ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

SUSTAINABLE SOLAR DRYER SETUP FOR HEALTHY AND EFFICIENT DRYING OF FOOD FOR OIC MEMBER STATE

A Thesis Presented to the Academic Faculty

By

SOUMAHORO BEN KHALIPHA (180021141)

FAYE RAUDA NYUYFONI (180021146)

JAINABA JAITEH (180021245)

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A dissertation on

SUSTAINABLE SOLAR DRYER SETUP FOR HEALTHY AND EFFICIENT DRYING OF FOOD FOR OIC MEMBER STATE

Approved by

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Prof. Dr. Md. Rakibul Islam

Head of the Department

Department of Electrical and Electronic Engineering (EEE) Islamic University of Technology (IUT) Gazipur-1704, Bangladesh

Supervised by

Dr Md. Taslim Reza

Professor of the Department

Department of Electrical and Electronic Engineering (EEE) Islamic University of Technology (IUT) Gazipur-1704, Bangladesh

Declaration of Authorship

This is to certify that the work presented in this thesis paper is the outcome of research carried out by the candidates under the supervision of Dr. Md. Taslim Reza, Professor, Department of Electrical and Electronic Engineering (EEE), Islamic University of Technology (IUT). It is also declared that neither this thesis paper nor any part thereof has been submitted anywhere else for the reward of any degree or any judgement.

Authors

SOUMAHORO BEN KHALIPHA

ID- 180021141

FAYE RAUDA NYUYFONI

ID- 180021146

JAINABA JAITEH

ID -180021245

Dedication

We would like to dedicate Thesis to our family who supported us Morally through tough times. They are our source of strength and pushes in working hard to becoming successful.

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ABSTRACT

Solar dryers are used to eliminate the moisture content from crops, vegetables, and fruits by utilizing solar energy to heat up air and to dry any agricultural crops. This helps in reducing wastage of agricultural product and helps in preservation of agricultural products. But it also makes transportation of such dried products easy and promotes the health and welfare of the people.

Until today in remote small communities, not only in the third world regions, but also in the western countries, people take advantage of the direct sun light to dry and preserve agricultural corps. Solar drying is not yet widely commercialized based on the limitations of the natural sun drying e.g., exposure to direct sunlight, liability to pests and rodents lack of proper monitoring and the escalated cost of the mechanical dryer. A solar dryer is therefore developed to cater for this limitation.

The purpose of this project is to improve food drying quality, and to cater for the limitation of the direct sun drying. The dryer is composed of solar collector, and a solar drying chamber constraining rack of four trays both being integrated together. The air enters in through air inlet, is heated up in the solar collector and channeled through the drying chamber where it is utilized in drying. There are different types of dryers and have their performance is differing as per the food and environment, A product like pepper, turmeric, chili, fruits and vegetables like mango, grapes, banana, papaya.

Chapter 1: Introduction

1.1. Introduction

This project is all about drying different types of foods at different temperature automatically. Drying of food grains in the fields by exposure to sun has been very common in many parts of the world. Solar dryer is a renewable energy resource which is widely used in the different application like to dry the fruits, vegetable, fish, meat, seeds and it is also used in the agriculture purpose. Solar dryer has been industrialized in the present century and created a demand for controlled drying of many agricultural products such as resins, chili, turmeric, mango, and etc. Since after drying such products retain the flavor, quality and appearance and thus have better sale prospects. Drying of agricultural products have been one of the most ancient skill of all time and is generally employed worldwide for better market value of the agro-based products.

Direct and uncontrolled sun drying is still the most common method that is being used to preserve and process agricultural products in most countries. The principle of the solar drying technique is to collect the solar energy by heating-up the air volume in solar collectors. Solar dryer is more economical compared to dryers that run on the conventional fuel/electricity because energy is conserved. Operation of drying involves both heat and mass transfer. It changes several parameters of the product during the process such as volume, density, mass, moisture content, humidity inside, product size, chemical changes along with the product quality. It is an important time and energy consuming process which lastly improves the standard of the product.

The main advantages of sun drying are low capital investments and reduced complexity. The other advantage is that such products could be dried in peak season and made available for consumption throughout the whole year. The main disadvantages of open-air sun drying, mostly are contamination, theft or damage by birds, rats or insects also it fairly is slow drying and no protection from rain, dew or any storm.

If not protected well from the above-mentioned hazards it could reduce the market value of products. It results in reduced food quality which makes the product inedible. Therefore, drying in a closed chamber with the heat of sun will remove the damages caused in open environment. And also prevent us from ultraviolent radiation. Hence the need of solar dryer is unavoidable. Solar dryers can be classified according to the mode of heat transfer as; conduction, convection and radiation.

1.2. Significance of this Research

The research on developing a sustainable solar dryer setup for the efficient and healthy drying of food holds significant importance for the member states of the Organization of Islamic Cooperation (OIC).

1. Food Preservation and Security: most under-developed OIC member states often face challenges in preserving and efficiently utilizing their agricultural products, leading to significant post-harvest losses. By providing an innovative solution through the sustainable solar dryer setup, this research contributes to enhancing food preservation techniques, reducing food waste, and improving food security within the region. One of the main benefits of solar dryers is that they can be used to preserve food by drying it in a way that retains its nutrients and flavor.

2. Sustainable Development: The adoption of sustainable technologies is crucial for achieving sustainable development goals. Which is eradicating world hunger. The solar dryer setup in this research relies on renewable energy from the sun, reducing reliance on fossil fuels and minimizing the carbon footprint associated with traditional drying methods. By promoting sustainable practices in the food industry, this research aligns with global efforts towards mitigating climate change and promoting environmentally friendly solutions. Solar dryers are powered by renewable energy, which can help reduce reliance on fossil fuels and lower greenhouse gas emissions.

3. Economic Empowerment: By improving the efficiency and quality of food drying processes, the sustainable solar dryer setup has the potential to change the economic empowerment of OIC member states. Effective preservation and value addition to agricultural produce can result in increased market opportunities, improved income generation for farmers and producers, and overall economic growth within the region. It could be used as a means of entrepreneurship for small and medium size enterprises.

4. Health and Nutrition: The efficient and healthy drying of food facilitated by the solar dryer setup can have direct benefits on the nutritional value and safety of dried food products. Maintaining proper temperature and humidity levels during the drying process helps preserve essential nutrients while preventing the growth of pathogens and contaminants. This research contributes to ensuring that dried food products from OIC member states meet high standards of quality and safety. Reducing the contamination rates, food preserved using the food solar dryer is safe and healthy

5. Technology Transfer and Collaboration: The development and implementation of the modified solar dryer setup, incorporating the Arduino microcontroller and sensor

technology, can foster technology transfer and collaboration among OIC member states. Sharing knowledge and experiences in sustainable food drying methods can promote capacity building, innovation, and cooperation in the field of food preservation technology.

Overall, this research on the sustainable solar dryer setup for the drying of food in OIC member states offers a comprehensive solution that addresses the challenges of food preservation, sustainable development, economic empowerment, health, and technology transfer. By implementing this research, OIC member states can improve their food security, promote sustainable practices, and contribute to the well-being and prosperity of their communities.

1.3. Objectives of this Research

The main objectives of the research are as follows;

I. To design and develop a modified solar dryer setup that incorporates an Arduino microcontroller, humidity and temperature sensor, fan, and a 12- volt battery, with the aim of creating an efficient and controlled drying environment for various food products.
II. To evaluate the performance and effectiveness of the sustainable solar dryer in terms of its ability to maintain optimal drying conditions, such as temperature and humidity levels, throughout the drying process.
III. To assess the impact of the sustainable solar dryer on the quality and nutritional attributes of dried food products, including factors such as color retention, texture, taste, and vitamin content.
IV. To compare the energy efficiency of the sustainable solar dryer setup with traditional drying methods, considering factors such as energy consumption, operating costs, and the utilization of renewable energy sources.
V. To analyze the economic feasibility and potential benefits of implementing the sustainable solar dryer setup in OIC member states, including aspects such as cost-effectiveness, market potential, income generation, and the reduction of post-harvest losses.
VI. To examine the environmental sustainability of the sustainable solar dryer setup, considering its potential for reducing greenhouse gas emissions, minimizing reliance on fossil fuels, and promoting sustainable agricultural practices.
VII. To identify any challenges, limitations, or barriers to the adoption and implementation of the sustainable solar dryer setup in OIC member states, and propose strategies and recommendations to overcome them.
VIII. To contribute to the body of knowledge in the field of sustainable food drying techniques, particularly in the context of OIC member states, by providing empirical data, insights, and practical recommendations for improving food preservation methods.

