SOLAR PV-POWERED DRYERS IN AGRICULTURAL PRODUCE PROCESSING FOR SUSTAINABLE RURAL DEVELOPMENT IN THE PEOPLE'S REPUBLIC OF CHINA

Josephine Baffoe [1, †], Li-hua Ye [1, †, *], Yefan Shi [2], Hao Chen [1], Ai-ping Shi [1,]
[1] School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang 212013, China
[2] Puya Semiconductor Co., Ltd, Shanghai, China«
[†] Equally contributed to the study.
** Corresponding author: Li-hua Ye, Zhenjiang 212013, China,*

Article DOI: https://doi.org/10.36713/epra21443
DOI No: 10.36713/epra21443

ABSTRACT--
This research investigates how agricultural produce processing using solar PV-powered dryers can promote sustainable rural development in the People's Republic of China. These dryers reduce post-harvest losses and promote environmental sustainability by improving the effectiveness and quality of agricultural product preservation through the use of renewable energy. Significant financial gains may be made thanks to the technology, which gives farmers access to new markets and raises their revenue while boosting local economies by generating jobs. The viability and advantages of solar PV-powered dryers are improved by technological breakthroughs, supporting legislation, and extensive training programmes, even in the face of obstacles like upfront costs and the need for technical expertise. All things considered, their broad acceptance may greatly support food security, rural development, and sustainable agriculture practices in China.
KEYWORDS: *Solar-PV dryers; Photovoltaic (PV); P.R. China; Agriculture; Solar cabinet dryers; Hybrid solar-PV dryers* --

1. INTRODUCTION

Using more renewable energy offers the advantage of lowering pollution levels and dependency on fossil fuels (Awogbemi and Kallon, 2023). Therefore, to meet the Sustainable Development Goals (SDGs), each nation should prioritize the usage of renewable energy while creating its national strategies for energy sustainability (Awogbemi and Kallon, 2023; Messina et al., 2022a). For China's rural communities to achieve the SDGs, solar drying agricultural goods is crucial (Messina et al., 2022a; Shi et al., 2023; Wang and Zhou, 2013). In China's rural areas, solar PV-powered dryers have become a viable option for processing agricultural products (Kong et al., 2024; Messina et al., 2022b; Yu et al., 2024). Solar PV-powered dryers support sustainable rural development by promoting:

- Energy efficiency: Through the use of sustainable solar energy, solar PV-powered dryers dramatically lessen agricultural processing's need for fossil fuels and grid electricity. These solar-powered dryers provide a sustainable substitute for traditional drying techniques like open-air or fossil fuel-powered dryers, which are frequently ineffective and detrimental to the environment.
- Cost savings: Farmers may reduce their energy expenditures by using solar PV-powered dryers to avoid paying for fuel or electricity while using conventional drying techniques. Since sunshine is free and plentiful in rural regions, solar PV systems have low operational costs once installed. As a result, farmers have less financial strain and are more viable economically, which promotes sustainable rural development.
- Increased processing: To accommodate the various requirements of smallholder farmers and agricultural cooperatives, solar PV-powered dryers may be built with adjustable capacity and flexible designs. These dryers help farmers effectively process bigger volumes of produce, decreasing post-harvest losses and expanding market access by improving processing capacity and throughput. This improves rural populations' chances to generate revenue and ensure food security.
- Improved product quality: Dryers driven by solar photovoltaic cells allow for exact control over drying parameters including temperature, humidity, and airflow, which improves the consistency and quality of the final product. These dryers increase market value and customer satisfaction by maintaining the nutritional content, taste, and aesthetic appeal of agricultural products through the optimization of drying parameters. Higher profits for farmers and more rural economic growth follow from this.

- Environmental sustainability: When compared to traditional drying techniques, solar PV-powered dryers have a lower environmental effect since they emit no greenhouse gases or air pollutants while they are in use. These dryers aid in the mitigation of climate change and the improvement of air quality in rural regions by lowering dependency on fossil fuels and encouraging the adoption of renewable energy. Furthermore, the minimal carbon footprint that solar PV systems have throughout their lifetime contributes to their environmental sustainability.
- Technology transfer, and capacity building: In rural China, the use of solar PV-powered dryers encourages technology transfer and capacity development programs, giving local populations access to information and expertise in renewable energy technologies. In rural regions, training programs and seminars on solar energy installation, maintenance, and operation encourage entrepreneurship and generate job possibilities, promoting inclusive and sustainable development.

From the earliest people to the present, solar drying techniques have developed. Modern solar-PV dryers use electric-driven extractors (Yin et al., 2022), solar photovoltaic extractors (Gorjian et al., 2020), and solar photo-thermal converters (Mousazadeh et al., 2009) to speed up the drying process (Andharia et al., 2024). A relatively new initiative in China's solar thermal application portfolio is sun drying (Saini et al., 2023a). Only seven sets of sun dryers were available for pilot studies in the 1970s (Belessiotis and Delyannis, 2011; Saini et al., 2023a) when a small number of institutes began researching and developing solar drying (Belessiotis and Delyannis, 2011; Jia et al., 2018). Nonetheless, the Chinese government has actively supported the fast growth of sun-drying applications in recent years (jia et al., 2018; Zhou et al., 1993).

In China's rural areas, open-air sun drying is the traditional way of drying crops and byproducts (Ortiz-Rodríguez et al., 2022; Shahbazi et al., 2024). It is mostly dependent on the weather and environmental conditions, and it offers limited control over the drying quality (Ndukwu et al., 2023). For example, grit, dust, and insects frequently contaminate the dried items (Belessiotis and Delyannis, 2011). Rainfall is a major issue for post-harvest drying throughout the summer-autumn harvest season. In China's rural areas, the use of renewable energy has been expanding since the 1980s (Ortiz-Rodríguez et al., 2022; Zhou et al., 1993). While solar-PV dryers are utilized in some industrial processes, solar water heaters (Yang et al., 2023), solar cookers, and passive solar homes (Shahbazi et al., 2024) are valued for enhancing farmers' everyday lives (Ortiz-Rodríguez et al., 2022). According to the World Solar Summit report (Zhou et al., 1993), a relatively new initiative in China's solar thermal application portfolio is sun drying. With a total aperture area of 10.178 m^2, 108 sets of various types of solar-PV dryers have been constructed thus far, with 85% of those sets being constructed after 1983 (Belessiotis and Delyannis, 2011; Zhou et al., 1993). It is commonly known that China possesses a vast number of solar energy resources (Su et al., 2023). Chinese ancestors harnessed sun energy to insulate maize, salt, and clothes thousands of years ago. Until recently, simple applications such as solar energy street lamps, solar water pumps, solar heaters, and solar energy chargers were employed to enhance the lives of regular people (Hu, 2023). The popularity and potential of solar-PV dryers in Chinese agriculture have led to a thorough discussion of the revolution and current developments in this research. There is also an explanation of the contemporary solar-PV dryer kinds used in Chinese agriculture. In China and other regions of the world, this study aims to be a reference for researchers, policymakers, and students who are creating innovative solar-PV dryer technologies.

2. SOLAR PV ENERGY ADVANCEMENT IN CHINESE AGRICULTURE

PV generation in China currently has a 0 % share (Hu, 2023). Fortunately, the government has recognized the importance of PV generation, and some goals have been set in the strategic planning of Chinese renewable resource utilization from 2006 to 2020 (Awogbemi and Kallon, 2023). According to CDIC data (Liu et al., 2010), the object of renewable energy development in 2020 includes 0.3 billion kW of large water electric power, 30 GW of wind energy, 1.8 GW of solar PV generating system, 30 GW of biological energy, 0.3 billion m^2 of solar water heater, and 15 billion litres of biology fuel. Renewable energy will account for 25 % of the total energy supply in 2050, with PV generation accounting for 5 % (Al-Mamun et al., 2023).

In the last ten years, China's PV sector has grown dramatically. For example, the production of Chinese PV in 2007 was more than 1200 MW (Zou et al., 2017), with a global share of 35 %, ranking first in the world (Kumar Sahu, 2015). Various real-world applications have been employed to enhance people's daily lives (Che et al., 2022). Solar PV was critical in giving contemporary energy access to isolated populations (Urban et al., 2016). Agrivoltaics appeared as a technical innovation for solar PV application in the early 2010s (as shown by **Figure 1** below), when multiple factors merged to propel a spatial restructuring from centralized large-scale solar power plants in China's desolate west to smaller-scale distributed solar PV models in China's east and south (Hu, 2023). Unlike the much-discussed solar PV poverty alleviation projects that were directly initiated and promoted by state actors for poverty alleviation, agrivoltaics has served as an important strategy to alleviate the accumulation crisis of solar capitalism, albeit with formidable state power assistance. The combination of green capitalism and local governments encouraged agrivoltaic models throughout China (Senthil Kumar et al., 2020).

