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DESIGN AND FABRICATION OF SOLOAR POWERED REFRIGERATOR

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Abstract:
This project address the growing need for sustainable energy solutions due to the depletion of non-renewable resources. It proposes a design for a compact and affordable solar powered refrigerator, ideal for outdoor activities, medical supplies for rural areas, or picnics.
The refrigerator utilizes solar energy through a solar panel and stores excess power in battery via a hybrid inverter and charge controller. The core cooling system comprises a compressor, evaporator, condenser, and expansion valve, operating efficiently to minimize energy consumption.
We choose to use a vapour compression refrigeration system for this project. This project aims to contribute to the development of senvironmentally friendly refrigeration technology which optimized energy usage.
Keywords: *Solar Power, refrigerator, non-renewable energy, sustainable energy, vapour compression.*

1. Introduction

Solar energy, has many uses for lowering the energy requirements of daily life because it is a plentiful supply of free energy from the sun. In addition to conventional lighting, refrigeration systems can be powered by solar energy, particularly in remote locations. It is anticipated that solar refrigeration will expand the application of solar energy. The process of keeping food cool is called refrigeration. Transferring heat from one place to another is the process of refrigeration. Heat is absorbed from a substance or space during this process, resulting in a temperature that is lower than the surrounding environment.
When a refrigerant consumes unwanted heat, the temperature rises, causing it to transform from a liquid to a gas it evaporates. Condensation is then used by the machine to release the heat and transform the refrigerant back into a liquid. This is referred to as "Latent Heat". This cycle is based on the physical idea that when a liquid expands into a vapor, it absorbs heat from its surroundings. The refrigerant is pumped into a closed looped pipe system to do this. The closed looped pipe structure prevents refrigerant contamination and regulates its flow. In the circle, the refrigerant would be both a gas and a liquid in the system.Solar refrigeration refers to a refrigerator that operates on electricity produced

by the sun. A solar-powered refrigerator is one that operates on electricity directly supplied by the sun, and can include photovoltaic or solar thermal energy. The sun Photovoltaic refrigerators work on the same concept as standard compression refrigerators, but they use low voltage DC compressors and motors instead of mains voltage ac models. To optimize energy efficiency, photovoltaic refrigerators have higher levels of insulation around the storage compartments, a battery bank for electricity storage, a battery charge regulator, and a controller that transforms the power from the battery to the form required by the compressor motor.
In this project we deals with solar powered vapour compression refrigerator system technology, and find out the COP of Ac supply and solar power.

2.Literature review

Todd Otanicar, Robert A.Taylor, Patrick E.Phelan(2012)
According to this literature, solar electric cooling expenses depend on the system's COP and decrease with decreasing PV costs. This is especially true for stable PV prices. On the other hand, solar thermal cooling results in lower solar collection costs overall, but higher refrigeration system costs relative to total expenditure.
Sanford A. Klien and Douglas T.Reindl(2005)
This article compares the operational characteristics of three methods for using solar energy for refrigeration below 0°C. All three cycles—Solar Electric, Solar Mechanical, and Absorption—have low Coefficient of Performance (COP) despite their potential. This low efficiency is caused by the complexity, expense, and bulkiness that come with accommodating the variability of solar energy and producing the required power locally, which makes expensive energy storage systems necessary.
Fateh Mulla et al. (2011)
For developing nations like Nigeria, the author designed and developed a photovoltaic-powered DC vapour compression refrigeration system. The system's use was demonstrated, and it can be applied to various climatic regions of Africa and used to store perishable food, enhance health services, and improve living conditions in isolated and rural areas without access to electricity.
Shashwata Chakraborty(2021)
The paper "Improvement of a Solar Powered Absorption Refrigeration System" addresses the need for alternative energy sources in light of the world's growing energy demands and the environmental damage caused by the use of fossil fuels. It highlights the potential benefits of developing a solar-powered absorption refrigeration system over conventional refrigeration cycles, including reduced energy scarcity, less wasted food

and medicine, lower greenhouse gas emissions, and increased accessibility to refrigeration systems worldwide, particularly in areas with difficult access to electricity.

