



Importance and Scope of Renewable Energy in Agriculture Sector

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Agriculture plays the core role in the provision of food security, livelihoods and economies in the rural areas. However, the issues of energy consumption growth, climatic changes, and unpredictability in the cost of fossil fuels are rather problematic to sustainable agricultural development. As another source of renewable energy, a solution to these problems is possible through the use of renewable energy, which is naturally replenished like solar, wind, biomass, and geothermal energy. The role and significance of the renewable energy in the agricultural sector through the analysis of sectoral energy requirements, technological use, environmental and economic advantages, policy supporting measures as well as current impediments to its use. The most important applications are solar-powered irrigation systems, cold storage systems, biomass-produced energy generation, biogas digesters, wind pumping systems, and controlled environment geothermal heating. Another source of energy is not merely renewable energy but also a strategic part of modernization of agriculture in terms of its sustainability, prevention of climate changes and economic progress of rural territories.

Keywords: Biogas Digesters, Geothermal Energy, Sustainable Agriculture, Economic Development

The economy of the surrounding world, the livelihood of the rural population and the food systems are all dependent on the agriculture sector. Radical solutions are needed to sustainable solutions to growing demands of food, fiber, and biofuel with the challenges of climate change, water scarcity, and the uncertainty of energy security. Renewable energy - energy which is derived by the self-renewable resources such as the sun, wind, biomass, hydro, geothermal amongst others has become one of the biggest enablers of sustainable agricultural development. Along with the reduction of greenhouse gas emissions, decrease of dependence on imported energy, rural electrification and climate-sensitive agriculture, renewable energy can also be applied in agriculture, and its application is potentially relevant; technologies exist, economic and environmental benefits may be obtained, policies are required to facilitate its use, the impediments to its use, and opportunities may arise in the future.

Agricultural Energy Demand

Agriculture is one of the largest consumers of energy and also has the potential of generating energy. Energy is required in agricultural activities:

- Farm Production: Pumping Irrigation, Tilling, planting, fertilizer, harvesting.
- Processing and storage Grain drying, refrigeration, milling and cold storage.
- Transportation: The flow of inputs and outputs in value chains.
- Facilities: Light, heating and ventilation of livestock house, greenhouse.

Climate Change, Agriculture and Energy Security

The phenomenon of climate change in the environment cannot be discussed outside the context of agriculture sector and energy consuming sectors:

- **Greenhouse Gas Emissions:** Agriculture sector produces a significant percentage of emission of gases (CO₂ consumption of energy, production of methane by livestock, production of nitrous oxide by soils etc). Another way of reducing carbon footprint is through a reduction in the use of fossil fuel in agriculture sector.
- **Volatility of the energy prices:** relying on fossil fuels will subject farmers to international market fluctuations that may strip the profitability.
- **Rural Energy Access:** In most developing countries, rural localities do not have the grid electricity and thus, agricultural production and mechanization is hard.

Renewable energy is a response to these problems with its stable low-carbon and decentralized energy that achieves the goals of mitigating climate change and energy security.

Renewables in Agriculture: Technologies and Applications

There are a number of renewable energy sources which could be used in the agricultural industry and the advantages of each of them are as follows:

1. Solar Energy

Solar energy is the most frequent renewable energy that is employed in agricultural sector bearing in mind that the cost of the panels has been on the decline and most of the farm lands are very remote.

[1]. **Solar Photovoltaics (PV):** High Solar PV harnesses sunbeams is lead to produce electricity.

Applications include:

- **Irrigation Pumping:** run on solar energy are used instead of diesel-powered engines to extract groundwater, which means that there is no cost of fuel consumption.
- **Cold Storage/Cooling:** Solar PV provides off-grid cold rooms, which save the loss of fruits and vegetables used after harvest.
- **Electric Fencing & Lighting:** Solar offers effective power in perimeter protection and facility illumination.

[2]. **Solar Thermal Systems:** Solar thermal does not generate electricity but heat:

- **Cooler temperatures:** The heating of greenhouses is performed by means of solar collectors throughout less favorable weather conditions.
- **Drying of Crops:** Solar dryers enhance quickness in removing moisture and help in better quality and a decrease in contamination.

