ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

Concentrating Solar Heat for Steam Generation and its Application in Dry Cleaning Industry

J.P. Kesari*, Karan Kohli , Lavish K. Bhaskar,Rishabh Jain

Associate Professor, Department of Mechanical Engineering, Delhi Technological University, Delhi - 110042
B.Tech Student, Department of Mechanical Engineering, Delhi Technological University, Delhi-110042
B.Tech Student, Department of Mechanical Engineering, Delhi Technological University, Delhi-110042
B.Tech Student, Department of Mechanical Engineering, Delhi Technological University, Delhi-110042

ABSTRACT: The Indian laundry industry is expected to grow at a rapid pace due to the increase in the number of independent households and increased reliability of app-based services.The Indian laundry is expected to grow at a rapid pace due to increase in the number of independent households and increased reliability on app-based services. It is expected to grow to $76 billion by the end of 2018. This growth in operations would also lead to increased cost of fuel and labor. For the process of drying of clothes, hot steam is required. Traditionally, this hot steam is generated by burning fuel in a boiler and converting water to steam, by transferring the heat generated to water flowing in pipes. However, this method is polluting, costly and requires higher maintenance. The same can be achieved using a Scheffler dish based heating system, wherein the conversion of water to steam would occur by using solar heat. This system would require large initial investment, but it would be compensated with a short payback period, leading to increased profits due to decreased operating costs. Also, this system would be non-polluting leading to less stress on the environment. This system would work in tandem with the existing boiler-based system so that in the event of unfavorable weather and inoperable conditions, the operation does not stop and the system continues to function. This paper presents two case studies of the implementation of Scheffler based heating system used in Hotel ITC Maurya and by Gajraj Dry Cleaners. These case analyses show that in the implementation of a solar heating system for dry-cleaning, the initial investment costs would be recovered in a short time. Estimation of daily savings of fuel and costs is also done. Finally, the annual saving is estimated on implementation of a hypothetical Scheffler-based heating system. The break-even point is calculated which shows that the recovery period would be small leading to faster recovery of costs and reduced costs. This paper shows that the implementation and faster recovery of costs would lead to a reduction in operating costs and maintenance costs

KEYWORDS: Solar thermal, Scheffler dish, Dry cleaning industry, Paraboloidal dish, India, Concentrated Solar heat**.**

1. INTRODUCTION

A) Dry Cleaning Industry in the World:

The dry cleaning industry in the United States of America has been struggling. With employment of about 1,50,000 and revenue of $9 billion in 2017, this industry is expected to have a drop in revenues to $8.7 billion in 2022. Such drop in revenue would occur due to increased federal regulations, unfavorable customer preferences and increased competition. In the United Kingdom, this industry has a revenue of £1.5 billion and is expected to grow to £2 billion, due to increase in disposable incomes and the rise of door-to-door laundry collection. In Canada, the $2 billion industry is expected to grow at 0.1%. This is because of the increase in usage of casual clothing and the shift in fiber types by manufacturers leading to lesser demand of dry cleaners. In Australia, the $2 billion industry is expected to grow at 3.7% due to increased rental service and outsourcing from hospitals and the hospitality sector.

B) Dry Cleaning Industry in India:

Laundry market in India is expected to grow from $40 billion in 2017 to $76 billion by the end of 2018 [2]. Such high growth is possible due to the proliferation of app-based laundry services. This is, in turn, helped by the increase in

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

incomes across the segments and high optimism across the businesses. Laundry industry is dominated by the unorganized sector, with 3-5 percent being catered by the organized sector.
The unorganized sector, being the majority player, is labor-intensive and relies on age-old techniques of steam generation. However, the organized sector, backed by global players, is using innovative techniques to utilize less energy, reduce the quantity of water and steam for washing and drying of clothes without compromising the quality of the fabric. The unorganized sectors, mostly dominated by dhobi Ghats and few small and medium-scale firms is quite rigid in its operation and would require huge capital and intensives to shift its operations to newer techniques. Whereas, the organized sector, still in its infancy, can accommodate changes in its operational cycle by taking a few risks and innovating. This freedom to innovate has led to rapid increase in investments, backed by foreign market leaders.
With the rise in disposable incomes and increasing work-times, the majority of young Indians are relying on app-based services to do their job. By the end of 2020, it is estimated that more than 3 million households would need laundry services on a weekly basis[2]. This business models provides various benefits to companies wherein they can focus on individual priorities and cater to specific customer needs. However, for this model to be successful, companies need to focus on the combination of front-end and back-end experience of the customer, thereby increasing market share and providing good service.
This industry, employing people mostly in the unorganized sector, has caused lesser accountability and professionalism in the work. The organized sector currently comprises of only 2-3% of the entire laundry market and is highly segmented. However, with the rise of app-based smartphone laundry services, it is expected to change. The professional service model is expected to bring accountability and faster service to the customers.