1.4. Main Contributions

2. The main challenge faced by the solar dryer is unavailability of sunlight. During the rainy and cold seasons, a hot temperature becomes a hassle to maintain
3. Also, Regulating Temperature and Humidity perfectly on some items. Trying hard to dry different types of foods, which have different temperature and water content is a huge blow
4. However, with the help of modern technologies using microcontrollers with some programming to ensure the balance in the system is being implemented.
5. Time is one of our biggest challenges because we couldn't collect enough data from the solar dryer.

1.4. Thesis Outline

Subject to the research objectives and targeted contributions mentioned above, this thesis is outlined as follows:

Chapter 1. Introduction

This chapter contains a general knowledge of what the sustainable solar dyer is all about. The significance of our research alongside the challenges faced.

Chapter 2. Literature review

Here we have the different existent types of solar dryers, background study and literature review. Its Advantages and limitations

Chapter 3. Methodology

This chapter has some modifications and improvements introduced in order to eradicate the above-mentioned limitations.

Chapter 4. Impact of solar dryer to OIC member states and discussion how helpful this device will be in OIC member countries of Africa, Asia, and Middle East.

Chapter 5. Conclusion and Future works

This chapter is a brief overview of the entire research. Discussions about the outcome and future prospects

Chapter 2: Literature Review

2.1. Introduction to Solar drying

Food preservation is a critical aspect of ensuring food security and minimizing post- harvest losses. Solar drying is very important as a sustainable and efficient method for preserving food in various regions, including the member states of the Organization of Islamic Cooperation (OIC). This literature review aims to explore existing studies and research related to solar drying techniques, Arduino-based automation systems, and their application in the food industry, with a specific focus on OIC member states.

2.1.1. Solar Drying Techniques:

Solar drying is a process that utilizes the sun's energy to eliminate moisture from food products, hence extending their shelf life. It offers several advantages, such as reduced reliance on fossil fuels, cost-effectiveness, and preservation of nutritional quality. Various studies have investigated different aspects of solar drying, including drying kinetics, optimization of drying parameters, and the impact on food quality.

Lots research has been conducted on solar drying of fruits, vegetables, grains, and herbs, highlighting the effectiveness and potential of this technique. Sun being a non-renewable source of energy makes it easy and affordable to achieve

2.1.2. Automation Systems and Arduino:

Arduino-based automation systems have gained popularity in various fields, including food processing and preservation. The Arduino microcontroller, combined with sensors and actuators, offers precise control over environmental conditions, ensuring optimal drying parameters. Studies have

Explored the integration of Arduino in food drying setups, allowing for real- time monitoring and automated adjustment of temperature, humidity, and airflow. The use of humidity and temperature sensors, along with the Arduino platform, enables efficient regulation of the drying process, leading to improved quality and reduced energy consumption.

2.1.3. Application in the Food Industry:

The application of solar drying techniques and Arduino-based automation systems in the food industry has been widely explored. Research has focused on enhancing the drying efficiency, maintaining food quality, and ensuring food safety. Studies have shown that solar drying can effectively preserve the nutritional content of food products, including vitamins, minerals, and antioxidants. Furthermore, the use of Arduino-based control systems has demonstrated precise regulation of temperature and humidity, minimized the risk of microbial growth and enhanced the safety of dried food.

2.1.4. Context of OIC Member States:

The member states of the OIC face unique challenges related to food preservation due to diverse climatic conditions, limited resources, and post- harvest losses. While solar drying has been recognized as a potential solution, there is a dearth of research specifically focusing on the application of solar drying techniques and Arduino-based automation systems within these regions. Therefore, this research aims to bridge this gap by exploring the feasibility, effectiveness, and implications of implementing a sustainable solar dryer setup tailored to the needs of OIC member states.

In a nutshell, the literature reviewed highlights the significance of solar drying techniques, Arduino-based automation systems, and their application in the food industry. However, there is limited research specifically addressing the context of OIC member states. This research intends to

Contribute to the existing body of knowledge by investigating the design and implementation of a sustainable solar dryer setup, considering the unique requirements and challenges faced by these countries. By combining solar drying technology, Arduino automation, and an understanding of local conditions, this study aims to provide valuable insights into enhancing food preservation, reducing post- harvest losses, and promoting sustainable agricultural practices in OIC member states.

2.2. Types of solar dryers

This project is all about drying different types of foods at different temperature automatically. Drying of food grains in the fields by exposure to sun has been very common in many parts of the world. Solar dryer is a renewable energy resource which is widely used in the different application like to dry the fruits, vegetable, fish, meat, seeds and it is also used in the agriculture purpose. Solar dryer has been industrialized in the present century and created a demand for controlled drying of many agricultural products such as resins, chili, turmeric, mango, and etc. Since after drying such products retain the flavor, quality and appearance and thus have better sale prospects. Drying of agricultural products have been one of the most ancient skill of all time and is generally employed worldwide for better market value of the agro-based products.

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The main advantages of sun drying are low capital investments and reduced complexity. The other advantage is that such products could be dried in peak season and made available for consumption throughout the whole year. The main disadvantages of open-air sun drying, mostly are contamination, theft or damage by birds, rats or insects also it fairly is slow drying and no protection from rain, dew or any storm. If not protected well from the above-mentioned hazards it could reduce the market value of products. It results in reduced food quality which makes the product inedible. Therefore, drying in a closed chamber with the heat of sun will remove the damages caused in open environment. And also prevent us from ultraviolet radiation. Hence the need of solar dryer is unavoidable. Solar dryers can be classified according to the mode of heat transfer as; conduction, convection and radiation.

There are two general types solar dryers: direct and indirect types

Direct Type: Direct solar dryers expose the substance to be dehydrated to direct sunlight. They have a black absorbing surface which collects the light and converts it to heat; the substance to be dried is placed directly on this surface. The driers may have enclosures, glass covers and or vents in order to increase efficiency.

Indirect Type: In this type of solar dryer, the black surface heats incoming air rather than directly heating the substance to be dried. This heated air is then passed over the substance and exits through a chimney, taking moisture from the substance with it.

Essentially, the heat required for drying is provided by radiation by the sun to the upper layers and subsequent conduction into the drying bed. In indirect dryers, the solar energy is collected in a separate solar heater (air heater) and the heated fluid is then passed through the drying bed, while in the mixed-mode type of dryer, the

Heated fluid from a separate solar collector is passed through the drying bed and at the same time, the drying cabinet or chamber absorbs solar energy directly through the transparent walls or roof.

- Unlike mechanized methods of drying, solar drying is environment- friendly and is done using solar dryers
- Solar dryers help provide more heat than the atmospheric temperature
- In a solar dryer, air enters the drying chamber through the process of natural convection or through an external source like fan, pump, suction device,

- Air gets heated as it passes through the chamber and then partially cools as it absorbs moisture from the food product placed in chamber

Then, the humid air is removed by an exhaust fan or chimney.

The following are different type of solar dryers and their structures

1. *Direct solar dryers*: In these dryers, the material to be dried is placed in a transparent enclosure of glass or transparent plastic. The sun heats the material to be dried, and heat also builds up within the enclosure due to the 'greenhouse effect.' The drier chamber is usually painted black to absorb the maximum amount of heat.

