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Design Analysis for Cold Storage Using Concentrated Solar Power

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ABSTRACT

There has been huge increase in usage of renewable energy throughout the world in past few years and solar energy is one of those. The main contribution to this increase has been due to cost reduction of solar PV systems which can convert solar energyinto electric energy. But solar energy can be utilized in other ways too. Instead of converting solar energy into electrical energy we can use heat of sun in different ways. One of the applications can be to use this energy for the purpose of cooling/cold storage using VARsystem.

Cold storages are an important part of value chain of agriculture. Agricultural commodities are perishable therefore decentralized cold storage system can help in long term storage of these commodities which could help farmers in increasing their income. Also long term storage would help in decreasing the food wastage and controlling the food inflation in India. These things will also help India in maintaining the food security and increasing the exports of agriculture commodities.

Therefore, this paper contains analysis for the possibility of using solar energy for the purpose of cold storage in rural areas where electricity has not reached yet or there is insufficient supply of electricity. For this purpose, we have studied solar cooling system (AC system) of 100 KW capacity present in technical block of National Institute of Solar Energy. Then accordingly we have analyzed the possibility of designing a cold storage whichcan be used in rural areas for storage of agricultural commodities.

Keywords— *Cold Storage, Vapor absorption Refrigeration(VAR) System, Concentrated Solar Power(CSP)*

I. INTRODUCTION

Renewable energy is continuously growing in the world and a lot factors have contributed this growth. One of the biggest factors is the cost for utilizing the renewable energy is continuously decreasing therefore both developed countries and developing countriescan effectively utilize the potential of renewable energy.

In India, Government of India is continuouslypressing on the need of increasing the percentage of renewable energy in the total energy production. One of the major ambitions of Indian Government is to increase the renewable energy potential to 175GW till2022.

Hence, various schemes related to increasing the potential of India in effectively utilizing the renewable energy are being launched. This includes Nation solar mission, solar parks, Nation biofuels mission, etc. If we see the data for 2019, the percentage of renewable energy for power generation has reached 23% which accounts for above 85000GW.

Among renewable energy, solar and wind energy accounts for major of its portion. This is because India has immense solar energy insolation from sun. This is mainly due to geographical position of India which lies in the tropical area of world.

In India, maximum energy is produced with the help of wind energy. This mainly includes areas of Gujrat, Karnataka, Kerala, Madhya Pradesh, Andhra Pradesh, Maharashtra, Telangana, Tamil Nadu and few other states. Then the second highest contribution is from solar energy. This solar energy has been mainly utilized with the help of solar panels which is a very effective technology to convert solar energy to electric energy. But the drawback is that it is not efficient and in future it can create immense problem of electronic waste. Therefore, there is need to develop technologies which can be efficiently used in different applications.

II. NEED FOR SOLAR BASED COLDSTORAGES

India has advantageous geographical position in terms of solar potential. It lies between tropic of cancer and equator which gets immense solar insolation. The need of the hour is to harness that solar energy to better utilise in various applications by different efficient technologies. The good thing is that India is trying to harness that solar potential by various forms. In past few years it has taken a big jump in increasing the solar photovoltaic to harness its potential. India has started with various programs to increase the useof solar energy it both urban and rural India. Most of those programs are driven with help of solar panels. This is because solar panels have been most successful in effectively using solar energy to convert it into electricity and then they can be used anywhere.

Therefore, most of solar based cooling system are driven with the help of solar panels and work using VCR cycle. Also the other methods to harness solar potential have not been developed effectively. But the there are various problems with solar panels too.

Firstly, the efficiency of solar panels in harnessing the solar energy has been very low and various institutes are doing the research to increase its efficiency.

Secondly, it can produce huge problem to electronic waste in the future because India still does not have effective policy in tackling the e- waste. Most of the e- waste are handled by informal sector which can be hazardous for both environment and labors handling the e- waste.

Therefore, there is need to develop solar based cooling system which can be used in rural and remote areas which can efficiently harness the solar potential to use it in for application in the cold storage. This can be done by using vapour absorption cycle which does not need solar panels and it can directly use the heat of sunlight to develop solar based cooling system.

