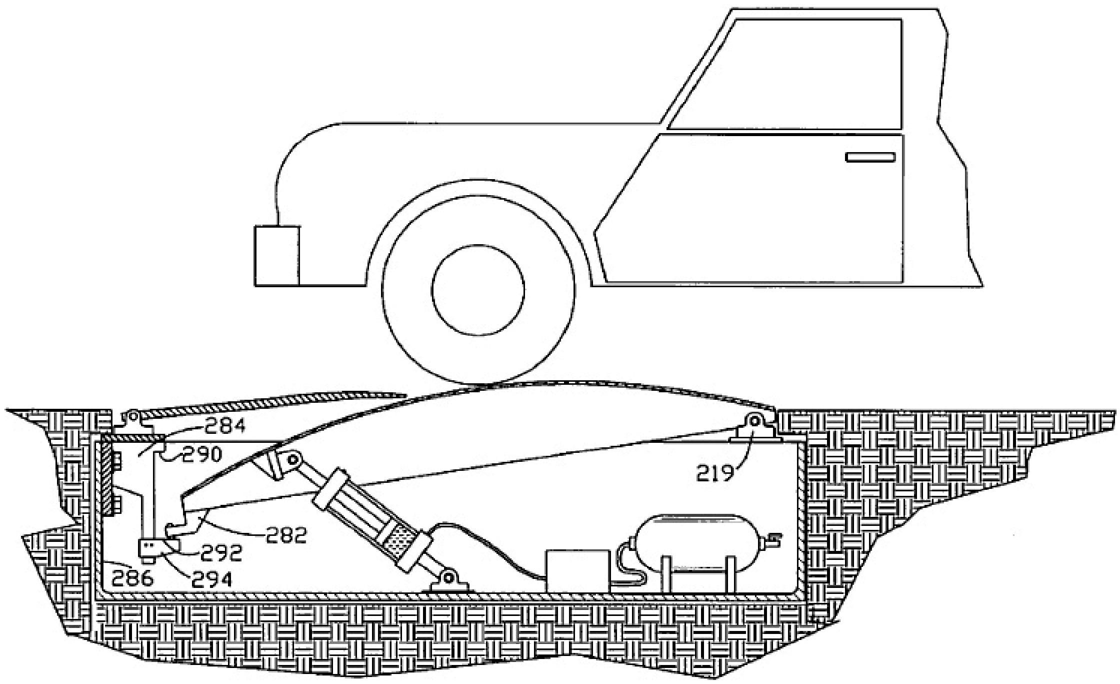
Motion Power

Motion Power is the name given to the technology by it's creators, New Energy Technologies Incorporated. The basis behind Motion Power is to harvest the wasted energy from your vehicle as it is coming to a stop and converting it in to a usable form of power that can be used to power virtually anything.

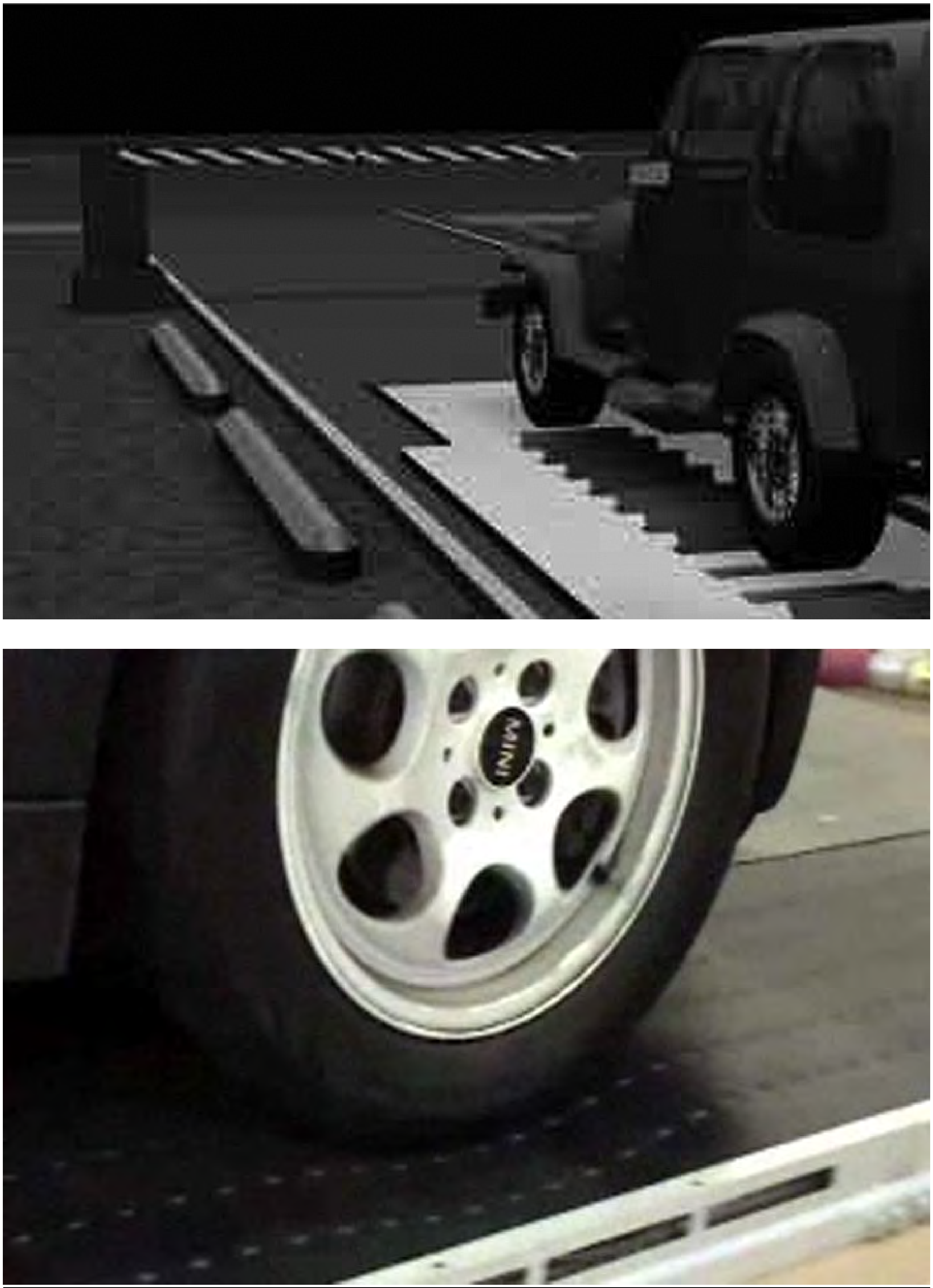
The system is designed to be placed where any vehicle is to be moving slowly or slowing down. According to the company, ideal places include freeway exit ramps, toll booths, stop signs, rest areas, as well as restaurant and bank drive-thrus.(New Energy, 2009).