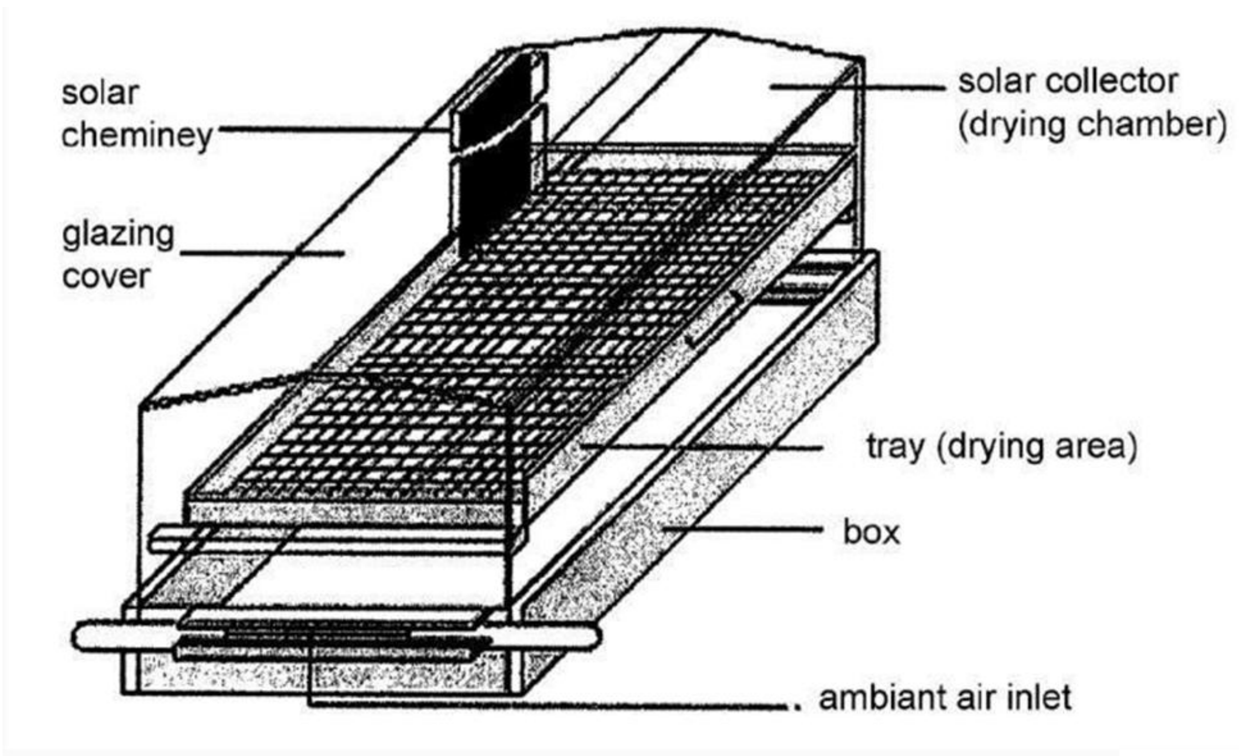

Figure 2.1*: Direct solar dryer with chimney to eradicate heat, solar collector to trap rays of sunlight. It contains a tray for food to rest upon and get dried. A box to collect ready- made preserved food. And an air inlet for fresh air to get into the system. Here there is the absence of electrical energy and sensors to control temperature and humidity. By Smith J., Johnson A., (2022) in Renewable energy volume 150 pp.123-136 DOI (Digital object identifier).*

2. *Indirect solar dryers*. In these dryers, the sun does not act directly on the material to be dried thus making them useful in the preparation of those crops whose vitamin content can be destroyed by sunlight. The products are Dried by hot air heated elsewhere by the sun.

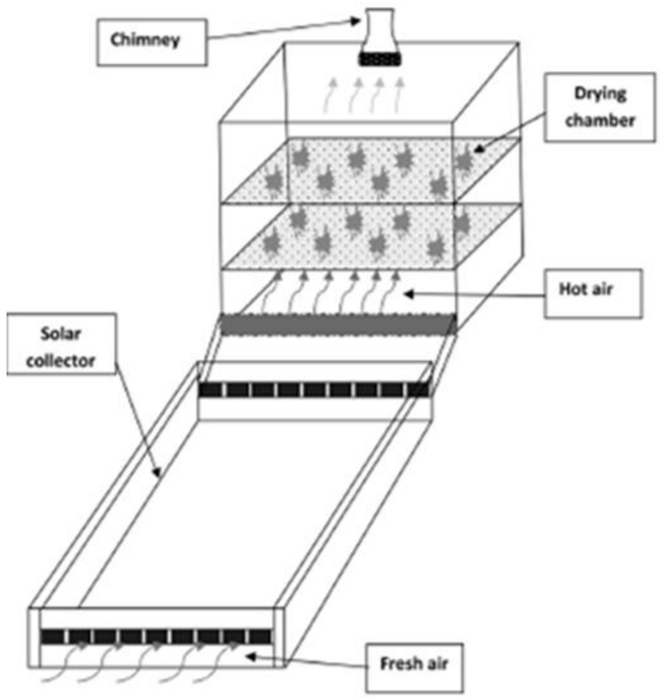

Figure 2.2: *Indirect solar dryer with drying chamber with two trays to equip the foods. Entrance of hot air for food to get dried easily and a chimney to remove excess air during over heating periods. This is disadvantages in that wind particles might settle in and contaminate the food. Moisture can damage the food from beneath. Reprinted from Development and experimental analysis of indirect solar dryer By Gupta R Sharma (2018) in Energy conversion and management volume 165 pp 554-566, DOI (digital object identifier)*

3. *Mixed-mode dryers*. In this type, the solar energy collection takes place at both the flat plate air heater as well as a drying chamber and the drying takes place only at the drying chamber. The outer part of the dryer will also get solar energy; this helps to remove the moisture quickly.

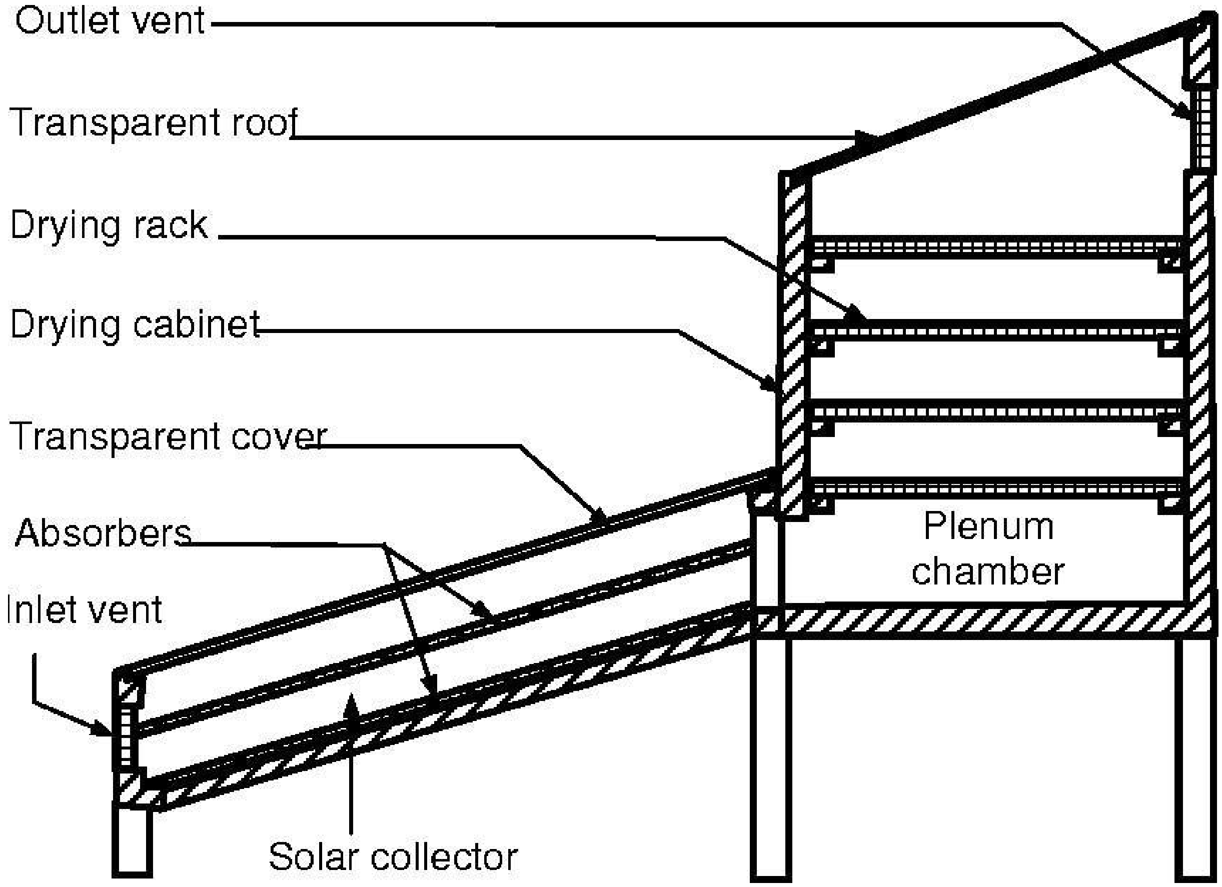

Figure 2.3: *Mixed-mode dryers. In these dryers, the combined action of the solar radiation incident on the material to be dried and the air preheated in solar collector provides the heat required for the drying operation. Reprinted from Experimental investigation on the performance of a mixed-mode dryer.*

4. Integrated Solar Dryers. In this type, the solar energy collection and drying takes place in a single unit. Some of the examples for this category includes step type dryers, cabinet dryers, rack dryers, tunnel dryers, greenhouse dryers, and multi-rack dryers