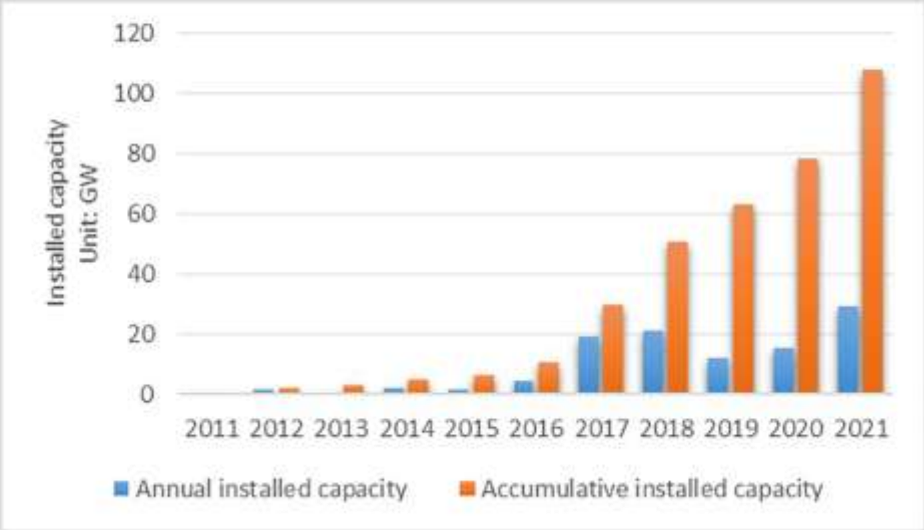

Figure 1 The increasing trend of distributed solar PV installation capacity in China (Hu, 2023). Reproduced with permission. License number 5684141496108.

3. MODERN TECHNOLOGIES IN SOLAR PV ENERGY UTILITY IN CHINESE AGRICULTURE

China has been a global pioneer in the adoption and implementation of contemporary solar energy technology (Liu et al., 2010). Significant progress has been made as a result of the country's commitment to clean energy and quick increase of solar power capacity (Fazal and Rubaiee, 2023). In China, where the government has aggressively promoted the use of renewable energy sources to address energy security and environmental issues (Morcilla and Enano, 2023), solar PV energy has found several applications in agriculture. Solar PV technology has been incorporated into different parts of Chinese agriculture, providing advantages such as lower energy costs, enhanced sustainability, and increased agricultural output (Irshad et al., 2023). Farm produce drying is a significant application where solar photovoltaics has shown a lot of potential. Since traditional methods like sun and wind drying were inefficient in previous decades, solar-PV dryers have addressed significant challenges by reducing drying times and preserving more agricultural products for sale in the future.

3.1 Solar PV-powered dryers for agricultural utility in China

Solar-powered agricultural dryers use solar energy to remove moisture from agricultural products such as grains, fruits, vegetables, and herbs (Satpathy and Pamuru, 2021). These dryers provide an ecologically responsible and cost-effective method of preserving and processing agricultural products by lowering moisture content to a level that avoids spoiling and increases crop shelf life (Barbosa et al., 2023). Solar collectors, which gather and concentrate solar energy, are installed on solar-PV dryers. These collectors, which can be constructed of glass, plastic, or metal, are intended to raise the temperature within the dryer (Nayanita et al., 2022). Within the solar-PV dryer, agricultural produce is put in a drying chamber or drying trays. To allow for appropriate air circulation, the drying chamber is frequently outfitted with perforated trays or shelves. The drying chamber is circulated by a solar-powered fan or blower. The heated air drawn in by the solar collectors is directed into the chamber, where it collects moisture from the crops before being discharged, sending the moisture away. Some sun dryers have temperature and humidity control devices to guarantee that the drying process is effective and that the crops are not overheated (Ramli and Jabbar, 2022).

Solar PV-powered dryers are rapidly being utilized in China to dry agricultural products effectively and sustainably at a solar-PV radiation intensity of 759.53W/m^2, the mass flow rate of air was 0.023 kg/s, and the solar-PV dryer's thermal efficiency at 2.59 %., lowering post-harvest losses, boosting crop quality, and minimizing environmental impact (Verma et al., 2023). Dryers powered by solar PV are utilized for drying grains such as rice, wheat, corn, and soybeans. This is critical for decreasing moisture and avoiding spoiling (Saini et al., 2023a). Solar-PV dryers are used to preserve the nutritious content of fruits, vegetables, and herbs while also increasing their shelf life and are used to efficiently dry herbs and medicinal plants in China, which has a strong heritage of herbal medicine (Kong et al., 2024). In the fish processing sector, solar-PV-powered dryers are used to dry and preserve fish and seafood products (Fazal and Rubaiee, 2023).

EPRA International Journal of Agriculture and Rural Economic Research (ARER)- Peer-Reviewed Journal
Volume: 13 | Issue: 5 | May 2025 | Journal DOI: 10.36713/epra0813| Impact Factor SJIF(2025): 8.733| ISSN: 2321 – 7847

Besides, the Chinese government has launched several initiatives and regulations to promote the use of solar PV-powered dryers, particularly in rural and agricultural areas (Liu et al., 2010; Zhou et al., 1993). These projects frequently include financial incentives, subsidies, and assistance with technology transfer and training (Shi et al., 2023). Furthermore, facilities like solar greenhouses are built and intended to serve as both drying facilities and agricultural-producing areas (Yang et al., 2023). These buildings are outfitted with solar panels and drying racks, allowing farmers to make better use of their land (Wang and Zhou, 2013; Yang et al., 2023). Some solar-PV dryers in China are hybrid systems that combine solar PV technology with other energy sources like biomass or biogas to enable constant operation even during overcast or rainy months (Wang and Zhou, 2013). Owing to China's dedication to renewable energy and sustainable agriculture, solar PV-powered dryers have become a significant tool for conserving and processing agricultural goods while decreasing environmental impact and boosting food security (Wanyama et al., 2023). According to market projections, the worldwide solar-PV dryer market was valued at USD 3.5 billion in 2023 and is expected to rise at a compound annual growth rate (CAGR) of 10.6 % from 2023 to 2031. In 2023, the hybrid type category accounted for 42 % of the market and is predicted to retain its dominance during the forecast period. The Asia-Pacific region dominated the market in 2023, accounting for 38 % of the total, and is predicted to expand at the quickest pace of 12.4 % from 2023 to 2031 (Saini et al., 2023b).

3.2 Solar-PV dryer types used in China

Solar-PV dryers in China are available in a variety of configurations, including tunnel dryers, cabinet dryers, and greenhouse dryers (Suresh et al., 2023). The sort of drier used is determined by the crops and the climate.

3.2.1 Solar-PV tunnel dryer type

Long, enclosed structures with sun collectors on one side and a drying chamber on the other are called solar-PV tunnel dryers (**Figure 2**) (Janjai and Bala, 2012). They are made up of a long, rectangular chamber that is covered with a translucent covering that lets light in and warms the air inside. The items being dried then experience moisture loss and drying out as a result of the hot air being blown around them. Compared to conventional drying techniques, solar-PV tunnel dryers offer several benefits, including lower energy costs, less impact on the environment, and higher-quality products (Bala and Janjai, 2012; Janjai and Bala, 2012). They are used in many different uses, such as drying textiles, medications, and agricultural goods.

Figure 2 Illustration of a sample solar-PV tunnel dryer (AADA, 2021). Reproduced with permission. License number 5684141496267.

3.2.2 Solar-PV Cabinet Dryer Type

Solar-PV cabinet dryers (**Figure 3**), on the other hand, are smaller, box-like constructions with a solar collector on top and drying trays within (Shakeel et al., 2023). They are suited for huge quantities of produce. They are used for lesser amounts of crops and are frequently portable. Solar-PV cabinet dryers are more compact and have a smaller design that makes them resemble enormous cupboards, in contrast to solar-PV tunnel dryers, which are long and rectangular (Chavan et al., 2011; Shakeel et al., 2023). In addition to using sunshine to heat the air inside the chamber, solar-PV cabinet dryers also circulate heated air around the objects they are drying (Chavan et al., 2011). They get dry and lose moisture as a result of this (Chavan et al., 2011; Janjai and Bala, 2012).

