SOFIA UNIVERSITY
Faculty of Economics and Business

SOLAR ROADWAYS

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Subject: Information Systems and Technologies

SOFIA 2015

Contents

Summary

Today more than ever we see and feel the consequences of the climate change. From melting ice caps, to the rising sea levels, weather changes and temperature rises, there are more and more natural disasters that we learn about from the news. People have come up with many different kinds of methods and solutions in order to fight these changes but not many of them are as effective as needed. Thus we need to step on more complex approaches and more general and interlinked solutions for solving the pressing problems.

There is, however, a technology that can help us to normalize our climate, but also help in our daily lives. We offer Smart Solar Roadways as one possible solution that can drastically change our way of living for better. Smart Solar roads combine different solutions in one – it can help us to improve energy production from solar panels, to collect and distribute rain water, to provide a digital platform for Smart city, to facilitate emerging electric cars and driver-less cars and much more! We believe that this approach can offer many additional benefits to citizens, to the environment and will contribute for sustainable development as a whole.

Some may call it even the next “Industrial revolution”, we like to think of it like a better tomorrow.

Introduction

The Earth's climate has changed throughout history. Just in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7,000 years ago marking the beginning of the modern climate era — and of human civilization.

Nowadays climate change is changing our economy, health and communities in diverse ways. Scientists warn that if we do not aggressively curb climate change now, the results will likely be disastrous. Carbon dioxide and other global warming pollutants are collecting in the atmosphere like a thickening blanket, trapping the sun's heat and causing the planet to warm up.

Although local temperatures fluctuate naturally, over the past 50 years the average global temperature has increased at the fastest rate in recorded history. Scientists say that unless we curb the emissions that cause climate change, average U.S. temperatures could be 3 to 9 degrees higher by the end of the century.

