Review Article

Carbon Farming: A Promising Approach to Climate Mitigation and Adaptation in India

ABSTRACT

This article addresses India's role in the reduction of GHG emissions, the impact of renewable energy and the application of solar energy. In response to the climatic challenges, India is meticulously stepping towards offsetting or the onset of carbon farming such as organic cultivation and solar energy interventions. Offset carbon farming area of 5. 387 Mha organic farming could sequester carbon annually of 6.567 mt, simultaneously; it has the advantage of reducing synthetic nitrogen fertilizer application doses ranging from a minimum of 0.27 mt and a maximum of 1.08 mt per hectare. Furthermore, solar energy can indirectly be used as SWH suitable for average family households contributing carbon credits of 771 kg-824 kg in addition to saving an annual electricity burden of around 1365 kWh to 1459 kWh and directly utilized for solar PV electricity generation of 1 MW will offset approximately 730 tons of CO2 emissions, which is equivalent to 33, 183 carbon-absorbing trees (22 kg of CO2 absorbed/ tree/year). Carbon farming has challenges encompassing economic, technological, policy, and knowledge-based barriers that require innovative solutions and concerted stakeholder efforts.

Keywords: Carbon Farming, Carbon sequestration, Flat plate collector, Organic farming, GHG emission, G-20, Solar panel, Photovoltaic cell.

1. INTRODUCTION

Carbon credit also known as carbon offsets or emission reduction credits, and term used to measure tons of carbon dioxide or its equivalent greenhouse gas is capsized trough climate resilient methods such as soil carbon sequestration, renewable energy, conservation ecology, blue carbon management, ocean alkalization and increase of power efficient machines/tools. Carbon credits are financial instrument used in carbon trading markets to stimulating step that reduce greenhouse gas emissions. Due to the climate change, Intergovernmental Panel on Climate Change (IPCC) laid stringent acts and regulation frameworks for alleviation of carbon dioxide emission. In India, the distribution of greenhouse gas (GHGs) emission from different sector is electricity & heat-35%, agriculture-23.18%, manufacturing & construction 15%, transportation-8.645%, building-5.08%, industrial process-4.67%, fugitive emission-2.78%, waste-2.67% and other fuel combustion-2.03 %(Statista.com). Consumption of nitrogen, synthetic fertilizers, in India was 17.6 Mt and its share of global GHGs emissions 14.7% through Industry emissions from synthetic nitrogen fertilizer production was 55.2±8.6 Mt CO_2 and Soil emissions from application of synthetic nitrogen in agriculture is 110.4±85.2 Mt CO_2eq (Menegat, *et al.,* 2022)

2. Cause for Global warming

If the concentration of CO_2increase, then there will be increase in heat trapping capacity of GHGs may leads to rise of temperature. India stands third largest GHGs emitter after China and the US. There are three major principal gas globally which contribute climate change are 72 % carbon dioxide(CO_2), 16% methane(CH_4) and 6% nitrous oxide (N_2O). The sources of CO_2 are fossil fuel combustion, deforestation, for CH_4 landfill, rice paddles, digestive track of livestock's (enteric fermentation and manure) and N_2O source fertilizers and animal waste (US EPA).

Among all GHGs, CO_2or CO_2equivalent (eq.) is used to represent impact on climate change. Therefore, the magnitude of global warming is measure by Global Warming Potential (GWP) scale developed by IPCC. GWP measures the amount of energy or heat that is absorbed by the 1 ton of GHGs emitted over given its life period. Further, the GHGs impact was determined by length of time it remains in atmosphere and ability of gas to absorb energy or heat. The pay-off of 1 ton of methane and nitrous oxide on warming the atmosphere is 25 and 298 times each that 1 ton of carbon dioxide. The atmospheric lifetime of methane gas is much shorter than CO_2 (around 12 years compared with centuries for CO_2), but Nitrous oxide molecules stay in the atmosphere for an average of 121 years.

3. Scope of Carbon Credit Farming in Indian Scenario

A number of possible routes are available for carbon farming to achieve cash carbon dioxide reduction (CDR) or sequestering carbon in their soils. This carbon credit scheme is available either through offsets or insets of carbon farming schemes.

3.1. Offset Carbon Farming:

In carbon offsets, carbon credits are generated by reducing carbon emissions or sinking carbon in from atmosphere through agricultural and land management's practices.

Carbon sequestration involves activities that enhance the capture and storage of carbon in plants and soil. This can be achieved through reforestation, afforestation, agroforestry, crop rotation, strip-till, no-till and cover crops. Reducing Emissions from Natural and Organic Agriculture is another aspect of offset carbon farming where minimizing or complete elimination of use of synthetic fertilizers and chemicals that reduce potent nitrous oxide gas emissions. Further, reduction of methane, a potent greenhouse gas, from livestock and rice paddies can be done by changing livestock diets, improved manure management, and alternative wetland rice cultivation method.