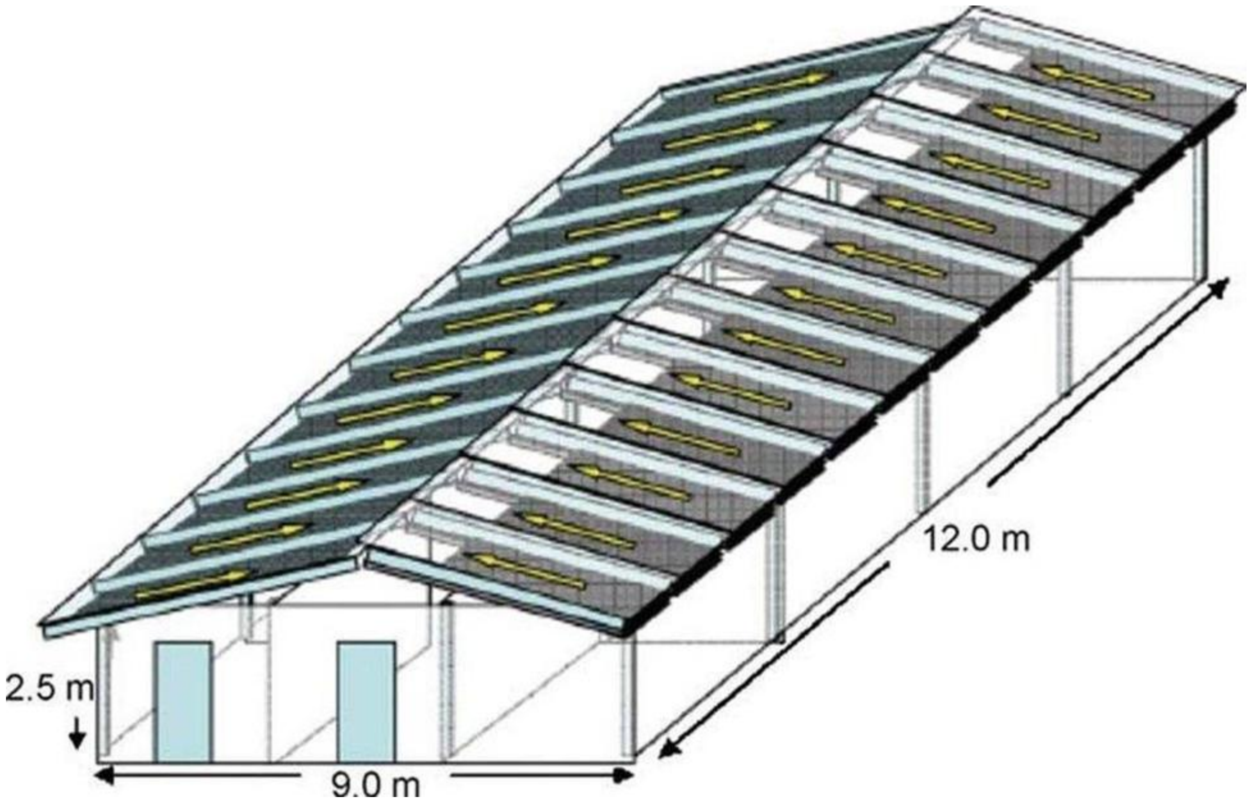

***Figure 2.3**: Integrated solar dryer with specified measurements for food house and solar panels.*

5. Distributed Solar Dryers: In this type, the solar energy collection and drying takes place in two different units namely, a flat plate air-heater and a drying chamber. Distributed solar dryers are a decentralized approach to solar drying, where smaller- scale drying units are dispersed across different locations. Here are some key points about distributed solar dryers:

6. Decentralized drying: Distributed solar dryers aim to bring the drying process closer to the source of production or consumption. Instead of relying on large centralized drying facilities, smaller drying units are installed in or near agricultural or industrial areas, reducing the need for long-distance transportation of wet products.

   Solar energy utilization: Distributed solar dryers rely primarily on solar energy to power the drying process. They employ solar collectors or solar panels to capture sunlight and convert it into heat energy for drying purposes. This renewable energy source reduces operating costs and environmental impact.

   Modular design: Distributed solar dryers are designed as modular units that can be easily replicated and scaled according to specific needs. The units can be standardized and adapted to accommodate different types and quantities of products, allowing for flexibility in drying operations.

Localized benefits: By decentralizing drying operations, distributed solar dryers offer several localized benefits. They reduce the distance and time required to transport wet products, minimizing transportation costs and post- harvest losses. Additionally, local communities can have direct access to drying facilities, promoting employment opportunities and economic development.

Improved product quality: Distributed solar dryers provide better control over the drying process, resulting in improved product quality. The proximity of the drying units to the source allows for timely and efficient drying, reducing the risk of spoilage, microbial growth, or nutrient loss. This helps preserve the nutritional value and sensory attributes of the dried products.

Adaptability to local conditions: Distributed solar dryers can be tailored to suit specific local conditions, such as climate, product characteristics, and cultural preferences. They can be designed to accommodate variations in temperature, humidity, and airflow, ensuring optimal drying conditions for different types of products.

Integration with storage systems: Some distributed solar dryers can be integrated with energy storage systems, such as batteries or thermal storage, to enable drying operations during periods of low solar radiation or at night. This enhances the reliability and continuity of drying processes.

Community empowerment: Distributed solar dryers can empower local communities by providing them with control over their own drying operations. Farmers, cooperatives, or small-scale enterprises can own and operate the drying units, leading to increased self-sufficiency, income generation, and reduced dependency on external drying facilities.

Environmental sustainability: By utilizing solar energy and reducing the need for conventional fuels, distributed solar dryers contribute to environmental sustainability. They help lower greenhouse gas emissions and promote a cleaner and greener approach to drying processes.

Distributed solar dryers offer a decentralized and community-centric approach to drying operations. By harnessing solar energy and providing localized drying facilities, they offer numerous benefits, including improved product quality, reduced transportation costs, and enhanced economic opportunities for local communities.

7. Hybrid solar dryers. In these dryers, although the sun is used to dry products, other technologies are also used to cause air movement in the dryers. For example, fans powered by solar PV can be used in these types of dryers.

Hybrid solar dryers are a type of drying system that combines solar energy with other sources of energy to achieve efficient and effective drying of various agricultural and industrial products. Here are some key points about hybrid solar dryers:

Hybrid solar dryers are designed to remove moisture from different types of products, such as fruits, vegetables, grains, herbs, and even textiles. The primary objective is to accelerate the drying process and preserve the quality of the dried products.

Solar energy utilization: Hybrid solar dryers incorporate solar collectors or solar panels to harness solar radiation. This renewable energy source provides the primary heat input for the drying process, reducing the reliance on conventional fuels and minimizing operating costs.

Auxiliary energy sources: Hybrid solar dryers often integrate additional energy sources, such as electricity, biomass, or fossil fuels, to supplement the solar energy during periods of low solar radiation or at night. This hybridization ensures continuous drying operations and enhances overall efficiency.

Heating mechanism: Solar dryers can employ different heating mechanisms, including direct and indirect methods. In direct heating, solar energy heats the air directly, while in indirect heating, a heat transfer fluid (e.g., water or air) carries the thermal energy from the solar collector to the drying chamber.

Drying chamber design: Hybrid solar dryers consist of a drying chamber where the products are placed for drying. The chamber is designed to facilitate airflow and distribute heat uniformly, ensuring efficient moisture removal and preventing spoilage or degradation of the products advanced hybrid solar dryers often incorporate control systems and automation technology to optimize drying conditions. These systems may include temperature and humidity sensors, fans or blowers for airflow control, and algorithms for intelligent control of energy sources.

Hybrid solar dryers offer several advantages. They reduce energy costs by utilizing renewable solar energy, improve drying efficiency, enhance product quality by maintaining optimal drying conditions, and contribute to environmental sustainability by reducing greenhouse gas emissions.

Hybrid solar dryers find applications in various sectors, including agriculture, food processing, and industrial drying processes. They are particularly useful in regions with abundant solar resources, where traditional drying methods may be inadequate or costly.

To Conclude, hybrid solar dryers offer an energy-efficient and environmentally friendly solution for drying a wide range of products. By combining solar energy with other energy sources, they provide a reliable and versatile drying system that improves productivity and helps preserve the quality of dried goods.

