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Solar Energy Generation Potential along

NATIONAL HIGHWAYS

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Prof. T. Harinarayana

Energy generation using solar photovoltaic requires large area. As cost of the land is growing day by day, there is a strong requirement to use the available land as efficiently as possible. The answer is here in exploring the potential of energy generation using the land above the national road highways by constructing a roof structure. This space can contribute to the energy generation without extra cost for the land. It also results in energy efficiency, for example improved vehicle movement, minimum energy for air-conditioning of the vehicle, also helps with minimum road repairs, longer vehicle tyre life due to the effect of sun shade and reducing wear and tear for road. Considering all this facts and after several compilation and computation of different models Ms. Pragya Sharma & Prof. T. Harinarayana at GERMI research team have suggested a new idea and published a research paper to generate energy from the sun without putting extra cost of land for solar photovoltaic panels.

If the concept is implemented throughout India, it not only increases the power generation to more than a few GW of electricity but also various other fringe benefits including longer road life, employment generation and reduced CO2 emission in environment etc and the additional advantage of shading on the roads using the space above the road highways for installation of solar panels. This results in improved vehicle efficiency by reducing energy losses due to heat inside the vehicle and also improves the life of the tires of all vehicle wheels due to the shade derived from the road. Combining, the two will result in both improved economy by energy generation and improved efficiency of the vehicle at the same time. One more advantage of the shade over the road is the life of the road and reduction of the cost due to road maintenance. It is a usual phenomenon on many roads that soon after the rains, pot holes usually develop. This will become a history if all roads are provided with solar panels above them. This is not only a new idea on the effective use of roadways and also an opportunity to meet the major challenge for the industry, i.e., land availability for the grid-interactive solar power plants.

Oregon has designed a Solar Highway, capable of producing 128,000 kWh of electricity per annum. The energy generated helps run the state's transportation system by providing electricity for signals, illumination, buildings, ramp metering and more

This is the first time ever of its kind, an approach to utilize solar energy to meet the global challenges like climate change, pollution, and energy insecurity and also to address the biggest challenge for the photovoltaic technology, i.e., land cost. Indian roads are paying a very vital role in the economy through transportation, whose share has been more than 60% and is also greater than railways. This means that efficiency of the vehicle and life of the road are equally very important. This kind of issues should need to be solved and should be answered soon as possible. It is well known that the availability of land is becoming more expensive and also becoming a rare commodity. In view of this entire factor, a concept has been put forwarded to use the existing land in a more effective way. An attempt for the possible use of the national highways presently being used for transportation only has been made through this idea. The suggestion is that they can also be utilized for power generation. For this purpose, with one-time investment, one

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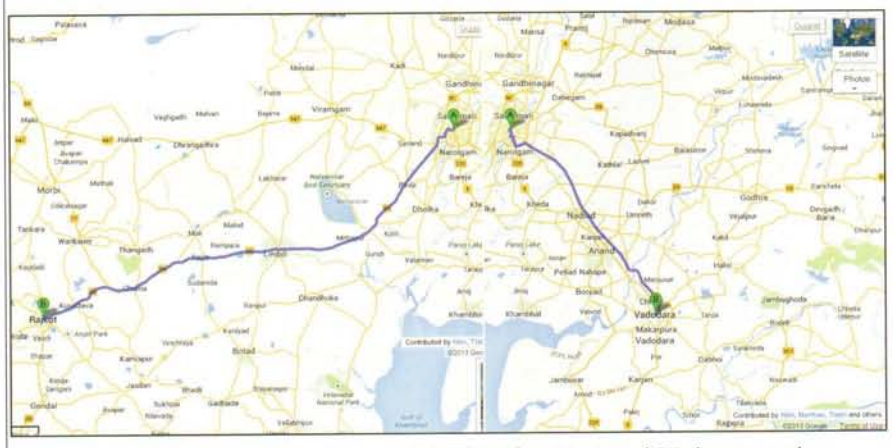

Google Map view of Ahmedabad-Rajkot National Highway and Ahmedabad-Vadodara National Express way

can construct a simple elevated structure covering the national highway roads.