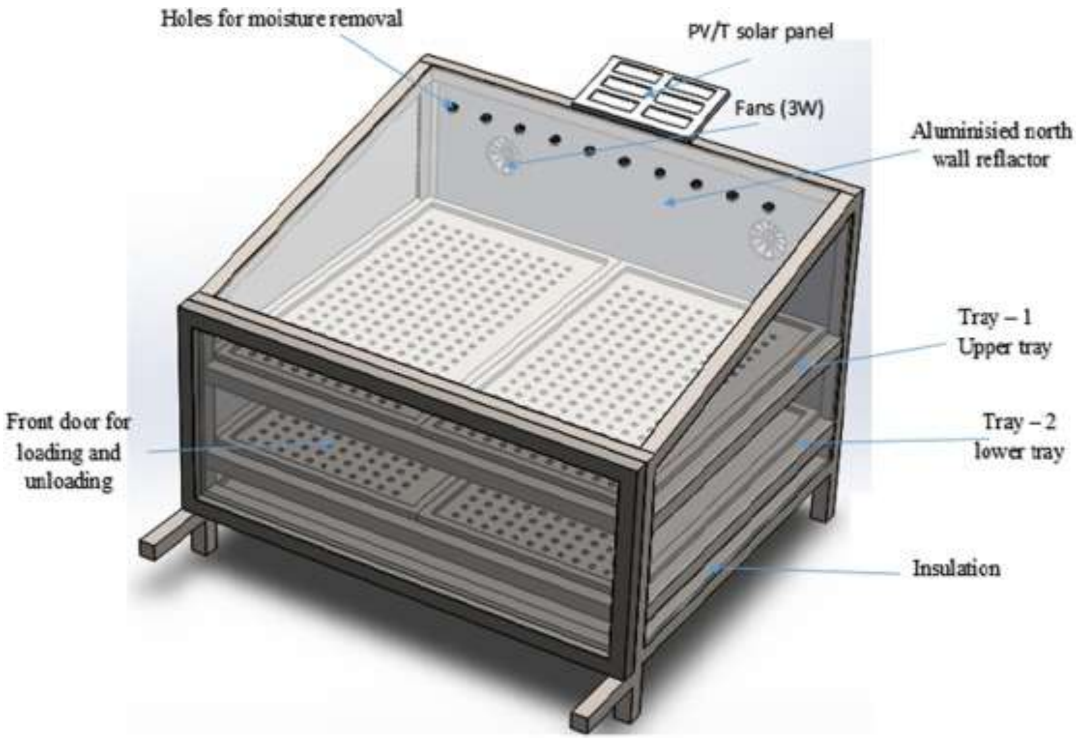

Figure 3 Illustration of a sample solar-PV cabinet dryer (Spall and Sethi, 2020). Reproduced with permission. License number 5684141499206.

3.2.3 Hybrid solar-PV dryer

Hybrid solar-PV dryers (**Figure 4**) are attached to greenhouses with transparent roofs and use solar collectors to dry produce (Reza Rouzegar et al., 2023). They provide regulated drying settings. Some solar-PV dryers are intended to function in tandem with other energy sources, such as biomass or electricity, to enable continuous operation even on overcast or nighttime days (Adamsab et al., 2019). Solar-powered agricultural dryers are a long-term solution for small and large-scale farmers, helping them to better manage their harvests, decrease food waste, and access markets for dried products. Their implementation helps to ensure food security and sustainable agriculture practices (Gitan and Al-Kayiem, 2023).

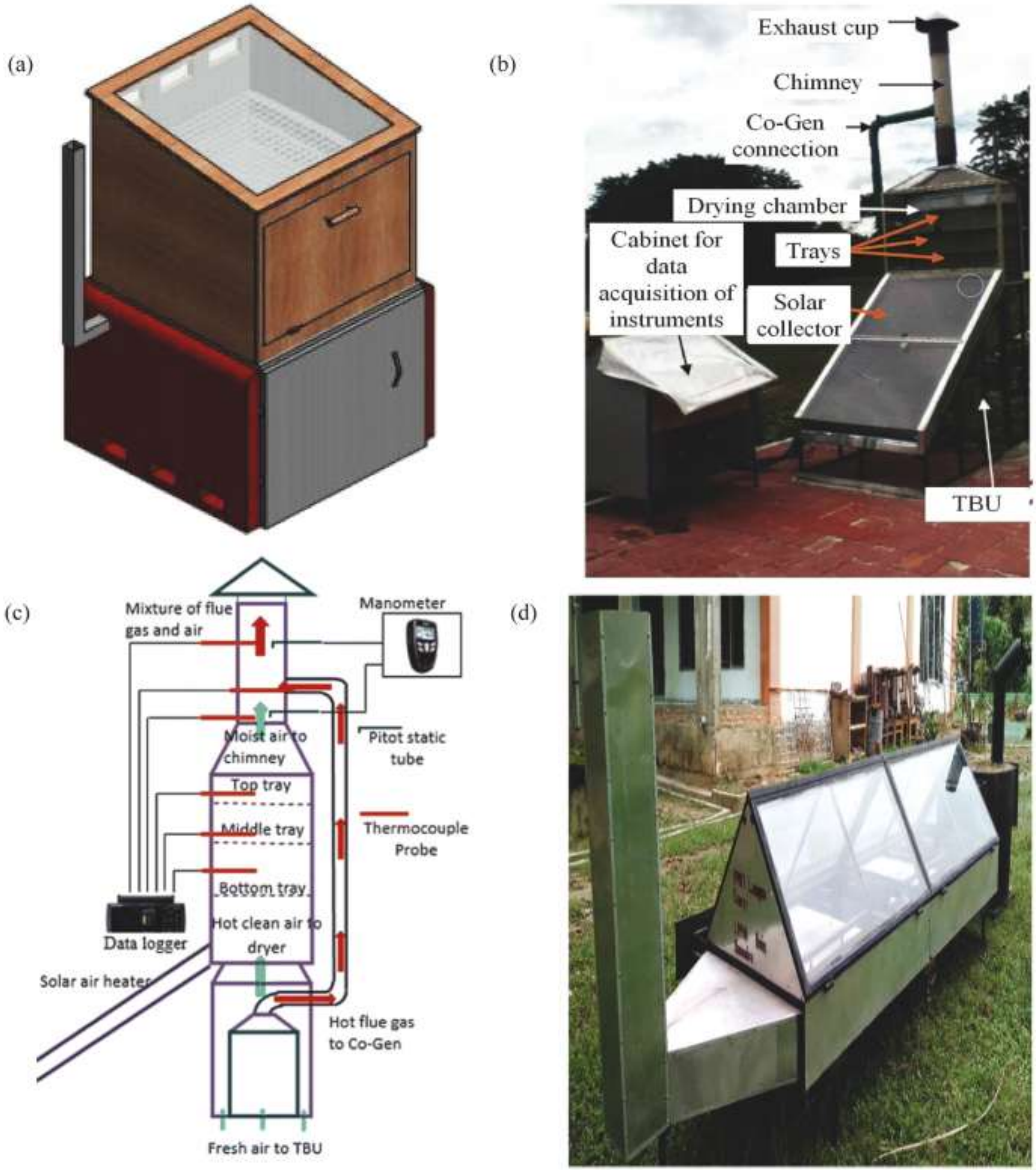

Figure 4 illustrates the design, simulation and application of hybrid solar-PV dryers (Jha and Tripathy, 2021). Reproduced with permission. License number 5684141497548.

Devoid of these primary types, the solar-PV dryers developed in China can be classified into five types.

3.2.4 The green-house type

This type of solar-PV dryer has the advantages of a simple structure and low cost. Its structure is somewhat like a conventional greenhouse. The drying materials in the greenhouse absorb solar radiation directly. Most of these kinds of dryers are operated in passive mode. The moisture evaporated from the drying material flows out through natural ventilation (Serm Janjai, 2012). Besides, more than ten sets of greenhouse solar-PV dryers have been built in Shanxi Province for drying red dates, cotton, fur lilies etc. since the 1970s (Serm Janjai, 2012; Wennerholm, 1993). A large-size greenhouse solar-PV dryer was built in Yiwu County for drying wooden boards (Li et al., 2009; Wennerholm, 1993). The greenhouse solar-PV dryers are also used to dry rabbit fur skin and preserved fruits in Hebei Province (Li et al., 2009).