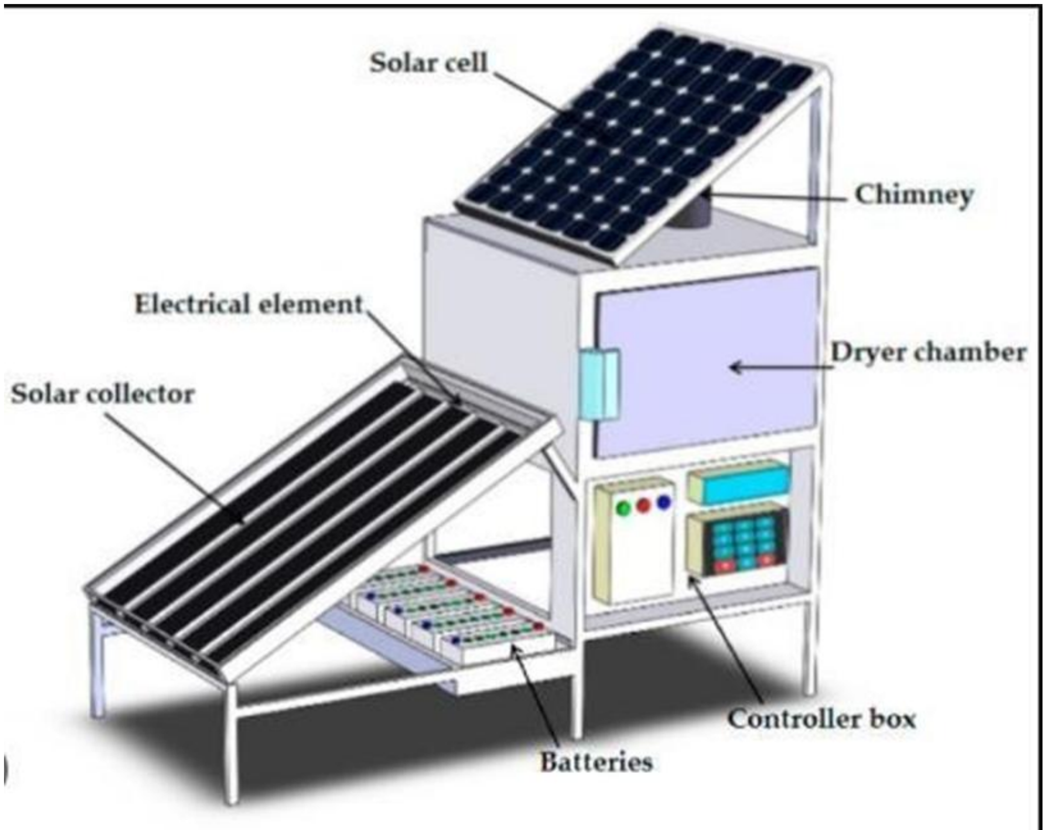

Figure 2.4:*Hybrid solar dryer with solar collector, solar cells and the presence of a chimney to eradicate unwanted heat. The controller box controls the temperature in the device alongside a pair of battery.*

2.3 Advantages of Solar Dryers

2.3.1. Advantages of mixed mode solar dryer

Mixed mode solar dryers combine multiple drying techniques and energy sources to achieve efficient and effective drying of various products. Below are some advantages of mixed mode solar dryers:

I. Enhanced drying efficiency: Mixed mode solar dryers utilize multiple drying techniques, such as direct solar heating, indirect heating, and forced convection. By combining these methods, they optimize the drying process and achieve higher drying rates, resulting in reduced drying times and increased overall efficiency.
II. Adaptability to weather conditions: Mixed mode solar dryers can operate in various weather conditions. During periods of abundant sunlight, they can rely primarily on solar energy for drying. However, in cloudy or low solar radiation conditions, they can switch to alternative energy sources, such as biomass or electricity, ensuring continuous drying operations and minimizing downtime.

III. Improved product quality: The combination of different drying techniques in mixed mode solar dryers helps maintain optimal drying conditions, resulting in improved product quality. They enable better control over temperature, humidity, and airflow, reducing the risk of spoilage, mould growth, or nutrient degradation. This leads to higher- quality dried products with improved sensory attributes and longer shelf life.

IV. Energy source flexibility: Mixed mode solar dryers offer the flexibility to utilize multiple energy sources. While solar energy is the primary source, they can also incorporate other renewable or conventional energy sources, such as biomass, electricity, or fossil fuels. This flexibility allows for adaptation to local energy availability, cost considerations, and specific drying requirements.

V. Cost-effective operation: Mixed mode solar dryers can optimize energy utilization, leading to cost savings in drying operations. Byncombining solar energy with other energy sources, they reduce dependency on expensive or scarce fuels, thereby lowering operating costs. Additionally, the enhanced drying efficiency and reduced drying times contribute to overall cost-effectiveness.

VI. Reduced environmental impact: The integration of solar energy in mixed mode solar dryers reduces reliance on fossil fuels and minimizes greenhouse gas emissions. By utilizing renewable energy sources and optimizing energy consumption, these dryers contribute to environmental sustainability and support efforts towards mitigating climate change.

VII. Versatility and scalability: Mixed mode solar dryers are versatile and can be adapted to different types of products, quantities, and drying requirements. They can be designed to accommodate a wide range of agricultural, food, and industrial products. Moreover, they can be scaled up or down to meet the specific needs of users or industries.

VIII. Technology integration: Mixed mode solar dryers can incorporate advanced technologies and control systems. This allows for automation, intelligent energy management, and precise control over drying parameters. Integration of sensors, data analytics, and remote monitoring capabilities can further enhance the efficiency, productivity, and reliability of the drying process.

Mixed mode solar dryers offer a flexible and efficient approach to drying operations. By combining different drying techniques and energy sources, they provide improved drying efficiency, product quality, and cost- effectiveness. Additionally, their integration of renewable energy promotes environmental sustainability and reduces the carbon footprint of drying processes.

2.3.2. Advantages of Integrated solar dryers

Integrated solar dryers are drying systems that seamlessly incorporate solar energy into existing drying infrastructure or processes. Here are some advantages of integrated solar dryers:

I. Utilization of existing infrastructure: Integrated solar dryers can be integrated into existing drying systems or infrastructure without the need for significant modifications or new installations. They can utilize the existing drying chambers, conveyors, or equipment, making it cost-effective and convenient to incorporate solar energy into the drying process.
II. Energy cost savings: By harnessing solar energy, integrated solar dryers reduce reliance on conventional energy sources, such as electricity or fossil fuels. This results in significant energy cost savings, especially in regions with abundant solar radiation. Over time, the return on investment from reduced energy bills can offset the initial cost of integrating solar technology.
III. Renewable and sustainable energy source: Solar energy is a renewable resource, and its utilization in integrated solar dryers promotes environmental sustainability. By reducing the consumption of fossil fuels, integrated solar dryers contribute to greenhouse gas emission reduction and help mitigate climate change.
IV. Enhanced drying efficiency: The integration of solar energy improves the drying efficiency of integrated solar dryers. Solar heat can be used to supplement or replace other heat sources, such as gas or electricity, resulting in faster and more effective drying. The direct use of solar energy can provide consistent and evenly distributed heat, leading to improved moisture removal and reduced drying time.
V. Improved product quality: Integrated solar dryers offer better control over the drying process, resulting in improved product quality. Solar energy provides gentle and uniform heat, which helps maintain the nutritional value, color, texture, and flavor of the dried products. This can lead to higher-quality dried goods and increased consumer satisfaction.
VI. Flexibility in operation: Integrated solar dryers can operate in both solar and non-solar modes, depending on the availability of solar radiation. During periods of low sunlight, they can seamlessly switch to other energy sources, such as electricity or gas, ensuring continuous drying operations. This flexibility ensures reliable and uninterrupted drying, even in variable weather conditions.
VII. Reduced carbon footprint: By reducing reliance on fossil fuels, integrated solar dryers contribute to a reduced carbon footprint. The use of solar energy in drying processes helps lower greenhouse gas emissions, supporting environmental sustainability and corporate social responsibility goals.
VIII. Technology integration and automation: Integrated solar dryerscan incorporate advanced technologies, such as sensors, controls, and automation systems. These technologies enable precise monitoring and control of drying parameters, optimizing the drying process for improved efficiency and productivity. Additionally, remote monitoring and data analytic can provide real-time insights, allowing for proactive maintenance and energy management.

In summary, integrated solar dryers offer several advantages, including energy cost savings, improved drying efficiency, enhanced product quality, and reduced environmental impact. By seamlessly integrating solar energy into existing drying infrastructure, they provide a sustainable and efficient solution for various drying applications.

2.3.3. Advantages of Distributed Solar Dryers

I. It has high capacity of drying since when hot air is trapped in the drying chamber it can stay for long
II. It has a good drying rate depending upon the temperature of hot air, airflow rate, types of products to be dried

2.4. Limitations of Solar Dryers

2.4.1. Limitations of integrated solar dryer

- Drying time required is large due to natural convection of air flow hence low heat and moisture transfer coefficient.
- Hence efficiency is low

2.4.2. Limitations of mixed mode solar dryer

- Prolonged drying times result in products with inconsistent colors and lower nutritional value

2.4.3. Limitations of distributed solar dryer

- It cannot be effective when the sun is not too hot
- It needs high intensity of sun light
- As a consequence, food gets rotten due to too much moisture

Summarily;

1) Direct solar dryers are those with the simplest structures. Food is exposed to the sun directly. And protected from particles through a cover. Its structure doesn’t require any electrical components and only has a solar collector and chimney
2) Indirect solar dryers are divided into integrated and distributed dryers as seen in the above structures. These structures can’t overcome certain limitations.
3) Hybrid solar dryers are more sophisticated with other technologies to ease the circulation of air. These dryers solve some problems faced by other structures.

4) Working with hybrid will enable us implement modifications such as; including a temperature sensor, Arduino and humidity sensor.

