Campus solar roadways: a feasibility analysis

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1. INTRODUCTION

A **solar roadway** is a series of structurally engineered solar panels that can be driven and walked upon. The road surface generates electricity using solar power photovoltaic cells. This energy can be used to signage the road through a layer of embedded LEDs, heat the road to prevent frosting through heating elements and possible excess electricity could be used for charging electric vehicles or be channeled into the power grid [1].

2. STRUCTURE

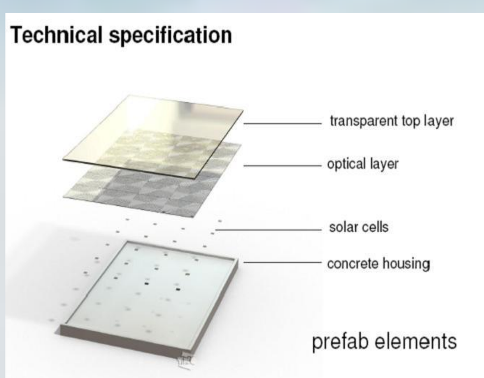

Fig.1. CPATT solar road panel prototype.

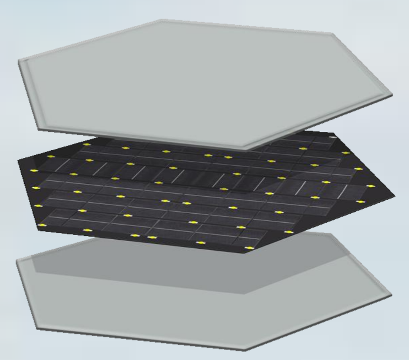

Fig.2. Solar Roadways solar road panel prototype.

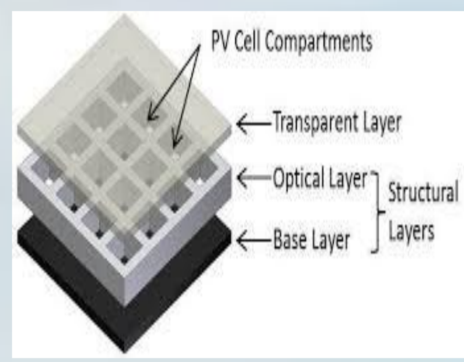

Fig.3. Exploded view of the solar road panel conceptual design (Northmore and Tighe, 2012).

- Road Surface Layer :
  The road surface is made of transparent tempered glass of high strength.
  The sunlight can pass through it to the cells from which electric energy is being collected [1,3].

- Optical Layer :
  The layer consists of the solar power photovoltaic cells and a number of ultra capacitors which store energy for future use [1,3].

- Base Plate Layer :
  It has the responsibility of distributing the power that is collected from the previous layer. The energy is then transmitted to the power grid to which it is connected or used to charge electric vehicles [1, 3].

3. ADVANTAGES

- **Smart roads**:
  They contain microprocessors that connect to a central network and support smart grid applications which optimize city traffic. Moreover, they collect sunlight and produce electric energy **– Smart cities**

- **Safer travel** :
  They contain LED lights built into the solar module that signage and direct drivers. These lights use stored solar power, ensuring self-sufficiency.

- **Clean Energy** :
  Renewable solar energy is being produced, thus greenhouse gases are reduced as well as the need for fossil fuels and power plants. - **Less pollution**

4. DISADVANTAGES

- **Cost** :
  The initial cost of implementation is high. Furthermore, the repairing cost may be higher than conventional asphalt roads.

- **Efficiency** :
  Light can't pierce through shade created by nearby trees, or buildings, or dirt that covers up the pavement. The cars themselves are a major obstacle to the light as well. Lastly, solar panels need ventilation to perform optimally.

- **Safety** :
  Solar roads consist of transparent surfaces. This could mean glass that is characterized by low traction and friction.

5. CHALLENGES

- **Weight Limits**
  The Solar Roadways can handle trucks up to 113,398 kg [6].

- **Strength**
  When glass is tempered it becomes 4 to 5 times stronger than the non-tempered annealed glass and less likely to experience a thermal break. Solar Roadway® Panels are manufactured similarly to bulletproof glass [6].

