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A BRIEF OVERVIEW ON SOLAR ROADS AND ITS NECESSITY

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Abstract: Solar Roadways is an inspiring piece of technology that could become a reality and practical in the near future. What makes Solar Roadways interesting is that it may solve many problems that have been piling up from the past and some current issues. Such as, energy consumption, climate change and road hazards, which can be improved by this future technology. Using the surplus energy from Solar Roadways, we can significantly reduce the amount of greenhouse gases produced by not relying on non-renewable resources. In this way, we can reduce our carbon footprint and will help reduce the progression global warming. Solar Roadways is a technology entering the later phases of development, constantly improving efficiency and fine-tuning the details. Though the name implies that these are just for roadways, however, these Solar Road Panels can be installed on roads, parking lots, driveways, sidewalks, bike paths, playgrounds literally any surface under the sun.

Keywords **-** Solar road, Greenhouse gases, Global warming & Renewable energy**.**

I. Introduction

A. Solar Energy

Solar energy is the light and radiant heat from the Sun that influences Earth's climate and weather and sustains life. In the environmental context, it is also used to refer to the process of generation of electricity by tapping the solar energy.

Solar energy, radiant light and heat from the sun, is harnessed using a range of ever-evolving technologies such as solar heating, solar photovoltaics, solar thermal electricity, solar architecture and artificial photosynthesis.

Solar technologies are broadly characterized as either **passive solar** or **active solar** depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

B. Photovoltaic cell:

Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Mainstream materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the increased demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. A photovoltaic system (informally, PV system) is an arrangement of such cells designed to supply usable electric power for a variety of purposes, using the Sun (or, less commonly, other light sources) as the power source as shown in figure1.

Fig.1:A Photovoltaic Cell

C. Need of Solar

While a majority of the world's current electricity supply is generated from fossil fuels such as coal, oil and natural gas, these traditional energy sources face a number of challenges including rising prices, security concerns over dependence on imports from a limited number of countries which have significant fossil fuel supplies, and growing environmental concerns over the climate change risks associated with power generation using fossil fuels. As a result of these and other challenges facing traditional energy sources, governments, businesses and consumers are increasingly supporting the development of alternative energy sources and new technologies for electricity generation. Renewable energy sources such as solar, biomass, geothermal, hydroelectric and wind power generation have emerged as potential alternatives which address some of these concerns. As opposed to fossil fuels, which draw on finite resources that may eventually become too expensive to retrieve, renewable energy sources are generally unlimited in availability.

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Solar power generation has emerged as one of the most rapidly growing renewable sources of electricity. Solar power generation has several advantages over other forms of electricity generation.

D. Theory on Solar Roadways

Years ago, when the phrase **"Global Warming"** began gaining popularity, we started batting around the idea of replacing asphalt and concrete surfaces with solar panels that could be driven upon. Now it's time to gear up for manufacturing upon. We thought of the "black box" on airplanes: We didn't know what material that black box was made of, but it seemed to be able to protect sensitive electronics from the worst of airline crashes. Suppose we made a section of road out of this material and housed solar cells to collect energy, which could pay for the cost of the panel, thereby creating a road that would pay for itself over time. What if we added LEDs to "paint" the road lines from beneath, lighting up the road for safer night time driving**?** What if we added a heating element in the surface (like the defrosting wire in the rear window of our cars) to prevent snow/ice accumulation in northern climates**?** The ideas and possibilities just continued to roll in and the Solar Roadway project was born.

E. Definition of Solar Roadways

A solar roadway is a road surface that generates electricity by solar power photovoltaic cells as shown in figure2. One current proposal is for 12 ft x 12 ft (3.658 m x 3.658 m) panels including solar panels and LED signage that can be driven on. The concept involves replacing highways, roads, parking lots, driveways, and sidewalks with such a system. A layer of embedded LEDs will be used to create traffic warnings or crosswalks, and excess electricity could be used to charge electric vehicles or routed into the power grid. The electrical components will be embedded between layers of extremely durable, textured glass.

