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Performance Evaluation of Hybrid Cold Storage using Solar & Exhaust heat of Biomass Gasifier for Rural Development

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Abstract:- The paper mainly deals with performance evaluation (Energy analysis) of hybrid cold storage using solar & exhaust heat of biomass gasifier. The paper mainly focuses on the solar biomass hybridization for cold storage. During day time, the system will run on solar thermal energy and during night time, biomass gasifier will be used for the same purpose. Since biomass is available abundantly in rural areas and horticulture sector is also mainly concentrated in rural areas, thus biomass gasifier can be an ideal solution for power generation and cold storage.The exhaust of engine can be utilized for same purpose and direct biomass firing is also possible when the system has to be run as standalone system only. The solar Scheffler discs have been used as solar thermal technology and system for cold storage is based on water-ammonia absorption system. This system has also been designed to keep the rural development into consideration and will help in sustainable development of rural areas.

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1. Introduction

India is a predominantly a rural oriented country. Notwithstanding the present growth rates, it would be a long time before the population in the villages exceeds the population in the urban areas. More than 67 % of Indian population resides in rural areas and the dream of developed India is only possible through the development of rural areas. India is second largest country producing variety of fruits and vegetables[1]. Till recently, the fruit and vegetable industry is mostly concentrated in rural areas catering to the requirement of urban areas as well. Cold storage facilities for India's agricultural produce are falling short by more than 10 million tons of storage capacity [2]. Recent regional economic growth and changes in the dietary patterns have made both the production and consumption of fruits and vegetables increasingly important. The fruit and vegetable sector has a vital role in farm income enhancement, poverty alleviation, food security and sustainable agriculture in Asia, especially in developing country like India.

This sector, however, suffers greatly from post-harvest losses. Some estimates suggest that about 30-40 % of fruit and vegetables are lost or abandoned after leaving the farm gate [3]. Huge postharvest losses result in diminished returns for producers. Thus agricultural sector has a direct effect on rural population and the high returns on agricultural produce will greatly affect the economic conditions of farmers, which predominantly live in rural areas.Apart from developing the agricultural sector in all fronts, the post-harvest care is one of the major part of fruit and vegetable preservation. The low quality of agricultural produce in India is due to the non-availability of Cold storage in India. Further, the unavailability of electricity in rural areas adds to the woes of farmers as cold storage has to run for maximum hours on the electricity. Thus there is a need for sustainable development in rural areas and it is only possible through addressing the basic needs of these areas. The problem of power generation can be addressed by switching to renewable rather than by using the conventional electricity which may prove to be costly to these remote rural areas. The presence of large resources in rural areas can make it to sustain on its own. The need of the hour is to identify these resources such that they can be used for rural development. The another important problem apart from electricity availability is the need of cold storage in rural areas as both of them will play a direct role in economic and sustainable development of rural areas. Renewable energy resources one of the best option for continuous operation of cold storage in rural areas of this country.The average intensity of Direct Normal Irradiance (DNI) received in most of the parts of India is 4- 5.5 kWh/m2 /day [4]. Although solar thermal has good potential for operation of cold storage in this country but due to daily & seasonal variations it cannot be utilized continuously as per load requirement[6]. So, hybridization of solar thermal is most important to meet the load requirements for fruit preservation[5]. Solar thermal technology drives the thermal energy in peak sunshine hours [7] and exhaust heat from biomass gasifier drives in short transient during the day and at night time drives full load condition.Biomass can be one of the options for contributingtoward partial and full load energy requirements during low/ non sunshine hoursand supplement with each other seasonally.

One-dimensional methods provide a simple and reasonably accurate way but only limited geometrical information, whereas the two-dimensional are more accurate and they provide greater design detail; however, they are difficult to employ in design

