Agri-photovoltaic System

Growing Crops and Producing PV-based Green Energy Together

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Preamble

Food and energy are two basic requirements for human civilization. Production of food grain through photosynthesis process requires land as basic resources. Similarly, conversion of solar energy to electrical energy through photovoltaic process also requires land for its installation. Therefore, competition for land may arise in future for agricultural use and PV based electricity generation. There is possibility that solar PV based electricity production will be preferred over agriculture because of higher efficiency of photovoltaic process (~15%) than photosynthetic process (~3%) specifically in those areas where solar irradiation is available in plenty however, land productivity potential is low. Substantial focus on renewable energy based electricity generation in future with solar PV as a dominating contributor throughout the world may further aggravate the situation. However, food is the basic need for survival of human being. Therefore, it is thought of producing both simultaneously from a single land unit through agri-photovoltaic system.

Agri-photovoltaic System

Agri-photovoltaic system is defined as crop production and photovoltaic based electricity generation from a single land unit. The interspaces area of about 3 m to 9 m in between two PV arrays in agri-photovoltaic system as well as the areas below PV modules are utilized for growing suitable crops preferably short height, low water requiring and having certain degree of shade tolerance. In arid western Rajasthan and Gujarat, suitable crops for interspace area may be mung bean (*Vigna radiata*), moth bean (*Vigna aconitifolia*) and clusterbean (*Cyamopsis tetragonoloba*) during kharif season whereas cumin (*Cuminum cyminum*), isabgul (*Plantago ovata*), and chick pea (*Cicer arietinum*) during rabi season. Apart from these arable crops, medicinal plants e.g. gwarpatha (*Aloe vera*), sonamukhi (*Cassia angustifolia*) and sankhpuspi (*Convolvulus pluricaulis*) may be grown in interspace area. Areas below PV modules may be used to grow vegetables and spices e.g. turmeric, cucurbitaceous crops, brinjal, leafy vegetables etc. The electricity generated from PV modules in agri-photovoltaic system may be directly supplied to local grid through net metering system. For optimum PV generation, regular cleaning of deposited dust from PV module surface is essential and requires about 20-40 litre of water per kW_p system per month. The rainwater harvesting system from top surface of PV modules in agri-photovoltaic system has the capability to provide water for cleaning purpose and to recycle it. Apart from cleaning, harvested rainwater may provide irrigation of about 40 mm during rabi season. Potential capacity of harvested rainwater from agri-photovoltaic system covering 1 ha area is about 3.75-4 lakh litre of water at Jodhpur.

Potential Areas

The agri-photovoltaic system has very good potential in arid western Rajasthan and Gujarat in India because of plentiful availability of solar irradiation (5.3-6.0 kWh m^{-2} day^{-1}) in the region as compared to rest of the country (<5.5 kWh m^{-2} day^{-1})

Crops in solar farming

except Ladakh. Among twelve districts of western Rajasthan, availability of solar irradiation is high in Jaisalmer, Barmer and Jodhpur (>5.7 kWh m^{-2} day^{-1}) whereas comparatively low in Ganganagar, Hanumangarh, Churu and Jhunjhunu (5.3-5.5 kWh m^{-2} day^{-1}). In arid Gujarat, the Kachchh district has vast potential to harness solar energy. In contrast to it, low availability of water in these arid districts is a limiting factor to achieve potential crop yield. Therefore, water harvesting system from top surface of PV modules in the agri-photovoltaic will help in conserving rain water and to use it in crop production system and also in cleaning the PV modules.

Economics of Agri-photovoltaic System

The agri-photovoltaic system may bring huge opportunity to farmers of the arid western Rajasthan and Gujarat since rainfed based crop production is risky because of uncertainty and scarcity of rainfall. Potential income generation from agri-photovoltaic system covering 1 ha area is given in Table 1. Apart from the income from crop yield and electricity, agri-photovoltaic system provides several environmental benefits e.g. conservation and optimum utilization of rainwater, microclimate modification through cropping activity in the system which helps in optimum PV generation, providing surface coverage of crops and thus helps in reducing soil erosion and dust deposition on PV modules, improving the soil moisture regime by providing the wind driven evaporation process etc.

Way Forward

Thus the agri-photovoltaic system has huge potential in arid western Rajasthan specifically in Jaisalmer, Barmer and Jodhpur districts. Installation of such system will produce food as well as generate renewable based electricity from a single land unit whereas scarce rain water will be conserved and used efficiently. The agri-photovoltaic system has capacity to increase farmers' income in a fragile ecosystem. There is scope of improving the land equivalent ratio up to 1.41 by installation of agri-photovoltaic system.

Table 1. Brief details of agri-photovoltaic system and potential income from 1 ha* land

S.No.	Item	Value
1	Dimension of solar PV module of 250 W_p capacity; W_p stands for peak wattage capacity at standard condition (1 atm pressure, 25°C ambient temp and 1000 W m^{-2} solar irradiance)	~100 cm × 165 cm
2	Diurnal variation of solar irradiance	Reaches its peak of 700-900 W m^{-2} during 12:00-1:00 pm
3.	Annual average availability of solar radiation in India	~5.6 kWh m^{-2} day^{-1}
4.	Annual average availability of solar radiation at Jodhpur	~6.0 kWh m^{-2} day^{-1}
5.	Inclination of solar PV module	Latitude of the place of installation (at Jodhpur it is 26°)
6.	Area for 1 MW_p (~1000 kW_p) installation including accessory space for roads, inverter etc.	2 ha
7.	Maximum capacity of solar PV module installation in agri-photovoltaic system covering 1 ha land	0.5 MW_p (500 kW_p)
8.	Average effective availability of solar radiation in hours per day for electricity generation in India	3-5 hrs
9.	Average effective availability of solar radiation in hours per day for electricity generation at Jodhpur	4 hrs
10.	Electricity generation per day per kW_p installation at Jodhpur	1 kW × 4 hrs = 4 kWh or 4 unit
11.	Electricity generation from 1 ha land at Jodhpur (500 kW × 4 kWh kW_p^{-1} day^{-1})	2000 kWh day^{-1}
12.	PV generated electricity tariff	₹ 5 per kWh
13.	Approximate annual income from PV generated electricity in 1 ha at Jodhpur (2000 kWh day^{-1} × ₹ 5 per kWh × 300 effective days in a year at Jodhpur)	₹ 30 lakhs
14.	Cost for establishment of agri-photovoltaic system in 1 ha area	₹ 200-250 lakhs
15.	Interspace and below panel area for cultivation in agri-photovoltaic system	49% interspace and 24% below panel
16.	Potential amount of rainwater harvesting from 500 kW agri-photovoltaic system in 1 ha land at Jodhpur	~3.75-4 lakh litre
17.	Potential income from crop yield (e.g. mung bean-cumin)	₹ 0.5-0.6 lakhs

*For calculation from 1 acre land necessary conversion has to be made (1 ha = 2.5 acre)

Considering the above potential and benefits of agri-photovoltaic system, it is proposed to formulate a committee for formulation of a policy guideline for its adoption in famers' field.

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