Sabyasachi Aich and Jayashree Nayak(2020)

The author of this paper describes a solar-powered refrigerator that has a UPS installed for continuous operation. The refrigerator can operate on both AC and DC power, and it performs well in a range of solar irradiation levels. The system highlights its practicality and dependability in off-grid settings with its minimum internal temperature of 6°C and high coefficient of performance (COP) of 5.89. It provides effective cooling for a wide range of applications.

3. Materials and Methods

3.1. Experimental Set up

The experimental set-up comprises of two components, a cooling system and a power supply unit. The cooling unit is made up of a tub made of a domestic cooler, an AC-powered pump, an evaporator, a condenser, and an expansion valve. The cooler has a gross capacity of 109 liters. The maximum compressor power consumption is 138W, and the ozone-friendly R134a coolant is used. The process which enables cooling is the conversion of sunlight into DC electric power.as a result of the PV panel. The direct current electrical control drives the compressor, causing the refrigerant to circulate .

Vapour compression is the method used to accomplish refrigeration. A loop designed to extract heat from an insulated container The phase transition content and the thermal reservoir are both housed in this enclosure. The substance freezes as its heat is removed, imprisoning it. The freezer box with high insulation has the proper dimensions. The refrigerator can stay cool all year round thanks to the solar panel, variable speed compressor, and thermal storage shift mechanism. In order to maximize the transfer of solar power to storage thermal power, a compressor control system makes use of the energy available. The Power Unit converts the battery's DC supply to an AC that is useful for the compressor. It consists of a solar panel mounted to a charging controller with an integrated inverter that makes sure the battery is adequately charged. While the charge regulator ensures that the battery does not run out of power, it also implies that the cooling unit is limited to maintaining approved voltage and current. The device runs on a 12V-26AH valve-regulated lead-acid battery for over 8 hours when there is no sunlight. In order to achieve cooling, the solar-based cooling system is built with both a cooling unit and a solar power supply unit.

3.2. Solar Power Unit

Solar radiation is transformed directly into direct current electricity in this photovoltaic driven unit, which uses semiconducting materials. The process that allows refrigeration is the conversion of sunlight into DC electrical power through the PV board. The device includes charge controller as well as an inverter.

A charging controller is used to monitor the amount of electricity stored by the battery so that it does not charge above a certain threshold, resulting in battery damage. The battery stores DC, whereby an inverter needs the DC output to be converted to AC that can be used by the cooling unit. Under sunny conditions, the cooling device can be powered directly by the output of solar cells; when the sun's strength is reduced, the cooling device takes on the role of a primary energy source. The compressor is powered by a DC electric control, which forces refrigerant through a steam compression cooler to remove heat from a single enclosure. This box contains a phase shift component and a hot tank.

The components of solar refrigeration systems are:

3.2.1 Solar panel:

Sunlight is converted to DC energy by solar cells and is deposited in batteries by a charging regulator. In direct relation to the sunshine intensity it gets, electricity produced by the solar panel.Batteries like this can be directly powered by DC charges.The battery cables are connected to the inverter so that the DC from the solar system is turned into AC to enable the cooler to operate.

Fig.3.2.1 Solar panel

Specifications:

- ✓ Rated voltage: 17.5V DC 2A
- ✓ Rated power: 40W

3.2.2 Battery: For later use of electricity storage, it is important. The scale of the battery bank is determined on the basis of the average watt-hour and storage space requirements. The battery purpose stores energy from the solar cell, which is then loaded while there is no direct power in the solar cells. A battery of 100AH running on 12V DC is used in this plant.