3.2. Inset Carbon Farming:

The in-setting carbon mechanism is adopted by multinational companies such as PepsiCo, Coca-Cola, Unilever, Heineken, Walmart, Amazon, IKEA, Google, Apple, Bayer, etc., towards the strategic elimination of GHGs emissions within its own supply chain, manufacturing practices, waste management, and sustainable sourcing of materials to achieve goal. Most companies prefer to target agricultural production chain to sequester carbon through the implementation of regenerative agriculture practices, renewable energy adoption, and energy-efficient tools practice.

4. India Role in Alleviation of GHGs Emissions

Global warming is one of the greatest treat for future generation existence as some of the biological species are at the verge of extinction. Solving it demands requires framing policies and implementation of frameworks, acts and regulation to mitigate carbon emission on or off sites. Apart from this, it is also important to create awareness through teaching, training and publication to bring socio-cultural practice and behavioral changes. Towards climate resilient endeavour, India pledged a 33-35% reduction in the emissions intensity of its economy by 2030, compared to 2005 levels through various initiatives. The Government of India has launched National Action Plan on Climate Change (NAPCC) on 2008 was outlined eight national missions for achieve set target and to emerge as carbon neutral by 2070. These are national missions on solar, water, sustainable agriculture, sustainable habitat, sustaining the Himalayan ecosystem, green India, enhanced efficiency energy and strategic knowledge for climate change.

For this purpose, Indian organic farming and renewable energy sectors have made significant contributions to limiting climate change. The organic farming area of

5.392 million hectare (mha) was 3.848% (www.apeda.gov.in) out of the net sown area 140.1 mha and the manure-based organic farming sequestered annually 6.567 million ton(mt) carbon or 1,218 kg carbon per ha (www.pureecoindia.in). Further, organic farming eliminates carbon footprints of nitrogen fertilizer's production, processing and transportation.

In India, the recommended nitrogen fertilizer application per hectare is 120–200 kg for rice and 50–185 kg for wheat, resulting in minimum and maximum nitrogen fertilizer reductions due to organic farming is 0.27mt and 1.08mt, respectively (Sapkota, *et al.,* 2020).

5.0. Impact of Renewable Energy

Renewable energy sector is booming as it was witnessed recent G-20 summit launch Global Biofuel Alliance for mixing 20% ethanol in fossil fuel petrol. Renewable energy also known as non-conventional, permanent, energy produced from sources like the solar, wind, hydro and biofuels, that are naturally replenished, and do not get extinguished. Solar energy is considered the most promising source of limitless energy among all of them.

5.1. Application of Solar Energy

India, a tropical nation, enjoys 2300–3200 hours of sunshine each year, or around 300 days of acceptable solar radiation. Depending on the location, almost every region receives 4–7 kWh of solar radiation per square meter (Biswas, *et al.,* 2021). The energy industry, which is used to produce heat and power, is mankind's largest contributor to the climate catastrophe. Therefore, it is inevitable source of free and ample energy can be harvested broadly classified into two categories: (1) direct electricity generation using solar photovoltaic panels; (2) indirect conversion using solar thermal collectors (Pandey, *et al.,* 2022).

5.1.1. Solar Thermal Collector –Solar Flat Plate Water Heater

There are two distinct types of solar flat plate water heaters (SWH): active and passive. The primary distinction between the two is pumping of water through the SWH. The active type of SWH utilizes external electrical energy to pump water, while the passive type does not. The passive type SWH consists of following parts;

a. **Flat Plate Collector (FPC):** The FPC rectangular box is an essential component of the solar heating system. It is equipped with liquid heating conductive tubes, and the interior is completely covered in black paint to absorb the heat generated by solar irradiance. The box is sealed with a top cover made of transparent glass, and insulated along the sides and bottom to prevent heat loss. It is constructed from either aluminium sheet or wood, and is mounted on four stand-angular iron supports.