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optimization. Ejector refrigerators working on halocarbon refrigerants provide a high level of flexibility, but with the phasing-out of ozone-damaging refrigerants there is a need for research on alternatives. Ejectors can also be used in solar-powered refrigeration systems and absorption-refrigeration systems [9]. The combined production of power and cooling with an ammonia–water based cycle which is under investigation. Cooling is produced by expanding an ammonia-rich vapour in an expander to sub-ambient temperatures and it is shown that a compromise exists between cooling and work production. A new parameter, termed the effective COP, is used to relate the gain in cooling to the compromise in work production. When the parameter is used to optimize conditions for the rectifier, the effective COP values are good, having values of up to 5[10]. A parametric analysis is conducted to evaluate the effects of thermodynamic parameters on the performance of the combined cycle. It is shown that heat source temperature, environment temperature, refrigeration temperature, turbine inlet pressure, turbine inlet temperature, and basic solution ammonia concentration have significant effects on the net power output, refrigeration output and exergy efficiency of the combined cycle[11]. A conceptual polygeneration system based on solar-biomass hybrid cycle for the combined power, cooling & desalination. The extraction heat from the turbine is utilized for the cold production. Combined first and second law approach is applied and computational analysis is performed to investigate the various effects of the system. The COP of the cooling system is achieved to 0.6[12]. The thermodynamic analysis was performed for ammonia-water, ammonia-lithium nitrate and ammonia-sodium thiocyanate cycles. The performances of these three cycles are compared. It is found that ammonia-lithium nitrate and ammonia-sodium thiocyanate cycles are suitable alternatives to ammonia-water absorption systems. The performance of the ammonia-sodium thiocyanate cycle is slightly better than that of the ammonia-lithium nitrate cycle.R.Ayala, C.L. Heard [8] proposed an ammonia/lithium nitrate absorption refrigeration system with an ammonia mechanical vapour compression system which enhances the efficiency of the overall system. It based on the primary energy ratio this kind of hybrid system can operate more efficiently in developing countries than in developed ones. The maximum COP was obtained using 90% compression and 10% absorption. For this compression proportion, it was not necessary to supply heat to drive the absorption section, since the heat is supplied by the superheated ammonia at the compressor outlet.

2. System Description

The ammonia-water absorption refrigeration system for cold storage consists of four main components- condenser, evaporator, absorber and generator. Other auxiliary components include expansion valves, pump, rectifier and heat exchanger.Low pressure, weak solution is pumped from the absorber to the generator through the HE-3 operating at high pressure. The generator separates the binary solution of water and ammonia by causing the ammonia to vaporize and the rectifier purifies the ammonia vapour at temperature of 80-90^{0}C. The generator heat take from exhaust heat from the gasifier system and scheffler field as shown in Fig.1.