Fig.3.2.2 Battery

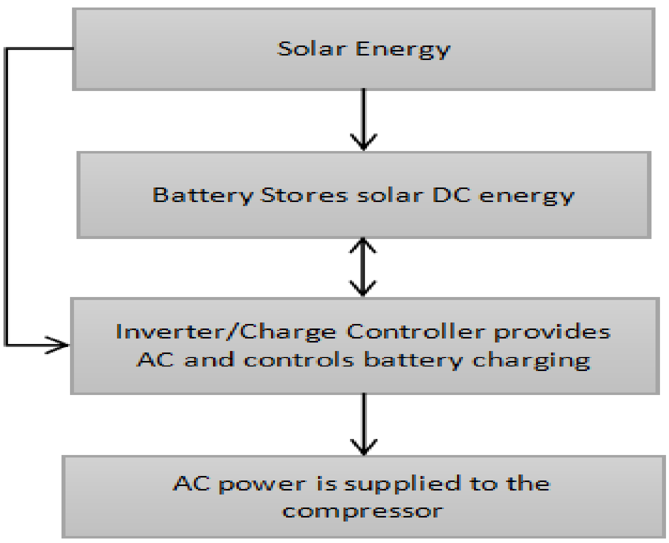
3.2.3 Inverter and Charge Controller:

The inverter with integrated load regulator is used for this project. A solar inverter is a converter type that converts the variable direct current (DC) output of a photovoltaic (PV) panel into an alternating current (AC) supply unit. A load controller adapts to the incoming energy amplification of the solar array. This prevents the battery from overcharging. A device with a single unit with a load controller and an inverter.

Specifications:

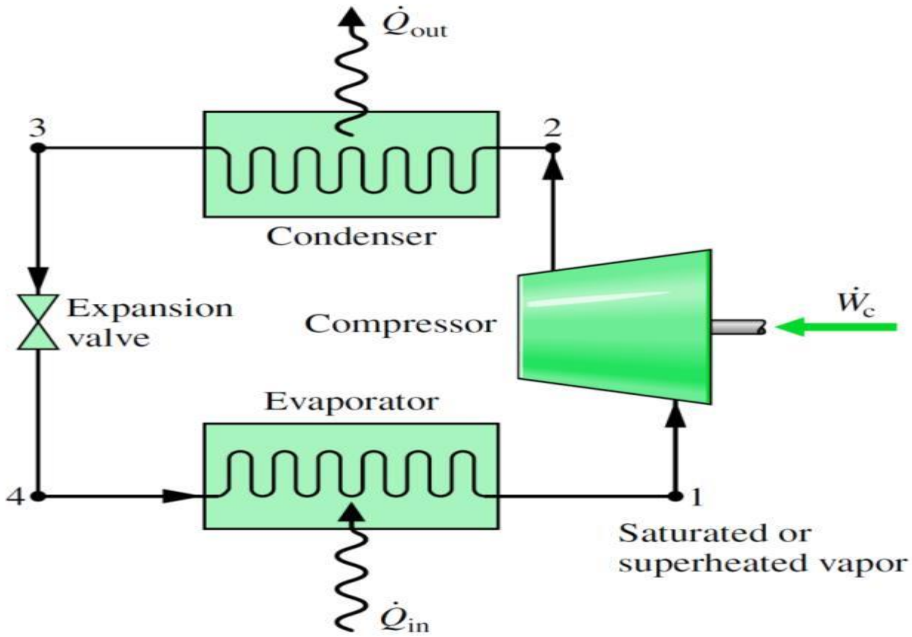
- ✓ Input voltage 12V DC
- ✓ Output voltage 230V AC
- ✓ 2000W PWN and Charger

The flow map shows how the cooler is powered by solar panels.



The solar systems of solar refrigerator comprise of the solar panel collects the solar energy. The solar panels are fitted with photovoltaic cells that convert the solar energy into electrical energy and store in the battery. During the normal running of the solar refrigerator the power is supplied directly from solar panel, but when the output power of solar panels is less, the additional power is supplied by the battery. The battery gets recharge when excess amount of power is produced by the solar panels.

4. Vapour Compression Refrigeration Process



4.1 Compression

At this point, the refrigerant is released as a low-pressure gas from the compressor. The coolant is then squeezed adiabatic and the machine is pressed highly.