III. ENVIRONMENT FORSTORAGE

S.NO.	Fruits/Vegetables	Temperature range (°C)
1	Apples	-1 - -4
2	Bean/Carrots/Cauliflowe r	0
3	Litchi/Orange	4-7
4	Onions	0-2
5	Strawberries	0
6	Sprouts	0-2
7	Potatoes	4-10

Table 1 –(Storage environment for different fruits)

The main application of cold storage is to provide an environment that would help in long term storage of agricultural products while maintaining the quality. This includes controlled level of temperature, humidity and air circulation within the cold storage. Also the agricultural products would keep releasing the heat. Therefore, the temperature has to be continuously monitored and controlled. Hence temperature control becomes the most important factor for controlling the environment inside thecold storage.

IV. COLD STORAGE ININDIA

Cold storages are an important part for agriculture in India. It is used for the storage of different food crops in refrigerated condition. By 2014, 727 lakh metrictons of storage capacity of food grains were already present. According to Press Information Bureau of Government of India 1303 cold storages were established between 2015-16 and 2019-20 with total capacity of 45 lakh metric tons. Despite this India has huge deficiency of cold storages and the existing facility is available to very few farmers.

Before green revolution, India was dependent on imports for agricultural products because Indian agriculture was primitive and there was absence of usage of technology in agriculture. But India became self- sufficient in agriculture after green revolution. This was a major success in achieving food security. But despite achieving food security, India has maximum number of malnourished children. According to Global hunger index 2019 India was ranked 102 among 117 countries. Every year tons of food grain gets destroyed due to lack of cold storage facility. Proper cold storage facility along with effective and efficient public distribution system could have avoided malnourishment and wastage of food grains to some extent.

V. COLD STORAGETECHNOLOGY

Cold storage refrigeration can be achieved using two technologies i.e.

1.) Vapor absorption refrigeration (VAR) – This technology has high instalment/initial cost but its operational cost is low and helps in saving the energy. However, it has limitation because coefficient of performance is low and it is difficult to achieve very low temperature through this technology.

2.) Vapor compression refrigeration (VCR) – This is cheaper technology in comparison to VAR. Most of the cold storages use this technology for refrigeration. It uses more energy than VAR system and coefficient of performance is better than VAR system.

This paper will mainly deal with vapor absorption refrigeration system to analyze the design for cold storage.

V. DESIGN ANALYSIS OF SOLARBASEDCOOLING SYSTEM

Cold storage can be made using solar power by two ways. One is using solar photovoltaic panel and other is using solar thermal collector. The diagram (Fig- 1) shows the detailed flowchart of two technologies.

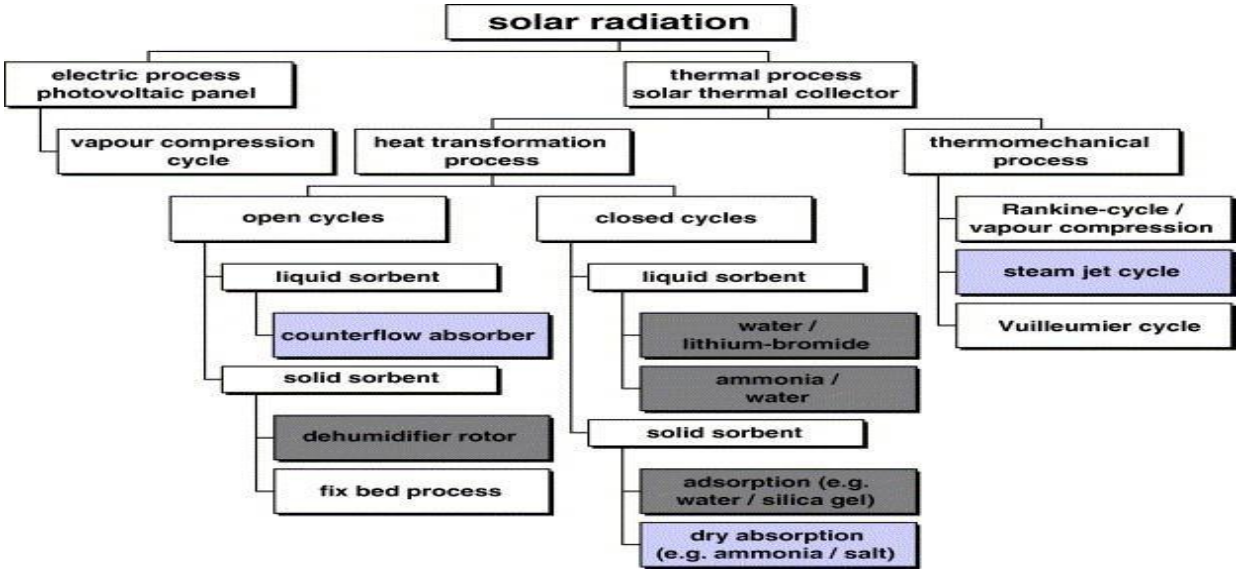

FIG – 1 (FLOWCHART OF DIFFERENT ROUTES OF SOLAR COOLING)

We have analyzed different technologies in National Institute of Solar Energy that are being used for different purposes. But we will be dealing specifically with design of triple effect solar cooling system (for the purpose of air conditioning) used at National Institute of Solar Energy. Then we will try to understand the design modifications required in the cooling system to use it for the purpose of refrigeration or cold storage.