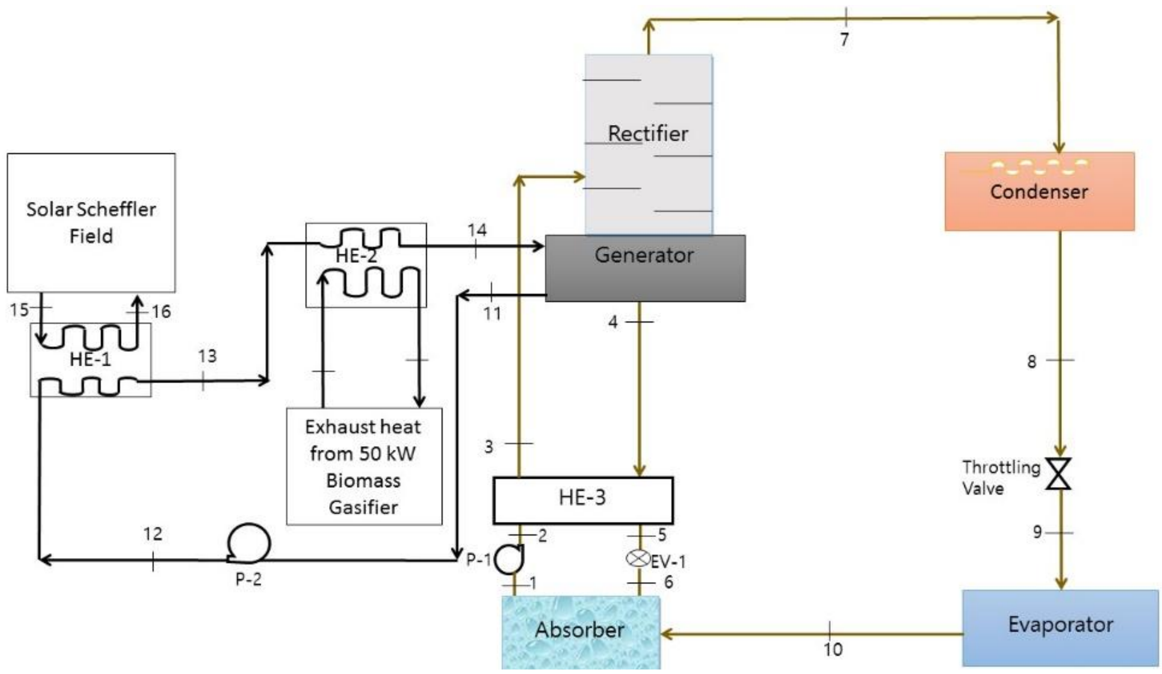

Fig.1 Line diagram of hybrid cold storage using solar & exhaust heat of biomass gasifier

High pressure ammonia gas is passed through the expansion valve to the evaporator as low pressure liquid ammonia. The high-pressure transport fluid(water) from the generator is returned to the absorber through the HE-3 and the expansion valve. The low

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pressure liquid ammonia in the evaporator is used to cool the vegetables and fruits. During the cooling process, the liquid ammonia vaporizes and the transport fluid (water) absorbs the vapour to form a strong ammonia solution in the absorber.

National Institute of Solar Energy (NISE), Government of India has developed and installed a50 kW solar-biomass hybrid cold storage cum power generation system for rural electrification. The system consists of a 50 kWbiomass gasifier including gas cleaning and cooling system, 50 kW 100% producer gas engine, heat recovery unit, 15 kW (NH_3-H_2O)vapor absorption cooling system, 4 scheffler dishes with 16 m^2area for each and cold storage room of capacity of 20 metric tons as shown in Fig. 2. The50 kW biomass gasifier system provides electricity and the waste heat of the engine (exhaust) that is used as the main source of energy for the cold storage. During the day time, when the sunshine is available the scheffler dishes along with engine exhaust provide heat to the system. During evening, when there is no sunlight, the gasifier is run to meet the evening electricity load and the cold storage will operate only on engine exhaust. In case, no sunshine is available and engine exhaust is also not sufficient, provision has been made for firing of producer gas in heat recovery system (HRS) to meet balance heat requirement for running the cold storage.Study is carried out for automation of process in different load condition.Study has been undertaken to optimize the system performance during different radiation and ambient condition.

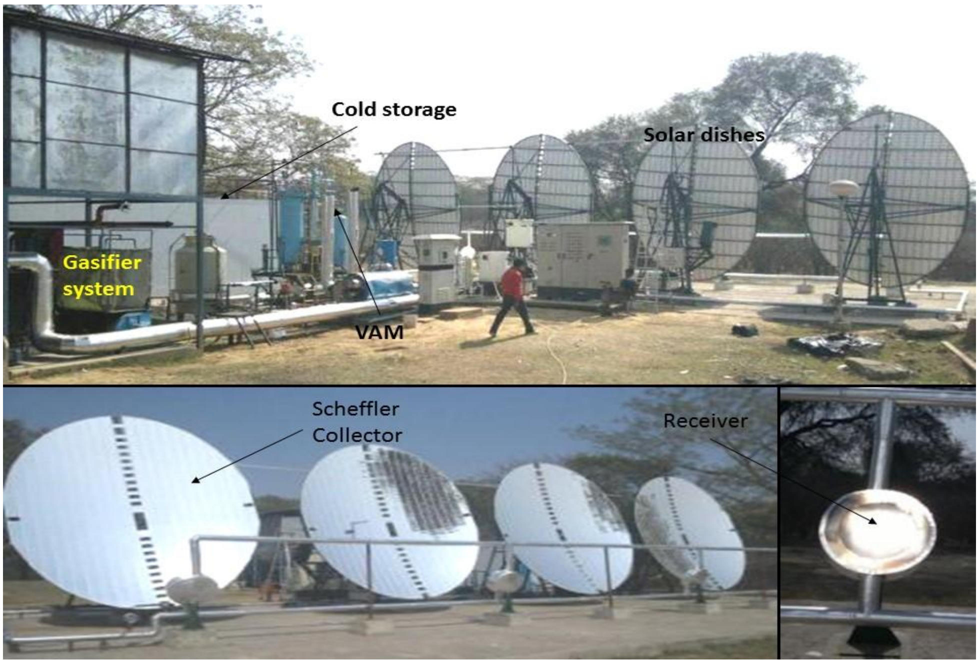

Fig.2 Experimental setup of hybrid cold storage using solar & exhaust heat of biomass gasifier at NISE