Fig.4.1 Compressor

Specifications:

- ✓ Rating: 80Watts, 230V
- ✓ Starting current: 4.5A (AC)
- ✓ Running current: 0.6A

4.2 Condensation

High pressure, high-temperature gas releases heat energy and condensation. The condenser is in contact with the heat storage tank of the cooling system. The gas discharges heat to the hot tank, because of external work on the gas. As high pressure vapor, the coolant escapes.

Fig .Condenser

- **4.3 Throttling:**

Through throttling, the fluid refrigerant can be extended. This indicates that while the coolant is still liquid, it has low pressure and low temperature. A throttling valve could be a short distance or a strong tube. As the coolant is forced into the tubing, the stresses are decreased and the water content rises.

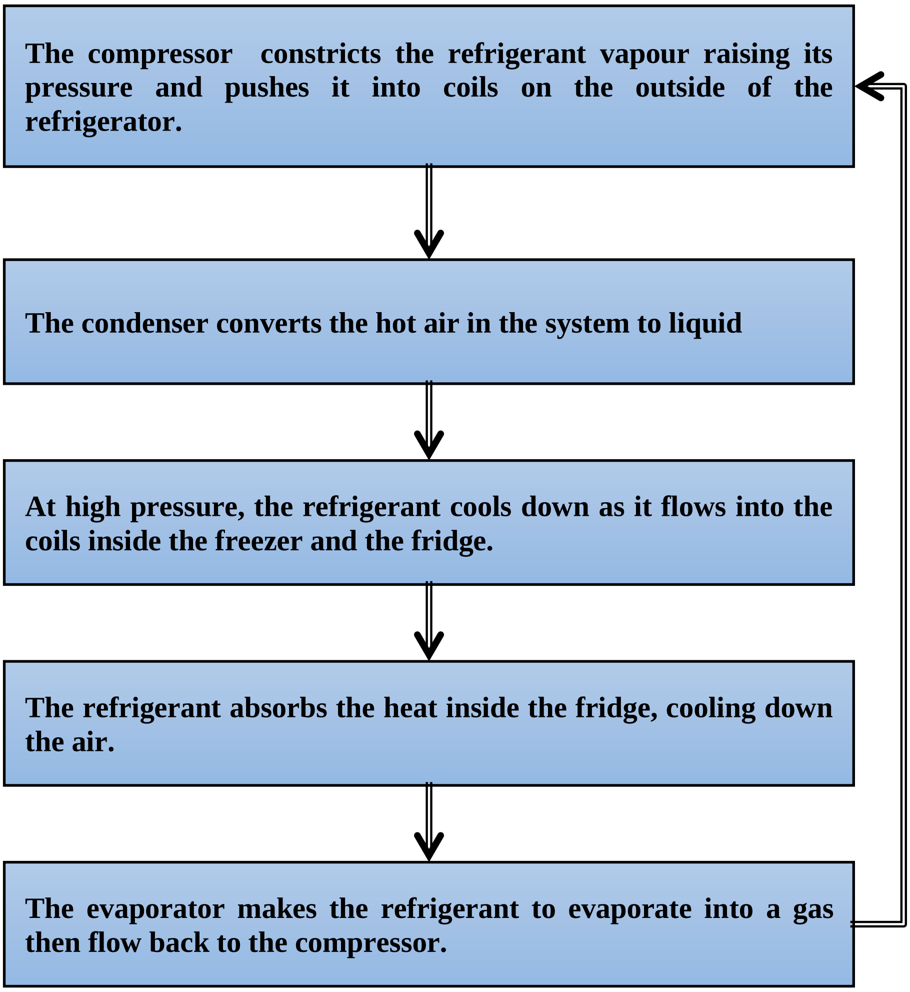
Fig.4.3 Capillary tube

4.4 Evaporation

The evaporator is reached by the low-pressure, low-temperature refrigerant that is in contact with the cool reservoir. Low temperature steaming of the refrigerant maintains excessive pressure. Heat is absorbed by the solvent from the cool reservoir, causing it to evaporate. At the commencement of the process, low temperature, low pressure gaseous refrigerant is supplied to the compressor at the beginning of the evaporator.

Fig.4.4 Cooling Space

The following figure is a flow chart for the vapour cooling cycle:



The main energy source in a vapour compression cooling system is the electricity needed to run the compressor and the solar system supplies it.