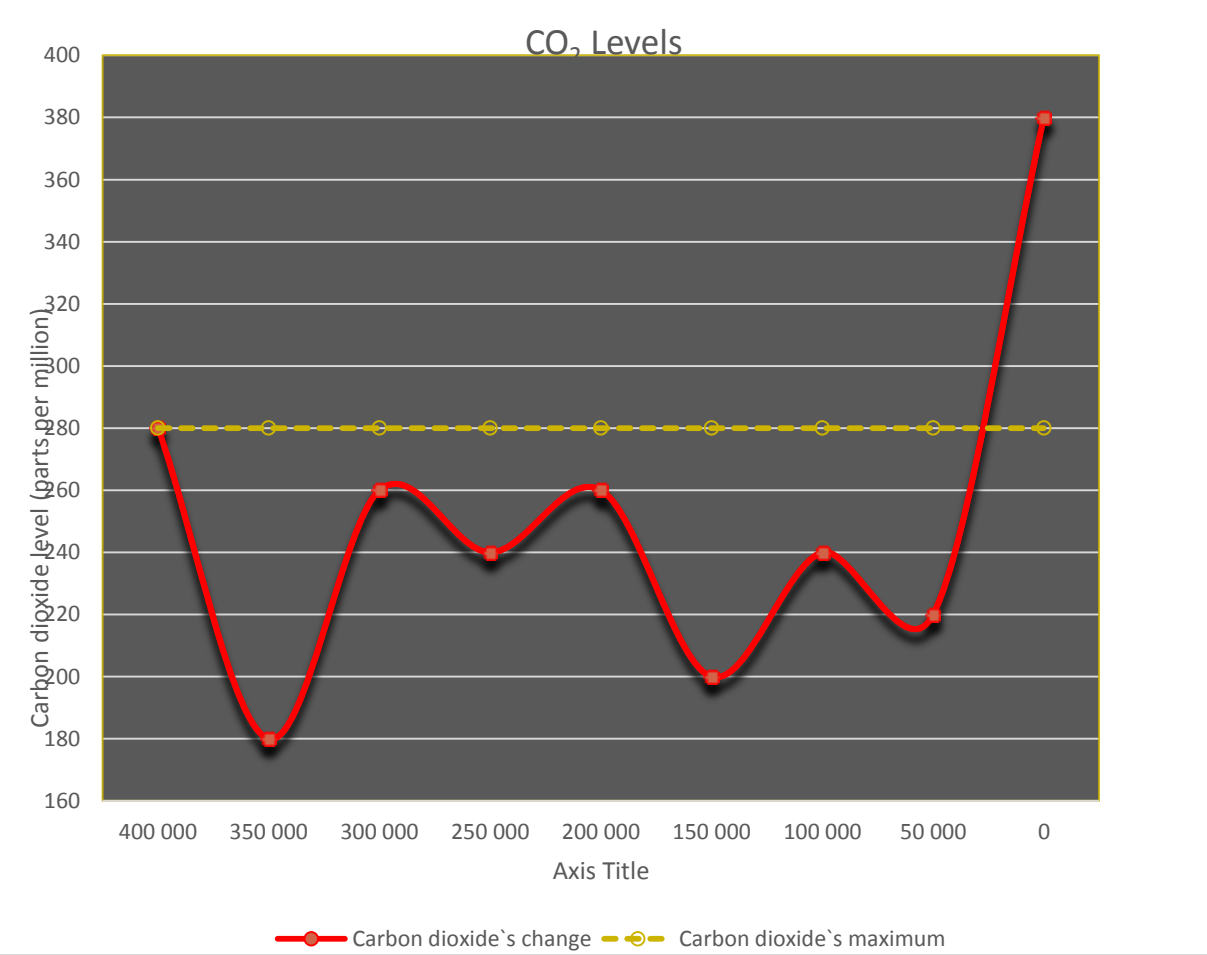
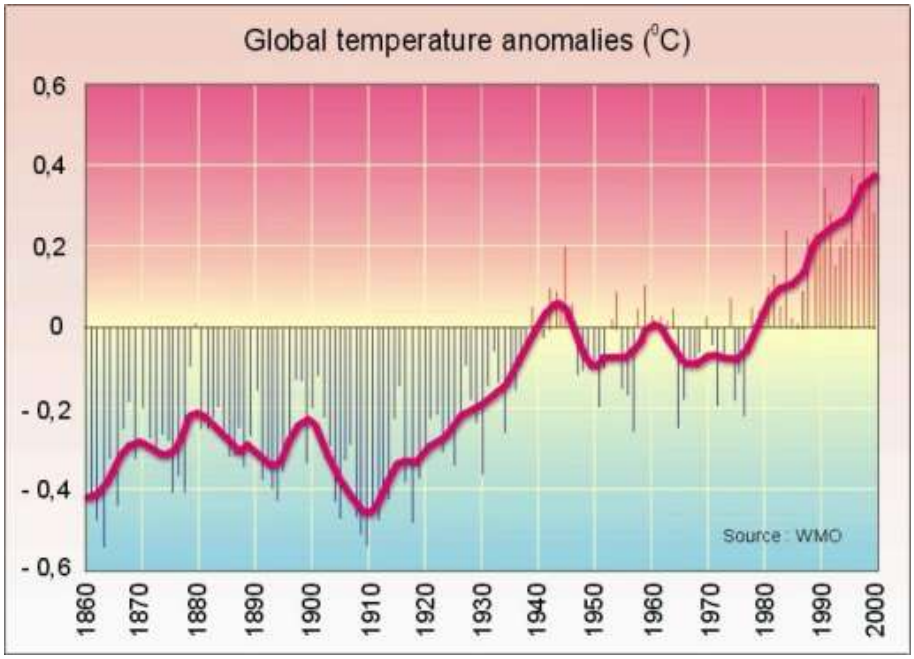


FIGURE 1 DYNAMICS OF CARBON DIOXIDE

Global warming is already causing damage in many parts of the world, including Europe and United States. Some statistics show that in 2002, Colorado, Arizona and Oregon endured their worst wildfire seasons ever. The same year, drought created severe dust storms in Montana, Colorado and Kansas, and floods caused hundreds of millions of dollars in damage in Texas, Montana and North Dakota (nrdc.org).

Since the early 1950s, snow accumulation has declined 60 percent and winter seasons have shortened in some areas of the Cascade Range in Oregon and Washington.

Nowadays the facts about global warming come in increasing speed. Based on the NAOA statistics[1], the combined average temperature over global land and ocean surfaces for September 2015 was the highest for September in the 136-year period of record, at 0.90°C (1.62°F) above the 20th century average of 15.0°C (59.0°F), surpassing the previous record set last year in 2014 by 0.12°C (0.19°F). Moreover, it is proven that this is the fifth consecutive month a monthly high temperature record has been set and is the highest departure from average for any month among all 1629 months in the record that began in January 1880. The September temperature is currently increasing at an average rate of 0.06°C (0.11°F) per decade.