C) Major Challenges faced by the industry in India:

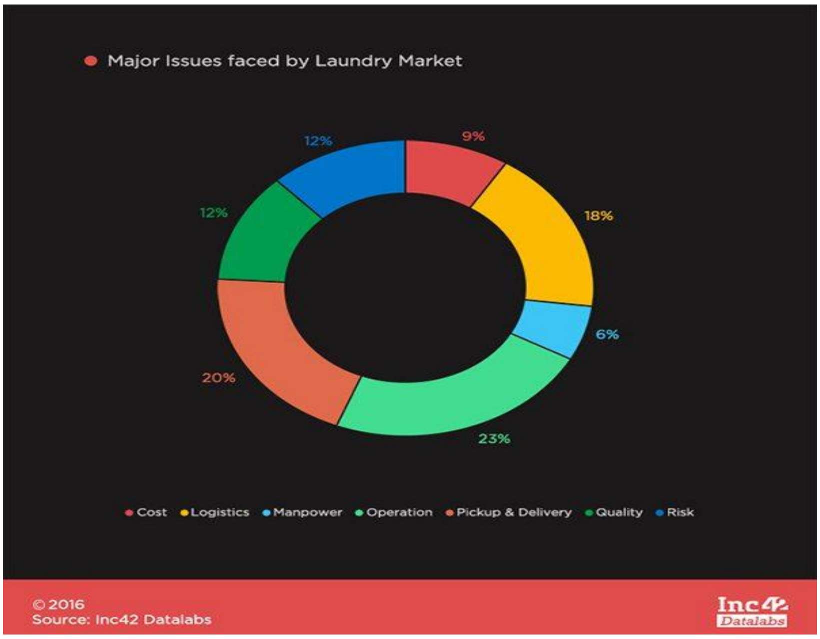


Fig 1: Major issues faced by the Laundry Industry in India (Source: Inc42)

There are many challenges that face these startups. Firstly, the two-way logistics of the industry is highly difficult. Startups, with limited funding, tend to have the most costs on this part of the business due to the early morning pickup of clothes and the late night delivery of the same. Therefore, startups which do not have high funds, are badly hit with less optimized logistics.
The costs involved in the business form the second major issue in the industry. Due to high initial investment and lesser revenues, the costs involved in the business are very high. Also, due to increased competition, the dwindling revenues do not help the businesses. And the lack of skilled manpower does not help as it leads to increased costs to hire the skilled workers.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

Finally, the quantity of orders is less and the risk involved is high. With a spoilt cloth, the amount payable back to the customer would be about 3-4X, thus leading to increased risk. Also, the pickup and delivery system involved is highly costly.

D) Scope of using Concentrated Solar Heat (CSH) in Laundry Industry:

In the cleaning industry, the dry-cleaning of clothes is a huge burden on the finances of the companies. The amount of fuel, be it diesel or coal, used to run the boilers reduces the margins of the dealers by a great deal and increases the prices of the same. Most of the dry-cleaning industry in India still use the basic technique of dry cleaning the fabric i.e. by washing the fabric in a solvent, spinning it to extract the extra solvent, followed by drying it in hot steam. Drying the clothes uses steam, which is generated by heating the water at a very temperature in a boiler and then using it to dry the fabrics.
With the advent of solar energy and the recent push by the Government of India towards a solar future, the process of dry-cleaning of clothes can be done using the same. The sun's rays can be reflected and concentrated using a parabolic reflector. These heat of these concentrated rays can be collected and transferred to water through the absorber. Water from the pipe then passes to the receiver and the steam then generated can be collected in an overhead pipe. It can then flow for the end-use application i.e. drying of clothes. This utilization of solar energy, which is abundantly available, would reduce the operating costs of companies and, in turn, would provide lower costs for the customer.
The cases being studied are the implementation of solar-based heating systems at ITC Maurya Hotel and Gajraj Drycleaners. Both the systems use Scheffler dishes of 16 m^2 area and use the heated water/steam for laundry and dry cleaning purposes. These systems show the effectiveness of Scheffler based heating systems as compared to traditional boiler based systems as they reduce costs to a large extent, have a longer life, lesser maintenance costs, and reduce pollution. The solar-based heating system would have a low payback period leading to a faster recovery of initial investment and increased profits and lower costs. Also, this system would be beneficial to the environment and would reduce the dependency on non-renewable fuels leading to their preservation.

