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Electric vehicle chargers and Solar PV for rural India

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Abstract

Considering rural India a major contributor to agriculture, many applications of electric vehicles, both light to medium and heavy-duty, apply to improving the produce and productivity. The major food produce is transported over trucks, and many agricultural farming tools require the use of tractors. The vision of increasing the penetration of electric vehicles by government and local companies materializes via a plan that integrates renewable energy with chargers. India is seeing one of the largest moves to cleaner energy generation, with a vision of more than 300GW from solar and wind power in the coming years. A study that derives the relationship between the number of vehicles in rural areas in India and documents the power required to supply using renewables is required for planning a sustainable future for people from low-income to underprivileged statuses. A total of more than 649,369 villages require clean and green power to meet the needs for energy demand for electrified trucks and tractors. To become more independent of the utility grid, a large-scale use of unutilized and underutilized spaces becomes a site for large solar and wind farms. Some farmers were interviewed to understand underutilized spaces on farmland in Akbarpur, Kanpur Dehat, India. The basis of the interview became a driving force to study whether a solar farm becomes a viable solution. The results were generated to identify the potential of the farm in providing power on an annual basis. Accordingly, a combination of level 2 and fast charger, as known from past studies, was proposed.

Keywords: Solar photovoltaics; Electric Vehicle Charging; Energy Conservation

1. Introduction

India has a diverse population that includes some underprivileged people in rural areas [1]. The major occupation for many rural populations is agriculture. The types of farming are dependent on the geography and availability of the technology and resources. Many farmers are equipped with advanced tools and techniques to increase production, whereas many rely on traditional methods. Mixed farming raises livestock and crops together. This allows the farmers to use hay production on their farmland to feed the livestock without compromising the need for regular crop production from the same farmland. Plantation agriculture is more oriented towards the specialized form of growing crops of one type on a large scale. The farmers maintain large tea, coffee, sugarcane, corn, and so on crops and do not switch between the crops during the seasons. Meeting your own needs for food production raises the term for subsistence farming. Such farming is not for profit generation. Intensive farming increases productivity on small lands, whereas extensive farming increases on large lands. Although a majority of farmland in India face water scarcity for wheat and rice production 75 and 65% respectively for each [2], farms continue to rely on monsoon rains to nurture the crops instead of modern water efficient irrigation techniques. Resources for water and land utilization are challenges in India and pose a major hurdle when promoting a newer technology use such as electric vehicles and solar photovoltaics for electricity utilization and generation. Off-grid power solutions for solar applications for rural saves costs [3] [4] and peer-to-peer integration helps with increasing power reliability [5]. And sustainable agriculture at rural areas may be supported by solar energy [6].

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Solar PV farm utilizes the photovoltaic effect to drive current into the external circuit from the potential difference created by the strike of the light onto the surface of the solar panels. The major components of a solar PV system includes panels of varying types, an inverter, a mounting system, battery storage, a monitoring, and a control system. They may either be grid-tied or work independently and thus mitigate many issues with GHG emissions and environmental harm from fossil fuels. The solar panels are attached in strings and then they are fed to combiner boxes that in turn feed inverter and group of inverters supply to the service point or to a battery bank. The use of a battery bank becomes an option, but the use of a battery bank provides a more steady power supply even when times solar irradiance is low or nil. Many areas in rural India have an excellent potential for solar power generation and observe many days with sunlight available.

The inherent benefits from solar photovoltaics is not limited to reduced GHG emission [7] but also extends to decreased pollution, water conservation, preservation of the environment, improvement of biodiversity, and improving the lifestyle of rural communities. Some argue that the environmental impacts from the materials utilized for manufacturing solar panels produce harm to the nature but when a life cycle assessment is compared for fossil fuel vs solar PV there are good promising future with solar or other renewables. The major challenge with solar farms is their upfront high cost of installation and thus a government support for the local communities in rural areas is not an option but a requirement [8]. Many government initiatives provide addition of roof-top solar without any fees or minimum incentivizes them for the initiative. However, for farmers a policy that provides a significant funding for installations is required to increase the farms with solar farms to supply their home power and EV charging needs.