[1] National Center for Environmental Information - https://www.ncdc.noaa.gov/sotc/global/201509

Anti-global warming measures

One of the key issues for global warning are the increased levels of CO_2. Carbon dioxide removal projects seek to remove greenhouse effects from the atmosphere. Methods include those that directly remove such gases from the atmosphere, as well as indirect methods that seek to promote natural processes that draw down and sequester CO_2. But they are fighting the symptoms, not the source of the problem. Not that they are not effective but for a major and long-term change, we should invest in an idea with a different approach.

Many experts face two main industries largely influencing the production of CO_2 – car transport and energy production. Thus the biggest impact will have the technologies reducing pollution from vehicles and power plants. Right away, we should put existing technologies for building cleaner cars and more modern electricity generators into widespread use. We can increase our reliance on renewable energy sources such as wind, sun and geothermal. And we can manufacture more efficient appliances and conserve energy.[2]

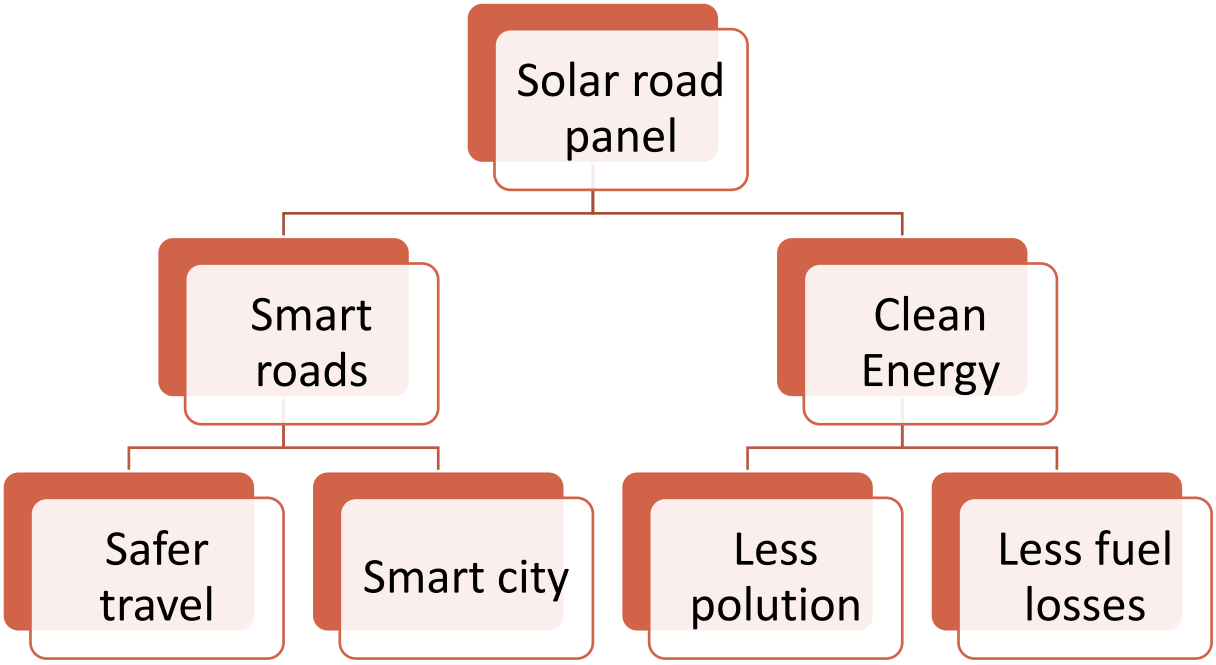
Fortunately, there are technologies today that may help solving the global warming problem. But going further there can be more technological solutions that can help us to develop further.

[2] http://www.nrdc.org/globalwarming/f101.asp

Solar Roadways

Our idea is to increase awareness and to step on further work and further development of the concept of Solar Road technologies, developed by Solar Roadways Inc[3]. Solar Roadways Incorporated is a startup company based in Sandpoint, Idaho, that is developing solar powered road panels. Their technology combines a transparent driving surface with underlying solar cells, electronics and sensors to act as a solar array with programmable capability.