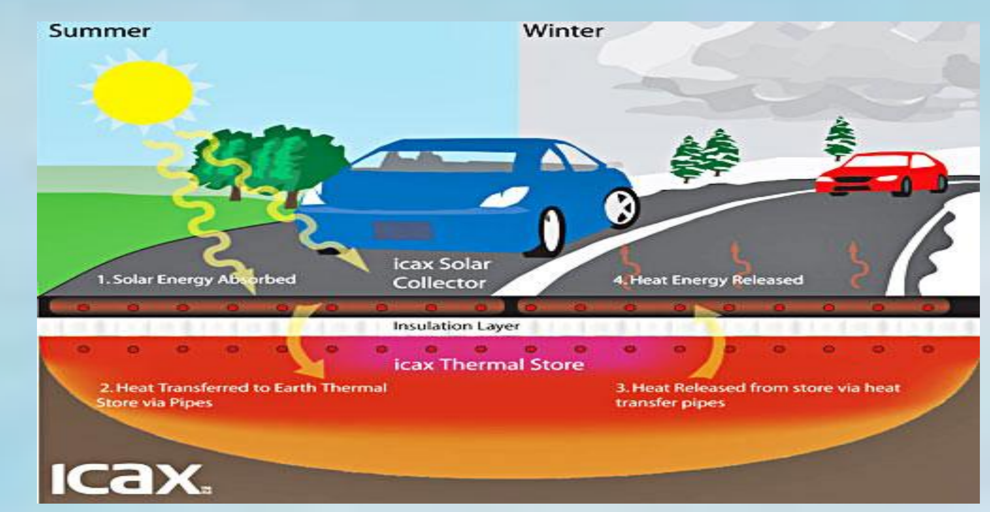

Fig.4. Solar road design.

- **Texture/Traction**
  SR panels are expected to provide the same or greater traction than current asphalt roads (at a minimum) - even in the rain. The final testing results showed the texture was sufficient to stop a vehicle going 80mph (129kph) on a wet surface in the required distance. The test results apply to motorcycles and bicycles as well [6].

- **Longevity and Durability**
  SR panels have been designed to last a minimum of 20 years. Solar cells are the limiting factor: they can work for 30 years. The hexagonal shape was chosen so that any force from vehicles is distributed to multiple surrounding panels [6].

- **Hardness**
  Asphalt has a hardness of 1.3, whereas the glass has a hardness of 5.5-6.0 (higher) [6].

- **Hills/ Curves/ Crowns**
  SR panels can be installed on hills and curves and accommodate the typical 3% crown that roads have. The panels were shrunk to about 0.371 m^2 and the shape was changed to hexagons to make the installing easier [6].

- **Repair/ Replacing Damaged Panels**
  Each SR panel contains a microprocessor, which communicates wirelessly with surrounding panels. If one of the panels is damaged, the surroundings report the problem. The panel then is swapped out and reprogrammed in a few minutes. The damaged panel is returned to a repair center. Moreover, SR panels are completely impervious to water and therefore no potholes will be shaped [6].

- **Cleaning**
  A clean panel produces only 9% more power than a dirt covered one. Moreover, SR panels are easier to clean. It is apparent that most roads with high speed vehicles are quite clean, except of spills from oil, transmission fluid, etc. A possible solution for those substances is titanium dioxide (TiO_2), which turns substances like oil and grease into a powder, which would be blown off by wind or washed by rain [6].

- **Disasters**
  Only the damaged panels will stop producing power. Furthermore, Solar Roadways® can double as an early warning system to alert residents of an impending disaster. The road lines could flash to alert the drivers and could create detours to redirect residents away from areas of danger [6].

6. EXAMPLES

Fig.5. Cycling lane in Amsterdam.

Amsterdam (Netherlands) -2014: A 70-metre stretch of solar panels installed on a cycling lane north of Amsterdam. The panels contain LED lights to signage, heating elements to prevent frosting. Moreover, they have microprocessors to communicate with each other, a central control station and vehicles [2].

Tourouvre (France)-2016: The 1 km paved solar roadway is named WattWay and was launched in 2016 near Normandy. It consists of 2800 m^2 of photovoltaic cells - enough to power the village's street lights. It was constructed by laying the prefabricated flat solar panels over asphalt roadway and the panels were integrated to the local power grid. It costed 5 million euros and was expected to supply 280 MWh/year [2].

Fig.6. The Wattway Project in France.

Fig.7. The first solar-powered highway in China.

Shandong Province (East China)-2017: The "world's first solar-powered highway" is constructed using solar panels with a thin sheet of clear concrete above them. It covers enough to generate about 1 GW/year. The panels were built to instantly melt snow and provide power for the street lights.
The new stretch is two kilometers and will not be able to support too heavy trucks. There are two lanes plus an emergency lane, and the pavement can handle 10 times more pressure than standard asphalt [2].

