

PHOTOVOLTAIC CELLS AS INTEGRATED INFRASTRUCTURE: ANALYSIS OF SUSTAINABILITY AND EFFICACY



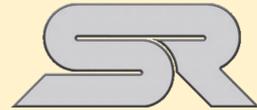
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SOLAR ROADWAYS

- Energy consumption has annually risen and the demand for a clean, sustainable energy source has only increased
- Harnessing solar energy through photovoltaic cells is a promising option, but the cost and large amount of area they require are significant drawbacks

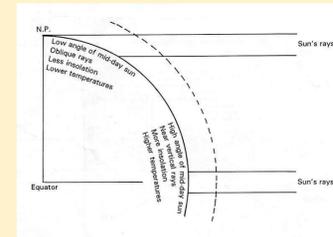


- Solar Roadways is a company that has designed solar panels that can also function as a drivable surface
- They propose that replacing the current roads with a "smart" infrastructure that can generate clean energy while providing numerous additional benefits

POWER AND ENERGY USE

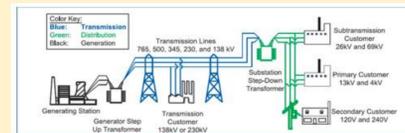
Power Generation

- Less effective compared to traditional solar panels because the angle of the panel cannot be optimized
 - Two solar panels were tested at the location in Minnesota, one at the optimal 72 degrees and one at 0 degrees to simulate the average road. The solar panel placed along the horizon generated 32% less energy than its counterpart
 - Cars can also block out the sunlight at times
- Total possible power generation
 - 16,690 square miles of road in the United States, 4.73×10^9 MWh if Solar Roads were installed across every roadway in the United States
 - To give a reference, the United States generated 3.95×10^9 MWh across all energy sources in 2011.



Smart Power Grid

- Current power system is centralized as shown in the figure to the right
- Decentralized power generation and storage offers better protection from power outages
- The smart power grid created by the installation of solar road networks has increased efficiency
 - If one part of the system is interrupted the rest can still continue to function
 - Due to the distance power must travel from the centralized station some is lost, because the energy is being generated along the length of the entire road that would minimize the power loss
 - Increased reliability of energy distribution and less loss of money from power outages in the form of lost output and wages, spoiled inventory, and delayed production

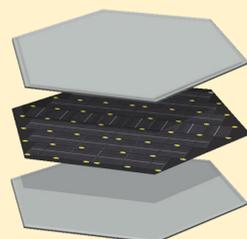


STRUCTURAL FUNCTIONALITY

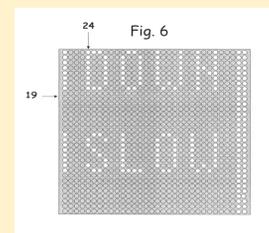
- The road is comprised of individual photovoltaic cells housed in protective casing
- Each unit is hexagonally shaped to allow flexibility in construction of the road
- Three layers, top, middle, and bottom are needed to protect the PV cells within

Layer	Function
Top Layer	The top layer is made of a tempered glass that can withstand 100,000 pounds over the legal driving limit and allows light through • Textured top layer makes surface safe to drive on
Middle Layer	The middle layer houses the photovoltaic cell that produces electrical energy • Energy is produced in the form of Alternating Current but converted to Direct Current • LEDs and all optical elements are stored in the middle layer
Bottom Layer	The bottom layer provides insulation and stability for each unit • Bolts secure each unit to the underlying concrete surface

- Units function individually but store energy in a central storage unit



APPLICATIONS BEYOND POWER



Application	Description
LED Lighting	<ul style="list-style-type: none"> • LEDs built into the road can replace road paint and will never fade or need correction • Lights improve visibility at night or during rain or fog
Visual Programming	<ul style="list-style-type: none"> • Units act individually and can be programmed to display different configurations • Parking lot patterns can be changed instantaneously • Crosswalks or hazard zones can be created or remove
Elimination of Power Lines	<ul style="list-style-type: none"> • Power lines can be eliminated • The roads are built with subterranean "channels" that can house cables • Elimination of above ground power lines means less power outages
Heating Element	<ul style="list-style-type: none"> • Built-in heating element maintains a temperature above freezing point of water • Snow can be melted off the road in winter, saving money and improving safety
Electric Vehicle Charging	<ul style="list-style-type: none"> • Researchers hope that one day electric cars can be charged while driving on the road using inductive charging

SUSTAINABILITY

Economic Sustainability:

- Case study – French solar roadway - one of two solar roadways in existence, created by Colas in December of 2016
 - France: 5.2 million dollars, expected to generate 280 MWh a year. At that rate, ignoring the cost of maintenance or replacement, it would take 155 years to begin to make a profit. Traditional solar panels take 7-20 years to make a profit.
- For Solar Roadways, it cost \$100,000 to install their first 12x20 foot patch of solar road. Considering that there are 16,690 square miles of road in the United States, it would cost \$193.567 trillion dollars to install Solar Roadways' model on every road in the United States.

Area	Initial Cost
12x20 Square Foot Area	\$100,000
16,690 Square Miles of Road	\$193,560,000,000,000

- But, as the cost of solar energy continues to fall, it is possible that eventually Solar Roadways could become economically sustainable. But in the meantime, they will continue to face heavy criticism for their high cost

Environmental Sustainability

- Solar cells reduce the carbon footprint - approximately half the greenhouse gasses are caused by the burning of fossil fuels
- Facilitate the transition to electric vehicles

Social Sustainability

- Because a solar roadway is a public good and freely accessible to all of society, the institution of this infrastructure supports social life, although the short-term installation will limit transportation for a short time, improved ease of maintenance will improve social infrastructure and quality of life for the future
- Because of reduced carbon emissions, public health would be improved.
- The creation of a smart power grid also improves the ability of the public to access electricity.

FINAL DETERMINATION OF FEASIBILITY

- While the construction of a solar roadway is entirely possible, the technology is not where it needs to be for the project to be economically practical
- The energy produced by the roads is not enough to pay for the costly investment
- The societal benefits are great but obstacles such as cost and efficiency currently stand in the way
- Research into this project should continue as it is a worthwhile endeavor that will provide energy and safety in the future