Thermodynamic Analysis:

First law of thermodynamics is used to analyze the performance evaluation of hybrid cold storage using solar & exhaust heat of biomass gasifier. The energy equation is mainly defined for the major components of the hybrid cold storage using solar & exhaust heat of biomass gasifier. The energy, analysis has been investigated by several authors **[13-16]**. The following energy balance equation of major components of cooling system are expressed as:

The useful heat gain $\left(Q_1\right)$ is defined as

$$Q_1 = Q_{solar} \times \eta_{E,Scheffeler} \tag{1}$$

Where Q_{solar} is the solar energy falling on Scheffeler field may be expressed as

$$Q_{solar} = A_{ap} \times DNI \tag{2}$$

The energy efficiency $\left(\eta_{E,Scheffeler}\right)$ of the Scheffeler field is expressed as

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$$\eta_{E,Scheffeler} = \left(\eta_{opt} \times COS\theta\right) - a_1 \frac{\left(T_m - T_o\right)}{DNI} - a_2 \left[\frac{\left(T_m - T_o\right)^2}{DNI}\right] \quad (3)$$

Where η_{opt} is optical efficiency of the scheffeler technology, a_1 is the first order coefficient of the collector efficiency $\left(W/m^2\text{-}^0C\right)$, a_2 is the second order coefficient of the collector efficiency $\left(W/m^2\text{-}^0C^2\right)$, T_m is the mean temperature of the fluid is defined as

$$T_m = \frac{T_{15} + T_{16}}{2} \quad (4)$$

The mass flow rate of fluid $\left(m_{fluid}\right)$ is calculated as

$$m_{fluid} = \frac{\eta_{E,Scheffeler} \times A_{ap} \times DNI}{\Delta T \times C_p} \quad (5)$$

Where, C_p is the specific heat of heat transfer fluid, ΔT is the temperature difference of heat transfer fluid across the Scheffeler field is expresses as

$$\Delta T = \left(T_{15} - T_{16}\right) \quad (6)$$

Generator: $Q_g = m_4 \cdot h_4 + m_7 \cdot h_7 - m_3 \cdot h_3$ (7)

Condenser:

$$Q_C = m_7 \cdot h_7 - m_8 \cdot h_8 \quad (8)$$

Evaporator: $Q_e = m_9 \cdot h_9 - m_{10} \cdot h_{10}$ (9)

Pump-1: $W_{p-1} = m_3 \cdot h_3 - m_2 \cdot h_2$ (10)

HE-2: $Q_{HE-3} = m_2 \cdot h_2 + m_4 \cdot h_4 - m_3 \cdot h_3 - m_5 \cdot h_5$ (11)

The coefficient of performance of the ammonia based cooling system is expressed as

$$COP = \frac{Q_e}{\left(Q_g + W_{P-1}\right)} \quad (12)$$

3. Results and discussions

1. The COP of the system (VAM) was found to vary from 0.55 to 0.60. The maximum COP obtained was 0.60.
2. Electricity from biomass gasifier was generated and fed to the smart grid for end use and simultaneously the VAM worked properly on engine exhaust, auxiliary firing and solar thermal (Scheffler disc).
3. The highest Condenser Temperature of the VAM was found to be 26.83 ^{0}C.
4. The highest generator temperature was found to be 85.91 ^{0}C. At this temperature, the highest COP of 0.60 was observed.
5. The temperature of – 4.24 ^{0}C was achieved inside the evaporator of the VAM.
6. The auxiliary firing required to run the VAM was found to be dependent on engine exhaust and power output. If the engine exhaust is less, more wood needs to be burned for auxiliary firing and vice versa. The auxiliary firing was found to be zero at peak output of engine-generator. Auxiliary firing quantity was inversely proportional to exhaust output/electrical load consumption.