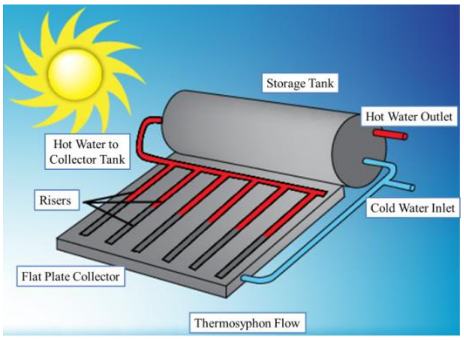
b. **Heating Pipes:** it consist of number of 0.5-1 inch closed conductive copper or steel or vacuum glass pipes. These pipes assembled inside flat plate collector where heating and passage of liquid takes place inside pipes based on thermosyphon and capillary flow principle. Further, for the thermosyphoning process to work correctly, the base of the hot water storage tank must be situated at least 1 to 2 feet (300 to 500 mm) above the top of the flat plate collectors. Also, these collectors are made up of many evacuated glass tubes that are connected in parallel. The most common types are glass-glass tubes and glass-metal tubes, which are made of tubes fused to one another on one end. While single evacuated tubes with an aluminium curved plate attached to a copper pipe in the inner part are very efficient but may present some vacuum loss issues as their seal is glass to metal, the selective coating on the inner glass tube in glass tubes absorbs the majority of the solar radiation that is available.

c. **Hot Water Storage Tank:** the solar water heating system component has special design to store the heated water based on the size of the FPC and Sunshine exposure time.

$$Solar\ heat, \frac{KJ}{Sec} = \frac{\rho * v * \Delta u}{\Delta t}$$ -----------(1)

Where,

ρ=Water Density (Kg/m³)



v= Water Volume (m^3)
$\Delta u = 4.18\ (T_2 - T_1)$ (KJ/Kg)
Δt=Sunshine time (Sec.)

5.1.2. Sizing a Solar Flat Plate Water Heater:

Figure 1. Solar Flat Plate Water Heater

The size of a solar thermal system is contingent upon a variety of factors, including the amount of hot water required, the desired temperature, and the amount of energy consumed.

For example, an area of 1000 cm^2 (one square foot) can heat approximately 10 liters per day, reaching temperatures of up to 70^oC. A flat plate solar water heating system with a total area of 2.01 m^2 and a 200 L storage tank is best suitable for an average four-person household. This SWH system could benefit from annual carbon credits of 771 kg to 824 kg in addition to saving annual energy burden around 1365 kWh to 1459 kWh with a solar incidence of 39.4% to 34.2% (Mohammed, *et al*.,2021)

5.1.3. Direct Electricity Generation: Solar Photovoltaic Panels

When solar radiation photons strikes on the surface of solar cells (photovoltaic cells-PV), it creates photovoltaic effect will directly converted sunlight into electricity without mechanical intervention. These PV cell is the basic building block of a PV system, individual cells can vary from 0.5 inches to about 6.0 inches across and one cell only produces 1 or 5 Watts. There are three main sizes of solar panels or module to know: 60-cell, 72-cell, and 96-cell are capacity of power output between 250watts to 450 watts. Solar array is set of solar modules arranged to meet power demands as shown in figure 2 below (https://www.eia.gov). The solar panel consists of following parts;

a. Solar Photovoltaic (PV) Module:

PV cells are created by doped silicon n-p type semiconductor materials. These solar cells are sandwiched between front transparent antiglare glass and back plastic, polyvinyl fluoride film, rigid panel as shown in fig.3(A). These solar cells are sandwiched between front transparent antiglare glass and back polyvinyl fluoride film as shown in figure A. The n-type semiconductor produced by doping Phosphorus, a pentavalent, group V element and this thin wafer is embedded with metallic conductor are enclosed with module encapsulater. The p-type semiconductor is made by doping Boron, a trivalent, group III element and this thicker sheet is embedded with metallic conductor are enclosed with module encapsulater. The photovoltaic effect is caused when sunlight passes through the top thin layer, n-type semiconductor, over the depletion zone through the thick, p-type semiconductor fig.3(B). (https://www.chrvojeengineering.com)

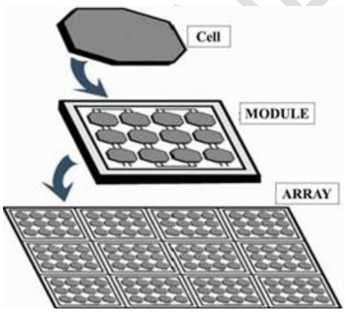


Figure 2: PV system

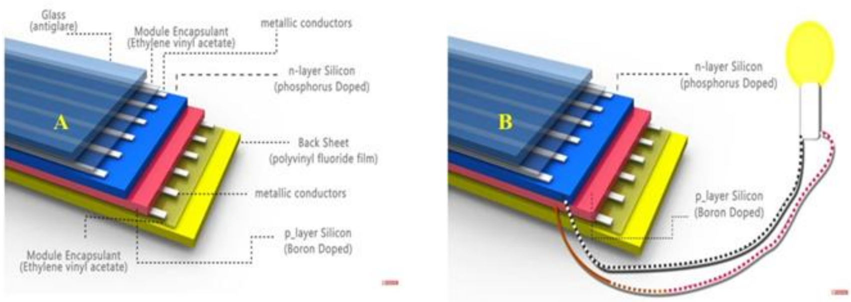


Figure 3: Configuration and working of solar photovoltaic (PV) cell

Figure **4.** Solar panel racking system

b. Support Frames:

The mounting system that secures the solar array to the ground or rooftop is referred to as a support frame. These frames made up of steel or aluminium is either fixed stationary type or movable type to modify the orientation of the panels, optimizing their exposure by tilting them towards the sun's rays.

c. Electric Cables:

These are the cables that carry energy from the system to the users.

d. Inverter:

The electronic equipment is responsible for converting the energy generated by the modules (known as direct current, or DC), into the kind of energy used by consumers at home or at the workplace, known as alternating current, or AC.

5.1.4. Applications of Direct Solar PV Cells

Sun light directly used to generate DC current through PV modules are installed in various means of applications demand are broadly classified as;

1. **Roof Top Solar (RTS) Programme:** Under rooftop solar scheme, Central Financial Assistance (CFA) of 40% for RTS systems up to 3 kW capacity and 20% for capacity beyond 3 kW and up to 10 kW is provided.

***Figure* 5.** Solar Roof Top PV Panel system

2. **Solar Parks**

Solar parks programme was introduces with objective of facilitating solar project developer to set up solar parks in a plug-and-play model. This scheme alone has a target capacity of 40 GW. All States and Union Territories are eligible for getting benefit under the scheme. In this flagship, the Pavagada Solar Park in Tumkur district of Karnataka would be the largest solar park in the world with capacity of 2,000 MW was developed at once in 11,000 acres area.

According to annual report of mnre website, the aggregated solar parks approved capacity in Andhra Pradesh, Madhya Pradesh, Maharashtra and Rajasthan were 4,000 MW, 2,750 MW, 1,500 MW and 3,351 MW, each respectively.

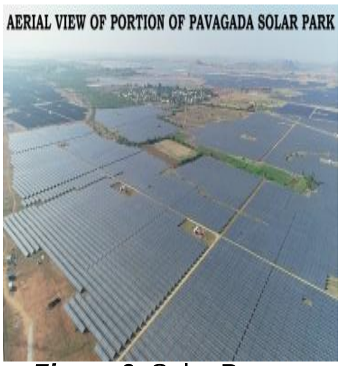


***Figure* 6.** Solar Power Parks

3. **Greening of Islands**

This program's heart hub was to install 52 MW of distributed solar PV electricity that was connected to the grid in order to completely changeover the Andaman & Nicobar and Lakshadweep islands to green energy.

4. **Solar Cities**

The resolution of solar cities is part of the broader movement towards sustainable and renewable energy sources, aiming to reduce CO_2 and tackle climate change. In Indian context, at least one city of each state, which is more tourist destination or state capital, is being developed as a solar city. All electricity needs of the city will be fully met from renewable energy sources, primarily from solar energy.

5.1.5. Sizing of a Solar PV Panel:

India is a tropical country. Lying entirely in the Northern hemisphere the mainland extends between latitudes 8°4'N and 37°6'N. Being part of tropic zone, the country has assessed solar potential of about 748 GW. A standard solar panel for residential use will contain 60 solar cells and have an average length of 65 inches with an average width of 39 inches.

The average solar panel in a commercial setting will have 72 solar cells, a length of 78 inches, and a width of 72 inches. In the year 2015, India target was to raise 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022, targeting an investment of US$ 100 billion (Ahmad, *et al.,* 2018). Further, the solar power installed capacity has reached around 61.97 GW which includes solar projects of 52 GW from ground-mounted, 7.82 GW from rooftop, and 2.09 GW from off-grid (street and home light, and solar pumps) (https://mnre.gov.in).