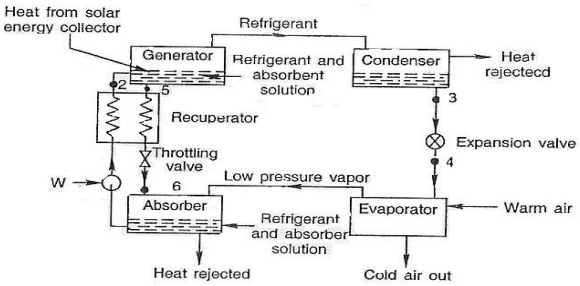

Fig- 2 Diagram of VAR cycle

A. DESIGN ANALYSIS

Cold storage using concentrated solar power should use vapour absorption refrigeration system for cooling purpose.

The basic design should consist of a solar thermal collector to collect the heat energy from sun, generator, absorber, pump, refrigerant, absorbent, evaporator and condenser.

But for cold storage system we need a more efficient system to maintain a low temperature inside the cold storage. For this purpose, different types of absorptionsystems are available. This includes single effect absorption system, double effect absorption system, double effect absorption system and triple effect absorption system. Every system needs different input temperature and each has different efficiencies.

B. Solar Thermal Collector

Different types of solar thermal collector are available. Each collector has different characteristics.

Solar thermal collectors are of two types:

B.1 Non- concentrating (Flat plate collector)- These have generally flat surfaces to collect the solar energy. Hence it does not concentrate the solar energy at one point. Typically, it consists of three parts i.e. transparent sheet, absorber and pipe. A flat plate collector has very lowefficiency. Therefore, it can cannot increase the temperature inside the generator of VAR cycle to desired level. Hence, it would be impractical to use it for the purpose of cooling. But it can be used for other purposes like water purification and desalinization.

B.2 Concentrating Solar Power (CSP) / Concentrating Thermal Collectors

Different types of concentrating solar thermal collector are available to get the required temperature for generator of VAR cycle and each system has different thermal efficiency. Also every one works on same principle that is the light gets reflected with help of reflector and then an absorber is present in absorb the light to increase the temperature of the fluid. The innovative idea of concentrated solar power is that it captures and concentrates the incident sun rays to provide the heat required to heat the flowing fluids and so that the flowing fluid may be use for different purposes. Another aspect of CSP plants isthat this can be equipped with a heat storage system in order to generate electricity even when the sky is fully covered with clouds or after sunset. This significantly increases the CSP capacity factor as compared to solar PV system and, mostly it helps in the production of dispatch able electricity, which can be beneficial for both grid integration and economic competitiveness.

Therefore, CSP technology benefit from advancement in solar concentrator and thermal storagetechnologies, while other components of the CSP plants are based on rather mature technologies and may not to be expect to see rapid costreductions.

CSP plants can be divided into two group, the firstone is the solar collectors concentrate the sun rays along a focal line and the second one is a single focal point (very high concentration factors). In line-focusing systems, it includes parabolic trough and linear Fresnel based plants and it have single-axis tracking systems. In point-focusing systems, it includes solar dish systems and solar tower based plants and it has two-axis tracking systems to concentrate the energy of the sun. CSP plants needed adequate direct solar radiation in order to heating the working fluid. As we know that only strong direct sunlight can be concentrated to the temperatures required for heating flowing fluids. This limits CSP to hot, dryregions.

Economically at present, requires a CSP plant with direct normal irradiance levels (DNI) of 2 000 kWh/m2/year or even more There are many parameters that are responsible for optimum plant designing but thermal energy storage plays main role in designing. It increases costs, but allows higher capacity factors, dispatchable power generation when the sky is cloudy. So due to investment in thermal energy storage, cost also increases.