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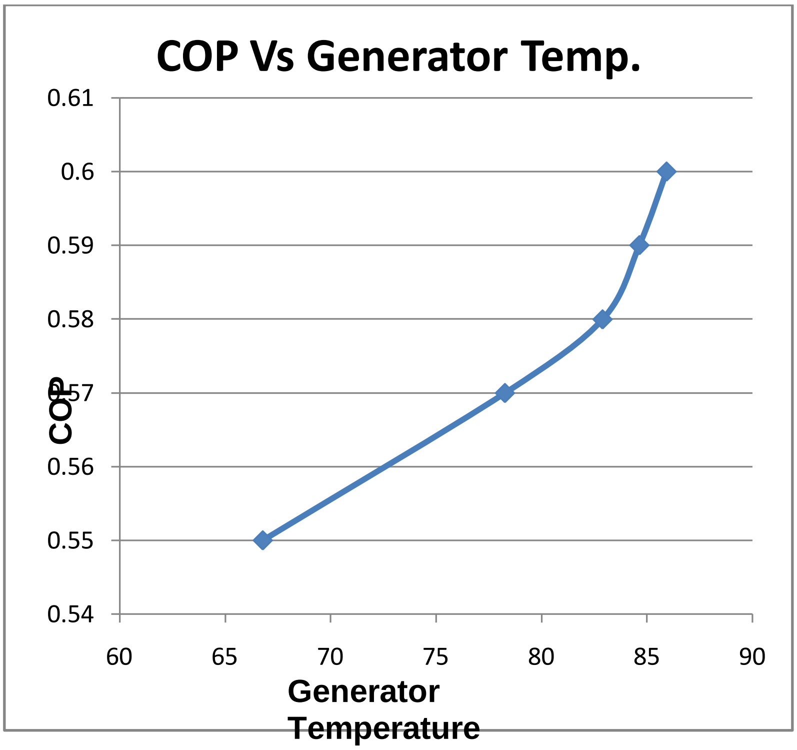
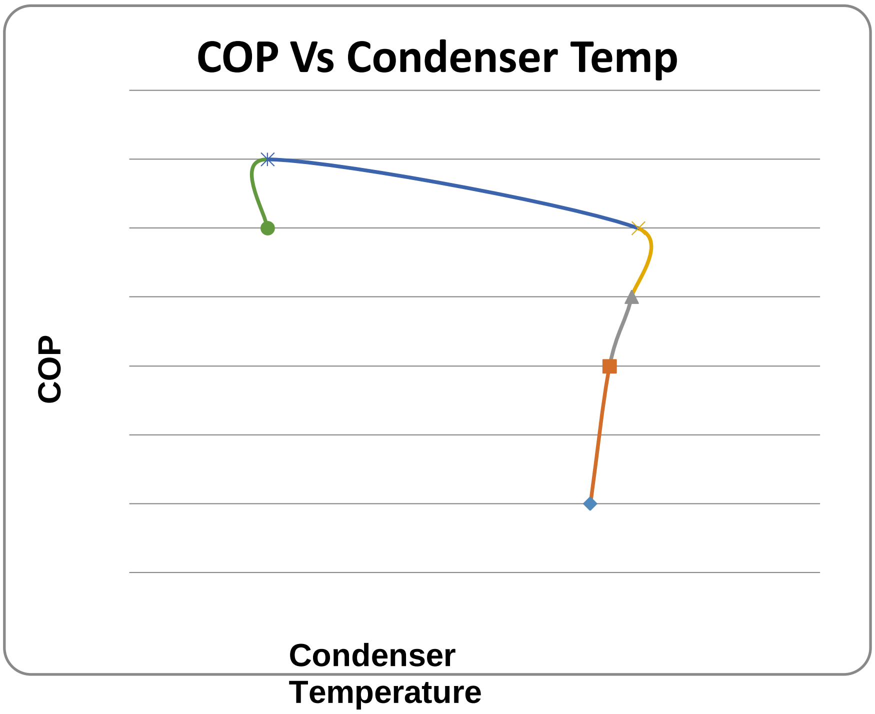
4.1 COP v/s Generator Temperature.



Graph No. 4.1 Generator temperature v/s COP

The effect of generator temperature on COP is shown in the graph. The results showed the COP to increase with the increase in generator temperature. The highest generator temperature obtained was 85.91 ^{0}C at COP 0f 0.60.