There are many variations of the system and throughout the research project, the proposal team has seen first hand how this new technology is evolving. First it was a collapsible speed bump, then it became a speed bump with collapsible fins on top, and now it has turned into a speed bump with a collapsible rubber top surface that now allows large trucks to travel over it. Another plus to the new design is it helps the vehicles slow down at these stopping points, providing an extra safety feature (AllCarsElectric, 2009). When a vehicle drives over the device, a portion of the system collapses (whether it is the entire device, a series of fins, or the newest rubber form) and the energy from the portion collapsing is captured inside the device and transferred to the device being powered.

Early research shows that a vehicle driving over the device at 5 miles per hour will produce a total of 2,000 watts of energy, of which 60% is lost instantly, leaving 800 watts to be used or stored. As speed increases the force of the vehicle becomes greater and the power output increases substantially (M. Patel, personal communication, October 15, 2009).



Source: United State Patent Number 6010277, 2000



Source: New Energy Technologies Inc., 2009

One of the best features of the system is that it is very inexpensive to purchase and install. According to Meetesh Patel, CEO of New Energy Technologies Inc., the traffic device itself will only cost between $1,500 and $2,000 (M. Patel, personal communication, October 15, 2009). Another great feature is that the system is simply installed on top of an already built surface, meaning that the installer would simply place it on the roadway and hook it up to the electrical system and it would be able to start producing power instantly. This quick installation is important to minimize the lane closures and traffics backups at airports.

One important note about energy harvesting, is that it is not free. Since the devices take energy away from the vehicle traveling over it and makes it slow down, more friction is caused and the driver of that vehicle is needing to produce more energy to overcome it (S. Christensen, personal communication, October 1, 2009). In essence the vehicle is having to create more energy to travel over the device, so the operator is having to pay for the amount of energy being used. It can be thought of as a small tax against these operators for driving at the airport.

Energy Storage

Due to the energy harvesting device still being in development, New Energy Technologies has not designed the perfect solution for energy storage. Currently, the devices that are installed simply light a single light for the time the vehicle is driving over the device, causing the energy to be used instantly. At an airport, peak vehicular traffic is obviously during the day. However, airfield light usage is primarily at night, unless of course there are inclement weather days cause the lights to be on longer. Therefore, it was vital for our team to research and propose a system that we thought would work the best, while being cost effective. We looked at three different storage solutions including capacitors, batteries and flywheels. We made our decision based on what is readily available in today's market on the scale needed.

Capacitors and Battery Solutions

An electrical grid provides energy flow to an area. A grid is a spider web of electricity, branching out from the main power plant. It gives an area an even flow of electricity throughout the day, and the use of capacitors, batteries and flywheels help to provide this flow (Nasr, 2009). First, a capacitor is an energy conductor built with the intention of storing a charge. It is made up of two parallel plates with an insulating material between the two, called a dielectric. These two plates are both conductors and hold a charge, and when in a circuit, produce an electrical field (Morrison, 2003, pp. 40-44). Electrons move through the circuit and will flow across the capacitor until the voltage across the capacitor equals the voltage from the source. After the capacitor is fully charged, it will continue to hold this charge even if disconnected from the source. If disconnected from the circuit and overall source of power, a capacitor can act like a battery, and continue to hold the original charge for an extended period of time (Floyd, 1981/1997, p. 488). However, the length of time is determined by the type of capacitor.

Currently the use of capacitors in the market today is growing. The technology is increasing by the day, and scientists are finding better ways to improve capacitors. Back in July, 2007, "North Carolina State University physicists deduced a way to improve high-energy-density capacitors so that they can store up to seven times as much energy per unit volume than the common capacitor" (American Physical Society, 2007). Some of today's top developers of capacitor and energy storage technologies are working on projects to better the industry. One of these developers is Maxwell Technologies out of San Diego, California. They are one of the leaders in the development of ultra capacitor design and manufacturing (Maxwell Technologies, 2009). A case studyn was preformed by Datawell BV using ultracapacitors manufactured by Maxwell Technologies. In the case study, Datawell produced a buoy, called the Directional Waverider(DWR), which "uses three accelerometers to measure wave height and wave direction,and also monitors sea surface temperature" (Van Weeren, Joosten, Scrivens, &Schneuwly, n.d.). Due to the remote location of buoys on the ocean, the technology had to be low maintenance and extremely durable. They produced energy with the useof solar panels located on the top of the buoy, and stored energy in batteries. This method proved ineffective due to the nature of batteries, cost and complexity of the systems.

Datawell then improved the system by adding Maxwell Technologies BOOSTCAP ultra-capacitors to the system, which in return, doubled the lifetime of the batteries and cut down on complexity and vulnerability of the system (Van Weeren, Joosten, Scrivens, & Schneuwly, n.d.). The capacitors also provide a simple maintenance free way to increase overall performance and reliability of the buoys.