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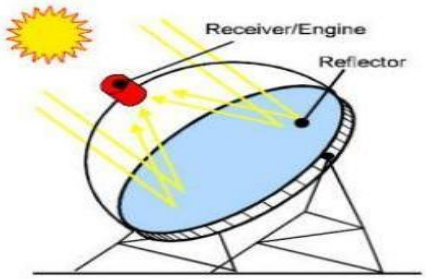


B.2.I. Parabolic dishsystem

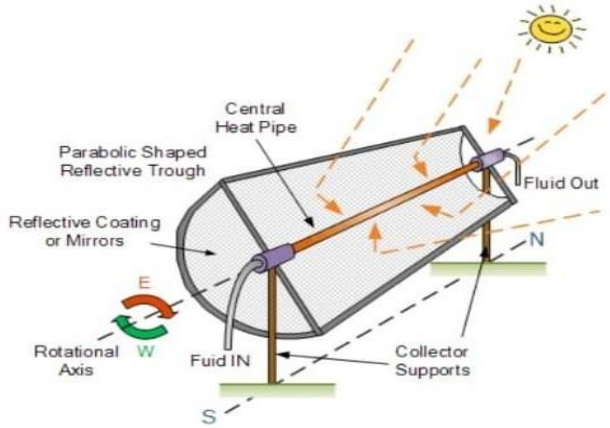
Figure- 3 (Parabolic dish system)

Parabolic disk collector is among the latest innovations in the field of solar thermal collector. The biggest advantages are

1.) It has very high efficiency and losses are negligible. Hence, it can increase the temperature very high in comparison to other solar collectors.

2.) It requires less space/ foot print. Therefore, it can be used at uneven terrains like mountains or region with high slope whereas other systems cannot be used.

3.) It does not require large cooling systems



B.2.II.Parabolic trough collector(PTC)

Figure- 4 (Diagram of Parabolic troughcollector)
Source: Alternative Energy Tutorials

It consists of four different parts namely reflector, collector, absorber, motor.

Reflector can be made up of solar grid aluminium and it is parabolic in shape. Collector is a transparent tube present at the focus point of reflector plate. Absorbers is present inside the collector to absorb the sunlight. It is of black colour to efficiently absorb the sunlight. The heat transfer fluid (Usually water) flows inside the collector to transfer the heat from PTC to vapor absorption machine (VAM). Motor is used to rotate the reflector to efficiently capture the sunlight at different position of the day. This system is generally aligned along North-south direction because the sun moves from east to west. This helps in maximum capture of energy. Main advantage of PTC is that it has high efficiency and it can increase the temperature up to more than 200 degrees Celsius in the VAM.

It is most widely used technology among CSPs. But there is possibility of improvement in performance and cost reduction. It is the fully grown technology and lower chances in development risk. Parabolic

troughs collector and solar tower technology when work together with thermal storage system gives better performance and can meet required demand.

B.2.III.Power tower system

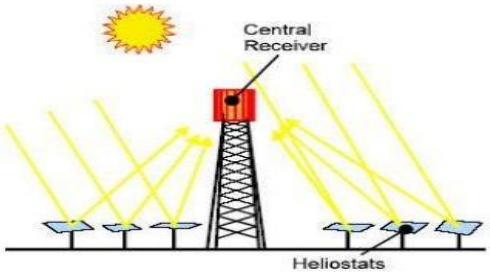


Figure- 5 (Diagram of power tower system)

Power tower system uses a mirror (called heliostats) which track the movement of sun. The sun rays get reflected from mirrors to a receiver present at top of the tower. The tower is present between the mirrors. The main features of this system are

1.) The system is more efficient and can increase the temperature of the fluid up to 600 degrees Celsius. Therefore, it can be also used in turbine generator system to produce electricity using high pressured steam.

2.) It can also help in efficient thermal storage. Because higher temperature generation helps in increased thermal storage within the same cost.

3.) When solar tower system works on higher temperature by using molten salt or other alternative as a heat transfer fluid with thermal energy storage system have great potential for minimizing cost and gives better efficiency.

4.) So, solar towers when works by using molten-salt as a high temperature heat transfer fluid and storage medium may be the best CSP technology in future, this is due to minimum energy storage costs, by high capacity factor, better efficiency of the cycle and their optimum output capability.