4.2 COP v/s Condenser temperature



Graph No. 4.2 Condenser temperature v/s COP

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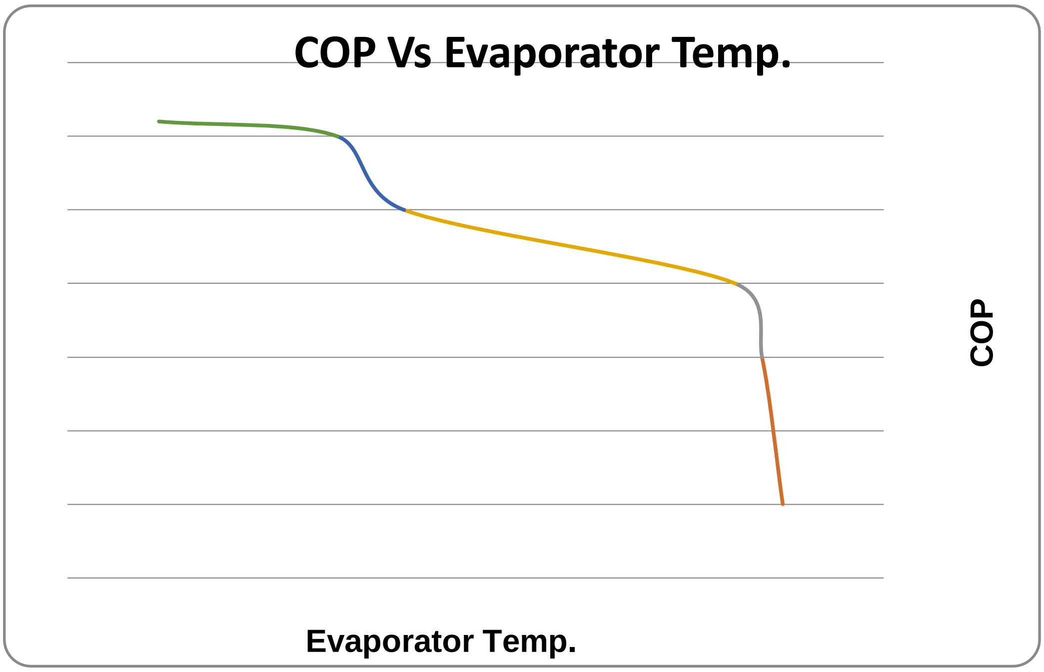
The results of various calculations showed the trend of COP at various operating condenser temperatures. The COP of the system (VAM) increased with the increase in Condenser Temperature. The highest condenser temperature obtained was 26.83 ^{0}C at COP of 0.60

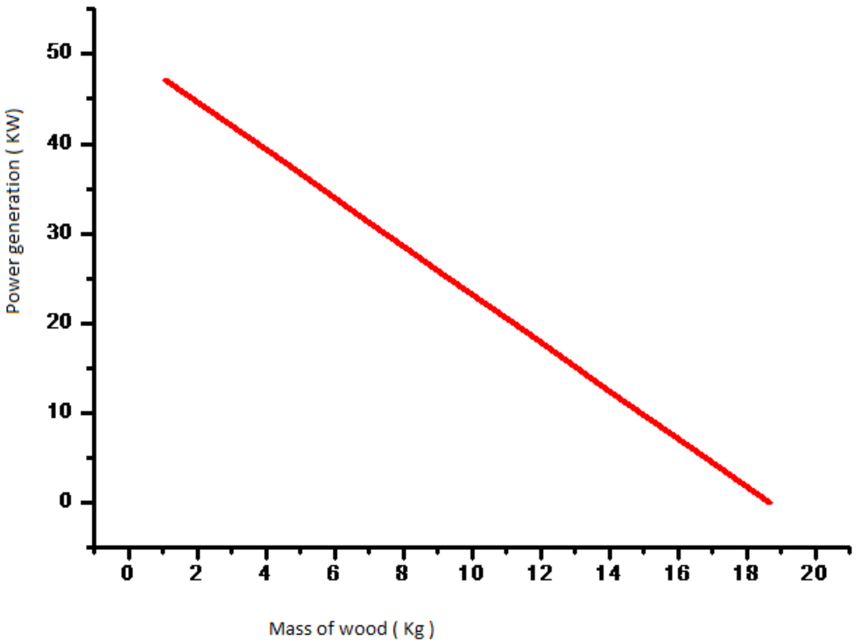
4.3 COP v/s Evaporator Temperature.