As evidenced above, the use of capacitors is still on a smaller scale, but it is growing rapidly. A press release by Lux Research, Inc. shows this projected increase in super capacitor demand. "The overall market is expected to expand from $208 million last year, to an $877 million market in 2014, according to a new report from Lux

Research" (Jacques, 2009). It also goes on to state that many of the markets top manufacturers, such as Panasonic, NEC- Tokin, and as noted earlier, Maxwell Technologies, are going to benefit the most from this economic growth. They will acquire new companies, and expand the uses of capacitors in more fields, diversifying the industry along the way.

Along with the use of capacitors for energy storage, there is also a technology which has been present in the industry for a long time. This technology is the use of cells and batteries. Battery power has been around since 1800 when Alessandro Volta created it and the uses for batteries has continued to grow (Brain & Bryant, 2000). Millions of people use batteries in their daily lives and never recognize the fact that they are using them. Whether they are talking on their cell phone, checking their email on their laptop, or starting their car, they are using batteries. The technology seems so primitive now, but in reality it is constantly improving, with new materials and longer life spans, battery power is proving to be one of the best forms of electrical power around. When we are talking about batteries, we are not talking about AA, C, or D type batteries, we are talking larger scale. The only negative side effect of a battery is that with the age of the battery, its reliability and overall charge decreases (Brain & Bryant, 2000). This inverse effect between age and reliability makes this method less cost effective, but effective none the less. The use of rechargeable batteries would also help to solve this problem. Once the energy is produced it will get stored onto the battery, and just like your laptop you can use the battery life while you are not directly connected to a power source, or you can tap into the battery for its usage instead. You can use the battery for a partial discharge, which can maintain the batteries life and durability. If you fully drain the battery, it can be potentially damaged and might cost you more by replacing it sooner.

Overall, battery power is simpler but less cost effective than the use of capacitors, but if the two are used together, like Datawells Waverider technology, the battery can prove to be useful.

Flywheels

As the team has already presented, kinetic energy is energy associated with an object's motion. This energy can be stored by the use of flywheels. Flywheels store energy by accelerating a rotor up to a very high rate of speed and maintaining the energy as kinetic energy. In a way, they are like chemical batteries with a few more advantages: they do not contain acids or other hazardous materials and are not affected by extreme temperatures (Heiney, 2004). Other benefits include that they will last around 20 years, are more compact, taking up only 10-20% of the space required for the same output from batteries, and maintenance is usually less frequent and complicated (U.S. Department of Energy, 2003).

The basic components of a flywheel energy system include a rotor, motor, bearing system, vacuum housing, and power electronics. The rotor is the most important component because it controls the amount of energy that can be stored. Flywheels store power in direct relation to the mass and momentum of the rotor and to the square of its rotational surface speed. Therefore, the best way to increase the amount of energy a flywheel can store or take on is to make it spin faster. It's important to remember that the surface speed is what is critical, not simply the rotations per minute (RPM). A flywheel with a larger diameter can have the same amount of energy as a smaller flywheel that spins faster. The flywheel is then able to release the energy by reversing the charging process and using the motor as a generator. As the energy is released, the rotor slows until all of the energy is discharged.

Maintaining energy in the flywheel systems requires that any resistance to the spinning rotor to be minimized. Most high energy designs today feature magnetic bearings and place the spinning rotor in a vacuum housing. However this in turn minimizes the transfer of heat out of the unit. This loss of heat causes the battery life to decrease; therefore, many systems now have a type of cooling system built into the unit. Due to the separation of the power and energy components in the unit, they can be optimized for either power or energy. To better the power, one must focus on the motor or generator and power electronics. However, to increase the energy density, one must use a larger, higher speed rotor. Low speed systems typically have a heavy steel rotor and rotate at speeds below 10,000 RPM. High speed systems spin a lighter rotor with speeds between 20,000 and 60,000 RPM (Baxter, 2006). These high speeds systems are normally constructed from composite materials such as fiberglass or carbon fibers.

In 2003, a total of six companies were producing and offering DC flywheels. Today that number is around eighteen. Flywheel purchase costs usually vary between $100/kW to $300/kW. The lower end of the range will represent large but lower RPM models. Maintenance is simple and inexpensive, ranging from $20/kW to $40/kW. Initially flywheels will cost more than typical batteries. However, they require less maintenance and will last much longer. Thus they will be less expensive on a life-cycle basis (U.S. Department of Energy, 2003).

Battery Costs

Purchase cost = $13/kWm * 250 kW * 10 minutes =	$32,500
Installation cost = $30/kW * 250 kW =	$7,500
Total initial capital cost =	$40,000
Capital replacement cost every 4 years =	$40,000
Annual maintenance cost = $2.25/kWm * 250 kW * 10 minutes =	$5,625
Annual floor-space cost = 0.22 ft2/kW * 250 kW * $10/ft2 =	$550
Annual standby power consumption cost = 250 kW * 8760 hours * 0.01% * $0.063/kWh =	$14

Flywheel Costs

Purchase cost = $200/kW * 250 kW =	$50,000
Installation cost = $30/kW * 250 kW =	$7500
Total initial capital cost =	$57,500
Bearing replacement cost every 5 years = $10/kW * 250 kW =	$2,500
Vacuum pump replacement every 7 years = $5/kW * 250 kW =	$1,250
Annual maintenance cost = $5/kW * 250 kW =	$1,250
Annual floor-space cost = 0.08 ft2/kW * 250 kW * $10/ft2 =	$200
Annual standby power consumption cost = 250 kW * 8760 hours * 1% * $0.063/kWh[a] =	$1,380

Source: Federal Energy Management Program, 2003

Proposed System Installation

It is important to set forth the way we propose this system be installed. Our group has presented the design, as well as the storage system to provide the energy when needed. The team has decided to use flywheels for our storage needs because of their high capacity, small footprint and cheap maintenance costs.