Types of vehicles that rural farmers use includes two wheeler for commute, tractors for farming and transportation, trucks for shipment of the food produce, and car/ vans for other commute purposes. However, technology in innovating to ensure quicker EV transition [9]. Many farmers do lack some essential tools for transportation and relies on sharing resources or using alternative with physical labor. But these aspects are outside of the scope of work of this study. It is considered that an average farmer will have a tractor and a two wheeler for commute. They will use them often for charging via solar farms given depletion of fossil fuel and increasing costs of gasoline and diesel will make trigger the farmers to start purchasing electric driven tractors and two wheelers.

India is supposedly having largest number of tractors and there are major commercially available electric model of tractors from varying sizes of 15 to 60 horsepower motors. Users have a varied selection based on criteria of how much power they require [10]. Although the electric tractors have been launched in 2020 their sales are not significantly picked up in the market [11]. The availability of local manufacturing of the trucks in India allows cost reductions. However, with steady supply and demand curve there will be cost reduction at production and along the supply chain network. Additionally, with many competitors entering EV market there is likelihood of price competitive products in the market.

This paper is framed in sections: Methods that talk about the concept of farmland for solar PV and EV charging hub. Results show the output from NREL SAM simulation for a 500kWDC solar farm at Akbarpur, Kanpur Dehat, India. The Conclusion and Discussion touch base on challenges and aspects of how this study would be useful for rural areas and policymakers. The electrical safety and hazards related with the battery electric vehicle was not considered in this study. Also, the interviews from the farmers in Akbarpur, Kanpur Dehat, India, were indicators of the availability of unutilized farmland specific to them and may not be generalized for all. But there is a strong indication of unutlized farmlands spaces across the area that was studied.

2. Methods Adopted

A concept was developed based on known solar photovoltaic technologies in thin film and these were applied to the farms that have underutilized or unutilized spaces that becomes perfect location for solar farm. Since, majoring of the farming tractors and truck are parked near farm area or atleast at close vicinity there are provisions to utilize the unutilized or underutilized farmland spaces with EV charging hubs [12]. The authors have presented the research on large scale electrification in United States and recommended utilities to be prepared with charging electrification plans and providing power [13] [14]. The study also utilized the plans provided for gasoline stations that require some upgrades to ensure there is a charging station available with amenities [15] for the general public while they wait. However, in this case the farmers may be comfortable with elongated charging times with level 2 charger and thus may allow mixed usage of level 2 and fast chargers. Fig. 1 gives an over view of a plan for the farmland to have a solar farm at underutilized space with ground mount solar PV and remaining available for farming. A peer-to-peer interconnection has proposed for connection from independent farms [5].

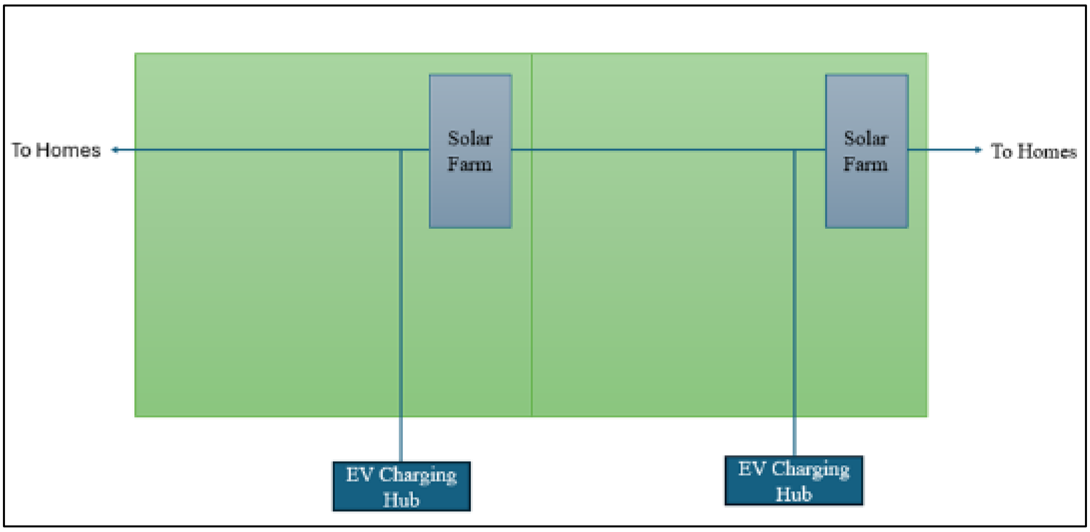

Figure 1 Concept of Solar PV and EV Charging Hub

A group of farmland owners in the area upon interview indicated a more than 25% of the farmland owned by them was under-utilized. This became the starting point to apply solar farm on existing farmland while they grow crops alongside of the solar farm.