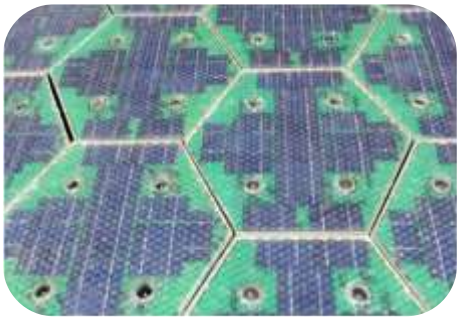
The company was founded by Scott and Julie Brusaw in 2006. The company envisioned replacing asphalt surfaces with structurally-engineered solar panels capable of withstanding vehicular traffic. The proposed system would require the development of strong, transparent, and self-cleaning glass that has the necessary traction and impact-resistance properties.



The idea is not only to collect solar energy and rain water but to also make smart roads. Roads that illuminate themselves at night, heat themselves in the winter and are easily programmable to direct drivers. But much more, the potentials of the technology allow us to further contribute to some more green concepts as smart city, the connected things and IoT, smart gird applications, hybrid and electric cars and other. Therefore, from the initial idea to

[3] http://www.solarroadways.com/intro.shtml

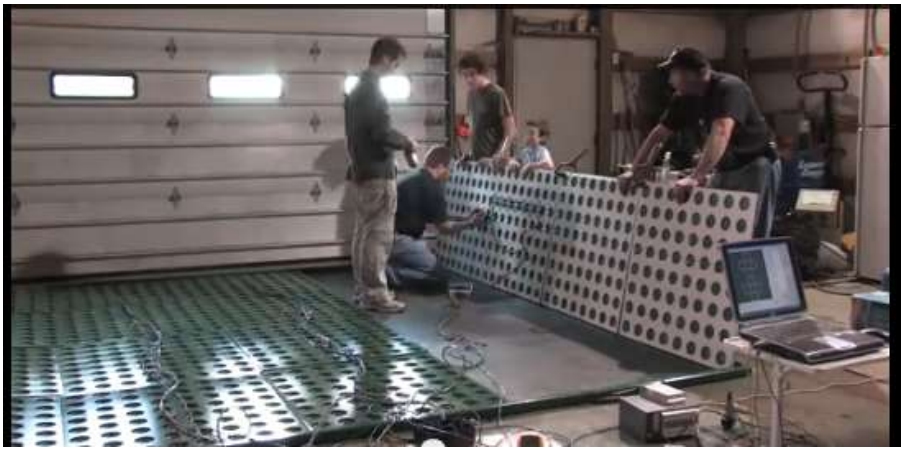
put the normal solar panel to a better and much more practical use, there can be derived many new benefits.



Solar road panel

Panels melting snow

The panels are power independent, meaning that they recharge themselves. But the excess energy can be exported directly to the electrical power grid.



Are the solar panels practical?

The short answer is yes!

People may ask themselves "**Isn't glass softer than asphalt**?" and the answer is "no". This table shows object ranked according Mohs' Scale of Hardness.

0,7	Graphite
1,3	Asphalt
3,0	Copper Penny
5,5-6	Knife Blade
5,5-6	Plate Glass

By comparison, it is asphalt that is soft. But Solar Road Panels are made of tempered glass and tempered glass is 4-5 times stronger than non-tempered glass.Further testing has revealed that the surface of the panel road is less slippery than a normal road.

And they are easy to maintain. During winter, they melt the snow off them, making it safe for driving but also possible to collect sunlight.

Water collection and treatment:

The rain or snow water can flow off of the road and through the grates to a filtration area. The water is gravity fed through filtration socks (or other treatment options that customers may wish to add) and into a storage tank below the frost line. The water can be discharged into an existing drainage system or it can be pumped from the storage tank in either direction along the road. Destinations may include a bigger filtration facility, an aquifer, or an agricultural center.

But nothing lasts forever, so in a case of malfunction or any sort of damage on one or more panels, the other panels can report the problem. Each of the panels contain their own microprocessor, which communicates wirelessly with surrounding panels.

A single operator could load a good panel into his/her truck and respond to the scene. The panel could be swapped out and reprogrammed in a few minutes. The damaged panel would then be returned to a repair center.

Repair will be much quicker and easier than our current maintenance system for asphalt roads. We've learned that in the U.S., over $160 billion is lost each year in lost productivity from people sitting in traffic due to road maintenance.

Some other implications:

In future, solar panels can also be used to charge electric cars. They can be recharged at any conveniently located rest stop, or at any business places that incorporates Solar Roadways Panels in their parking lots for. Owners can plug-in their cars in and recharge while they're eating or shopping. Engineers are even investigating ways to use mutual induction to charge EVs while they are driving down the Solar Roadway.