Fig 2:Solar Highway Consisting of PhotoVoltaic cells

E. Indian Road Network

India has a road network of over 5,472,144 kilometres (3,400,233 mi) as on 31 March 2015, the second largest road network in the world. At 1.66 km of roads per square kilometre of land, the quantitative density of India's road network is higher than that of Japan (0.91) and the United States (0.67), and far higher than that of China (0.46), Brazil (0.18) or Russia (0.08).However, qualitatively India's roads are a mix of modern highways and narrow, unpaved roads, and are being improved. As on 31 March 2015, 61.05% of Indian roads were paved

Table I Road Survey Of India (As On 2015-Source: Tourism statistics 2015)

S No	Road Classification	Total Distance (Kms)
1	National Highways	79116
2	State Highways	169227
3	Other PWD Roads	1066747
4	Panchayat Raj Roads	1725318
5	Rural Roads	3159639
6	Urban Roads	310955

II. Literature Review

C.W. Cheng et al (2009) described that the optical efficiency of light emitting diode (LED) has exceeded 72 lm/W in 2006. This implies that energy can be saved about 75%, as compared to mercury lamps widely used in roadway lighting. In some remote areas where the grid power cannot reach, independent solar-powered lighting using high-power LED provides a promising solution. However, the cost of solar photovoltaic device may cause the application of solar-powered LED roadway lighting to be not economically feasible. He investigated the design of the solar-powered LED roadway lighting using high-power LED luminaire (100 W) and estimates the installation cost for a 10 km highway with 2 lanes. LED luminaries are installed on both side of the road with staggered arrangement. The pole distance is 30 m. The cost comparison of LED lighting using grid and solar power with the conventional mercury lamps was carried out. It shows that the installation cost is 22 million USD for LED powered by grid power and 26 million USD for solar-powered. The total installation cost of conventional mercury lighting is 18 million USD. The excess cost of LED mainly comes from the cost of LED lamp and solar PV. But, the cost of power generation and electrical transmission line can be greatly reduced since about 75% energy was saved for LED. This permits the use of smaller copper wire and shorter line length for solar-powered system which in turn saves installation cost. The payback time for the excess investment of LED is 2.2 years for LED using grid power and 3.3 years for LED using solar power.

Kleomenis Kalogeropoulos et al (2013) studied the movement of vehicles on the roads, during summer, can sometimes hide risks involved in direct sunlight. In places where the relief is complicated, road network usually consists of a road complexity. This complexity in conjunction with the motion of a vehicle on a road and the position of the sun at the same time may result in the loss of vision in some sections of the road. They described a GIS-based methodology of the spatiotemporal analysis of this phenomenon. Thus, for a given study area, in this case of Milos Island, Greece, the geometry of the road network, the terrain morphology and the solar radiation (in specific time intervals during summer) have been analyzed. The result of this procedure is a map illustrating the sections of the road where direct sunlight includes a serious amount of risk for the drivers. Applying this methodology for long periods of time may lead to prevention policies adoption related to accidents of direct exposure to sunlight. Moreover, this methodology could be an additional module in car navigation systems.

Kulkarni et al (2013) proposed Solar Roadway is a series of structurally-engineered solar panels that are driven upon. The idea is to replace all current petroleum-based asphalt roads, parking lots, and driveways with Solar Road Panels that collect energy to be used by our homes and businesses. The renewable energy generated by solar road panels will replace the current need for fossil fuel which is used for generation of electricity as also oil used for driving the vehicles which in turn reduces the greenhouse gases nearly to half. The implementation of Solar Roadways Technology will create the clean energy boom, spurring private investment on a massive scale, with relatively little extra cost. An intelligent highway infrastructure and a self-healing decentralized power grid that will eliminate our need for fossil fuels. Solar Roadways will also features wildlife preservation, the elimination of impervious surfaces, law enforcement, DUI detection, counter-terrorism, etc.

Harshil Shah et al (2014) identified that the world is facing problem of energy sources which don't have enough energy sources to comprehend even the basic need of the present and future is going to be worse as most of our conventional energy sources will be gone in nearly 10-15 years in future. So scientists today are trying their best to use non-conventional energy sources for our daily use of energy. In this context we can say India is lucky as it has a vast supply of non-conventional energy source and that is sun. In India sun shines for nearly 300 days a year. Being an agriculture country India is blessed with sunlight. 90% of solar energy is being wasted and just converted in to heat energy.India has a great substitute of conventional energy sources in the form of solar energy. Vehicles can run on using solar energy by placing solar cells on the roof we can get enough energy to run basic house hold products of the house which can save a lot of money on day to day need and even a lot of conventional resources can be save.