Graph No. 4.3 Evaporator temperature v/s COP

The minimum evaporator temperature of - 4.24 ^{0}C was achieved. The result of calculations shows the trend at lower evaporator temperatures greater COP is achieved.

4.4 Mass of Wood for Auxiliary Firing corresponding to Power Generation.



Graph No. 4.4 Mass of Wood used In auxiliary firing v/s Power generation.

Auxiliary firing quantity was inversely proportional to exhaust output/electrical load consumption. The relationship between auxiliary firing required to run the VAM and power generation, corresponding to engine exhaust is given. In case of peak output ,ie. if the energy output of generator is 50 KW, no biomass firing is required as the engine exhaust is sufficient to run the VAM. However, in case our electric output is zero. i.e, generator isn't producing any electricity/output, in that case at least 18.66 kg of biomass is required to run the VAM, as the engine exhaust will be zero. Similarly, if the electric output is 47.093 (i.e. less than desired

output) , nearly 1.085 kg of biomass is required for auxiliary firing. This shows for the running of VAM, auxiliary firing is dependent on engine exhaust, which is in turn dependent on the power generation.

References:

[1] Annual report of National Horticulture Board. agricultural & processed food products export development authority; 2014-15. http://apeda.gov.in/apedawebsite/six_head_product/FFV.htm .
[2] Report of The Energy and RFesearch Institute (TERI),New Delhi, 2012-13. http://www.teriin.org/index.php?option=com_ongoing&task=about_project&pcode=2009RT01
[3] Shyamsingh (2015), ASSESSMENT OF SHELF LIFE AND ORGANOLEPTIC VALUES OF SOME VEGETABLES BY ECOFRIENDLY METHODS TO ENHANCE THE LIVELIHOOD OF MARGINAL FARMER OF GORAKHPUR REGION (U.P.)
[4] Solar Radiation Energy over India. Indian Meteorological Department and Ministry of New and Renewable Energy, Govt. of India, 2008.
[5] Technology Roadmap: Solar Heating and Cooling, IEA, 2013.
[6] U.Sahoo,R.Kumar, P.C.Pant, R.Chaudhury, Scope and sustainability of hybrid solar–biomass power plant with cooling, desalination in polygeneration process in India, Renewable and Sustainable Energy Review 51(2015) 304–316.
[7] V. Raja Boopathi, V.Shanmugam, A review and new approach to minimize the cost of solar assisted absorption cooling system, Renewable and Sustainable Energy Review 16 (2012) 6725-673
[8] R. Ayala, C.L. Heard, F.A. Holland, Ammonia/Lithium nitrate absorption/ compression refrigeration cycle. Part II. Experimental Applied Thermal Engineering 18 (1998) 661-670.
[9] Sun, Da-Wen, I.W. Eames, Recent developments in the design theories and applications of ejectors e a review. Journal of the Institute of Energy 68 (1995)65-79.
[10] C. Martin, D.Y. Goswami, Effectiveness of cooling production with a combined power and cooling thermodynamic cycle. Applied Thermal Engineering 26 (2006) 576-582.
[11] Jiangfeng Wang, Yiping Dai, Lin Gao, Parametric analysis and optimization for a combined power and refrigeration cycle. Applied Energy 85 (2008) 1071-1085.
[12] U.Sahoo, R.Kumar, P.C.Pant, R.Chaudhary. Development of an innovative polygeneration process in hybrid solar-biomass system for combined power, cooling and desalination. Applied Thermal Engineering 120 (2017) 560–567.
[13] Ibrahim, O.M., Klein, S.A. Thermodynamic Properties of Ammonia-Water Mixtures. ASHRAE Trans.: Symposia, 21, 2,1495-1502, 1993.
[14] Lecuona A, Ventas R, Venegas M, Zacarias A, Salgado R. Optmimum hot water temperature for absorption solar cooling. Solar Energy 83, 1806-1814, 2009.
[15] Feng X, Yogi GD (1999). "Thermodynamic properties of ammonia-water mixtures for power-cycle applications" Energy, 24: 525-536.
[16] Mishra RD, Sahoo PK, Gupta A (2006). "Thermoeconomic evaluation and optimization of an aqua-ammonia vapour-absorption refrig. system" Int. J. Refrig., 29: 47 59.