For our system, the Motion Power devices would be installed on the roadways and wired to the flywheels. The flywheels could be installed in pre-existing or newly built facilities, but access to the electrical grid is important. All of the Motion Power devices would be connected to the flywheels and when needed, the flywheels would release the energy into the grid.

We suggest as an emergency backup, having diesel powered generators; while still being connected to the conventional grid. For redundancy, just in case the conventional grid goes down, there will still be a way to provide energy to bring aircraft safely back to the ground.

Case Studies

To help show how effective this system could be at airports across the world, our team focused on two Northern Ohio airports. The team chose Kent State University Airport (1G3) located in Stow, Ohio as well as Cleveland Hopkins International Airport in Cleveland, Ohio. The two were chosen because they are both on different sides of the airport spectrum.

Kent State University Airport is a general aviation airport serving mostly flight training and averages 198 aircraft operations per day (AirNav, 2008). The airport was chosen because the airport information is readily available for research and provides a good example that this system could power much more than just airfield lighting at smaller airports.

Cleveland Hopkins International Airport is a large airport, consisting of mainly commercial air traffic and averages 670 aircraft operations per day (AirNav, 2007). The airport was chosen at it is the closest large airport to Kent State University and as students, we are most familiar with the area and the size of the field.

Kent State University Airport - Stow, Ohio

Kent State University Airport is a general aviation airport located in Stow, Ohio. The facility consists of a single runway configuration, with a system of taxiways linking the ramp on the west side of the strip. Runway 1 & 19 is 4000 feet long by 60 feet wide. Each runway is equipped with a 4-box visual approach slope indicator (VASI) and medium intensity runway lights (MIRL). Blue taxiway lights are also on the taxiways leading to the ramp areas. It is important to note that the bulbs themselves are not actually colored, but the elevated stand has a colored cover. Both ends also have runway end identifier lights that are out of service indefinitely, therefore will not be included in this study (T. Friend, personal communication, November 17, 2009).

Source: Google Earth, 2009

One of the main factors that sets Kent State University Airport apart from larger commercial service airports is that the runway lights are pilot controlled and only turned on when needed. This sets the energy use for these lights as being much less than the larger airports, therefore less energy is needed. Once activated, Kent State University's pilot controlled lighting system stays lit for 15 minutes and is then reset to the off position (T. Friend, personal communication, November 17, 2009).

According to Thomas Friend, airport manager for Kent State University Airport, the airport uses lighting with two different wattages, 30 and 45 watts. He could not tell the group how many of each there were, so for this case study the team is going to assume every light is 45 watts, except for the VASI system which each bulb runs at 200 watts.

Runway	38
Taxiway	110
Threshold	24
VASI	8
Total	180

Source: Kent State University Airport, 2009

From the numbers provided above, 172 lights run at 45 watts and 8 lights run at 200 watts. These numbers are the wattage the bulbs use per hour. Per hour at Kent State University the runway, taxiway and threshold lights use a total of 7,740 watts per hour. The VASI systems use a total of 1,600 watts per hour. The total for all lights combined is 9,340 watts per hour or 9.34 kilowatts.

Once again, with pilot controlled lighting being the ideal system so the lights at small airports are not always on, energy is not constantly needed throughout the night. Above, we presented the idea that each vehicle that travels over the device at 5 miles per hour will produce a usable 800 watts (.8 kilowatts) of energy that can be stored. For one hour of the lighting being activated, Kent State University would need to have at least 12 vehicles to power the system.

A hypothetical situation would be a bad weather day and night at Kent State University with one aircraft needing the lights every 15 minutes so the lights stay on continuously for the full 24 hours in a day. The total wattage for a full 24 hour day would be 224,160 watts or 224.16 kilowatts. This means that the airport needs 281 cars to travel over a device to power the lighting for a full 24 hour period. With multiple installations, the amount of cars needed would be divided by that amount of installations.

With the amount of cars needed to power the system, the team proposes to install a 2 device system and a fly-wheel capacity of 450 kilowatts. The team chose 450 kilowatts for redundancy and we elect to install the highest quality at $300 per kilowatt. For a full 24 hour day of lighting at 10.8 cents per kilowatt, the energy that is used costs $24.21.

The following table shows installation costs for the devices and flywheels versus the cost of the energy used per year at an average rate of 3 hours per day. The team chose 3 hours per day because of the pilot controlled lighting and an airport that does not see many operations during the night. The following table shows purchase, installation, and storage costs.

System Costs

Numbers used from Federal Energy Management Program Chart

MotionPower Device Purchase Cost (2x)	$4,000
Flywheels	
Purchase Cost	$135,000
Installation Cost	$13,500
Total Initial Capital Cost	$152,500
Flywheels	
Bearing replacement cost every 5 years = $10/kW	$4,500
Vacuum pump replacement cost every 7 years = $5 per kW	$2,250

Prepared by Tanner Johnson

Since existing space at the airport could be used, the group has not compiled building or storage space for the flywheels.

The following satellite image shows where the devices would be proposed to be installed and changes to traffic flow.

Prepared By Tanner Johnson

Our proposal team has come to the conclusion that the system is just not a cost effective solution to only power the airfield lighting. If the system was used to power all airport facilities it may be viable, but since our group focused on airfield lighting those results are unknown. Ultimately, cost is the deciding factor as there would no doubt be enough vehicular traffic to sustain the system.

Cleveland Hopkins International Airport - Cleveland, Ohio

Cleveland Hopkins International Airport is a large commercial service airport located in Cleveland, Ohio. The airport serves as a hub for Continental Airlines and serves nearly 12 million passengers annually. With that many people transiting through the airport, it is obvious that a lot of vehicle traffic comes with it. Whether it be taxi cabs, transit buses, employees, or people dropping off or picking up loved ones; the amount of vehicular traffic is substantial.