Generally, the components are used in the refrigeration unit area:

- ✓ Compressor
- ✓ Condenser
- ✓ Expansion Valve
- ✓ Evaporator
- ✓ Cooling Chamber
- ✓ Fan for the cooling the compressor

5. Coefficient of Performance(COP)

The coefficient of performance of a heat pump (a heating system) is the ratio of energy transferred from the hot reservoir to the work input. As a result, it is referred to as a heating coefficient of performance. In contrast, the coefficient of performance for a refrigerator(cooling system) is the ratio of energy removed from the cold reservoir to work input. As a result, it is known as a cooling coefficient of performance.

The Coefficient of Performance is calculated as follows,

$$COP = \frac{\text{Output}}{\text{Input}} \quad (1)$$

$$COP = \frac{QC}{W} \quad (2)$$

COP of Refrigerator is,

$$COP = \frac{QC}{QH-QC} = \frac{T1}{T2-T1} \quad (3)$$

We calculated the COP of AC supply and solar power,

Given the following data of Ac supply:

The temperature of evaporator(T1) = -13.8

The temperature of condenser(T2) = 28.5

Using equation of 2, the COP was computed to be: COP = 1.41

COP with solar power,

The temperature of evaporator(T1) = -11.5

The temperature of condenser(T2) = 32.7

Using equation of 2, the COP was computed to be: COP = 1.65

6. Results & Discussions

In this section we are about to address the results obtained from the study made on Refrigerator with both the sources ie AC supply and Solar Panel. The overall performance of the refrigerator depends upon the cooling effect of the refrigerant. The experimental methods includes two cases namely 1. Cooling Temperature with AC Power Supply and 2. Cooling Temperature with power supply from Solar Panel. The Coefficient of Performance is also evaluated using the formulae for both the cases.
The study investigated the performance of a refrigerator operating under conventional AC power and solar power sources, focusing on the Coefficient of Performance (COP) as a key metric.

6.1 Performance of Refrigerator with AC Power Supply

The performance of the Refrigerator is evaluated with conventional AC power source, the evaporator (T1) temperature was measured at -13.8°C, while the condenser (T2) temperature stood at 28.5°C. By Applying formula, the COP was determined to be 1.41, reflecting the efficiency of the refrigerator system under standard operating conditions. The above data is computed using the experimental data obtained by taking readings over the course of 90 minutes with 10 minutes interval.

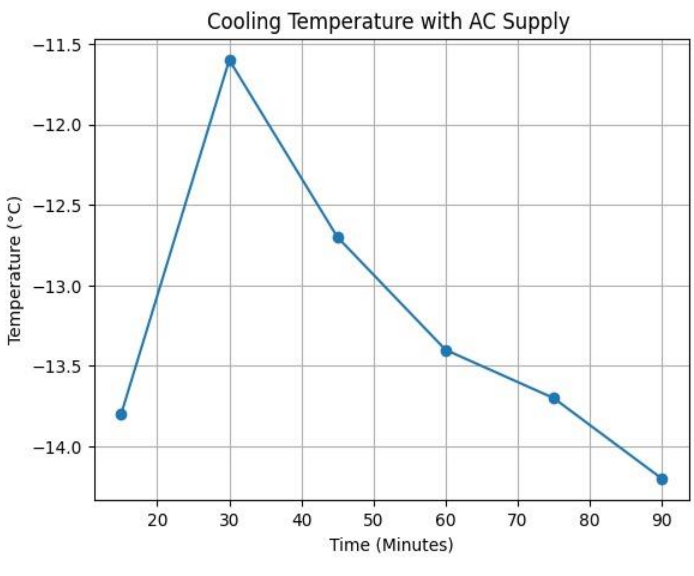


Fig.6.1 Cooling Temperature vs Time

6.2 Performance of Refrigerator with Solar Power Supply via PV panel

In contrast, when the refrigerator operated with solar power, the temperatures at the evaporator (T1) and condenser (T2) were -11.5°C and 32.7°C, respectively. Remarkably, the COP increased to 1.65, indicating enhanced performance and efficiency compared to the conventional AC power supply.