By the way, using electric cars would eliminate most of the other half of the cause of global warming and could virtually wean the world off oil entirely.

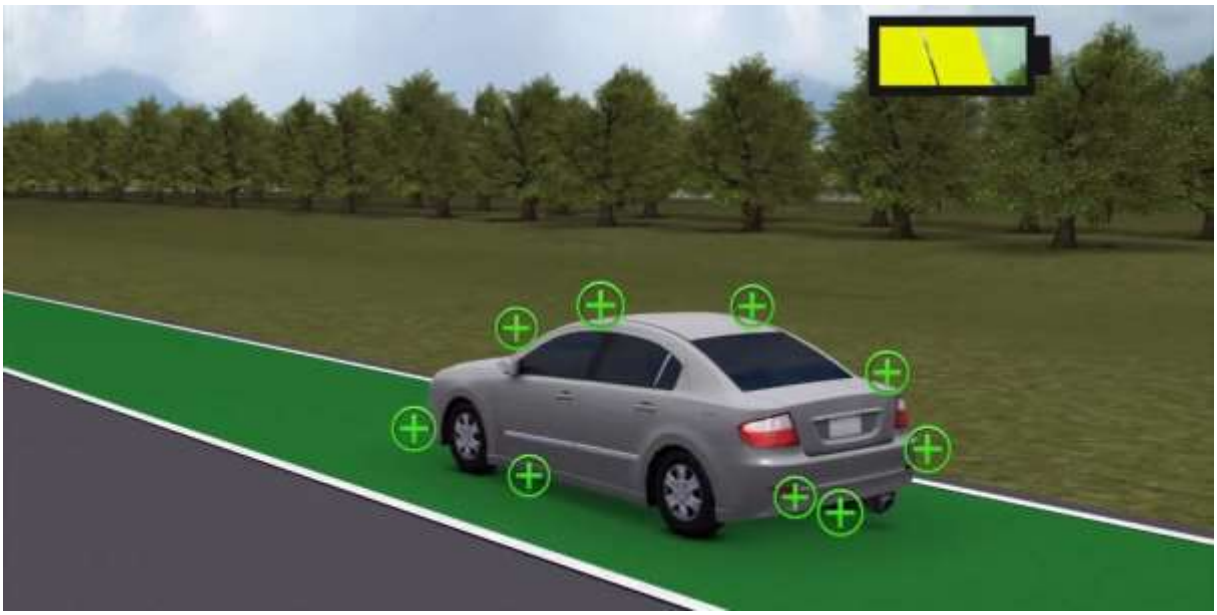
EXAMPLE OF A SMART ROAD

SMART ROADS CAN GIVE INSTRUCTIONS

THEY CAN ALSO WARN DRIVERS OF OBSTACLES ON THE ROAD

Electric cars

The panels are power independent, meaning that they recharge themselves. But the excess energy can be exported directly to the electrical power grid. They can also be used to charge electric cars. They can be recharged at any conveniently located rest stop, or at any business places that incorporates Solar Roadways Panels in their parking lots for. Owners can plug-in their cars in and recharge while they're eating or shopping. Engineers are even investigating ways to use mutual induction to charge EVs while they are driving down the Solar Roadway. By the way, using electric cars would eliminate most of the other half of the cause of global warming and could virtually wean the world off oil entirely.



CAR CHARGING WHILE DRIVING ON THE ROAD

Smart GRID

With the Solar Roadway, the road can become the power grid, eliminating the need for unsightly utility poles and relay stations. Power is generated everywhere - every road, parking lot and driveway. No more power outages, roaming or otherwise. The Solar Roadways generates "secure" energy; it can't be deliberately shut down. Not by terrorists, not by power companies, it simply can't be shut down. A smart grid would be more automated and more "self-healing," and so less prone to failures. It would be more tolerant of small-scale, variable power sources such as solar panels and wind turbines, in part because it would even out fluctuations by storing energy.

The money question and business models

According to company managers, it's too early to calculate cost information. Nowadays the project is under development and in testing phase.

The only project currently installed is a prototype parking lot, which consists of 108 prototype Solar Road Panels in Sagle, Idaho. The town of Sandpoint, Idaho has the first public projects already lined up for solar panel use. The current tests are for developing five pilot projects on non-critical applications such as downtown sidewalks, a train station and part of an airport tarmac. All the year-round data about performance will be streamed to the public for monitoring. The second application could be on tribal lands, which have their own rules governing roads.