II. LITERATURE REVIEW

Jesko describes the different types of solar concentrators and further classifies them. This is done based on the newest research so as to classify each and every type of solar collector.
Naik et al. describe the use of scheffler dish in medium temperature applications. They describe the design and development of various concentrating solar thermal technologies long with its application in the Indian market. It reviews the need for such technologies, potential markets, and barriers and recommendation for deployment of available solar thermal technologies used for generation of medium temperature 80-250 ^{O}C.
Anita et al. analyzed the performance of scheffler reflectors using different thermal optimization techniques. Thermal efficiency of scheffler concentrator is analyzed in 3 phases. Firstly, by pre-heating inlet water at 50 ^{O}C. Secondly, by painting the receiver black using acrylic matt finishing paint, giving maximum heat absorptivity. Lastly, by covering the receiver with toughened glass to minimize convection loss.
Mercer describes the design of solar cooker using scheffler dish. The system was experimentally analyzed its behavior was predicted when subjected to solar conditions in Rajasthan, India. The calculation was done for monthly intervals nd the results were then used to generate third order polynomials to that describe the energy into the storage unit during the collection period, from 7 AM to 4 PM in Iowa and 8 AM to 5 PM in Rajasthan. These polynomials allow for subsequent calculations involving the behavior of the system throughout the collection period.
Desale et al. carried out an experimental study of scheffler reflector water heater, in which they measured the water temperature and then designed a reflector for 5-liter water capacity. The reflector had an arear of 2.7m^2 and the experiment measured values of radiation on dish, ambient temperature, water temperature, wind speed, altitude angle at an interval of 5 minutes. In this way, the time for max heat gain which was between 12 AM to 2 PM was found and a model was developed using it. Through dimensional analysis, and then using Buckingham's π Theorem. The generated equations showed that the water temperature is primarily affected by the ratio of product of angle and dish area to the wind speed.
Swati et al. analyzed the thermal performance of scheffler reflector at Gajraj Drycleaners. Parameters like water temperature, solar radiation, and wind speed were measured from 10 AM to 2 PM at an interval of 5 minutes. It was found that low efficiency of reflectors was due to optical and thermal losses and can be increased by increasing the receptivity of reflectors, by proper design of the parabola and with silver coating the mirror glass.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

Akhade et al. analysed the performance of 2.7 m^2 scheffler reflector by keeping 10-liter water at a fixed focus. The experiment was conducted from 10 AM to 2 PM for different days and readings of ambient temperature, radiation, water temperature, wind speed was taken at an interval of 10 minutes. It was concluded that to use scheffler reflectors for household cooking, the intensity of solar radiation falling on it must be maximum.
Vanita et al. describes the performance analysis methodology of parabolic dish solar collector system used for heating thermic fluid for process heating application. The design parameter like rim angle and arc length are derived from basic equations and properties of thermic fluid is also known. By using the various heat transfer equations, their efficiencies are calculated at regular intervals of one hour. Various losses are also considered while calculating the efficiencies. It shows that by using an insulated receiver with glass cover, convective heat transfer losses can be decreased and overall efficiency can be increased.
Dafle et al. describes the design, fabrication and performance evaluation for 2 bar pressure and 110 ^{O}C temperature cooking application using a 16 m^2 scheffler reflector. The efficiencies are calculated by considering various design parameters and losses. The average efficiency for a week is found to be 57.41%.