Anjali Tiwari et al (2015) described that Smart highway and smart road are terms for a number of different proposals to incorporate technologies into roads for generating solar energy, for improving the operation of autonomous cars, for lighting, and for monitoring the condition of the road. Solar roadways use solar panels, photovoltaic effect, LEDS and microprocessor chips with circuitry boards. The future of the roadways will consist of solar roadways taking energy efficiency and artificial intelligence into consideration.

Rajeev Ranjan (2015) when the phrase "Global Warming" began gaining popularity, The researchers started batting around the idea of replacing asphalt and concrete surfaces with solar panels that could be driven upon. The solar Roadways can save the world from energy crisis and climate change. The day by day the human beings are looking for the answers to our deteriorating highway infrastructure, our crumbling power grid, and the climate crisis. For all such questions the answer is "SOLAR ROADWAYS". An intelligent highway infrastructure and a self-healing decentralized power grid will eliminate our need for fossil fuels and also it will lead to less investment in antiquated technology and overhead power lines. As the day by day the price of petroleum products are getting huge hike & resources are very less there will be no longer feasible material such as asphalt for our road surfaces. When Solar Road Panels are refurnished, the solar cells will be upgraded to newest technology, which will allow keeping up with population growth and increased energy needs.

In 2009, 'solar roadways' in U S received a contract from the Federal Highway Administration to build the first ever Solar Road Panel prototype. During the course of its construction, the technocrats learned many lessons and discovered new and better ways to approach this project. Using this technology 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 and 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.

Vipul Jain (2015) scrutinized the viability of solar roads in India. Solar roads are a farfetched project but certainly not a science fiction idea. Solar roads are basically roads made up of high strength solar panels. They have the strength to support automobiles as giant as 12 fire engines at a time. They would be used to generate electricity, spectacle LED indications on road and even

power electric vehicles amid additional benefits. It has already been implemented in some parts of the world, commencing with Netherlands. The idea is to make multi-functional, self-sustainable roads that require insignificant upkeep.

III. Working Principle Of Solar Roadways, Design Requirements & Its Construction

A. Working Principle of Solar Roadways

A solar roadway is a series of structurally engineered solar panels that are driven upon. The idea is to replace current petroleum-based asphalt roads, parking lots, and driveways with solar road panels that collect energy to be used by homes and businesses, and ultimately to be able to store excess energy in or alongside the solar roadways. Thus renewable energy replaces the need for the current fossil fuels used for the generation of electricity, which cuts greenhouse gases and helps in sustainable development. Parking lots, driveways, and eventually highways are all targets for the panels.

B. Solar Road Construction

Existing prototype panels consist of three layers as shown in figure 3.

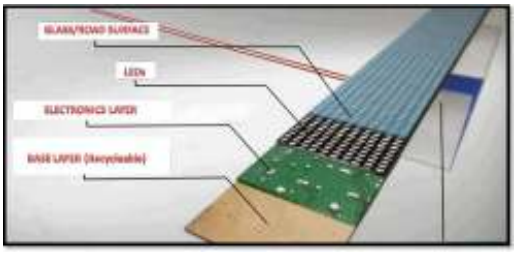

Fig.3:Solar Road Prototype Panels

1. Road surface layer:

Translucent and high-strength glass, it is rough enough to provide sufficient traction, yet still passes sunlight through to the solar collector cells embedded within, along with LEDs and a heating element. The road surface layer as shown in the figure 4 needs to be capable of handling today's heaviest loads under the worst of conditions and to be weatherproof, to protect the electronics layer beneath it.

Fig.4:Layer of Road Surface

The hardness valuse of various materials are compared with glass material used in the constrcuction of solar roads as shown in the table 2

Table 2 Hardness Of Various Materials

Hardness	Material
0.7	Graphite
1.3	Asphalt
3.5	Brass
5-5.5	Knife Blade
5.5-6.0	Plate glass
6-7.0	Steel file

2. Electronics layer:

It contains photovoltaic cells which absorbs solar energy. It also contains a microprocessor board with support circuitry for sensing loads on the surface and controlling a heating element with a view to reducing or eliminating snow and ice removal as well as school and business closings due to inclement weather. The microprocessor controls lighting, communications, monitoring, etc. With a communications device every 12 feet, a solar roadway can be an intelligent highway system.

3. Base plate layer:

While the electronics layer collects energy from the sun, it is the base plate layer that distributes that power as well as data signals (phone, TV, internet, etc.) down the line to all homes and businesses connected to the solar roadway. It needs to be weatherproof to protect the electronics layer above it.