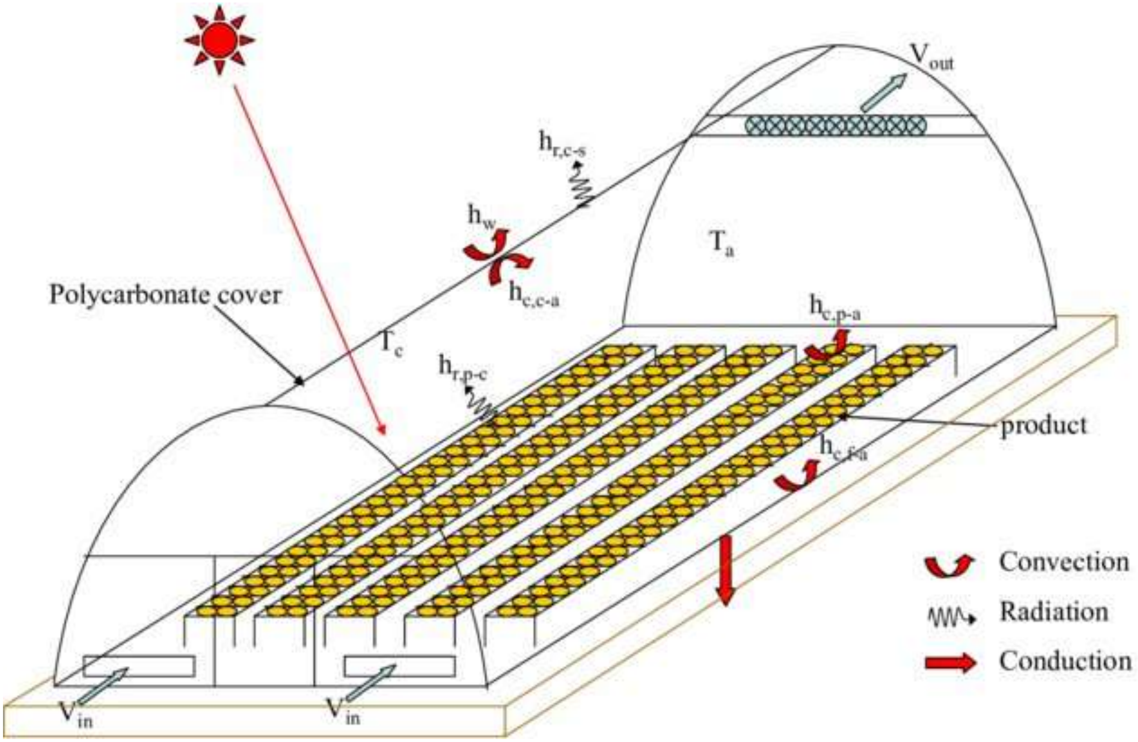

Figure 5 Schematic illustration of the greenhouse type of solar-PV dryers (Serm Janjai, 2012). Reproduced by CC BY 4.0

3.2.5 Air collector type of solar-PV

The so-called air collector type solar-PV dryer means the drying objects are dried by the hot air heated through the solar air collector (Zhang and Zhu, 2022). The air is heated up to 60-70 °C and then enters the drying chamber. The drying process in the chamber is a convective heat and mass transfer process (Lingayat and Chandramohan, 2021; Zhang and Zhu, 2022). A blower is installed in the collector system to enhance the drying process (Zhang and Zhu, 2022). Several large-size air collectors- solar-PV dryers are under operation in China, such as a timber dryer in Ganzhou, a solar drying kiln for candied fruit in Xinhui, a medicine herb in Shanghai, a solar drying cabinet in Loyang Ceramics Arts and Crafts Factory and a melon seed dryer in Lanzhou (Janjai and Bala, 2012; Wennerholm, 1993). Furthermore, the greenhouse solar-PV dryer generally cannot meet the requirements of drying high moisture content objects, such as fruits and vegetables. due to its small air temperature rise despite its high efficiency (Akash et al., 2024). A few types of combination solar-PV dryers have been built, the typical one is located in Dongguan County, Guangdong Province (Wennerholm, 1993).

3.2.6 Concentrator type of solar-PV

Using a solar concentrator would be an option to obtain a much higher air temperature for fast drying. From 1979-1981, five sets of pilot concentrated solar-PV dryers were built for grain drying (Janjai and Bala, 2012). After a period of operation, no encouraging results were reported. So, this type of solar-PV dryer has been given up for further development due to its complicated structure, high cost, and difficult operation and maintenance problems (Janjai and Bala, 2012; Mugi and Chandramohan, 2021; Wennerholm, 1993).

3.2.8 The integrated type of solar-PV

In this type of solar-PV dryer, the solar collector is integrated with the drying cabinet (Spall and Sethi, 2020). An axial blower is mounted at the connection passage between two arrays of the drying unit (collector/cabinet). Since this unit has a higher aperture area/air space volume ratio, say 3-4 times larger than that of conventional greenhouse type, hence, a rapid temperature rise can be obtained (Wu et al., 2024a). The objects for drying loaded on a tray with four rollers can be pushed into the dryer along a rail track. The forced air flow circulates through the tray. The moisture released off the materials is carried away by exhausted damp air. A part of damp hot air can be recirculated and mixed with the fresh air flowing into the system through a controllable exhaust flap. Hence, better performance of the system can be obtained (Wu et al., 2024b). The integrated solar-PV dryer has the advantage of low thermal inertia, high and rapid temperature rise, higher thermal efficiency, simple structure, low cost and flexible combination (O'Shaughnessy et al., 2088). It has been widely disseminated since it was first built in Guangzhou in 1983 (Wennerholm, 1993). At present, this type of solar-PV dryer takes a ratio of about

30% of the total amount of solar-PV dryers in China due to its cost-effectiveness (Li et al., 2009; Wennerholm, 1993).

4. QUALITATIVE IMPACTS OF SOLAR DRYING ON FARM PRODUCE

Food drying alters several physio-chemical and nutritional properties as a result of heat and mass transfers (Goel et al., 2024a). When compared to sun drying, it was shown that solar drying with air recycling decreased colour changes and volume shrinkage of dried pistachio nuts (Goel et al., 2024a; Thongcharoenpipat and Yamsaengsung, 2023). According to a study (Chen et al., 2005), samples of dried lemons that were dried using hot air at 60 °C had a duller colour than those that were dried using complementary solar drying (Goel et al., 2024a). Compounds bound to insoluble fibre sections in the product or released by cell wall breaking are soluble or insoluble depending on the characteristics of the drying air, particularly temperature (Goel et al., 2024a). In comparison to hot air and open-air sun-dried samples, it was shown in a study that solar-dried bitter gourd and capsicum kept significant components such as polyphenols, flavonoids, and vitamins A and C (Goel et al., 2024a; Noor Mohammed et al., 2024). It was discovered that there was a maximum loss of vitamin C when Indian gooseberry (amla) shreds were dried using hot air as opposed to sunshine (Goel et al., 2024b). A similar study (Chen et al., 2005; Goel et al., 2024b) found that amla fruits dried by indirect sun drying retained more vitamin C than fruits dried by direct drying. When organic plums were dried in an oven or outdoors with high oxygen concentrations and temperatures, the vitamin C in the plums quickly degraded (Goel et al., 2024a).

Besides, a few examples of product quality changes that might happen during solar drying include product browning, case hardening, nutrient migrations, and loss of all volatile components (Chen et al., 2005; Goel et al., 2024b). Carefully choosing drying techniques is essential to guarantee high-quality products. Direct daylight is essential for dates because it helps them acquire a characteristic hue (Mohana et al., 2020). In a similar vein, sun-drying Arabica coffee intensifies the taste that is developed later on during roasting (Goel et al., 2024a). Furthermore, for longer drying times, some crops-like those used to create coffee, tea, rice, and cocoa beans, and nuts-need lower drying temperatures. When coffee beans are dried in sun dryers with dark solar collectors, it has been shown that the beans dry faster and yield higher-quality dried items (Goel et al., 2024a; Majumder et al., 2022). The bulk of spices may be dried with direct and indirect sun dryers. Solar-PV dryers with greenhouse systems have been utilised to dry heat-sensitive items without sacrificing product quality. Food grains like rice are dried using mixed-mode passive solar-PV dryers because the rice they produce is considerably whiter than rice dried in the sun (Goel et al., 2024b; Majumder et al., 2022; Mohana et al., 2020). Research on the quality evaluation of black turmeric dried in a mixed-mode sun drier found that variations in quality characteristics were caused by the thermal degradation of the pigments, oxidation, and enzymatic or non-enzymatic browning that happened during drying (Zhang et al., 2024). Moreover, certain fruits drastically lose ascorbic acid while they are in the sun (Goel et al., 2024a).