III. LAUNDRY PROCESS FLOW CHART

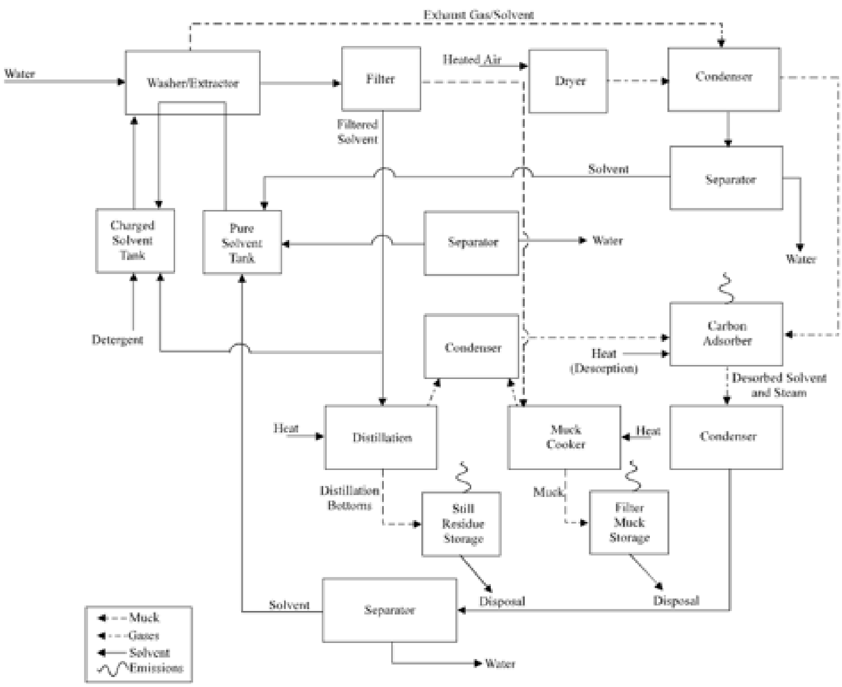


Fig 2: Laundry Process flow chart

Dry cleaning of fabrics involves three steps – washing the fabric in solvent, spinning the fabric to extract the extra solvent and drying by hot steam. Generally, two tanks are used for washing. In one tank, pure solvent is present while in the other charged solvent solvent is present which contains small amounts of detergents. Clothes are cleaned in charged solvent and rinsed in pure solvent.
After washing of the clothes is complete, used solvent is filtered and one part of the filtered solvent is sent to charged solvent tank to wash the load. The other part of the solvent is distilled to remove oils, fats, and other components and is then returned to pure solvent tank. The collected dirt(solids) is removed once a day. Sometimes, the solids maybe cooked to recover additional solvent. Still and cooked vapors are vented to the condenser and separator to reclaim more solvent. Recovered solvent is sent to the pure solvent storage tank.
When washing is complete, the clothes are transferred to the dryer. In the dryer, the clothes are tumbled using hot air stream. The condenser off gases are vented to a carbon adsorption unit wherein, additional solvent recovery takes place.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

Recovery of this solvent is achieved by desorbing with steam, at the end of each day. The desorbed solvent and water are condensed and separated and solvent is sent to the pure solvent storage tank.
A plant using petroleum or fluorocarbons would differ in certain aspects. In a petroleum plant, recovery of solvent would not be possible in the washer and dryer. Whereas in a fluorocarbon unit, carbon adsorption unit would not be present. Instead, an unvented refrigeration unit would be used.

IV. SCHEFFLER DISH

Scheffler dish is a lateral section of a paraboloid which concentrates the sun's rays over a fixed focus. Scheffler dish is made up of a number of flat shaped mirrors or reflective films that are mounted on a structural frame. The dish can have daily as well as seasonal tracking of the sun. The dish rotates about the north-south axis parallel to the earth's axis to track sun's movement. The axis of rotation passes through the center of gravity of the reflector, thereby, enabling it to maintain gravitational equilibrium. It can also change its inclination angle while staying directed at the sun to obtain a sharp focal point. The focus lies at the axis of rotation. At the focus, the solar radiation is concentrated and its heat is captured and transferred to water in the receiver. This leads to the generation of hot water or steam for end-use application.