The greatest challenge of designing a solar road panel is that the design requirements for pavement structures and solar modules frequently contradict each other. These requirements have been outlined below, divided into the structural and electrical requirements respectively.

Structural Design Requirements*:* The structural design requirements for a solar road panel are as follows:

i. The structure must be able to support the cyclic distributed load from vehicle tires without failing through deformation, fracture, or other means; it is expected that 480 kPa is a typical design stress requirement from tires contacting the panel

ii. The transparent layer cannot deflect over the cell compartments so much that the layer transmits load to the solar cells

iii. The structure must be corrosion resistant to salts and other potential contaminants

iv. The design must be modular and facilitate easy maintenance

v. For this prototype's purposes, the panel must be made out of readily available components and materials

vi. To accommodate construction, testing, and the measurement units of available components, the designed panel should have 0.91 m (3 ft) side lengths and be of sufficient thickness to satisfy the other requirements

vii. The weight of the panel must be low enough so that two people can maneuver it for testing and installation purposes

Electrical Design Requirements*:*

The electrical design requirements for a solar road panel are as follows:

i. The panel should be designed so that no shading of the solar cells occurs

ii. The interconnection between the cells should be strong enough to withstand potential deflections from the optical layer

iii. The panel must be weatherproof so that water and other contaminants are not able to interfere with the electronics

iv. There must be a diode installed on the output electrical line of the panel to block reverse currents, as this would damage the solar cells within the panel

G. Intelligent Highway

We're barely keeping up with the costs of maintaining our roads and bridges as it is, and the cost of construction materials is skyrocketing. New materials and technologies have to be found to replace our current archaic system.

The Solar Roadway is an intelligent road as shown in figure5 that provides clean renewable energy, while providing safer driving conditions, along with power and data delivery. The Solar Roadway will pay for itself through the generation of electricity along with other forms of revenue. The same money that is being used to build and resurface current roads can be used to build the Solar Roadways. Then, since coal-fired and nuclear power plants will no longer be needed, the costs of all electricity generation plants can also be rolled back into the Solar Roadways. Add to the costs of power distribution systems (power poles, relay stations, etc.)

Fig.5:A Solar Road with ITS

There is no need to expend energy lighting desolate roads when no cars are traveling, so the intelligent roadway will tell the LEDs to light up only when it senses cars on its surface - say 1/2 mile ahead and 1/4 mile behind the vehicle as it travels. This way, drivers will know an oncoming car is ahead when they see the lights on the other side of the road begin to light up ahead.

The LEDs can also be programmed to move along with cars at the speed limit, warning drivers instantly when they are driving too fast. The Solar Road LEDs as shown in figure6 will also be used to paint words right into the road, warning drivers of an animal on the road, a detour ahead, an accident, or construction work. Central control stations will be able to instantly customize the lines and words in real time, alleviating traffic congestion and making the roads more efficient as well as safer.

Fig.6:Solar Road with LED Indicators

Cities and towns will be able to customize the lines for roads and parking spaces to meet their own unique needs. For example, here in Sandpoint, Idaho, we have Lost in the 50's Weekend each May. Currently, the city puts out orange cones to remark the parking places and block off streets for the parade, car show, and street dance. With Solar Roadways, they would push the "Lost in the 50's" button which would repaint the road lines instantly. After the celebration, they would equally quickly return to the default setting.

G. Traffic Control

Serious problem while travelling which results in delay in time and thus in economy is experienced by everyone is **traffic jam.**

So what's the solution? Each Solar Road Panel contains a **microprocessor** as shown in figure7 that monitors and controls the panel, while communicating with neighboring panels and the vehicles traveling overhead. This means that road user have a communications device every few feet in the road, every road & everywhere.

Fig.7: Solar Road with Microprocessor

Imagine what the road user can do with this kind of control: the dashed road lines that is visible on the highways indicates to "travel" at the designated speed limit. If a car is moving faster than the road lines, which indicates that car is going too fast. If a car is being passed by the line, which indicates the driving is too slow. Based on these indications, one can maintain the proper speed while never having to look at speedometer.

The road can warn the driver about the traffic congestion ahead and even recommend detours around it. The driver can enter a destination into onboard GPS and an arrow can appear in the road directly ahead of your vehicle to "lead" you there, rather than audibly describing how to get to your destination.