Our team set out and made Cleveland Hopkins it's main priority for a case study because from our research and knowledge on the system, we knew it had the potential to be ground breaking at larger airports.

At first, our team thought we would propose putting in as many devices as possible to maximize the system. However, we soon came to realize that it would not be necessary to do so.

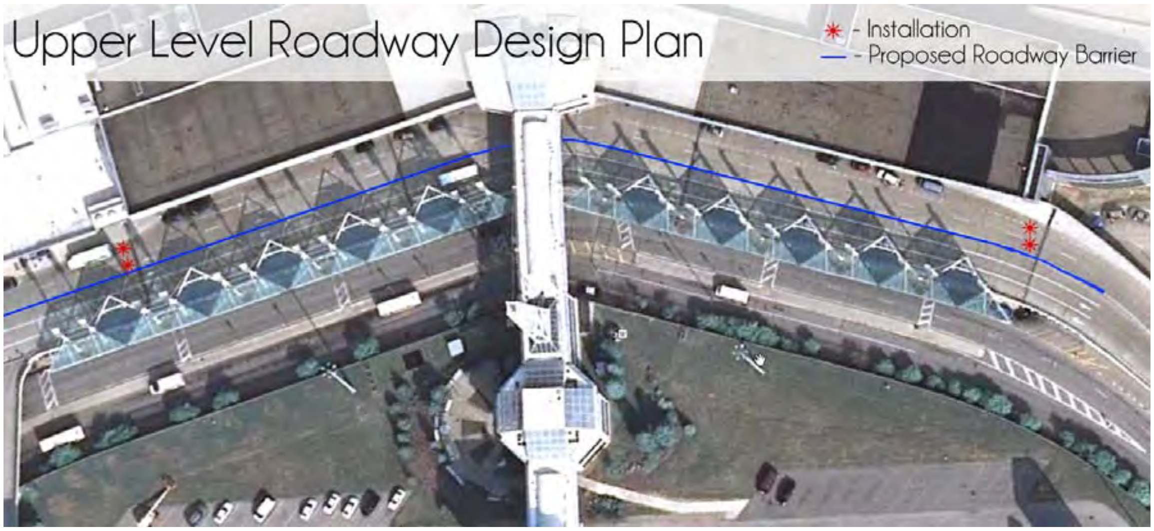
According to Cleveland Hopkins Deputy Commissioner Dennis Savas, the airfield is host to approximately 7,000 lights on the airfield. Mr. Savas provided the group with costs associated with running half the lights or all lights for a typical night of 8 hours and then for a bad weather day of 24 hours. The following table provides that information:

Cleveland Hopkins International Airport
Lighting Costs

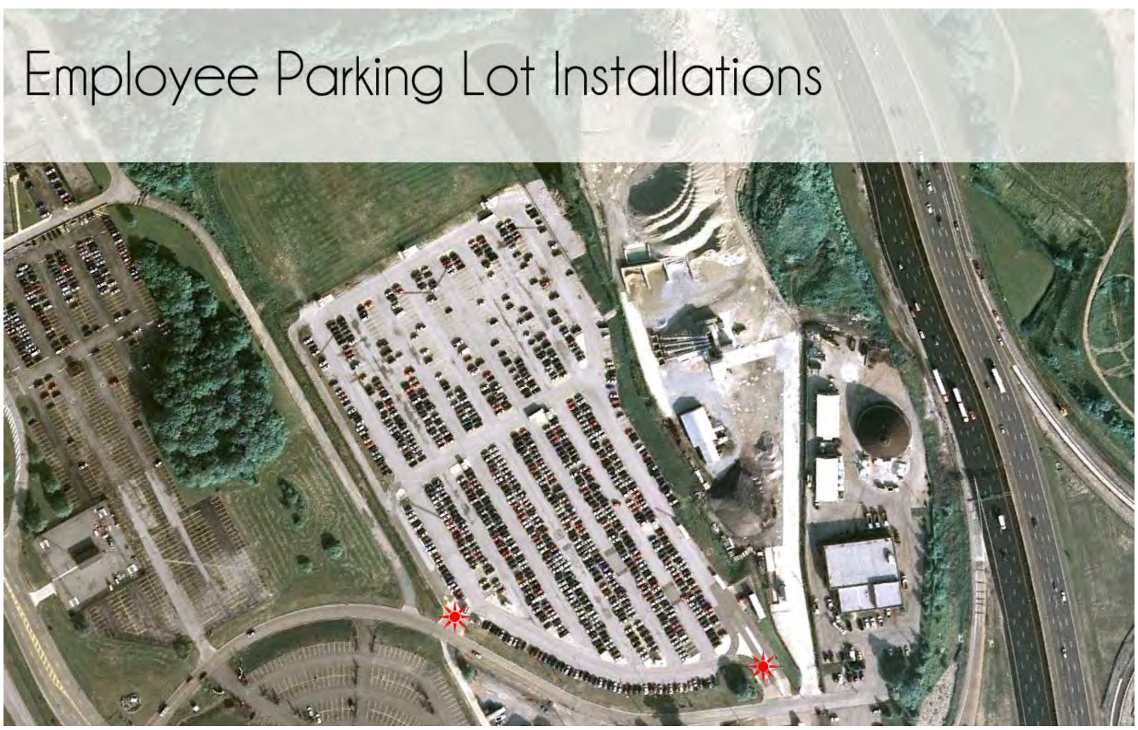
	Half Lighting 350kW/hr	Full Lighting 700kw/hr
8 Hours	$224	$560
24 Hours	N/A	$1,680

Prepared By Tanner Johnson

Our group spoke with the general manager of Standard Parking, the company in charge of the parking garages at Cleveland Hopkins International Airport. According to the information received, the parking garages see an average of 1,000 cars enter and 1,000 cars leave per day throughout the 3 parking decks at the airport. This gives us a total of 2,000 vehicles in the parking decks alone. This does not take into consideration vehicular traffic constantly moving about the terminal to pick up and drop off passengers or the employee parking lot. The following figures show potential and proposed installation points for the Motion Power devices to be installed, as well as changes to current traffic flow to maximize power output by vehicular traffic.