2.1. Implementing Solar PV Farmland in Akbarpur, Uttar Pradesh, India

A farmland owner was contacted in the local area in Akbarpur, Kanpur Dehat and upon his permission an analysis were performed using open source software NREL SAM. The system was selected to occupy a portion of land that the owners confirmed were not utilized for agricultural purposes. This allowed the study to get into the details of how to best utilize the land space with solar photovoltaics. A system for 500kWDC was designed to occupy about 2,631 sq meters of the land area and promised them with significant power generation that could meet their home energy needs and partially any EV charging needs. Table 1 provides the system profile. Fig. 2. Shows an areal view from google maps were the farmland is located. Fig. 3 and 4 were the NREL SAM results after running the simulation for a 500kWDC system. Farmers will seek for energy efficiency at homes with efficient appliances and LED lighting [16] [17].

Table 1 Profile

Location	**Akbarpur, Kanpur Dehat, UP**
Installed Capacity	500kWDC
Module Area Estimate	2,631.579 sq meters
Tilt	28.6 degrees North
Annual AC energy in Year 1	776,171 kWh
DC capacity factor in Year 1	17.7%
Energy yield in Year 1	1,552 kWh/kW

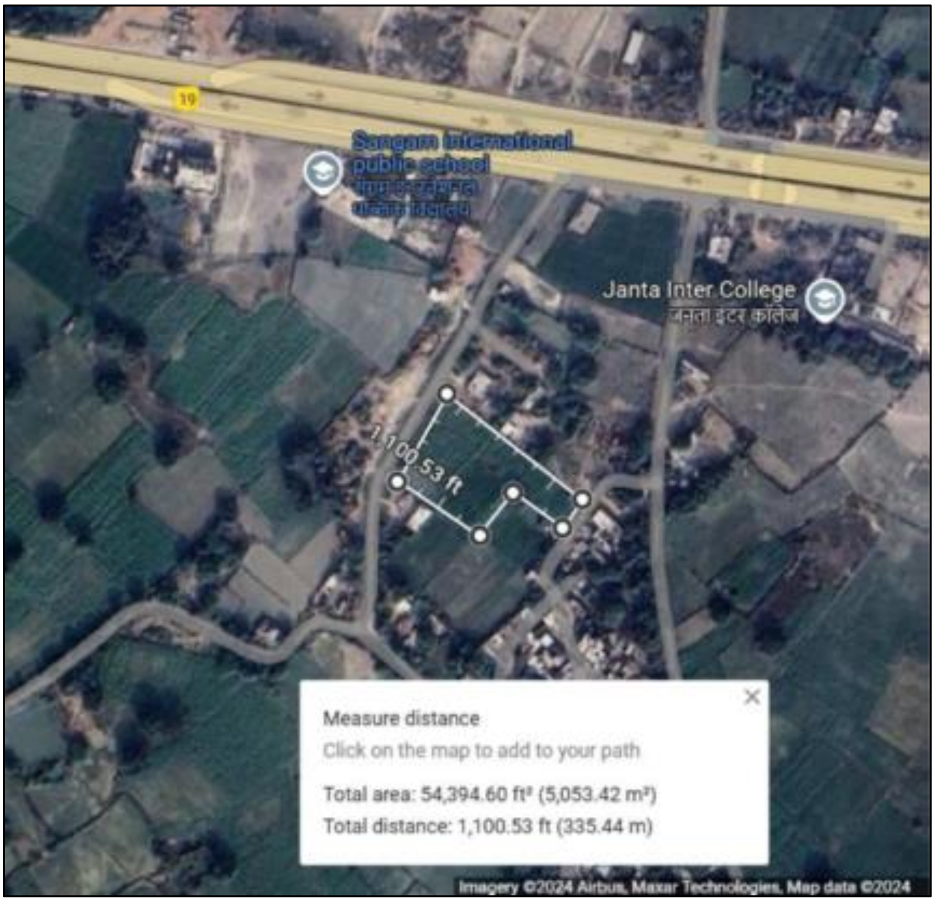

Figure 2 Farmland Areal Snapshot (Google Maps) **[18]**

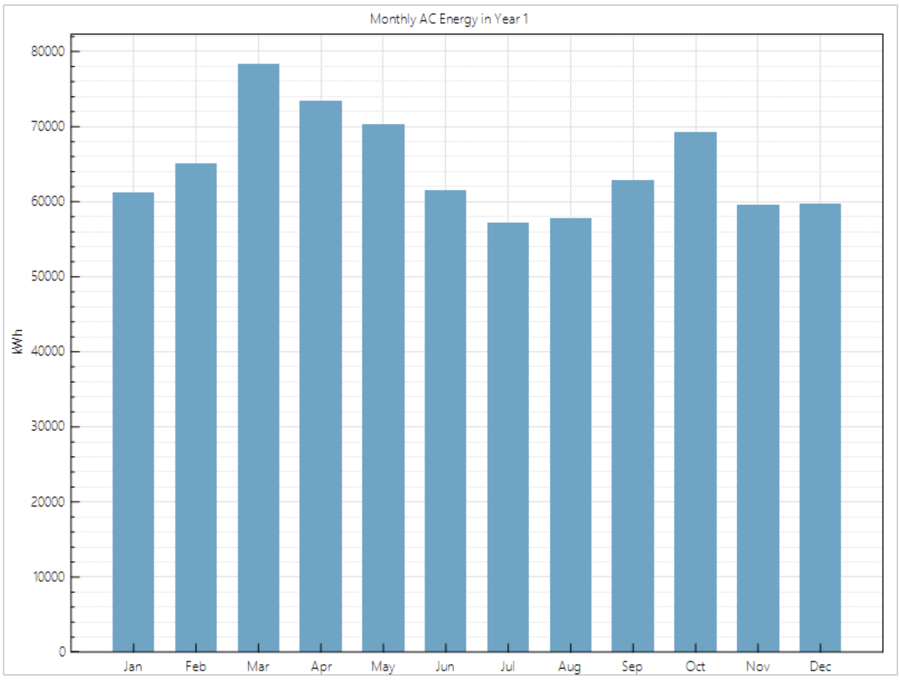

Figure 3 Energy Generation by Year

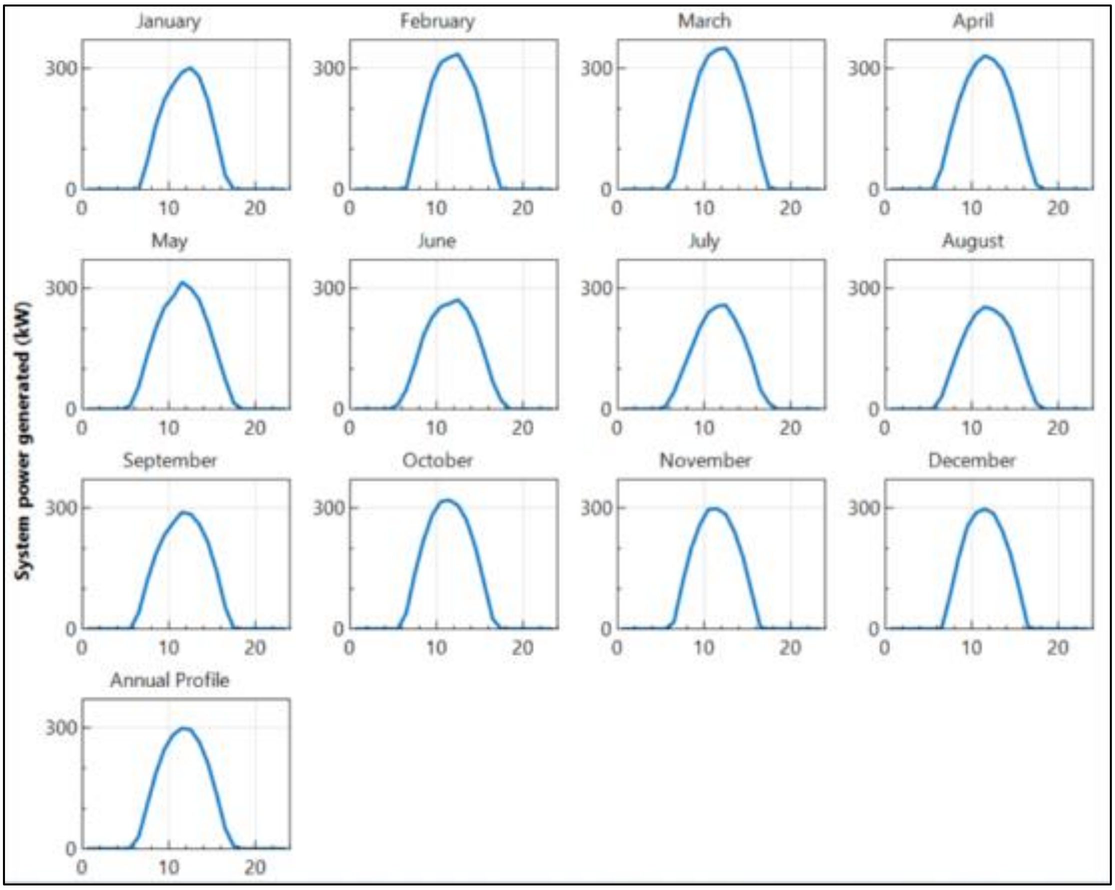

Figure 4 Energy Generation by Month

The addition of charging hubs with mixed combinations of slow and fast chargers ensures farmers are at peace of mind with readily available infrastructure at their disposal. When there is loss or shortage of power from utility services, these solar PV acts as an excellent tool to meet the demand for charging their small EVs. However, security issues with theft of the equipment becomes a challenge with charging hubs at distant locations near farmlands. Based on the CO2 generated per kWh the total CO2 reduction is calculated.