Crosswalk panels can alert drivers when pedestrians are on the crosswalk. Once the crosswalk panels detect a pedestrian, the LEDs within the crosswalk begin flashing and a warning is displayed in front of oncoming vehicles. Watch the following demonstration:

If a vehicle crosses the center line too many times within a given distance, a ring of LEDs can be drawn around the vehicle, which will travel with it indefinitely. This will warn other drivers of a potential danger and will alert law enforcement officials of a potential problem. It may just be someone tuning their radio, reading a map etc. but it may also be an impaired driver on his/her way to taking out a family of four. The Solar Roadways could drastically reduce the number of deaths/injuries caused by impaired driving.

H. Calculation of annual solar energy output of photovoltaic cell

The global formula to estimate the electricity generated in output of a photovoltaic system is :

E = A * r * H * PR

E = Energy (kWh)

A = Total solar panel Area (m²)

r = solar panel yield (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

IV. Advantages And Disadvantages Of Solar Road Ways

A. Advantages Of Solar Roads

1) Renewability and life-span:

The main advantage of the solar roadway concept is that it utilizes a renewable source of energy to produce electricity. It has the potential to reduce dependence on conventional sources of energy such as coal, petroleum and other fossil fuels. Also, the life span of the solar panels is around 20 years, much greater than normal asphalt roads, which only last 7–12 years.

2) Military and rescue assistance

In the event of an environmental disaster or military emergency, solar roadways would provide power when it is needed most. As solar power is renewable, it obviously requires no external connection to an artificial power source.

3) Roadways already in place

Another advantage of solar roadways is that they do not require the development of unused and potentially environmentally sensitive lands. This is currently a very controversial issue with large photovoltaic installations in the Southwestern US and other places. But since the roads are already there, this is not an issue. Also, unlike large photovoltaic installations, new transmission corridors – perhaps across environmentally sensitive land – would not be required to bring power to consumers in urban areas. Transmission lines could simply be run along already established roadways.

4) Lighting up of roads:

By adding LEDs beneath the transparent panel, road can be lightened up for safe night travel and aesthetic look.

5) Initial Cost:

The average cost of asphalt roads in 2016 was roughly $30 per square foot. The cost does not include maintenance (pot hole repair, repainting lines, etc.) or snow/ice removal. The average lane width is 12 feet, so a 4 lane highway would be 12' (width per lane) x 4 (lanes) x 5280' (one mile) = 253440 square feet. Multiply this by $30 per square foot and your one-mile stretch of asphalt highway will cost $7603200.00 and will last an average of seven years. The design of Solar Roadways is to last at

least 21 years (three times that of asphalt roads), at which time the panels would need to be refurbished. Adding no additional cost to the current asphalt system, this will allow us to invest about $48 ($16 x 3) per square foot. This means that if each individual panel can be made for no more than $6912.00, then the Solar Roadway can be built for the same initial cost as current asphalt roads. However, asphalt roads don't give you anything back.

B. Disadvantages of Solar Roads

1) Maintenance costs*:*

They are more because road surfaces accumulate rubber, salt, soil and other substances that block sunlight and must be removed. The durability of the panels may also be less, further increasing maintenance costs.

2) Seasonal efficiency:

In India the solar road will work efficiently in summer, while it will give comparatively less efficiency in other seasons due to lack of solar radiations. Where as in the countries where summer lasts for more than half of year this technique can be efficiently used.

3) Needs a town planning:

If these roads are to be used town planning plays a vital role as these roads needs a accurate orientation of buildings, roads, sanitary lines, parking lots, playgrounds, etc.

V. Conclusion

Solar Roadways has taken the first step to creating the world's largest solar panel. For roughly the same cost of the current systems (asphalt roads and fossil fuel burning electricity generation plants), the Solar Roadways can be implemented. There would be no more Global Warming in solar roads. No more power outages (roaming or otherwise). When compared to conventional roads, solar roads have safer driving conditions. Solar roadways are having far less pollution when compared to other roads. It stands for a new secure highway infrastructure that pays for itself. It also aims to be a decentralized, self-healing, secure power grid. Solar Roadways will have no more dependency on foreign oil. However, installation cost is very high this new technology is capable of replacing the costly fossil fuel system and can give us clean energy without any climate change.

Therefore, it's time to upgrade our infrastructure (especially roads & power grids) with the 21st century technology i.e. "Solar Roadways".

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