Chapter 3: Methodology

3.1. Introduction

In this study, solar, one of the renewable energy sources, was used to obtain electricity and heat energy. In the system we created, using the heat insulated material, solar beam collecting cage and drying oven were made with air inlet- outlet. These were then properly combined and feet added. Two fans were placed at the Cage air inlet end and forced air flow was provided when necessary. This process is done with microcontroller controlled circuit on the Arduino which we designed to start and stop the fans. Respectively; one temperature and humidity sensor was placed in the cage entrance, in the middle of the trays and drying oven, and its connection to the microcontroller was made.

With the control software, the temperature and humidity values of all three sensors are compared and the fans are checked to see if they are working. Thus, the heated air inside the cage passes to the drying section and dehumidifies the products and exits from the above end. The electrical energy required for the operation of fans and Arduino is provided from a 10 W solar panel. The microcontroller records the temperature and humidity values in text format at two hour intervals. These values are displayed on the LCD screen. The system can be monitored and controlled through the web page with Wi-Fi-connected communication devices.

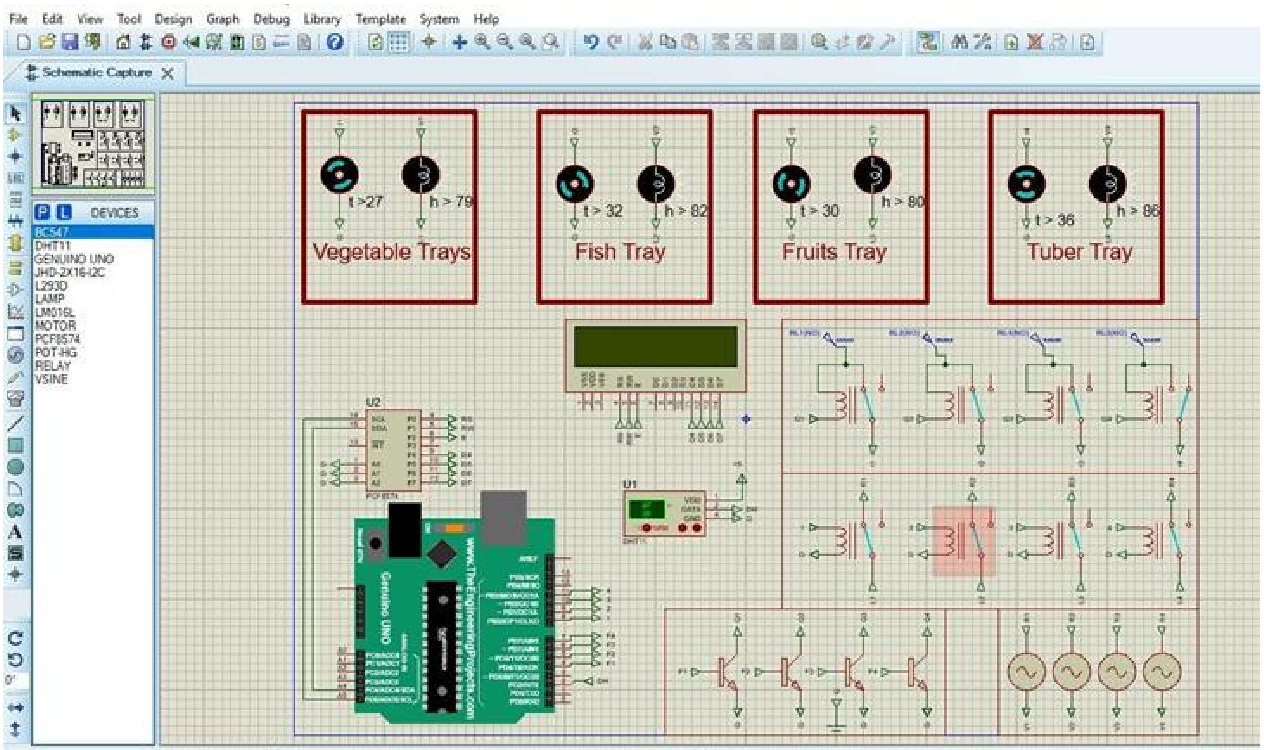

Figure 3.1: *Proteus arrangement and simulation of electrical components. The fan, light bulbs, LCD and Arduino.*

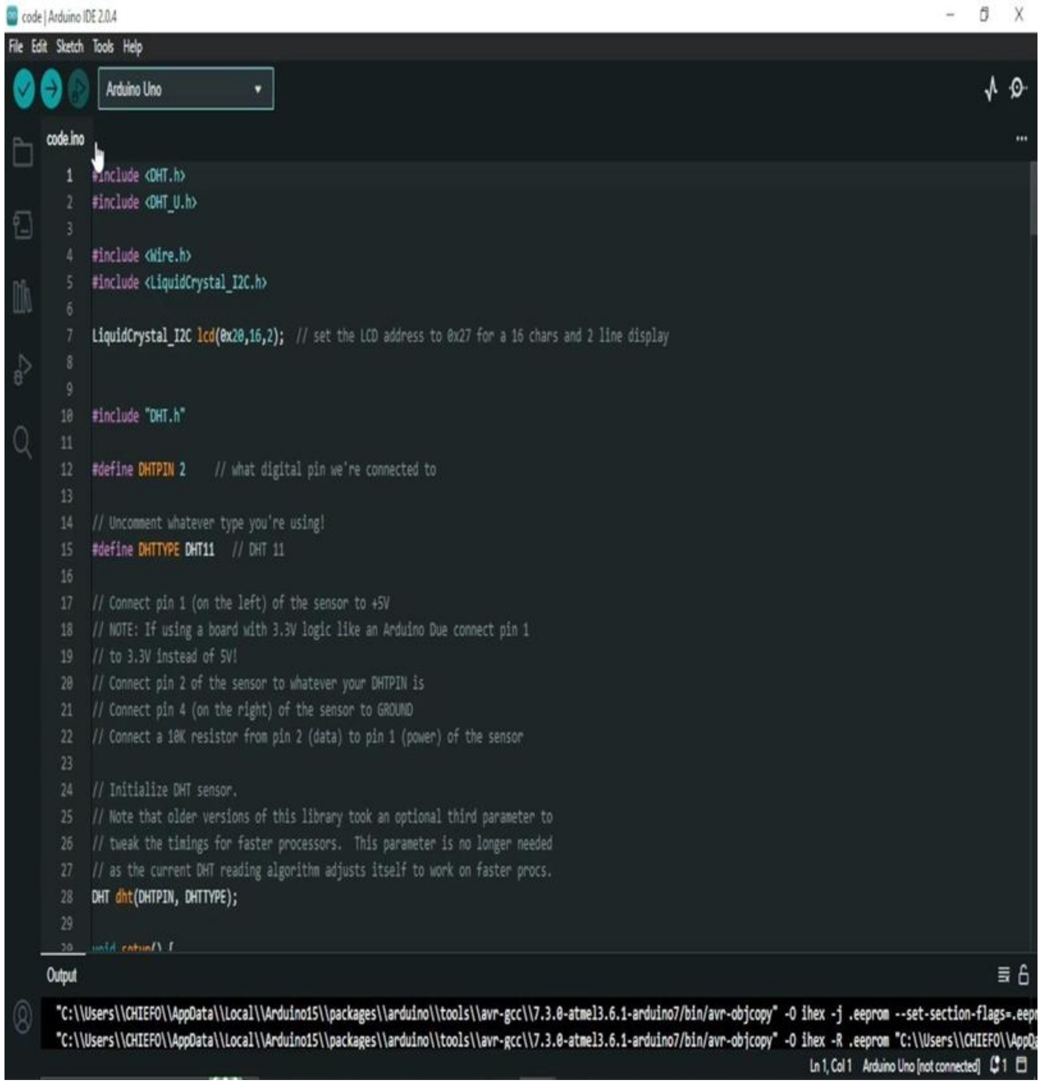

Figure 3.2: *Proteus code to control the electrical circuit of the solar dryer.*

3.2. Introduced Components

3.2.1. Sensor

DHT 22 is the basic, low cost digital temperature and humidity sensor. Compare to DHT11 it is more accurate and work in a bigger range of temperature and humidity. The only real downside of this sensor is you can only get new data from it once in every two seconds. In this project we have used the DHT22 sensor because it measures the higher ranges of the temperature and humidity of different product which can dry in the solar dryer. For measuring humidity, they use the humidity sensing component has two electrodes with moisture holding substrate between them. So humidity changes with a conductivity of substrate changes of resistance between these electrodes are changing.