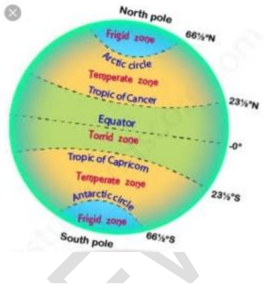


***Figure* 7.** Latitudes and heat zones

Table 1. Energy payback period and GHG's emissions various among different type of PV panel are detailed (Peng, *et al.,* 2013);

Sl No.	PV panel	Pay-back period	GHG emissions
1	Mono-crystalline silicon (mono-Si)	1.7 to 2.7 years	29–45 gCO_{2eq}/kWh
2	Multi-crystalline silicon (multi-Si)	1.5–2.6 years	23–44 gCO_{2eq}/kWh
3	a. Amorphous silicon (a-Si) b. CdTe thin film c. CIS thin film	0.75–3.5 years	10.5–50 gCO_{2eq}/kWh

5.1.7. SolarElectric(Photovoltaic)SystemCalculations–Offgridsystemonly

I. *EstimatingSolarElectric(PV) SystemSize:*

Modern photovoltaic (PV) solar panels will typically provide 8 to 10 watts per square foot of solar panel area (as a general "rule of thumb"). For instance, 200 square feet (20ft x 10 ft) is the size of a roof. This would generate about 9 watts per square foot, or 1,800 watts (1.8 kW) of electricity in 200 square feet.

II. *ConvertingPower (wattsorkW)toEnergy(kWh)*

A power source that produces 1,000 watts of electricity for an hour is said to be producing one kilowatt-hour (1 kWh). A solar energy system typically produces energy for 5 hours every day. Therefore, if your solar energy system has a capacity of 1.8 kW and operates for 5 hours per day, 365 days a year, it will generate 3,285 kWh in a year (1.8 kW x 5 hours x 365 days).

III. *PV System Capacity Required (kW of PV) :*

Annualelectricity usage, kilowatt-hours= Monthly Usage x 12 months. Electricity

6.0. Benefits and Challenges of Carbon Credit Farming integrated with Solar energy:

6.1. Benefits:

Carbon Sequestration: Trees and vegetation planted on farmland sequester carbon, helping to offset carbon emissions from other sources. This carbon sequestration can be quantified and traded as carbon credits in carbon markets.

Clean Energy: Solar panels provide a sustainable source of electricity or heat, reducing the reliance on fossil fuels and cutting greenhouse gas emissions associated with conventional energy sources.

Financial Incentives: By participating in carbon credit programs, farmers can earn revenue through the sale of carbon credits, offering an additional income stream.

Sustainable Agriculture: Solar energy can enhance the sustainability of farming operations, making them more energy-efficient and reducing operational costs.

6.2. Challenges and Considerations:

Upfront Costs: Installing solar energy infrastructure can require a significant initial investment, although it often pays off in the long run through reduced energy bills and potential carbon credit revenue.

Land Use Planning: Careful consideration is needed to ensure that solar installations do not conflict with agricultural land use and can coexist with farming activities.

Regulatory Compliance: Compliance with local regulations and permitting for solar installations is essential.

Monitoring and Reporting: Robust monitoring and reporting systems are necessary to accurately quantify and verify carbon sequestration for carbon credit certification.

In summary, carbon credit farming with solar energy is a holistic approach that aligns environmental and economic goals. It contributes to climate change mitigation, renewable energy generation, and sustainable agriculture. While there are challenges to overcome, the integration of carbon credit farming and solar energy represents a promising solution for a more sustainable and resilient agricultural sector.

While implementing a carbon credit scheme, that also poses several challenges; the challenges are given below:

1. Regulatory and Environment Policy: The effectiveness and stability of renewable energy, regenerative farming practices, afforestation, and reforestation credit schemes are often influenced by the regulatory and policy environment. Frequent policy changes or a lack of supportive policies can create uncertainty for market participants.
2. Verification and Tracking: Accurately verifying the production and delivery of carbon credits via renewable energy, regenerative farming practices, afforestation, reforestation, and other sources can be complex. Thus, tracking these sources ' carbon footprint is time consuming and costly and often requires specialized expertise and technology
3. Market Oversupply: Companies investing in renewable energy, regenerative farming methods, afforestation, reforestation, and energy-efficient technology are having trouble because of lower pricing and less incentives brought on by market overstock.
4. Complexity and Transparency: Lack of capacity building and awareness among small and medium sized enterprises (SMEs) to participate in carbon credit markets can be a barrier and complex. Ensuring transparency and ease of participation can help overcome this challenge.
5. Market Fragmentation: Different regions and countries often have their own credit systems and standards, leading to market fragmentation.

7.0. Conclution

To build safer climate to the next generation, invariably, one has to think of harnessing free and regenerative sources of renewable energy production routes. These greenery paths not only results way forward safer climate, balanced ecosystem and evades fossil fuel dependency. To combat climate change, fundamentally, there can be top down approach and/or bottom up approaches such as domestically framing policy and implementing framework, forming rules and regulation, and capacity building, awareness programs, changes in behavioural perception and socio-cultural options, respectively. India had pledges to reduce CO_2 or CO_{2eq} GHGs by meeting energy requirement 50% from renewable energy by 2030 and has target to achieve net zero carbon by 2070.

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