3. Results

Since the given farmlands belong to less privileged communities in the area, it brings a huge economic boost to the local farmers in meeting their energy needs. This is going to ensure power resiliency from power outages. Additionally, an equivalent GHG emission reduction from 1,552kWh/ kW is going to reduce 1,242 kg of CO2. About 50,000 residents in the area are going to see a positive impact from the solar photovoltaic installation.

4. Discussion

A review of literature was performed to understand the technologies in solar pv and electric vehicle charging. The farming methods do have implications on the type of tools and vehicle used. These are good indicator that with EV transition there will be a shift required at farmers end to purchase and utilized EV alternates for tractors and two wheelers. There will be a significant amount of load that will add to the grid with charging needs for the risen EV tractors and two wheelers. The paper placed a plan together to utilize unutilized farmland spaces and occupy a solar farms that supports the home and EV charging power needs. The interviews with local farmers revealed that there were about 25% of each of their farmland that remained unutilized throughout the year and thus that became a candiate for solar farm. Once of a farmland located in Akbarpur Kanpur Dehat was studied using NREL SAM and the total power output with 500kWDC farm was evaluated and it provided with major energy savings and GHG emission reduction.

Given there are factors that drive the electric tractor purchases by the farmer and are also driven by government initiatives. The solar PV and chargers go incidental to the shift to electrification. There are many other challenges that farmers may prioritize against the proposed green infrastructures, such as identifying better ways to harness rainwater or seeking support with reservoirs to supply water that is a deficit for the wheat and rice produce. Some of these challenges make the shift slower, but eventually, when gasoline and diesel prices hike there will be an expedited move is anticipated. Some farmers produce large amounts of sugarcane that provides excellent raw materials for ethanol production which is an alternate for gasoline or atleast blended with gasoline to fueling. So, a mix use of this alternate fuel to drive vehicles may become an alternate for many farmers and cost would be driving factor for decisions on need of electrification.

5. Conclusion

By use of potential available for solar energy from rural farmlands, a detailed Solar PV installation and its feasibility was presented in this paper. Local communities and farmland owners will benefit from power generation from unoccupied farmlands. EV chargers were located close to farmland to support electric vehicles for farming equipment. The resultant power generation from solar PV from the ground mount solar panels enhances the rural electrification moves from both customers and the government. Feedback from local farmland owners on readiness for such a shift to clean energy with the usage of solar integrated with EV chargers became a selling point and attraction for the rural population. The reduction of carbon emissions from such initiatives is driven by government awareness programs. Budgeting for FPV applications for rural area as per [19] and design as per [20] is recommended for future scope of work.

Compliance with ethical standards

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Disclosure of conflict of interest

Nil. This is author's original work.

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