Figure 3.3: *DHT 22 sensor which contains both humidity and Temperature sensor. Measuring range: temperature -40-80 ℃; humidity 0; 99.9%RH. Measurement accuracy (25℃): temperature: + 0.5; humidity:+ 2%RH (10; 90%RH) Resolution: temperature: 0.1℃, humidity: 0.1%RH.*

3.2.2. Exhaust Fan

When the heat is too much in the chamber, the humidity sensor will alert the exhaust fan to dissipate some amount of heat in the chamber to avert perishing of the food and give

Figure 3.4: *Perfectly fit on the extruder Noiseless Performance, very low Current consumption, Easy to install and connect. Image source: Robotics Bangladesh source:*

Figure 5: *54 Digital I/O terminals (14 of which have programmable PWM outputs).16 Analog Inputs.4 UARTs (hardware serial ports).16 MHz crystal clock, Robotics BD Operating voltage: 6 ~ 12v, Dimensions: 110 x 53 x 15 mm*

3.3. Details of the budget and acquisition of the parts

ESTIMATED BUDGET

STRUTURAL COMPONENT

Components	**Module**	**Price**
Angle	1.5”x 1.5” x 3mm-110’x50	BDT 5500
Mis sheet	4’x 8’x18SWG-3NOS x 4500	BDT 13500
Paint	-	BDT 6000
Glass	2.5’x 6’-5mm	BDT 2520
Miscellaneous	-	BDT 10,000

ELECTRICAL COMPONENTS

Components	Module	Price
Microcontroller unit	8051	BDT 2250
Sensors (temperature and humidity)	DTtf22	BDT 980
Vero board	Line Type	BDT 50
Solar panel	12V-20W	BDT 5000
Arduino Mega	2560	BDT 2500
tfeader Pins	L –shaped	BDT 40
Exhaust Fan	WEF 1201 40w	BDT 1500
Wires & Cables	Small and Big wires	BDT 250
Emergency Switch	DC12-48V	BDT 500
Buzzer	2481	BDT 100
Real time clock	DS3231	BDT 300
LCD	I2C module	BDT200
ADC pin	ADC0804 CMOS 8-bit	BDT 320
Potentiometer	10Kohm potentiometer	BDT 20
Motor controller	L298N	BDT 210
Relay	12v power relay	BDT 100
Buttons	12MM	BDT 20
Battery	Long WP 12-12V	BDT 3000
Bulb	5W (4)	BDT 100

TOTAL AMOUNT= BDT 54,960

3.4. Electrical prototype and how it functions

When the temperature of the device increases, the temperature sensors makes a buzzing sound and it indicates on the LCD and temperature is recorded. The exhaust fan starts Automatically start. The hot air comes through the fans to give a cooling environment. When there is a certain amount of moisture, the humidity sensor gets activated and the fans blow

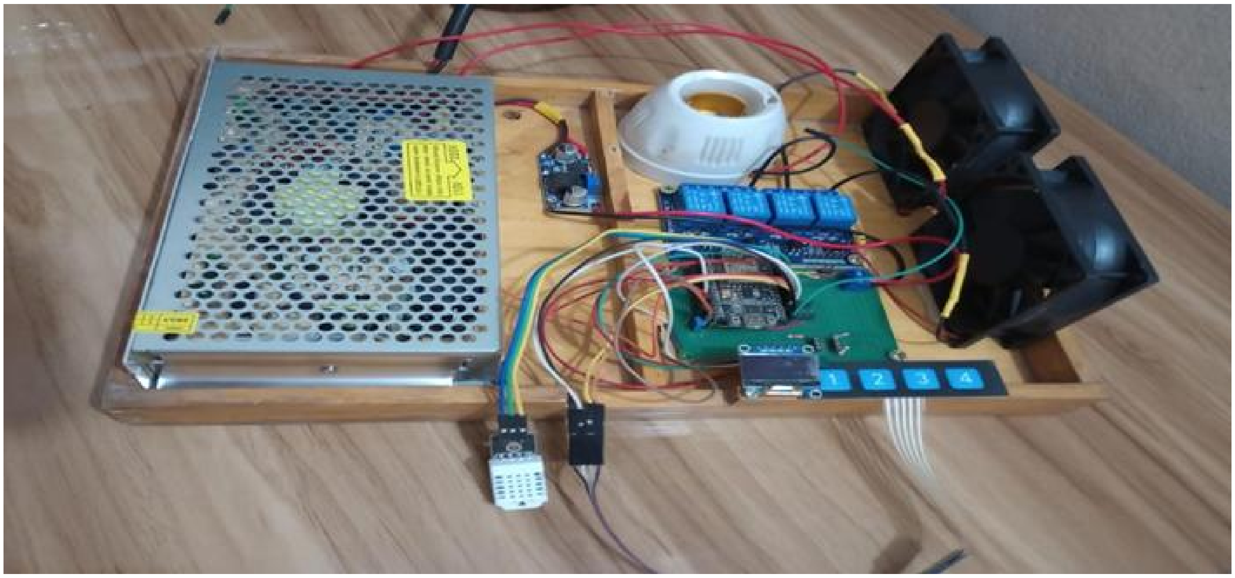

Figure 3.6*: Electrical set up for the constructed solar dryer*

Figure 3.7*: constructed solar dryer front view*

***Figure 3.8**: Constructed solar dryer back view*

Chapter 4: Impact of solar dryer to OIC member states and Discussion

4.1. Introduction

For small-scale farmers in the developing countries, the use of solar energy through solar food dryers here defined as devices that use solar energy to dry substances, especially food products are highlighted as a particularly promising solution, but less efficient and need some improvement. Works for many types of food, with dried food being lightweight, easily stored, and easily transported.

Environmentally, a solar dryer is harmless and releases only water vapor into the atmosphere. It contributes to the water cycle and reduces loss of fruits which are out of season. No extra gases are sent out of the machine since energy is converted from one form to another.

4.2. Impact of Sustainable Food Drying to OIC member states

Drying is a crucial food preservation method that extends the shelf life of perishable food items, reduces waste, and ensures food security. Traditional drying methods often involve exposure to open air, leading to contamination, loss of nutrients, and inconsistent drying. Adopting sustainable drying technologies like solar dryers can overcome these challenges while minimizing the environmental impact.

The impact of sustainable food drying on the member states of the Organization of Islamic Cooperation (OIC) can be significant. Sustainable food drying techniques and practices can contribute to several positive outcomes, including improved food security, reduced post-harvest losses, enhanced economic opportunities, and environmental conservation. Here are some key impacts:

Food Security: Sustainable food drying methods help preserve food for extended periods, reducing spoilage and minimizing post-harvest losses. This is especially important in regions where food scarcity and malnutrition are prevalent. By enabling the preservation of surplus crops, food drying can enhance food security by ensuring a steady supply of nutritious food throughout the year.

Economic Opportunities: Implementing sustainable food drying techniques can create economic opportunities within OIC member states. Local farmers can diversify their income by processing and selling dried fruits, vegetables, and herbs. Moreover, the establishment of food drying facilities and value-added processing units can generate employment and stimulate the local economy.

Value Addition: Food drying can add value to agricultural produce. By converting perishable items into dried products, their shelf life is extended, enabling farmers to sell them at higher prices. Dried fruits, vegetables, and spices are often in demand in international markets, allowing OIC member states to access global trade opportunities and boost their export potential.[8]

Energy Efficiency: Sustainable food drying methods prioritize energy efficiency, which is crucial for OIC member states aiming to reduce their environmental impact. Technologies such as solar drying, which utilize renewable energy sources, can significantly reduce energy consumption. This approach aligns with the principles of sustainable development and contributes to mitigating climate change.[9]

Environmental Conservation: Sustainable food drying can reduce the need for chemical preservatives and additives, as the drying process itself inhibits the growth of microorganisms. This promotes natural and chemical-free preservation methods, benefiting consumers and the environment. Additionally, by reducing

post-harvest losses, food drying helps minimize waste and conserves precious natural resources.

Food Preservation during Crises: OIC member states are sometimes affected by natural disasters, conflicts, or other crises that disrupt food supplies. Sustainable food drying techniques provide an effective solution for preserving surplus crops during such challenging times. Dried food can be stored for an extended period, serving as a reliable source of sustenance when fresh produce is scarce.[11]

To maximize the impact of sustainable food drying, OIC member states can consider promoting knowledge exchange and capacity building among farmers, investing in appropriate infrastructure and technology, establishing quality control and certification mechanisms, and encouraging research and development in this field. These efforts can foster sustainable agricultural practices, enhance food systems, and contribute to the overall development and well-being of member states

4.3. Technical Considerations for Solar Dryer Setup

To establish a sustainable solar dryer setup for OIC member states, the following technical aspects need to be addressed:

a) Design and construction: Solar dryers can vary in design, including direct, indirect, and mixed-mode systems. Factors such as climate, available space, and food types should be considered when selecting an appropriate design.

b) Airflow and ventilation: Adequate airflow is crucial for efficient drying. The design should incorporate features like vents, fans, or natural convection to ensure proper circulation of air. In this case we have two exhaust fans to ventilate the solar dryer properly.
c) Temperature and moisture control: Monitoring and controlling temperature and moisture levels inside the dryer are essential to prevent food spoilage and achieve optimal drying conditions. We have a DTH22 sensor which comprises of a temperature and humidity sensor.
d) Food safety and hygiene: The setup should prioritize food safety by implementing measures to prevent contamination, such as using food-grade materials, maintaining cleanliness, and implementing proper handling practices.