2. Wind Energy

The wind energy involves the use of turbines and the kinetic energy of the air flow.

- **Wind Pumps:** The traditional windmills are applied to pump the water which is consumed by livestock, or irrigate more land.
- **Wind-Electric Generators:** Bigger turbines have access to, or provide power to, microgrids or farm operations.

The wind energy can supplement solar energy particularly in areas where wind seasonally varies providing portfolios that are diversified in energy.

3. Biomass and Biogas

Biomass under the biomass category include crop residues, animal manure and agro industrial wastes.

1. **Biomass Combustion:** Direct burning of the straw, husks and crops which produce energy is used to produce heat like:

- Drying grain
- Providing heat to the processing units.

2. **Biogas Digesters:** Organic waste is leading to anaerobic reaction in digester to produce biogas like methane (CH₄) mainly, carbon dioxide (CO₂) etc. that could be used to in many ways.

3. Cooking and heating

- Electricity generation through gas engines.
- Fertilizer made using the digestate.

4. Geothermal Energy

Geothermal systems are systems that use subsurface heat to:

- Heating greenhouses
- Temperature control of aquaculture water.
- Poultry and livestock barns

Geothermal offers uninterrupted and dependable heat at low operation expenses although it is site specific.

Positive aspects of Renewable Energy in Farming

Implementation of renewable energy offers ecological, economical and social benefit.

1. Environmental Benefits

- **Less Carbon Emission:** With the substitution of the fossil fuels with renewables, the Carbon emissions will be reduced and this will aid in fight against climate changes.
- **Less Air Pollution:** Cleaner energy decrease pollution in air and also reduce hazardous emissions gases.
- **Sustainability Resource:** Solar and wind do not require any water to produce power that is used to conserve fresh water in deserts.
- **Improved Soil and Water Quality:** Biogas digester and other activities contribute to the minimization of run off the nutrients and odour.

2. Economic Benefits

- **Reduced Operational Costs:** Solar and wind do not incur the cost of diesel and electricity bill and instead they provide free or cheap energy.
- **Higher Profitability:** Saving in energy can be invested in farm inputs, technology and expansion.
- **Creation of Job:** Rural Employment Installing, maintaining and operating renewable systems create jobs in the rural area.
- **Value Added Products:** Cold storage and processing things with an extended shelf life span and market length of the product and increased incomes of the farmers on a renewable base.

Renewable Energy Sources in Agriculture (Examples)

1. **Solar-Powered Irrigation in India:** Solar irrigation pumps have been used to replace the diesel irrigation pumps in the agrarian areas of India; this has ensured that water is available all season long, the fuel costs are low and the emissions are minimal. Subsidies and financing of government programs have increased uptake. The farmers are reporting of higher crop intensity and less operational risks.
2. **Agricultural systems with solar panels have been proposed (Agrivoltaics):** In agrivoltaics, agrivoltaics are placed over crops which are not heavily shaded. This dual purpose of land boosts the production of energy and also enables agricultural production which boosts the land productivity.

Barriers and Challenges to Renewable Energy Adoption in Agriculture

There are obvious advantages but some barriers to adoption exist:

1. **Financial Constraints**
 - **High initial Costs:** Biogas stations, solar PVs and wind turbines are very costly to during installation.
 - **Adverse Financing:** Smallholder farmers do not have access to financing options.
2. **Knowledge and technical barriers**
 - **Skill Gaps:** Farmers can be unskilled in technical areas of operation and maintenance.
 - **Design and Planning:** Renewable systems have to be designed and planned to fit the patterns of farm energy production.
3. **Policy and Regulatory Issues**
 - **Inequalities in Policies:** The absence of good policies or other subsidies may dishearten investment.
 - **Grid Interconnection Problems:** Grid Farmers who produce energy in excess can not necessarily connect with the grid due to regulatory obstacles.
4. **Limitations to Land and Resources**
 - **Land Use Conflicts:** The need to use land between energy and food production (particularly, bioenergy crops) may be in conflict.