4.1 Economic aspects of solar drying on farm produce

The economic evaluation of a solar-PV dryer greatly influences the viability of any modifications utilised to improve it. It helps determine the cost-effectiveness of research-based innovations. The life cycle, annualised costs, and payback period of dryers are used to assess their economic feasibility (O'Shaughnessy et al., 2088). However, some factors, including the type of material being dried, the location, capacity, and size of the dryer, as well as its design and efficiency, affect this analysis (Goel et al., 2024a). It is necessary to compare the drying processes using electrical and solar-PV dryers to get the annualised cost. Because of fluctuations in the price of fossil fuels and electrical energy, the annualised cost technique is not reliable (Mohana et al., 2020).

Important factors in the computation include the environment, the design, kind, size, and efficiency of the dryer's system, as well as the physical properties of the materials being dried. For example, studies have shown that solar drying is more profitable for cash crops like coffee and tea in India than it is for vegetables like tomatoes and cabbage (Goel et al., 2024b). A 1000 kg capacity greenhouse-style drier in Thailand should pay for itself in around two years (Jha and Tripathy, 2021). According to a separate analysis, the payback period (PBP) for a solar-PV dryer with a total fixed cost of US$71,111 and yearly fuel consumption expenditures of US$33,600 is around two years (Goel et al., 2024a, 2024b). When evaluating solar-PV dryer technologies at market price and without accounting for any positive environmental effects, estimates of their economic returns relative to traditional drying procedures are often much higher. Other benefits like increased yields, less land usage, and improved quality should be taken into account to create a more realistic cost-benefit analysis.

5. CURRENT CHALLENGES ASSOCIATED WITH SOLAR-PV DRYERS IN CHINESE AGRICULTURAL USE

Many obstacles stand in the way of the successful implementation of solar-PV dryers in Chinese agriculture. These obstacles include the nation's varied climate, financial concerns, lack of technological know-how, and current farming methods. To fully utilise solar drying technology for sustainable agriculture and increased food security in China, several issues must be resolved. The reliance on weather patterns is one of the main difficulties (Reza et al., 2009). There are areas of China's huge landmass with wildly fluctuating sun radiation. The effectiveness and dependability of solar-PV dryers are greatly impacted by inconsistent sunshine brought on by cloudy or wet weather, especially in the northern parts during the winter and the southern regions during the monsoon season. Due to these seasonal restrictions, solar-PV dryers are less useful throughout the year, which limits their practical use in a variety of scenarios.

Besides, a major additional obstacle to solar-PV dryers is their high beginning costs. Building and installing these systems may be expensive, especially if you want to install the most feature-rich types. Small-scale farmers are faced with a dilemma since they might not have the money to purchase such equipment. The initial cost of solar-PV dryers is further increased by the expensive cost of long-lasting, high-quality materials, which limits their accessibility to a larger segment of the farming community. Also, the adoption of solar-PV dryers is further complicated by difficulties related to design and efficiency (Saini et al., 2023c). It can be particularly difficult to achieve consistent drying, especially in bigger units or those with insufficient air circulation. This can result in uneven drying and lower-quality products. Moreover, inadequate insulation and structural defects may lead to substantial heat dissipation, hence reducing the overall effectiveness of the drying procedure.

Furthermore, users of solar-PV dryers are always concerned about longevity and maintenance (Demissie et al., 2024). For these systems to operate properly, they need to be maintained regularly, which takes time and technical expertise that many farmers may not have. Furthermore, materials can corrode or deteriorate over time due to exposure to severe external conditions. This results in clear coverings becoming brittle or discoloured and structural elements requiring regular repairs or replacements. Farmers' insufficient technical expertise also restricts the efficient application of solar-PV dryers (Demissie et al., 2024; Saini et al., 2023c). Many farmers may lack the knowledge necessary to build, use, and maintain these tools efficiently, which might result in incorrect use and less-than-ideal drying outcomes. This problem is made worse by limited access to technical assistance and training programmes, which makes sun-drying technology installation more difficult.

The adoption of solar-PV dryers is also heavily influenced by economic factors (Patel et al., 2024). To reap the financial rewards of employing solar-PV dryers, farmers must have access to marketplaces where there is a need for dried goods. Farmers may find it difficult to justify the first investment in solar-PV dryers since, in contrast to conventional drying techniques, the economic benefits may not be immediately obvious. Maintaining uniformity in the quality of dehydrated goods is crucial for their marketability, however, it can be difficult with different drying methods and environments (Demissie et al., 2024). Adhering to food safety requirements and standards for dehydrated goods can be challenging in the absence of adequate infrastructure and understanding, which makes the use of sun-drying technology even more challenging (Aniesrani Delfiya et al., 2024). Another difficulty is integrating solar drying technologies with current farming methods (Wu et al., 2024b). Farmers can be hesitant to abandon tried-and-true practices that they are comfortable with. The acceptability of new technologies is heavily influenced by cultural customs and preferences; therefore, for solar-PV dryers to be widely adopted, they must blend in with the local environment and be seen as culturally acceptable.

A multifaceted strategy is needed to address these issues, including better technology and design to increase productivity and cost-effectiveness, financial assistance to lower startup costs, and extensive training initiatives to give farmers the know-how and abilities they need. Important actions also include expanding dried product market access and passing laws that encourage the application of renewable energy technology in agriculture. By using these tactics, China can effectively address the obstacles related to solar-PV dryers and fully use their promise for sustainable farming methods and enhanced food security. Solar-PV dryers can become a practical and widely used way to preserve agricultural goods by resolving these complex difficulties, which would greatly improve the nation's agricultural sustainability and economic resilience.

5.1 Prospects of solar-PV dryers in Chinese agriculture

The potential of solar-PV dryers in Chinese agriculture appears bright, considering the nation's growing emphasis on renewable energy and sustainable growth. Reduce post-harvest losses, increase food security, and improve agricultural product preservation with the use of solar-PV dryers. Even if there are obstacles to their acceptance, there is a compelling argument for their increased usage in China given the potential advantages and continuous technological developments.

5.1.1 Technological advancements and adaptations

The ongoing advancement and localization of technology is one of the main opportunities for solar-PV dryers in China. New developments in solar-PV dryer designs have prioritised durability, cost reduction, and efficiency improvement (Patel et al., 2024). Particularly intriguing are hybrid solar-PV dryers, which combine solar energy with electric heaters or biomass as auxiliary heating sources (Jha and Tripathy, 2021). Even in areas with less continuous sunshine, like the southern China monsoon season or the northern winter, these systems can guarantee consistent drying performance. Furthermore, a range of agricultural environments and crop kinds may be served by the construction of modular solar-PV dryers that can be enlarged or altered following particular requirements (Jha and Tripathy, 2021). Solar-PV may be made more affordable and culturally acceptable by combining conventional architectural methods with locally sourced materials.

5.1.2 Economic benefits and market opportunities

The use of solar-PV dryers has substantial commercial potential (Philip et al., 2022). Farmers may boost their revenue by growing the amount of marketable products they grow by decreasing post-harvest losses. Additionally, solar-PV dryers may assist farmers in producing high-quality dried goods that satisfy consumer demands, creating new local and international revenue streams and market prospects (Demissie et al., 2024). China's booming urban markets and burgeoning middle class in particular are driving demand for premium, value-added agricultural products. To realise these economic gains, financial incentives and government regulations are essential. Small-scale farmers may find it easier to use solar-PV dryer technology if subsidies and grants are available to cover the initial setup expenses (Patel et al., 2024). Additionally, generating demand and guaranteeing that farmers receive fair prices for their produce may be accomplished by highlighting the advantages of dried goods through marketing campaigns and quality certifications.

5.1.3 Environmental and Sustainability Advantages

China's overarching objectives of lowering carbon emissions and advancing sustainable agriculture methods are in line with solar-PV dryers (Li et al., 2024). Solar-PV dryers reduce greenhouse gas emissions by minimising the requirement for conventional energy sources and relying instead on sustainable solar energy. This is especially important now that China is working to fulfil its obligations under international climate agreements and is still addressing environmental issues (Rahman et al., 2022). Solar-PV dryers not only help the environment but also improve food security by prolonging the shelf life of agricultural products and cutting down on waste. This is particularly crucial in isolated and rural locations with limited access to refrigeration and other preservation techniques. Solar-PV dryers can help stabilise the food supply and lessen food scarcity during certain seasons by offering a dependable method of crop preservation.