Prepared By Tanner Johnson



Prepared By Tanner Johnson

Our team proposes to install 14 of the devices to maximize harvesting potential. This includes installations at the employee parking lot, pick-up and drop-off points of passengers, parking lots and garages, as well as the airport hotel.

To determine how many vehicles were needed to power the lighting system, we needed to compute our figures based by the numbers acquired from Mr. Savas. To run half the lighting for a typical 8 hours a day for a whole year, it would take 1,022,000 kW. To run the full lighting system for 8 hours a day for a whole year it would take 2,044,000 kW. To run the full lighting system constantly throughout the year, a total of 6,132,000 kW of power is needed. While running it a full 24 hours everyday of the year is impractical because the weather is not that bad in Northern Ohio, it gives the group an idea of the maximum power the system could ever need to run. The following figure shows the amount of times a device needs to be driven over per day and year to provide enough lighting for the year. The number of compressions is a total for each device throughout the airport, each number does not represent compressions per device.

Cleveland Hopkins International Airport
Device Compressions Needed Per Year

Half Power / 8 Hours	Full Power / 8 Hours	Full Power / 24 Hours
1,277,500	2,555,000	7,665,000
3,500 / day	7,000 / day	21,000 / day

Prepared By Tanner Johnson

The numbers above should prove that the probability of this system working at a large airport is great. One has to realize that many vehicles will run over more than one device and since security reasons prohibit stopping at airports, many vehicles will drive in circles to find their party and run over multiple speed bumps as well. When you throw in the amount of bus and taxi cab traffic, the group has no doubt the system could very much work at a larger airport. Cleveland Hopkins has over 9,000 on-airport jobs. The group took a conservative estimate and saying half of that number drives and parks in the employee lot during a typical week and runs over a device when entering and then exiting the lot. This would give us 9,000 compressions totaling enough power to run for nearly 3 periods at half power. It is important to realize that the lighting system is not always on half or full power. It changes with the weather condition, so the group feels there would be enough vehicular traffic to provide power to the lighting system.

Energy storage is a huge deciding factor at a large airport. Since more energy is needed, the more the storage system will cost. We propose installing a system that can store 20,000 kW of power. Since on full power, lights will use 16,800 kW in a 24 hour period, we feel storage for a day plus some extra for redundancy should be more than enough. Cleveland Hopkins emergency generators will provide lighting for 24 hours in case of emergency (D. Savas, personal communication, November 16, 2009).

Costs are another large factor on whether or not the system will work. The following figure is a break down of what the system will cost to install and maintain.

System Costs
Numbers used from Federal Energy Management Program Chart

MotionPower Device Purchase Cost (14x)	$28,000
Flywheels	
Purchase Cost	$6,000,000
Installation Cost	$600,000
Total Initial Capital Cost	$6,628,000
Flywheels	
Bearing replacement cost every 5 years = $10/kW	$200,000
Vacuum pump replacement cost every 7 years = $5 per kW	$100,000

Prepared By Tanner Johnson

Depending on weather throughout the year, airfield lighting could cost anywhere between $81,760 to $613,000. The average of the two being $347,480. It would take nearly 20 years to break even if the energy was only used for airfield lighting. Our suggestion would be to use the energy for other uses besides airfield lighting when available to help cut other energy costs.

Our proposal team does feel that the system is a viable investment for a large airports future. While the initial investment is large and the payback might seem like a long time away; it is a step in the right direction to becoming a self-sustaining society.

Safety Risk Assessment

One of the largest goals of aviation is to promote safety throughout everything that takes place. Safety has been considered in the design and implementation of our system and has taken utmost precedence. Our team is proud to say that our system actually improves safety at the airports it would be installed at.

Our system comprises of a set of speed bump like devices that are installed on roadways that capture energy. Vehicles have the tendency to slow down when traveling over a speed-bump so placing them in areas of high traffic where slow speeds are necessary are ideal. It provides an extra level of safety for pedestrians traveling by foot on airport grounds.

Our system integrates into an already existing system, therefore there are minimal other concerns. Our team proposes that if the system were to go offline, that the electrical grid still have a connection to more conventional power production should the need arise and all gaps are covered.

Conclusion

Our group has concluded that the introduction of Motion Power technology at airports can be a viable long-term solution for alternative energy use. The technology is groundbreaking in that it uses an already existing source that is a constant at airports around the globe and puts it to use.

Our proposal includes two case studies based on using the system to power airfield lighting at a general aviation airport as well as a large commercial airport. Our group found our study on the smaller general aviation airport to be in-conclusive and we feel that is because we were only focusing on airfield lighting. The failure was not due to inadequate resources, but it's cost effectiveness so we feel other needs should be addressed such as lighting all airport facilities, rather than just airfield lighting.

The case study on the large commercial airport proved to be a success and provides an example for a viable long-term solution for energy production at airports. It not only provides large amounts of renewable energy, but an extra layer of safety of customers at airports. Initial costs are high, but in the long term airports will start profiting from the system. The great part about it is that the airport not only benefits, but the entire environment around the airport will benefit.

Our group worked with industry professionals to conduct our research and provide these case studies. As said above, the system may not work at every airport, but it is a great step forward in implementing renewable energy at airports across the world, by using a constant resource that is available everyday at the airports.