B.2.IV.Linear FresnelSystem

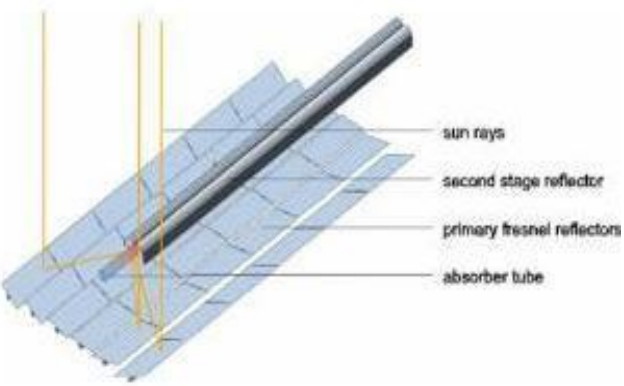


Figure- 6 (Diagram of Linear fresnel System)

This system is very similar to trough collector system. It has large number of collectors which are placed in parallel. The mirrors are placed flat and light reflects towards absorber pipe placed at center of mirrors.

Each line of mirror contains a tracking device. This helps in individual tracking of each line of mirror and maximum amount of solar energy is captured using absorber.

There are many advantages of this system in comparison to PTC.

1.) It uses flat mirrors. Therefore, mass production becomes easier. This helps in cost reduction

2.) The wind pressure/ load on this system is lower. Therefore, it also has better structural stability.

3.) The surface of mirror per receiver is greater in this case.

But there are some disadvantages too.

1.) The optical efficiency is lower.

2.) The cosine losses of the system are greater.

Solar tower and linear Fresnel systems also have potential to minimize their capital costs and improve the unit performance. But due to longer running experiences of parabolic trough collector technology, it is most reliable.

C. REFRIGERANT AND ABSORBENT

Water – Lithium Bromide absorption system has a lot of advantages. It is non-toxic and inflammable. Its COP is also higher than ammonia-water absorption system. it can be easily used for the purpose of air conditioning using solar energy as input. But it cannot be used for refrigeration purpose because temperature below 4 degrees Celsius cannot be achieved. But negative temperature is required for refrigeration purpose.

Ammonia water absorption system can be used for both air conditioning and refrigeration purpose.

Condenser is both air cooled and water cooled. Also this system does not have crystallization problem but water – Li Br system has major problem of crystallization. In the operation of an H2O/LiBr absorption chiller, a crystallization of the solution has to be avoided by internal control of the heat rejection temperature in the machine.

Another advantage of ammonia water absorption system is that it does not need cooling tower which is required in case of water- lithium bromide system.

But the disadvantage of this system is that since absorbent(water) is volatile, a part of it gets vaporized and goes with the refrigerant vapor, and therefore, a rectifying system is required.

D.VAPOUR ABSORPTION MACHINE (VAM)

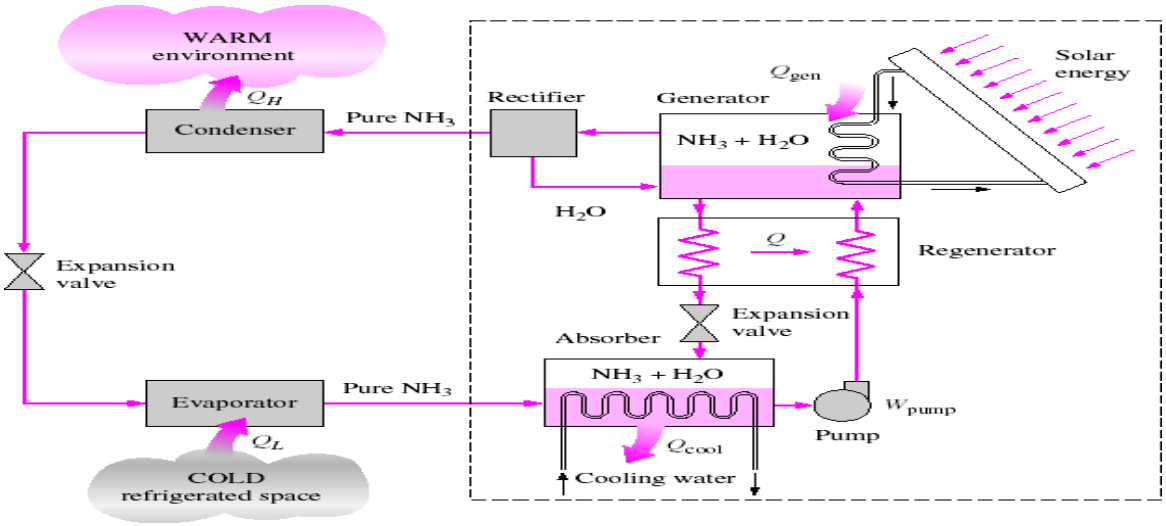


Fig – 7 (Vapor absorption machine using ammonia water absorption system)

It consists of absorber, generator, heat exchanger, pump generator, rectifier, evaporator, condenser, absorbent and refrigerant.