5.1.4 Enhancing Farmer Livelihoods and Rural Development

The use of solar-PV dryers may greatly improve farmer livelihoods and advance rural development (Ukoba et al., 2024). Providing farmers with the knowledge and abilities to operate and maintain solar-PV dryers, training programmes and technical assistance may increase their output and revenue (Sianipar, 2022). Creating farmer groups or cooperatives can help to fortify community bonds and offer a means of pooling resources to construct sun-drying facilities. Utilising solar-PV dryers may also boost local economies by generating demand for goods and services necessary for the installation, upkeep, and functioning of the dryers. In addition to promoting general rural development, this may result in the creation of jobs and economic diversification in rural regions.

5.1.5 Research and Development Initiatives

Continuous research and development efforts are essential to the advancement and widespread use of solar-PV dryers. Research organisations, agricultural colleges, and technology businesses working together may spur innovation and guarantee that designs of solar-PV dryers are customised to meet the unique requirements of Chinese farmers (Demissie et al., 2024). The development of new technologies may be sped up and their transmission to the agriculture industry made easier with government assistance for research and development.

6. CONCLUDING REMARKS

In P. R. China, the incorporation of solar PV-powered dryers into agricultural produce processing offers a game-changing chance for sustainable rural development. By utilising renewable energy, these cutting-edge drying systems improve the effectiveness and calibre of agricultural product preservation, tackling the pressing issue of post-harvest losses. Solar PV-powered dryers facilitate China's larger objectives of lowering carbon emissions and promoting environmental sustainability by decreasing dependency on conventional energy sources. The economic advantages are significant since industrial dryers help farmers create high-quality dried goods that can be sold in profitable marketplaces, boosting their earnings and enhancing their standard of living. Adoption of this technology can also boost regional economies by creating jobs and increasing demand for associated materials and services. Solar PV-powered dryers are a practical and advantageous alternative despite certain obstacles, such as the initial investment and technical expertise needed. These are offset by continual technological developments, supporting government regulations, and financial incentives. Cooperative approaches and extensive training programmes can help to further promote the uptake and efficient application of this technology. Solar PV-powered dryers have a lot of potential to boost rural China's economy, encourage environmental sustainability, and increase agricultural production. Assuring food security and attaining sustainable rural development may be made possible by their broad adoption, which will support the nation's sustainable development objectives.

Competing Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability
All the data generated or analysed during this study are included in this published article.

Ethical Approval
Not applicable

Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding
Key Technologies Research and Development Program of Anhui Provincehttps://doi.org/10.13039/100016073 [2016YFD0701002, 2019YFD1002500]; Key Technologies Research and Development Program of Anhui Province [HX20210387]; Anhui Provincial Key Research and Development Plan; Priority Academic Program Development (PAPD) of Jiangsu Higher Education Institutions; National Natural Science Foundation Project (52272367).

Author contributions
Josephine Baffoe: Conceptualisation, Methodology, Writing-Original Draft, Writing-Review and Editing; **Li-hua Ye**: Resources, Writing-Review and Editing, Supervision; **Yefan Shi:** Resources, Validation, Formal analysis; **Hao Chen**: Writing-Original Draft; **Ai-ping Shi:** Formal analysis, Writing-Review and Editing

REFERENCE

1. *AADA, 2021. Solar Tunnel Dryer For Fish Drying - Africa AADA [WWW Document]. URL https://africaaada.org/projects/solar-tunnel-dryer-for-fish-drying/ (accessed 5.24.24).*
2. *Adamsab, K., Saif, M., Saif, S., Khamis, I., Talib, W., 2019. Hybrid powered intelligent irrigation system using Oman Falaj and solar energy. Mater Today Proc 41, 260–264. https://doi.org/10.1016/j.matpr.2020.09.033*
3. *Akash, F.A., Shovon, S.M., Rahman, W., Rahman, M.A., Chakraborty, P., Monir, M.U., 2024. Greening the grid: A comprehensive review of renewable energy in Bangladesh. Heliyon 10. https://doi.org/10.1016/j.heliyon.2024.e27477*
4. *Al-Mamun, Md.R., Roy, H., Islam, Md.S., Ali, Md.R., Hossain, Md.I., Saad Aly, M.A., Hossain Khan, Md.Z., Marwani, H.M., Islam, A., Haque, E., Rahman, M.M., Awual, Md.R., 2023. State-of-the-art in solar water heating (SWH) systems for sustainable solar energy utilization: A comprehensive review. Solar Energy 111998. https://doi.org/10.1016/J.SOLENER.2023.111998*
5. *Andharia, J.K., Markam, B., Patel, J., Maiti, S., 2024. Study of a mixed-mode solar dryer integrated with photovoltaic powered dehumidifier. Solar Energy 273. https://doi.org/10.1016/j.solener.2024.112505*
6. *Aniesrani Delfiya, D.S., Lincy Mathai, Murali, S., Neethu, K.C., Anuja R Nair, George Ninan, 2024. Comparison of clam drying in solar, solar-hybrid, and infrared dryer: Drying characteristics, quality aspects, and techno-economic analysis. Solar Energy 274. https://doi.org/10.1016/j.solener.2024.112554*
7. *Awogbemi, O., Kallon, D.V. Von, 2023. Towards the development of underutilized renewable energy resources in achieving carbon neutrality. Fuel Communications 17, 100099. https://doi.org/10.1016/j.jfueco.2023.100099*
8. *Bala, B.K., Janjai, S., 2012. Solar drying technology: Potentials and developments. Energy, Environment and Sustainable Development 69–98. https://doi.org/10.1007/978-3-7091-0109-4_10*
9. *Barbosa, E.G., Araujo, M.E.V. de, Oliveira, A.C.L. de, Martins, M.A., 2023. Thermal energy storage systems applied to solar dryers: Classification, performance, and numerical modeling: An updated review. Case Studies in Thermal Engineering 45. https://doi.org/10.1016/j.csite.2023.102986*
10. *Belessiotis, V., Delyannis, E., 2011. Solar drying. Solar Energy 85, 1665–1691. https://doi.org/10.1016/j.solener.2009.10.001*
11. *Chavan, B., A Yakupitiyage, 2011, 2011. Drying performance, quality characteristics, and financial evaluation of Indian Mackerel (Rastrilliger kangurta) dried by a solar tunnel dryer. Science & Technology 16.*
12. *Che, X.J., Zhou, P., Chai, K.H., 2022. Regional policy effect on photovoltaic (PV) technology innovation: Findings from 260 cities in China. Energy Policy 162. https://doi.org/10.1016/j.enpol.2022.112807*
13. *Chen, H.H., Hernandez, C.E., Huang, T.C., 2005. A study of the drying effect on lemon slices using a closed-type solar dryer. Solar Energy 78, 97–103. https://doi.org/10.1016/J.SOLENER.2004.06.011*