<u>Interactions with Industry Professionals</u>

Interacting with our group for a large portion of the project and providing technical specifications for the Motion Power system was Meetesh Patel, Chief Executive Officer of New Energy Technologies Inc. Dr. Patel is leading the charge with this innovative technology and was vital to our success in obtaining the information and bringing it forth to the aviation community.

Also helping our group was Cleveland Hopkins International Airport Deputy

Commissioner Dennis Savas. Mr. Savas is in charge of airport maintenance and provided us with information the number of lights and costs to operate those lights. This information was vital to us to come up with our feasibility study of the system at large airports.

Thomas Friend, airport manager at Kent State University Airport, was on hand throughout the project to help us with our case study regarding general aviation airports. He provided us with materials and resources on airport lighting at general aviation airports. His input on the matter and information we obtained helped come up with our solution for general aviation airports.

Lastly, Mr. McAndrews of Standard Parking at Cleveland Hopkins International Airport provided us with information on the amount of traffic at the airport on an average day. This allowed us to get an idea on what was going to be feasible and what would not be.

To help us better understand the physics behind the system, Dr. Stanley Chistensen, retired Physics professor at Kent State University; provided us with valuable information to lead us in the right direction in our research on the science behind it.

Appendix A - Contact Information

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Appendix B- Description of Kent State University and the Aeronautics Program

Established in 1910 as Kent Normal School by a statutory act of the State of Ohio, Kent State University has evolved into the second largest state university system in Ohio, the "birthplace of aviation," as well as the oldest and largest state university in Northeast Ohio with over 35,000 graduate and undergraduate students at Kent campus, the home of the Aeronautics Program, and seven regional campuses around Northeast Ohio.

The internationally known events of May 4, 1970, which involved the tragic loss of four students during a period of national unrest, have also influenced institutional purpose and contributed towards the evolution of Kent State University into a well known leading university in the United States and the entire world. In transcending these events, Kent State University has become renowned for the broad range and distinction of its academic programs, innovative research, collaborative partnerships, and broad-based policies on faculty work.

Kent State University ranks among the top 90 public universities in the United States, according to the Carnegie Foundation for the Advancement of Teaching. This Carnegie ranking places Kent State University in an elite group among the 3,900-odd colleges and universities in the United States. Kent State University's institutional purpose is fulfilled, in part, through providing numerous associate degree programs in various technical and business fields at the seven regional campuses, some 271 academic programs of undergraduate study, 214 academic programs at the master's level, and 59 areas of doctoral study in the Colleges of Architecture and Environmental Design; the Arts, Arts and Sciences; Business Administration; Communication and Information; Education; Nursing; and Technology, the academic home of the Aeronautics Program.

In addition to the preceding colleges, which are administered and headed by academic deans who report to the University Provost, Kent State University has the College of Research and Graduate Studies, College of Continuing Studies, the Honors College, as well as diverse centers, institutes, and research bureaus in specific areas, such as the world-renowned Glenn H. Brown Liquid Crystal Institute.

With Kent State Airport dating back to 1917, aviation education at Kent State University has evolved into a nationally renowned and accredited degree program with areas of specialization in Aeronautical Studies, Aeronautical Systems Engineering Technology, Aircraft Maintenance Technology, Air Traffic Control, Aviation Management, and Flight Technology. Flight training is provided with Kent State University's fleet of 25 single- and twin-engine airplanes under 14 CFR Part 141.

Under the leadership of Dr. I. Richmond Nettey, then Senior Academic Program Director of Aeronautics and now Associate Dean of the College of Technology, the Aeronautics Program became the first and only aviation program to become accredited by the Aviation Accreditation Board International (AABI) in Ohio on 16th February 2006. In fall 2007, the FAA authorized the only Air Traffic–Collegiate Training Initiative (AT-CTI) program in Ohio at Kent State University. At present, the Aeronautics Program at Kent State University remains the first and only accredited aviation program in Ohio and the first and only FAA approved CTI program in Ohio – birthplace of aviation.

<u>Appendix C- Description of Non-University Partners Involved</u>

There were no non-university partners associated with the production of this submission.

Appendix E – Evaluation of Educational Experience

Student Evaluations

Rachel Aungst:

The FAA design competition gave me an outstanding learning experience, giving me insight into information I would have never researched or learned about in the first place. The project we developed might in fact one day impact aviation, and it was great seeing our contribution towards its development.

As a team our group underwent various challenges, mainly deciding what our topic would be. We eventually choose our topic based on the fact that we thought it would provide the biggest impact and benefit towards the current aviation industry. It was also a challenge finding all the information we needed, but we gained the knowledge from various experts throughout the industry. The knowledge we gained from these experts was very crucial in presenting our project as a whole; it was in a sense the foundation of our project.

After completing the project I gained better skills that will helpfully benefit me later on in life. Some of these skills range from teamwork, to better research and development. People in the aviation industry constantly use these skills in their day to day work experience. By harnessing these skills now, I can only see them improving my work experience in the long run.

Steve Egert:

Yes, the FAA Design Competition provided a very meaningful learning experience. I have learned a great deal through our research and case study. I also believe that our research will have a positive impact in the aviation community and world as a whole. One of the largest challenges was researching a very new technology; it was somewhat difficult to find information, especially because some of the technical data was proprietary information.

To develop our hypothesis, we broke the design into different components and studied each step in the energy making process, from how much the kinetic generator could produce, to how much traffic flow an airport has. As well as energy storage and power consumption with and without an LED lighting system.

Industry participation was very important to our project. Not only from the aviation industry itself, but a lot of our help was found in other industries.

I have learned about the airport lighting system, and how much power it takes to power an airport as well as how much traffic flows through airport parking decks and drop off areas and the amount of energy potential this traffic has. I have also learned through my colleague's research a lot about this new kinetic generator and how it works, as well as energy storage. I believe that this project helped me understand something very new and made me see the large potential this has for saving a great deal of money for airports and also slightly reducing carbon emissions by harnessing energy that is otherwise mostly wasted.