As a total of 104-MW potential of solar energy generation exists along the Ahmedabad- Rajkot national highway and a total of 61-MW potential of solar energy generation exists on the Ahmedabad- Vadodara national express highway. This way, huge potential of solar energy generation exists on the national highways with capacities based on the length. This leads to not only meeting the energy demand but also reduction in CO2 emissions by minimizing dependency on conventional sources hence promoting renewable energy resource on a very large scale and this is the best answer for the national threats called GHG emission for any country.

A more detailed study on environmental damages by CO2 emission and transportation shows power generation using photovoltaic generates huge amount of electricity without combustion of fossil fuels, as electricity generation through fossil fuels is the largest source of CO2 emission, and this can helps to reduce the dependency on fossil fuels and transportation of fossil fuels.

In summary, the national highway space can contribute to the huge amount of energy generation without extra cost for the land. If the concept can be utilised well this can be a part of the key concept of solar grand plan.

Apart from this, there are various fringe benefits. For example, if implemented, it improves vehicle efficiency, use of minimum energy for air conditioning vehicles, more tire life due to shade, etc. Another fringe benefit of this road rooftop solar project is increase of the life of the road from wear and tear on the highways, and this helps to reduce the fund requirement for road repairs. Another benefit is rainwater harvesting at selected locations. This increases the groundwater level and helps to reduce the fluoride and arsenic content in the groundwater. This approach can become the answer for the various concerns and helps in reaching a goal for a sustainable transport system. This concept requires an urgent need for an attractive policy by the government of India to increase the solar potential if one dreams to realize it in a very less duration of time.

The findings of research paper "Solar energy generation potential along national highways" is based on the modelling study of Ahmedabad-Rajkot national highway road and Ahmedabad-Vadodara national expressway is published in International Journal of Energy and Environmental Engineering.

As a well known fact for solar PV power generation, the cost of the power plant also depends on the land value. As the cost of solar photovoltaic is continuously decreasing, the major challenge now lies on the land cost. Land is becoming a scarce resource in India in recent years, and per capita land availability is low. Land is often considered as the topmost challenge for deploying solar energy technology. Keeping this in mind how to use the available land in an effective way the study is carried out along the two national highways for energy generation using solar photovoltaic technology and to demonstrate this approach on the use of land and its solar potential, two areas, namely Ahmedabad-Rajkot national highway road and Ahmedabad-Vadodara national expressway, are taken for modelling. The total span of the Ahmedabad-Rajkot national highway is 205 km, and that of the Ahmedabad-Vadodara national express highway is 93 km as shown in google map overview. The modelling part has been done by choosing the four-lane Ahmedabad-Rajkot national highway and six-lane Ahmedabad-Vadodara expressway (four-lane highway with two service roads) for finding the potential of solar energy generation. The total span of the Ahmedabad- Rajkot national highway length is 205 km. Each lane on the national highway has a width of 3.5 m, and thus for two lanes, the total width is 7m. For both sides (to and fro), the total width available for solar panels above the road is 14m. This width of the road has been also measured using measurement tapes from various places along the national highway to measure the accuracy of Google Earth Pro software for modelling purposes. Similarly, for the Ahmedabad-Vadodara express highway, the span of the road is 93 km in length. The width of the express highway is 20 m, out of which 14 m is for the two-lane national express highway. Additional 3 m is the extra road available on both sides of the national express highway or service road. Additional information on the national highways is also provided from virtual observation of the road using Google Earth Pro software, for example, the lengths of the road unavailable due to certain environmental reasons like bridges, crossing, unusable road, thick vegetation, etc.

Modelling the national highways

In modelling, the description of the various parameters and dimensions considered to estimate the solar potential along the Ahmedabad-Rajkot national highway, i.e., the length of the highway

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identified suitable or unsuitable for the solar photovoltaic system installation as a roof of the road for energy generation. As described earlier, the length of 205 km with a two-way road (four lanes) with a width of 14 m. Thus, the total area (Area = Length ×Width) available for solar panel installation is 2.87 km2. Although the length of the highway is 205 km, all along the highway, the road is not usable due to certain parameters, for example, environmental issues like thick vegetation, bridges on ponds, or overhead bridges for road crossings with other roads.