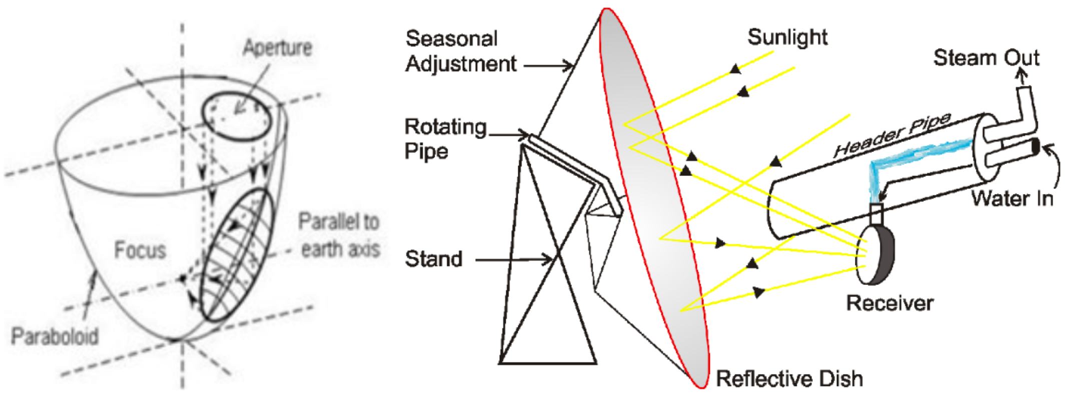


Fig 3: Scheffler System

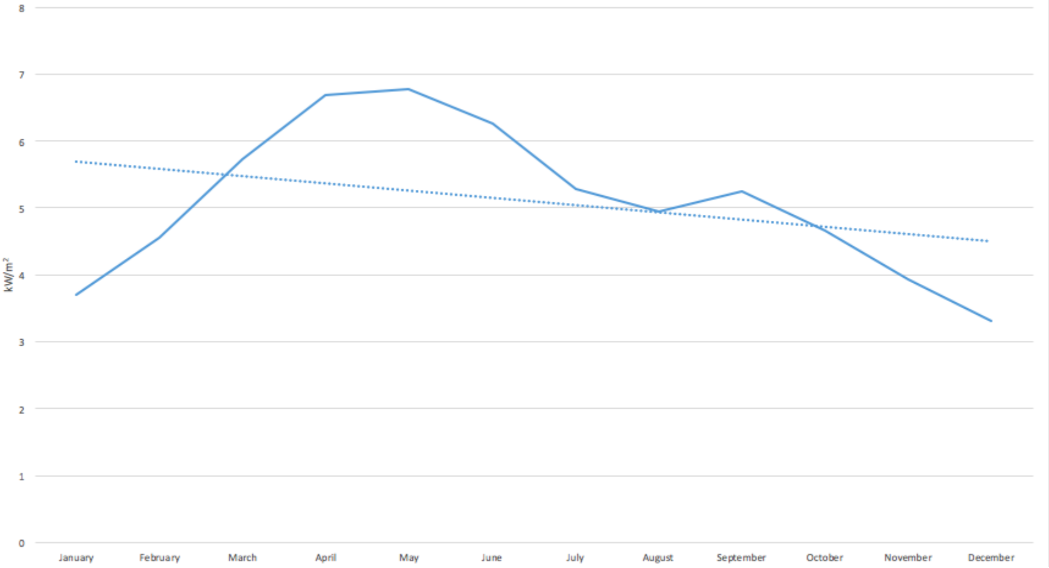
Various components of a scheffler dish system are: the scheffler reflector, receiver, tracking system, thermal storage system, and the dish stand. The tracking system present can provide both daily as well as seasonal tracking of the dish. Daily tracking occurs by moving the dish in east-west direction while seasonal tracking occurs by moving the dish in north-south direction. The thermal storage system is present so as to store heat in the event of favorable weather conditions and to provide the stored heat during adverse weather conditions, when it is not sunny or it is raining. An auxiliary sub-system can be added in the system so that the supply of steam is always present and the system continues to function even during unfavorable conditions.
Scheffler reflector is currently available in two designs, 16 m^2 and 32 m^2 dishes. Scheffler dish system can be used for low-medium process heat applications. The dish can obtain temperatures up to 150-200^O C as per the specific requirements in the industry. A 16 m^2 dish can generateabout 12 bar pressure and about 180^O C temperature. The thermal capacity equivalent of a 16 m^2Scheffler reflector is about 30000 Kcal/day to 35000 Kcal/day depending upon the manufacturing precision and DNI on a clear sunny day.
DNI refers to the Direct Normal Irradiance values which implies the amount of solar radiation entering the receiver depending upon the site, size of concentrator i.e. diameter and reflectivity. The thermal efficiency of a 16 m^2 Scheffler dish is about 42%.