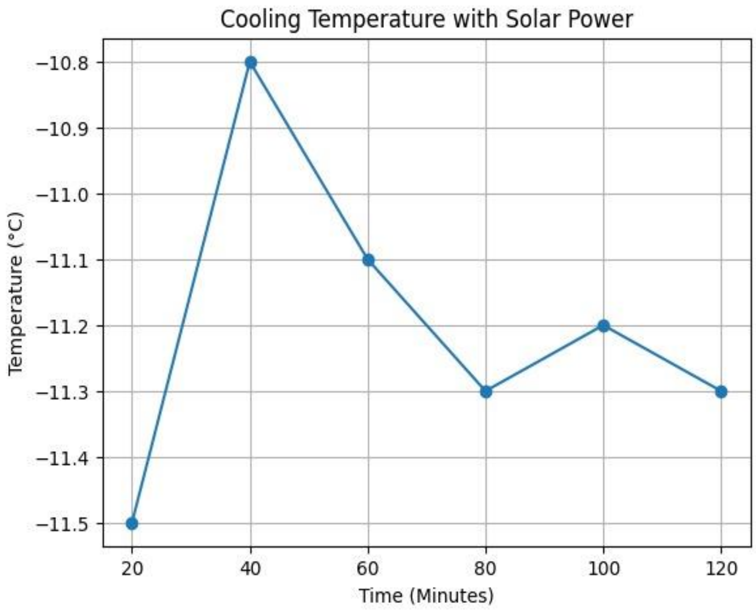


Fig. Cooling Temperature vs Time

The higher COP observed with solar power can be attributed to various factors. Firstly, the utilization of solar energy as a renewable resource offers a sustainable and environmentally friendly alternative to conventional power sources. Additionally, advancements in solar technology and system design may contribute to improved efficiency and performance.

The findings underscore the potential benefits of integrating solar power into refrigeration systems. By harnessing solar energy, refrigerators can operate more efficiently while reducing reliance on non-renewable energy sources, thereby mitigating environmental impact.

Furthermore, the results highlight the importance of continued research and development efforts aimed at optimizing solar-powered refrigeration systems. This includes exploring innovative technologies, improving system components, and refining operational strategies to maximize energy efficiency and overall performance.

Conclusion

The design and fabrication of a solar-powered refrigerator present a promising solution for sustainable cooling in off-grid areas or during power outages. By harnessing solar energy, this refrigerator offers an eco-friendly and reliable cooling alternative. Through meticulous design considerations and efficient fabrication techniques, the system ensures optimal performance while minimizing environmental impact. Overall, this innovative approach holds great potential for addressing energy challenges and promoting sustainable development globally.

References

[1] Sanford A. Klein, Ph.D., Fellow ASHRAE, and Douglas T. Reindl, Ph.D.,Solar Refrigeration, 2005, American Society of Heating, Refrigerating and Air_x0002_Conditioning Engineers, Inc. ASHRAE Journal, (Vol. 47, No. 9, September 2005).

[2] Selvaraju, A. and A. Mani ,2004, Analysis of an ejector with environmentfriendly refrigerants, App. Thermal Engineering, 24, 827 – 838.

[3] Todd Otanicar, Robert A. Taylor, Patrick E. Phelan,"Prospects for solar cooling – An economicand environmental assessment"-Solar Energy 86 (2012) 1287–1299.

[4] Kim, D.S., & Infante Ferreira, C.A. (2008). Solar refrigeration options – a state-of-the-art review, international journal of refrigeration (31) 3–15.

[5] R.Z Wang, R.G Oliveria, Adsorption refrigeration- An efficient way to make good use waste heat and solar energy,2006, ScienceDriect, Institute of refrigeration and cryogenics.

[6] Cimsit C, Ozturk I. Analysis of compression–absorption cascade refrigeration cycles. Appl Therm Eng 2012;40:311–7.