7. ALTERNATIVE SUGGESTIONS FOR THE CAMPUS OF NTUA

1st Suggestion:
Solar Road
A solar road of 300m could be constructed on the Campus of NTUA to provide electric energy to the campus ' buses . The road could be connected to the power grid to either sell the excess energy or for it to be used for other needs of the campus.

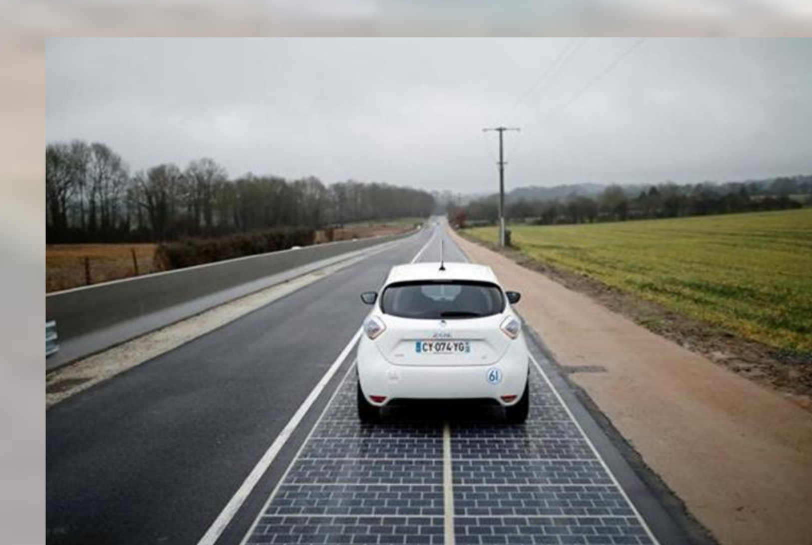

Fig.8. Solar Road.

2nd Suggestion:
Parking with Solar Panels
Solar panels of 3014 m^2 could be placed at a parking area inside the campus to produce solar energy and charge the campus' buses. Moreover, additional energy could be send to the power grid and used for other purposes in campus.

Fig.9. Parking with solar panels for buses.

3rd Suggestion:
Bus station with Solar Panels
Solar panels could be placed above all the bus stations to collect solar energy and charge the buses of the campus. Excess energy could be used to charge mobile phones.

Fig.10. Bus station with solar panels.

8. COST ANALYSIS OF THE SUGGESTIONS

Suggestions	m^2 [4]	€/m^2	€ per solution
Solar Road	2400	400-500	1.080.000
Parking Area	3014	270-330	843.920
Bus Stops	226	270-330	63.280

9. CONCLUSION

The solar road panels can make a major environmental as well as social difference. Firstly, they can provide a significant renewable source of energy which will positively impact the climate change. Moreover, smart roads can optimize city traffic so that less fuel will be needed, work productivity will not be lost and accidents will be minimized. In conclusion, these panels may need a big investment at first but they will pay off in the long term both financially and environmentally.

10. REFERENCES

[1] S. Praveen, Pandu Kurre, A.Vamshi Chaitanya, "A Brief Overview on Solar Roads and its Necessity", Indian J.Sci.Res. 17(2)(2018), pp 381 - 387 ,ISSN: 2250-0138 (Online)
[2] C.N. Papadimitriou, C.S. Psomopoulos, F. Kehagia, "A review on the latest trend of Solar Pavements in Urban Environment", Energy Procedia 157 (2019), pp 945-952
[3] Andrew B. Northmore & Susan L. Tighe, "Performance modelling of a solar road panel prototype using finite element analysis", International Journal of Pavement Engineering, 17:5 (2016), pp 449-457, DOI: 10.1080/10298436.2014.993203
[4] A. Petsou, M. E. Merakou , T. Iliopoulou, C. Iliopoulou, P. Dimitriadis, G. Koudouris, K. Kepaptsoglou & D. Koutsoyiannis, "Campus solar roads: Optimization of solar panel and electric charging station location for university bus route", EGU (2019)
[5] M. E. Asimomiti, N. Pelekanos, P. Dimitriadis, T. Iliopoulou, E. Vlahogianni & D. Koutsoyiannis, "Campus solar roads: Stochastic modeling of passenger demand", EGU (2019)
[6] Solar Roadway®, accessed in 20/03, (2019) www.solarroadways.com/Specifics/Glass

This work is part of a collaborative student project and was conducted in collaboration with those in References [4,5].

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