14. *Demissie, Y.A., Abreham, R.E., Wassie, H.M., Getie, M.Z., 2024. Advancements in solar greenhouse dryers for crop drying. Energy Reports 11, 5046–5058. https://doi.org/10.1016/j.egyr.2024.04.058*
15. *Fazal, M.A., Rubaiee, S., 2023. Progress of PV cell technology: Feasibility of building materials, cost, performance, and stability. Solar Energy 258, 203–219. https://doi.org/10.1016/J.SOLENER.2023.04.066*
16. *Gitan, A.A., Al-Kayiem, H.H., 2023. Assessment of hybrid solar-thermal multi-chamber dryer integrated with desiccant dehumidifier for uniform drying. Solar Energy 262. https://doi.org/10.1016/j.solener.2023.111880*
17. *Goel, V., Dwivedi, A., Singh Mehra, K., Kumar Pathak, S., Tyagi, V. V., Bhattacharyya, S., Pandey, A.K., 2024a. Solar drying systems for Domestic/Industrial Purposes: A State-of-Art review on topical progress and feasibility assessments. Solar Energy 267, 112210. https://doi.org/10.1016/J.SOLENER.2023.112210*
18. *Goel, V., Dwivedi, A., Singh Mehra, K., Kumar Pathak, S., Tyagi, V. V., Bhattacharyya, S., Pandey, A.K., 2024b. Solar drying systems for Domestic/Industrial Purposes: A State-of-Art review on topical progress and feasibility assessments. Solar Energy 267, 112210. https://doi.org/10.1016/J.SOLENER.2023.112210*
19. *Gorjian, S., Singh, R., Shukla, A., Mazhar, A.R., 2020. On-farm applications of solar PV systems. Photovoltaic Solar Energy Conversion: Technologies, Applications and Environmental Impacts 147–190. https://doi.org/10.1016/B978-0-12-819610-6.00006-5*
20. *Hu, Z., 2023. Towards solar extractivism? A political ecology understanding of the solar energy and agriculture boom in rural China. Energy Res Soc Sci 98, 102988. https://doi.org/10.1016/j.erss.2023.102988*
21. *Irshad, A.S., Ludin, G.A., Masrur, H., Ahmadi, M., Yona, A., Mikhaylov, A., Krishnan, N., Senjyu, T., 2023. Optimization of grid-photovoltaic and battery hybrid system with most technically efficient PV technology after the performance analysis. Renew Energy 207, 714–730. https://doi.org/10.1016/j.renene.2023.03.062*
22. *Janjai, S., Bala, B.K., 2012. Solar Drying Technology. Food Engineering Reviews 4, 16–54. https://doi.org/10.1007/S12393-011-9044-6*
23. *Jha, A., Tripathy, P.P., 2021. Recent Advancements in Design, Application, and Simulation Studies of Hybrid Solar Drying Technology. Food Engineering Reviews 13, 375–410. https://doi.org/10.1007/S12393-020-09223-2/METRICS*
24. *jia, T., Huang, J., Li, R., He, P., Dai, Y., 2018. Status and prospect of solar heat for industrial processes in China. Renewable and Sustainable Energy Reviews 90, 475–489. https://doi.org/10.1016/j.rser.2018.03.077*
25. *Kong, D., Wang, Y., Li, M., Liang, J., 2024. A comprehensive review of hybrid solar dryers integrated with auxiliary energy and units for agricultural products. Energy 293. https://doi.org/10.1016/j.energy.2024.130640*
26. *Kumar Sahu, B., 2015. A study on global solar PV energy developments and policies with special focus on the top ten solar PV power producing countries. Renewable and Sustainable Energy Reviews 43, 621–634. https://doi.org/10.1016/j.rser.2014.11.058*
27. *Li, H., Jin, X., Shan, W., Han, B., Zhou, Y., Tittonell, P., 2024. Optimizing agricultural management in China for soil greenhouse gas emissions and yield balance: A regional heterogeneity perspective. J Clean Prod 452. https://doi.org/10.1016/j.jclepro.2024.142255*
28. *Li, J., Ma, L., Shannon, W., Wuming, Y., Lv, F., Yang, J., Qin, S., 2009. Background Paper: Chinese Renewables Status Report-October 2009.*
29. *Lingayat, A., Chandramohan, V.P., 2021. Numerical investigation on solar air collector and its practical application in the indirect solar dryer for banana chips drying with energy and exergy analysis. Thermal Science and Engineering Progress 26. https://doi.org/10.1016/j.tsep.2021.101077*
30. *Liu, L. qun, Wang, Z. xin, Zhang, H. qiang, Xue, Y. cheng, 2010. Solar energy development in China—A review. Renewable and Sustainable Energy Reviews 14, 301–311. https://doi.org/10.1016/J.RSER.2009.08.005*
31. *Majumder, P., Deb, B., Gupta, R., Sablani, S.S., 2022. A comprehensive review of fluidized bed drying: Sustainable design approaches, hydrodynamic and thermodynamic performance characteristics, and product quality. Sustainable Energy Technologies and Assessments 53. https://doi.org/10.1016/j.seta.2022.102643*
32. *Messina, S., González, F., Saldaña, C., Peña-Sandoval, G.R., Tadeo, H., Juárez-Rosete, C.R., Nair, P.K., 2022a. Solar powered dryers in agricultural produce processing for sustainable rural development worldwide: A case study from Nayarit-Mexico. Cleaner and Circular Bioeconomy 3, 100027. https://doi.org/10.1016/J.CLCB.2022.100027*
33. *Messina, S., González, F., Saldaña, C., Peña-Sandoval, G.R., Tadeo, H., Juárez-Rosete, C.R., Nair, P.K., 2022b. Solar powered dryers in agricultural produce processing for sustainable rural development worldwide: A case study from Nayarit-Mexico. Cleaner and Circular Bioeconomy 3. https://doi.org/10.1016/j.clcb.2022.100027*
34. *Mohana, Y., Mohanapriya, R., Anukiruthika, T., Yoha, K.S., Moses, J.A., Anandharamakrishnan, C., 2020. Solar dryers for food applications: Concepts, designs, and recent advances. Solar Energy 208, 321–344. https://doi.org/10.1016/j.solener.2020.07.098*
35. *Morcilla, R. V., Enano, N.H., 2023. Sizing of community centralized battery energy storage system and aggregated residential solar PV system as virtual power plant to support electrical distribution network reliability improvement. Renewable Energy Focus 46, 27–38. https://doi.org/10.1016/j.ref.2023.05.007*
36. *Mousazadeh, H., Keyhani, A., Javadi, A., Mobli, H., Abrinia, K., Sharifi, A., 2009. A review of principle and sun-tracking methods for maximizing solar systems output. Renewable and Sustainable Energy Reviews 13, 1800–1818. https://doi.org/10.1016/j.rser.2009.01.022*
37. *Mugi, V.R., Chandramohan, V.P., 2021. Energy and exergy analysis of forced and natural convection indirect solar dryers: Estimation of exergy inflow, outflow, losses, exergy efficiencies and sustainability indicators from drying experiments. J Clean Prod 282. https://doi.org/10.1016/j.jclepro.2020.124421*