Tanner Johnson:

As group leader, the FAA Airport Design Competition provided a very meaningful and valuable experience to my college career. Not only did it allow me to learn about airports as a whole, it allowed me to investigate the ever changing world of energy and do some research behind it. Anytime you can be exposed to new information, it is a great thing that will only open up doors throughout your life.

The most significant challenge had to be researching a technology that does not really exist yet. Since the technology we chose is still in the research phase, it was very hard to get the information we needed. The company doing the research was very hesitant to provide us with this proprietary information.

The expert participation really opened up a new experience for not only myself, but my group. As group lead, I felt it was important to delegate the tasks so that everyone in the group got to speak with a professional to obtain information for this project. Everywhere you go, people will tell that networking is just as important as your skills are for future jobs and I could not agree more.

The main thing I learned from this project is time management and to strive for the best. Our group was the largest at our university and at times, it was hard to handle and delegate tasks to certain people. With this being such a large project and then piling on a full time job, as well as a full time college schedule; time management was absolutely vital to partaking in this competition.

Chris Kowalski:

When asked to reflect back on our design concept for the Federal Aviation Administration I can only think of many great things. This competition brought out the best in our group, and involved both the cooperation and fortitude of each individual team member to accomplish all of the tasks at hand. With our leader Tanner Johnson in the lead we all pulled it together quickly and efficiently. This competition provided an excellent learning experience for me because of the nature of the project. It involved a lot of outside field work and individual research that provided and excellent hands on approach to learning new material and applying it to our daily lives.

As you know there won't always be a picture perfect scenario, and our group can account for this. With many people, comes many personalities, and as we know conflict might in sue. Thankfully in our group all of us worked together towards the common goal and put our differences beside us. We also overcame our individual struggles in the researching phase of our project. With our leader at the helm we all worked on our piece of the puzzle to accomplish our final piece. When we were brainstorming for an idea for the design competition we all were coming up with ideas and thinking about the validity of the idea and whether or not it could be a solid enough topic for research. When presented with the idea of the speed bump generators it seemed like one of the best and newest ideas on the market because of its safety and revenue producing capabilities. I believe that without participation in the industry this idea would have been impossible. Research can only get you so much information, and sometimes that field work provides a different approach on learning the material. Along with this new aspect on learning you also encounter expert advice on the topics as you talk to some of the people in the industry.

In a whole, this project provided an excellent learning experience for me. It gave me better research skills along with better skills while working in a group environment.

These skills are crucial in a individual’s life and this project provided a backbone for study. This design competition, I will gladly say, did provide me skills and knowledge to become a successful person in the aviation industry.

Britney Serenari:

The Federal Aviation Administration Design Competition provided a meaningful experience by allowing me to help develop a new technology for the industry in which I plan on making a career in. The project was something I would expect to work on at an actual job, not in a college class.

The biggest challenge was trying to get in contact with other companies and employees at airports around the state. However all of the group members were persistent and we eventually heard back from them and received a lot of important information. The information from actual professionals in the industry is the best and most useful information out there. These people work in the aviation industry on a daily basis and have hands on experience.

Another big challenge during this project was deciding on the topic. The whole group had to contribute by doing a considerable amount of research into different smaller topics before we could actually put the whole idea together. This project taught me how to work in a large group, how to coordinate ideas and experience with in depth research.

Ben Spratt:

The FAA Design Competition provided a valued learning experience for myself as a writer, researcher, and designer.   It enabled me to look into new technologies that can be used in our future and implement them into a feasible and practical use that will further the aviation industry. The challenges involved were primarily in the logistics of organizing group meetings and formatting our research. In order to complete our paper as a group it was imperative that full cooperation and one hundred percent effort was put into completing a very concentrated and specific goal that is our research paper. As a group, we had to form our hypothesis first by storming for an idea that would benefit the aviation industry and make the airport infrastructure more efficient. Eventually we decided the "speed bump" concept would greatly benefit any airport it would be established.

I would agree that this project helped to stress the importance of being able to work within a group to accomplish a similar goal, is a very valuable and under-rated experience that many take for granted. After seeing the end results of our project it is clear that team work and effort went into making a great idea for future airport design concepts. Collectively we established within ourselves the ability to rely on one another, act professionally, and put fourth great effort to see that we could deliver an outstanding idea for the future of the aviation world.

David Wiggins:

The Federal Aviation Administration competition provided a meaningful group experience The Federal Aviation Administration design competition allowed me to learn much valuable information regarding our current and future aviation industry. Discussions with professionals gave me a grasp on real life scenarios and how different aspects of the environment can play a role in the use of airport lighting. Overall, this was competition allowed me to learn much valuable information that could potentially be used in the future aviation industry.

Stuart Young:

Participating in the FAA Design competition was very valuable learning experience. It helped to build interviewing skills and team based interaction. The group project resembled more of a professional and work type environment.

One of the major issues that surfaced with in the group was the topic selection. Many ideas were brought to the table and each had a valuable argument. Our decision was narrowed to the practicality, benefit return, and environmental impact. Including multiple ideas was eventually ruled out in order to provide a thorough evaluation of the chosen topic.

The participation of professional insight was priceless. The professional assistance that was offered provided somewhat of a template that we strived to emulate to provide a quality report. Projects of this caliber are invaluable to any student. They provide a gateway to professional insight, and inspire such professionals to take interest in sharing their world.

Faculty Advisor Evaluation

Dr. Isaac Richmond Nettey:

As the largest group from Kent State University, this group of eight students managed to come together successfully to produce important work in the innovative area of harvesting kinetic energy from vehicular traffic at airports. Even more importantly, the group's work on this important project provided individual benefit for each team member through enhanced learning that transcended normal course lectures, class discussions and scheduled assignments in the Airport Management course during the fall 2009 semester.

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