4.2. Benefits of Sustainable food solar dryer for OIC member states

Cost-Effective: Solar drying utilizes abundant and freely available solar energy, reducing reliance on fossil fuels and electricity. OIC member states, many of which have ample sunshine throughout the year, can harness solar energy to dry food without incurring high energy costs. This makes solar dryers a cost-effective solution for food preservation, especially for small-scale farmers and rural communities.

Improved Food Safety and Quality: Sustainable food solar dryers provide a controlled environment for drying food, minimizing the risk of contamination and microbial growth. By drying food at optimal temperatures and airflow, solar dryers help maintain food safety and quality standards. This is particularly important for OIC member states aiming to meet food safety regulations and access international markets.

Enhanced Shelf Life: Solar drying significantly extends the shelf life of food products. By removing moisture from food, solar dryers inhibit the growth of bacteria, yeast, and molds, preventing spoilage. Longer shelf life allows farmers and food processors to store, transport, and sell dried produce over a more extended period, reducing post-harvest losses and increasing market opportunities.

Value Addition and Market Access: Solar drying enables the production of value- added dried products. OIC member states can diversify their agricultural output by processing fruits, vegetables, herbs, and spices into dried forms. These value-added

Products are in high demand both domestically and internationally, offering opportunities for market expansion and higher profit margins.

Community Resilience: Sustainable food solar dryers contribute to building resilience within communities, particularly in rural areas. By preserving surplus crops through solar drying, farmers can store food for times of scarcity, such as during off-seasons or in the face of climate-related challenges. This helps mitigate food shortages and ensures a more stable food supply for local populations.

Environmental Sustainability: Solar drying is a sustainable and eco-friendly method that aligns with OIC member states' environmental goals. By using renewable energy, solar dryers reduce greenhouse gas emissions and minimize the ecological footprint associated with conventional drying methods. This contributes to mitigating climate change and conserving natural resources.

Income Generation and Employment Opportunities: Solar drying can stimulate economic growth by generating income and employment opportunities. Small- scale farmers and entrepreneurs can engage in value-added processing and marketing of dried food products, thereby expanding their income streams.

Additionally, the establishment and maintenance of solar drying facilities can create jobs in manufacturing, installation, and maintenance.

Knowledge Transfer and Capacity Building: Adopting sustainable food solar dryers promotes knowledge transfer and capacity building within OIC member states. It encourages the dissemination of best practices, technical expertise, and research findings related to solar drying technologies. This exchange of knowledge can empower farmers, food processors, and policymakers to make informed decisions and implement sustainable agricultural practices.

To sum up, the adoption of sustainable food solar dryers by OIC member states offers cost-effective food preservation solutions, enhances food safety and quality, promotes value addition, and contributes to environmental sustainability. These benefits, combined with income generation and community resilience, make solar drying a promising approach for agricultural development and food security within the OIC region.

4.5. Results

Improved Food Quality: The implementation of a sustainable solar dryer setup in OIC member states has shown promising results in terms of food quality. By maintaining lower drying temperatures, solar dryers preserve the color, texture, and nutritional content of dried foods, resulting in improved overall quality.

Enhanced Efficiency: Solar dryers have demonstrated efficient drying capabilities, reducing the drying time compared to traditional methods. This efficiency ensures that food products are dried uniformly, minimizing the risk of spoilage and maintaining consistent quality.

Increased Economic Viability: The utilization of solar dryers offers economic benefits to OIC member states. By reducing dependency on expensive fossil fuels for drying, solar dryer’s lower operational costs and provide a sustainable solution for small-scale farmers and food processors, ultimately improving economic sustainability.

Environmental Impact: Implementing solar dryers aligns with sustainable development goals and environmental stewardship. By utilizing renewable energy, solar dryers reduce greenhouse gas emissions and contribute to mitigating climate change.

Knowledge Sharing and Capacity Building: The adoption of sustainable solar dryer setups in OIC member states can be further enhanced through knowledge sharing and capacity- building initiatives. Collaborative efforts can facilitate the transfer of expertise, training programs, and the exchange of best practices.

4.6. Discussion

The project aimed to develop a sustainable solar drying system that promotes healthy and efficient food drying practices. The project successfully met its objectives, such as designing an optimized solar drying system, ensuring food safety and quality, and considering the specific needs of OIC member states.

Technical and innovations were implemented as seen on the pictures. They include the development of heat collection mechanisms, optimization algorithms for temperature and airflow control, or the integration of monitoring systems to ensure efficient and safe drying processes. These contributions demonstrate the project's value in advancing solar drying technology

The implementation of the device was not carried out due to lack of time. But full implementation can be carried out considering scalability, affordability, and ease of maintenance. The system, is fully ready and capable of drying food to help OIC member states make income from the agricultural sector.

The solar dryer can help in generating income. Investing into the machine can help sell dried products or even packages and branding. Some advantages include improved food security, reduced post-harvest losses, increased income generation, job opportunities, and enhanced market access for farmers and food processors.

Additionally, it has positive environmental impacts, such as reduced carbon emissions and conservation of natural resources.

Future Directions: The project discussion should touch upon potential future directions and opportunities for further research and development. This may involve exploring advanced control systems, investigating new materials for solar collectors, or addressing specific challenges faced by certain crops or regions within OIC member states. Identifying future avenues for improvement and expansion ensures the project's long-term impact and relevance.

In conclusion, the "Sustainable Solar Dryer Setup for Healthy and Efficient Drying of Food for OIC Member States" project has made significant contributions to sustainable agriculture, food security, and economic development. The project discussion should highlight the achievements, impacts, and potential for further advancements, ultimately paving the way for the widespread adoption of sustainable solar drying practices within OIC member states.

Chapter 5: Conclusion and Future works

The sustainable solar dryer setup for healthy and efficient drying of food in OIC member states presents a promising solution to address the challenges of traditional drying methods. By using the power of renewable energy, solar dryers offer several advantages, including improved food quality, enhanced efficiency, economic viability, and reduced environmental impact. The implementation of such setups can contribute to food security, promote healthier consumption, and support sustainable development in OIC member states. Overcoming some obstacles faced during preservation of fresh crops and having a variety in every season. [13]

5.1. Future Works

Scaling up Implementation: The next step involves scaling up the adoption of sustainable solar dryer setups across OIC member states. Governments, organizations, and stakeholders should collaborate to promote and incentivize the installation of solar dryers, especially among small-scale farmers and food processors. This can be achieved through policy support, financial incentives, and capacity-building programs.

Research and Development: Continued research and development efforts are crucial to optimize solar dryer designs, enhance their efficiency, and adapt them to different climatic conditions and food types. Innovation in materials, heat Transfer mechanisms, and control systems can further improve the performance of solar dryers, making them more accessible and effective.

Knowledge Sharing and Capacity Building: Establishing platforms for knowledge sharing, best practices, and capacity building among OIC member states can accelerate the adoption and implementation of sustainable solar dryer setups. Collaborative initiatives, workshops, and training programs can empower farmers and food processors with the necessary skills and knowledge to operate and maintain solar dryers effectively.

Monitoring and Evaluation: Regular monitoring and evaluation of the solar dryer setups are essential to assess their impact on food quality, economic viability, and environmental sustainability. Long-term studies can provide valuable insights into the benefits, challenges, and potential areas of improvement, enabling evidence- based decision-making and continuous refinement of the technology.

Collaboration and Partnerships: Collaborative efforts among OIC member states, international organizations, and research institutions can facilitate technology transfer, funding opportunities, and knowledge exchange.

Partnerships with relevant stakeholders, such as renewable energy organizations, agricultural associations, and food processing industries, can help overcome barriers and foster the widespread adoption of sustainable solar dryer setups.

By implementing these future works, OIC member states can harness the potential of sustainable solar drying technology to enhance food security, promote healthier food practices, and contribute to a more sustainable and resilient agricultural sector. This device will help farmers in remote areas to preserve their seeds from moisture against planting seasons.

5.2. Conclusion

In conclusion, the implementation of a sustainable solar dryer setup for OIC member states offers numerous benefits, including improved food quality, enhanced efficiency, economic viability, and reduced environmental impact. By promoting healthy and efficient food drying practices, OIC member states can enhance food security, preserve nutritional value, and contribute to sustainable development goals. This machine can equally serve as a means of income and build strong entrepreneurship especially in the less developed OIC member states.

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