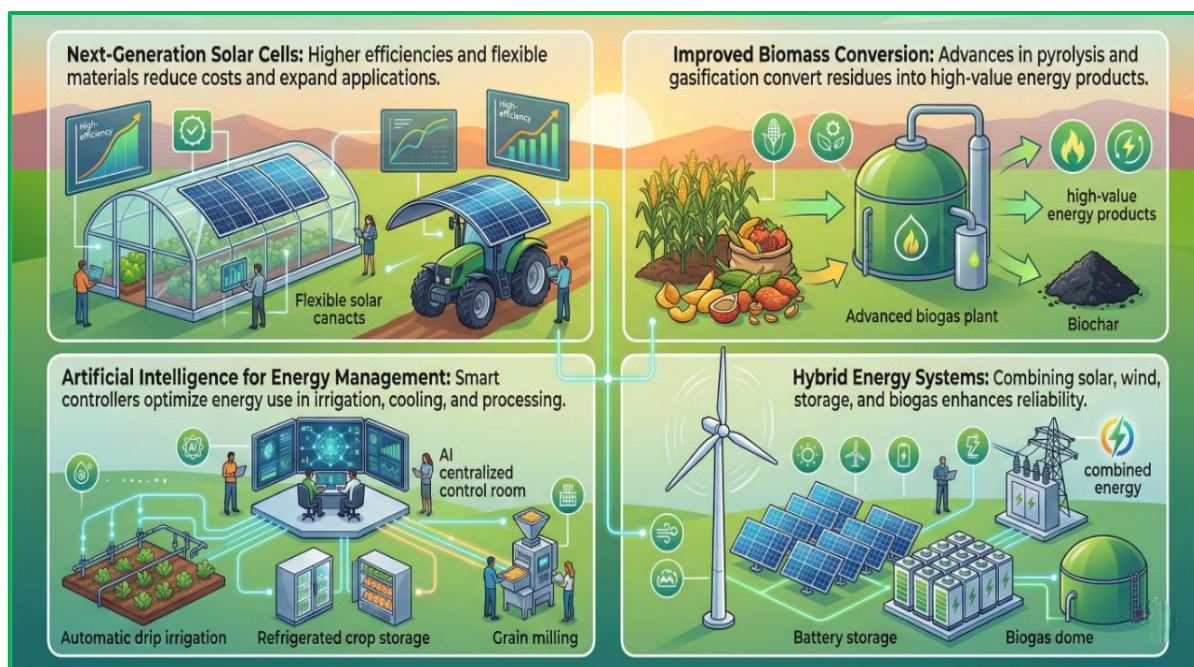


Fig. 1: Research and Innovation in Renewable Energy for Agriculture

Future Prospects and Vision

Renewable energy has a greater future in the agricultural sector:

- **Climate-Resilient Agriculture:** Adaptation of climate is founded on renewable energy that ensures that there is supply of water, cooling and even mechanization.
- **Decentralized Energy Economies:** Village scale energy infrastructure can be used to drive common processing and storage centers.
- **Circular Bioeconomies:** Biomass energy can be self-sufficient due to bioenergy and recycling of nutrients and biofertilizers.
- **Digital Agriculture Integration:** IoT and smart grids improve the efficiency and decision making of energy in farms.

The renewables will take over in agricultural energy portfolios as policy frameworks are tightening and technologies are still evolving.

Conclusions

At the core of sustainable food systems, climate mitigation, rural development, and energy security, renewable energy in agriculture is not a few-mode choice. The overlapping of environmental need, financial motivation, and technological progress renders renewable energy feasible and compulsory to the present-day agriculture. Renewable energy is relevant as it helps to reduce costs, emissions, and boost productivity and resilience. Renewable energy will become a stronger indicator of the future of agricultural modernization in the coming decade, taking farmers into the clean energy revolution, making rural economies stronger, and supporting the main agriculture in accordance with the world sustainability objectives.

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