When we use vapor absorption machine using ammonia water absorption system then very low temperature of up to -20 degrees Celsius. Also the input temperature required for this system is between 140- 160 degrees Celsius. Hence it can be easily used for storage of food items. But COP of this system is very low (0.6 - 0.7). If we want to increase the COP of the system, then double effect refrigeration system needed to be used. But double effect refrigeration using ammonia water absorbent system requires very high input temperature which is very difficult to achieve using solar energy alone. Hence, it we need an additional source of heat energy (example: waste heat of an engine) to provide very high input temperature. If we need very high temperature using solar energy alone then there is a need for change in design of solar thermal collector to make it more efficient and effective.

VI. OVERALL DESIGN POSSIBILITY

We analyzed various CSP technologies. Solar tower and Fresnel systems are quite thermal efficient but not commercially prove. Therefore, it would be better to use parabolic trough collector for CSP because it is commercially proven and it can increase the temperature up to 550 degrees Celsius. This temperature is optimal for ammonia water refrigerant system.

For the purpose of cold storage, we should use ammonia water absorption system. But this system also has safety concerns. Therefore, adequate safety measures have to be taken while designing the system. Also, when the system is operational there might beconcerns regarding leakage of refrigerant which can be dangerous for human health.

Vapor absorption machine can be designed according to figure 7 which should also contain rectifier.

Therefore, overall system can be designed accordingly.

VII. CONCLUSION

We have analyzed the design of solar cooling system present at N.I.S.E. Accordingly we have tried to analyze the possibility of designing a cold storage by CSP using VAR system. It was analyzed that we can design cold storage using CSP which would can be easily used at rural areas for storage of agricultural products. The space taken for this system would be large in comparison to conventional systems due to usage of solar field for CSP. Also the space available in rural areas are abundant.

Therefore, this system can be easily installed in rural areas. This system will have high initial cost and 3/4thof total cost would be initial cost. The rest of the cost would be operational and maintenance cost.

This system would use PTC as solar thermal collector, ammonia as refrigerant, water as absorbent and a vapor absorption machine.

But, there was need for further detailed analysis which could involve detailed calculation for design of each part of the system. The detailed calculation could have given more insights into the design of cold storage.

REFERENCES

[1] **S. Arun kumar, R. Raghvendran**, "Designand Fabrication of Solar Powered Lithium Bromide Vapor Absorption Refrigeration System", IOSR Journal of Mechanical and CivilEngineering

[2] **R Sai. Lavanya, Dr B.R. Murthy**, "Design ofSolar Water Cooler Using Aqua-Ammonia AbsorptionRefrigeration System", IJAERS/Vol. II/Jan-March.,2013/20-24

[3] Subhash Kumar, Dr.R.R Arakerimath "Comparative Study on Performance Analysis of Vapour Absorption Refrigeration System Using Various Refrigerants", IPASJ International Journal of Mechanical Engineering (IIJME), Volume 3, Issue 1, January 2015

[4] **Dr. R. S. Bharj, Surender Kumar**, "**Energy Efficient Hybrid Solar System for Cold Storage in Remote Areas**",International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 IJERTV4IS120400 Vol. 4 Issue 12, December-2015

[5] Surender Kumar, Dr.R.S. Bharj, "Design for Solar Hybrid Mobile Multipurpose Cold Storage system", International Journal of Technical Research & Science, ISSN No.: 2454- 2024

[6] Satish K. Maurya, Saurabh Awasthi, Suhail A. Siddiqui, "**A Cooling System for an Automobile Based on Vapour Absorption Refrigeration Cycle Using Waste Heat of an Engine.**", *Int. Journal of Engineering Research and ApplicationsISSN: 2248-9622, Vol. 4, Issue 3(Version 1), March 2014, pp.441-444*

[7] Veena Sinha and Alok Tripathi , "Integrating Renewable Energy to Cold Chain: Prospering Rural India", 2014 2nd International Conference on Sustainable Environment and Agriculture IPCBEE vol. 76

[8] Annual report 2019-20, Ministry of renewable energy.

[9] Annual report 2019-20, Ministry of renewableenergy

[10] Annual report 2018-19, Ministry ofAgriculture

[11] International energy agency, www.iea.org

[12] National Institute of Solar Energy, Gurgaon.