[7] N. Saravanan, R. Rathnaswamy and V. Ananchasivan, Design and Analysis of Cooling Cabinet for Vaccine Storage, Advanced Materials Research Vols. 984-985 (2014) pp 1180-1183, 2014.

[8] A. H. Uppal, B. Norton and S. B. Probert, A Low-Cost Solar-Energy Stimulated Absorption Refrigerator for Vaccine Storage, Applied Energy 25, 167-174, 1986.

[9] American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., 2010 ASHRAE Handbook Refrigeration, 2010.

[10] Bellos, E., Theodosiou, I.C., Vellios, L. and Tzivanidis, C., 2018. Investigation of a novel solardriven refrigeration system with ejector. Thermal Science and Engineering Progress, 8, pp.284-295.
[11] Jain, V., Kachhwaha, S.S. and Sachdeva, G., 2013. Thermodynamic performance analysis of a vapor compression–absorption cascaded refrigeration system. Energy conversion and management, 75, pp.685-700.
[12] R. Nikbakhti, X. Wang, A. K. Hussein, and A. Iranmanesh, "Absorption cooling systems - Review of various techniques for energy performance enhancement," Alexandria Engineering Journal, vol. 59, no. 2, pp. 707–738, 2020.
[13] D. A. Selvaraj and K. Victor, "Vapour absorption refrigeration system for rural cold storage: a comparative study," Environmental Science and Pollution Research, vol. 27, 2020.
[14] K.Kamaleswaran, M. Adammydeen, P. Harinath, M. Venkateshwaran, and V. Kirubakaran, "Reliable power and quality drinking water for rural household through integrative approach of solar PV system," International Journal of Energy Technology and Policy, vol. 12, no. 4, pp. 400–408, 2016.
[15]] I. Daut, M. Adzrie, M. Irwanto, P. Ibrahim, and M. Fitra, "Solar powered air conditioning system," Energy Procedia, vol. 36, pp. 444–453, 2013.
[16] C. Marimuthu and V. Kirubakaran, "Carbon pay back period for solar and wind energy project installed in India: a critical review," Renewable and Sustainable Energy Reviews, vol. 23, pp. 80–90, 2013.
[17] J. R. Patel, "Solar powered vapour absorption refrigeration (SPVAR) system as a rural microenterprise,"in Environmental Science, 2016.
[18] S. McCarney, J. Robertson, J. Arnaud, K. Lorenson, and J. Lloyd, "Using solar-powered refrigeration for vaccine storage where other sources of reliable electricity are inadequate or costly," Vaccine, vol. 31, no. 51, pp. 6050–6057, 2013.
[19] C. Aarthy Vigneshwari, S. S. S. Velan, M. Venkateshwaran, M. A. Mydeen, and V. Kirubakaran, "Performance and economic study of on-grid and off-grid solar photovoltaic system," in 2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS), pp. 239–244, Nagercoil, India, April 2016.
[20] C. Sreenath, S. S. S. Velan, C. Shankar, V. Rajakumaran, and V. Kirubakaran, "Experimental study on optimum area utilisation for maximum power output in solar photovoltaic system," International Journal of Energy Technology and Policy, vol. 11, no. 3, pp. 209–219, 2015.
[21] https://en.wikipedia.org/wiki/Solar-powered_refrigerator

[22] Seouk Park, I.L, 2009, Enhancement of entraining performance on thermal vapor compressor for multi-effect desalination plants by swirl effects of motive steam, Numerical Heat Transfer, Part A , 56 : 406-421.
[23] Bansal, N.K., Blumenberg, J., Kavasch, H.J., & Roettinger, T. (1997). Performance testing and evaluation of solid absorption solar cooling unit, Solar Energy, 61, 2, 127-140.
[24] K.R. Ullah , R.Saidur , H.W.Ping , R.K.Akikur and N.H.Shuvo, „„„A review of solar thermal refrigeration and cooling methods"", Renewable and Sustainable Energy Reviews 24 (2013) 499–513 @ Elsevier journals, March 2013.
[25] Shan, K.W. (2000). Handbook of air conditioning and refrigeration, McGrawHill.