38. *Nayanita, K., Rani Shaik, S., Muthukumar, P., 2022. Comparative study of Mixed-Mode Type and Direct Mode Type Solar Dryers using Life Cycle Assessment. Sustainable Energy Technologies and Assessments 53. https://doi.org/10.1016/j.seta.2022.102680*
39. *Ndukwu, M.C., Ibeh, M., Okon, B.B., Akpan, G., Kalu, C.A., Ekop, I., Nwachukwu, C.C., Abam, F.I., Lamrani, B., Simo-Tagne, M., Ben, A.E., Mbanasor, J., Bennamoun, L., 2023. Progressive review of solar drying studies of agricultural products with exergoeconomics and econo-market participation aspect. Cleaner Environmental Systems 9. https://doi.org/10.1016/j.cesys.2023.100120*
40. *Noor Mohammed, A., Chauhan, O.P., Semwal, A.D., 2024. Emerging technologies for fruits and vegetables dehydration. Food and Humanity 2, 100303. https://doi.org/10.1016/J.FOOHUM.2024.100303*
41. *Ortiz-Rodríguez, N.M., Condorí, M., Durán, G., García-Valladares, O., 2022. Solar drying Technologies: A review and future research directions with a focus on agroindustrial applications in medium and large scale. Appl Therm Eng 215, 118993. https://doi.org/10.1016/J.APPLTHERMALENG.2022.118993*
42. *O'Shaughnessy, E., Cutler, D., Ardani, K., R Margolis, 2088. Solar plus: A review of the end-user economics of solar PV integration with storage and load control in residential buildings. Elsevier.*
43. *Patel, P.M., Rathod, V.P., Patel, V.K., 2024. Development and enhancement in drying performance of a novel portable greenhouse solar dryer. J Stored Prod Res 105. https://doi.org/10.1016/j.jspr.2023.102228*
44. *Philip, N., Duraipandi, S., Sreekumar, A., 2022. Techno-economic analysis of greenhouse solar dryer for drying agricultural produce. Renew Energy 199, 613–627. https://doi.org/10.1016/j.renene.2022.08.148*
45. *Rahman, M.M., Khan, I., Field, D.L., Techato, K., Alameh, K., 2022. Powering agriculture: Present status, future potential, and challenges of renewable energy applications. Renew Energy 188, 731–749. https://doi.org/10.1016/j.renene.2022.02.065*
46. *Ramli, R.M., Jabbar, W.A., 2022. Design and implementation of solar-powered with IoT-Enabled portable irrigation system. Internet of Things and Cyber-Physical Systems 2, 212–225. https://doi.org/10.1016/j.iotcps.2022.12.002*
47. *Reza, M.S., Bapary, M.A.J., Islam, M.N., Kamal, M., 2009. Optimization of marine fish drying using solar tunnel dryer. J Food Process Preserv 33, 47–59. https://doi.org/10.1111/J.1745-4549.2008.00236.X*
48. *Reza Rouzegar, M., Hossein Abbaspour-Fard, M., Hedayatizadeh, M., 2023. Design, thermal simulation and experimental study of a hybrid solar dryer with heat storage capability. Solar Energy 258, 232–243. https://doi.org/10.1016/j.solener.2023.05.003*
49. *Saini, R.K., Saini, D.K., Gupta, R., Verma, P., Thakur, R., Kumar, S., wassouf, A., 2023a. Technological development in solar dryers from 2016 to 2021-A review. Renewable and Sustainable Energy Reviews 188. https://doi.org/10.1016/j.rser.2023.113855*
50. *Saini, R.K., Saini, D.K., Gupta, R., Verma, P., Thakur, R., Kumar, S., wassouf, A., 2023b. Technological development in solar dryers from 2016 to 2021-A review. Renewable and Sustainable Energy Reviews 188, 113855. https://doi.org/10.1016/j.rser.2023.113855*
51. *Saini, R.K., Saini, D.K., Gupta, R., Verma, P., Thakur, R., Kumar, S., wassouf, A., 2023c. Technological development in solar dryers from 2016 to 2021-A review. Renewable and Sustainable Energy Reviews 188. https://doi.org/10.1016/j.rser.2023.113855*
52. *Satpathy, R., Pamuru, V., 2021. Solar PV systems and applications. Solar PV Power 243–266. https://doi.org/10.1016/B978-0-12-817626-9.00006-X*
53. *Senthil Kumar, S., Bibin, C., Akash, K., Aravindan, K., Kishore, M., Magesh, G., 2020. Solar powered water pumping systems for irrigation: A comprehensive review on developments and prospects towards a green energy approach. Mater Today Proc 33, 303–307. https://doi.org/10.1016/J.MATPR.2020.04.092*
54. *Serm Janjai, 2012. A greenhouse type solar dryer for small-scale dried food industries: Development and dissemination. International Journal of Energy and Environment (IJEE) 3, 386–396.*
55. *Shahbazi, M.J., Rahimpour, H.R., Rahimpour, M.R., 2024. Agriculture Waste to Energy, Technologies, Economics, and Challenges. Reference Module in Earth Systems and Environmental Sciences. https://doi.org/10.1016/B978-0-323-93940-9.00204-8*
56. *Shakeel, S.R., Yousaf, H., Irfan, M., Rajala, A., 2023. Solar PV adoption at household level: Insights based on a systematic literature review. Energy Strategy Reviews 50, 101178. https://doi.org/10.1016/j.esr.2023.101178*
57. *Shi, Z., Ma, L., Wang, X., Wu, S., Bai, J., Li, Z., Zhang, Y., 2023. Efficiency of agricultural modernization in China: Systematic analysis in the new framework of multidimensional security. J Clean Prod 432. https://doi.org/10.1016/j.jclepro.2023.139611*
58. *Sianipar, C.P.M., 2022. Environmentally-appropriate technology under lack of resources and knowledge: Solar-powered cocoa dryer in rural Nias, Indonesia. Clean Eng Technol 8. https://doi.org/10.1016/j.clet.2022.100494*
59. *Spall, S., Sethi, V.P., 2020. Design, modeling and analysis of efficient multi-rack tray solar cabinet dryer coupled with north wall reflector. Solar Energy 211, 908–919. https://doi.org/10.1016/J.SOLENER.2020.10.012*
60. *Su, X., Xu, Z., Tian, S., Chen, C., Huang, Y., Geng, Y., Chen, J., 2023. Life cycle assessment of three typical solar energy utilization systems in different regions of China. Energy 278. https://doi.org/10.1016/j.energy.2023.127736*
61. *Suresh, B.V., Shireesha, Y., Kishore, T.S., Dwivedi, G., Haghighi, A.T., Patro, E.R., 2023. Natural energy materials and storage systems for solar dryers: State of the art. Solar Energy Materials and Solar Cells 255, 112276. https://doi.org/10.1016/j.solmat.2023.112276*
62. *Thongcharoenpipat, C., Yamsaengsung, R., 2023. Microwave-assisted vacuum frying of durian chips: Impact of ripening level on the drying rate, physio-chemical characteristics, and acceptability. Food and Bioproducts Processing 138, 40–52. https://doi.org/10.1016/j.fbp.2023.01.001*

63. *Ukoba, K., Yoro, K.O., Eterigho-Ikelegbe, O., Ibegbulam, C., Jen, T.C., 2024. Adaptation of solar energy in the Global South: Prospects, challenges and opportunities. Heliyon 10. https://doi.org/10.1016/j.heliyon.2024.e28009*
64. *Urban, F., Geall, S., Wang, Y., 2016. Solar PV and solar water heaters in China: Different pathways to low carbon energy. Renewable and Sustainable Energy Reviews 64, 531–542. https://doi.org/10.1016/J.RSER.2016.06.023*
65. *Verma, G., Dewangan, N., Kumar Ghritlahre, H., Verma, M., Kumar, S., Kumar, Y., Agrawal, S., 2023. Experimental investigation of mixed mode ultraviolet tent house solar dryer under natural convection regime. Solar Energy 251, 51–67. https://doi.org/10.1016/j.solener.2022.12.052*
66. *Wang, Y., Zhou, Q., 2013. Evaluation of Development of Agricultural Modernization in Central China. IERI Procedia 4, 417–424. https://doi.org/10.1016/j.ieri.2013.11.060*
67. *Wanyama, J., Soddo, P., Nakawuka, P., Tumutegyereize, P., Bwambale, E., Oluk, I., Mutumba, W., Komakech, A.J., 2023. Development of a solar powered smart irrigation control system Kit. Smart Agricultural Technology 5. https://doi.org/10.1016/j.atech.2023.100273*
68. *Wennerholm, H., 1993. Solar energy in China.*
69. *Wu, J., Zhang, X., Shen, J., Wu, Y., Connelly, K., Yang, T., Tang, L., Xiao, M., Wei, Y., Jiang, K., Chen, C., Xu, P., Wang, H., 2024a. A review of thermal absorbers and their integration methods for the combined solar photovoltaic/thermal (PV/T) modules. Elsevier.*
70. *Wu, J., Zhang, X., Shen, J., Wu, Y., Connelly, K., Yang, T., Tang, L., Xiao, M., Wei, Y., Jiang, K., Chen, C., Xu, P., Wang, H., 2024b. Real time dynamic analysis of solar PV integration for energy optimization. researchgate.net.*
71. *Yang, X., Zheng, X., Zhou, Z., Miao, H., Liu, H., Wang, Y., Zhang, H., You, S., Wei, S., 2023. A novel multilevel decision-making evaluation approach for the renewable energy heating systems: A case study in China. J Clean Prod 390. https://doi.org/10.1016/j.jclepro.2023.135934*
72. *Yin, H., Zadshir, M., Pao, F., 2022. Perspectives of the current, emerging, and future BIPVT technologies. Building Integrated Photovoltaic Thermal Systems 503–572. https://doi.org/10.1016/B978-0-12-821064-2.00008-0*
73. *Yu, M., Zou, L., Yu, J., 2024. Experimental investigation on the drying characteristics in a solar assisted ejector enhanced heat pump dryer system. Solar Energy 267. https://doi.org/10.1016/j.solener.2023.112265*
74. *Zhang, A.A., Xie, L., Wang, Q.H., Xu, M.Q., Pan, Y., Zheng, Z.A., Lv, W.Q., Xiao, H.W., 2024. Effect of the ripening stage on the pulsed vacuum drying behavior of goji berry (Lycium barbarum L.): Ultrastructure, drying characteristics, and browning mechanism. Food Chem 442. https://doi.org/10.1016/j.foodchem.2024.138489*
75. *Zhang, J., Zhu, T., 2022. Systematic review of solar air collector technologies: Performance evaluation, structure design and application analysis. Sustainable Energy Technologies and Assessments 54. https://doi.org/10.1016/j.seta.2022.102885*
76. *Zhou, Guanzhao, Yan, Lugunag, Wang, Shizhong, Li, Anding, 1993. World Solar Summit; Solar energy in China; 1993.*
77. *Zou, H., Du, H., Ren, J., Sovacool, B.K., Zhang, Y., Mao, G., 2017. Market dynamics, innovation, and transition in China's solar photovoltaic (PV) industry: A critical review. Renewable and Sustainable Energy Reviews 69, 197–206. https://doi.org/10.1016/j.rser.2016.11.053*