Accordingly, Table below shows that out of 2.87-km2 total area available on the Ahmedabad-Rajkot national highway, 0.2 km2 is found to be unavailable or, say, inappropriate for installation of the photovoltaic system due to certain factors as stated above. Hence, the effective area available on Ahemdabad-Rajkot national highway is 2.67 km2.

Similar to the Ahmedabad-Rajkot highway, Ahmedabad-Vaododara expressway has been considered for modelling. As described before, it has four lanes each with 3.5-m width and additionally has a service road of 3-m width on both sides of the road. The length of the expressway is 93 km with a total available road width of 20m ($4 \times 3.5 + 2 \times 3$). Accordingly, the total area available for solar panel installation is 1.86 km2. Out of the available area, a total of 0.14 km2 is unavailable due to the same environmental issues which have been discussed earlier for the Ahmedabad-Rajkot highway. Thus, similar to the Ahmedabad-Rajkot highway, the approximate effective area available on the Ahmedabad-Vaododara express highway is 1.72 km2. Apart from the computation of solar potential for the national highway using a series of solar panels mounted on the road roof area, two-layer solar panel installations has also been considered for the modelling part.

Based on the modelling results for the two national highways, a few interesting observations can be made. Although the Ahmedabad-Rajkot and Ahmedabad-Vadodara national highway lengths are 205 and 93 km, respectively, the effective length of the highways for erecting the road rooftop structures for placing the solar panels are 185.4 and 85.8 km, respectively. This way of selection of the highways is based on various factors as described earlier. From the modelling results, a 115-MW power generation along the Ahmedabad-Rajkot national highway is possible. However, due to the environmental and other restrictions, only a 104-MW electricity generation is feasible. However, if we use innovative concepts of two-layer solar panels one above the other, the energy generation can be enhanced. If we compute the energy generation for the whole year, the cumulative energy that can be generated is 163 GWh. This computation is based on the results and published in IJEEE Journal.

For the Ahmedabad-Rajkot highway, the energy generated with a width of 17 m requires 89 m in length for 50-kW photovoltaic system installations using PVsyst design simulations; hence, for 1 MW (i.e., 50 kW × 20), the required length of the highway, i.e., 89 m × 20, is equal to 1,780 m (1.78 km).

This value can be generalized and can be used to compute the potential for any length of the road. The total length of the Ahmedabad-Rajkot national highway is 205 km, out of which the total effective length available is 185.4 km (based on the computation; 185.4 km/1.78 km), and 104 MW is possible for the entire length of the highway. This way, for 104-MW systems, the energy generation is 163 GWh. If the solar panels lay one above the other i.e. two layer solar panel system with 1-m separation, the energy generation increases to 190 GWh; for 2-m separation, it is 216 GWh; and for 3-m separation, it is 229 GWh. Similar computations has been done for the Ahmedabad-Vadodara national expressway. Accordingly, 61-MW electricity generation is possible for the Ahmedabad-Vadodara expressway, and 96 GWh of cumulative annual generation is possible. If the solar panel system is layered one above the other 115 GWh is possible for 1-m separation, 132 GWh for 2-m panel separation, and 140 GWh for 3-m separation.

A total of 104 MW of electricity is feasible along the Ahmedabad-Rajkot national highway and 61-MW electricity generation is for the Ahmedabad-Vadodara expressway. The same concept can be extended for use on the 52,584-km national and state highways in India that have four lanes or more, for example, the four-lane Golden Quadrilateral highway which is 5,839 km which is having installation power capacity of approximately 4,418 MW. Similarly, this concept is also possible for the four-lane north-south to east-west (NS-EW) Corridor highway of 7,300 km. Accordingly, the NS-EW Corridor highway has 5,524-MW capacity of power generation. In a similar manner, it is also recommended to initiate solar panel installations on all the train track ways also. This will open up large potential of power generation in a very short period of time which is very much needed in India to have aggressive industrial growth which is presently in strong need for power ■

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