However, there can be enumerated a number of benefits for developing smart business models. As the panels can generate not only their own electricity but their own money as well, their implementation will depend largely on government regulations and public support.

The road incomes can be generated through:

. Through the generation of electricity

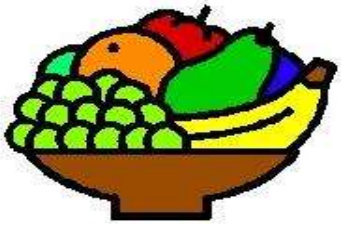
. By transporting cleaned storm water to municipalities or agricultural centers

. By leasing the roadside conduit (Cable Corridor) to entities such as utility companies, telephone, high-speed internet, cable TV, etc.

. By selling advertising in parking lots with the configurable LEDs

. By charging people or companies to recharge their electric vehicles

There can be developed further business models for Smart road implementation, maintenance and use. Thus, we strongly believe that more projects for Solar roads can provide further opportunities for finding the right manner to support this tremendous “paradigm change”.

Current roads	Solar Roads
	
Hard surface for vehicles	Hard surface for vehicles
	Roads remain snow/ice free
	Generates clean, renewable energy
	Embedded LEDs provide safer nighttime driving
	Impervious to potholes
	Modular for ease and speed of repair
	Can treat, store, and transport stormwater
	Provides safe haven for power and data cables
	Decentralized power system
	Autonomous vehicle infrastructure
	Electric vehicle infrastructure
	Cell phone "dead spots" eliminated
	Road can warn drivers about dangers ahead
	Modernized traffic monitoring systems
	Significantly cuts greenhouse gases
	Reduces dependence on fossil fuels
	Lowered accident rates due to additional safety features
	Protects wildlife
	Could promote reduction in auto and health insurance
	National security
As you can see, some of the benefits of Solar Roadways are very concrete. Others are more abstract and people will place different values on them depending on their belief systems: how much does an individual value safety, convenience, beauty, environment, or "the cool factor"?	

Controversies

Although financed on several rounds by US government agency's grants and then collecting about 2.2 mio USD through Indiegogo crowdfunding campaign, the company is subject of many skeptical discussions. One article from 2014[4] just make a review of some of the most popular ones:

Road safety

Driving or walking on a textured glass surface is completely different than asphalt, which is designed specifically to increase traction. Solar Roadways says that it has tested its wet textured glass surface at a university lab and has shown that it can stop a vehicle going 80 miles per hour within the required distance. However, more testing is needed;

Road durability

[4] http://www.greentechmedia.com/articles/read/Department-of-Transportation-Official-Discusses-Solar-Roadways

Durability is also not fully proven and tested on practice, but only through a 3-D modeling analysis. Therefore, additional implementation and testing can prove the durability of the solar panels.

Available materials and equipment

During the prototype phase, company had some problems with materials and specific equipment delivery, that were difficult to procure. But these issues with the prototype could be overcome with larger-scale automated production. Now the solar panels are broken down into four sections for easier manufacturing and then assembled onsite. With solar technologies advancements, the performance of the solar cells themselves can be further improved.

Undeveloped business case

The Solar Roadways declared that it would simply be a manufacturer and let service providers or governments figure out how to finance and build projects. Thus developing business models through complicated network of private, state and federal rules (US) for transportation planning, and involving revenue streams in the model can bring the project on practice.

Conclusion

The solar panel road panels and the smart roads that come with them can make a major environmental as well as social difference.

They can offer new major source of clean energy which on its own will greatly impact the climate in a positive way.

But smart roads can also optimize our traffic so that work productivity is not lost, fuel is preserved and many accidents are avoided.

These panels may be a big investment at first but they will, without a doubt, pay off in the long term, not only financially but environmentally as well.

As a conclusion, we would quote Scott Brusaw words:

Everyone has power. No more power shortages, no more roaming power outages, no more need to burn coal (50% of greenhouse gases). Less need for fossil fuels and less dependency upon foreign oil. Much less pollution. How about this for a long term advantage: an electric road allows all-electric vehicles to recharge anywhere: rest stops, parking lots, etc. They would then have the same range as a gasoline-powered vehicle. Internal combustion engines would become obsolete. Our dependency on oil would come to an abrupt end.

It's time to upgrade our infrastructure - roads and power grid - to the 21st century.

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