A) Theoretical Considerations

Based on the data available on the Internet[14], the following calculations have been made.
Firstly, the monthly global solar radiant exposure is plotted for Delhi. It shows that the maximum solar radiation falls on Delhi in the month May. The trend line shows that, with onset of Winter in the latter part of the year, the amount of

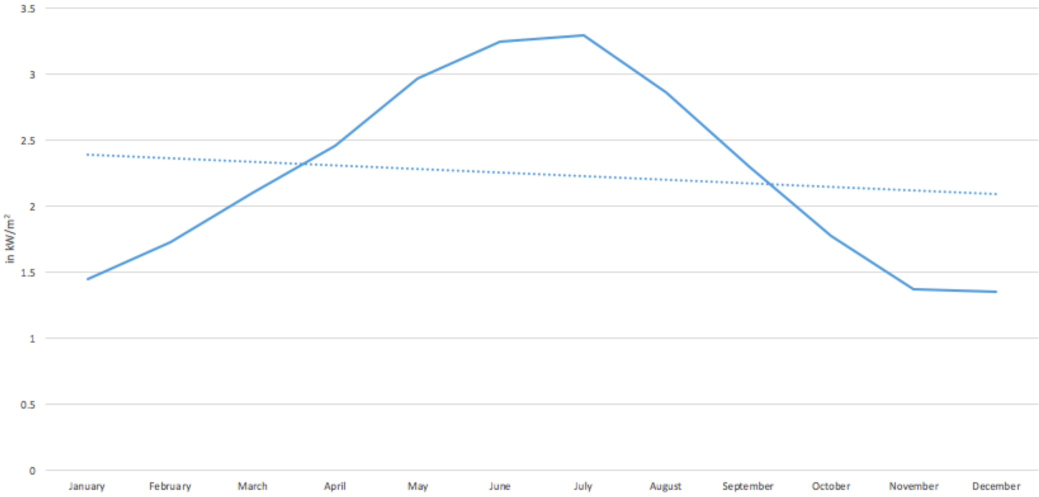
ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

solar radiation falling on Delhi falls. The average global radiation is about 5 kW/ m^2 which suggests that Delhi is very well-suited for the use of solar power.



Graph 1: Monthly Variation of Global Solar Radiant Exposure In Delhi

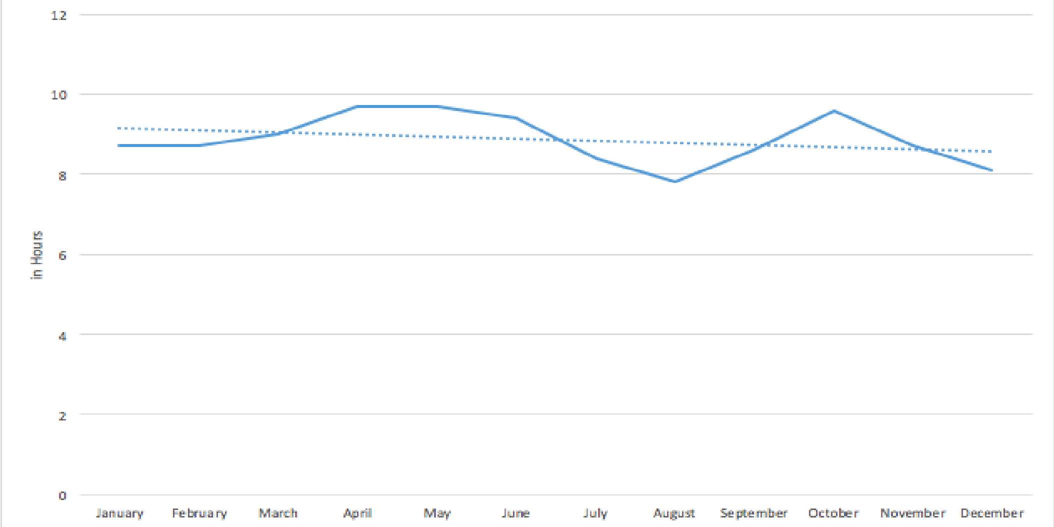
Secondly, the monthly variation of diffuse solar radiation in Delhi is plotted. The maximum diffuse radiation occurs in the month of July in contrast to the global radiation which occurs in May. But the trend of diffuse radiation is the same as global radiation, with maximum radiation occurring in the summer months followed by a decrease in the latter part of the year.



Graph 2: Monthly Variationof Diffuse Solar Radiation Exposure in Delhi

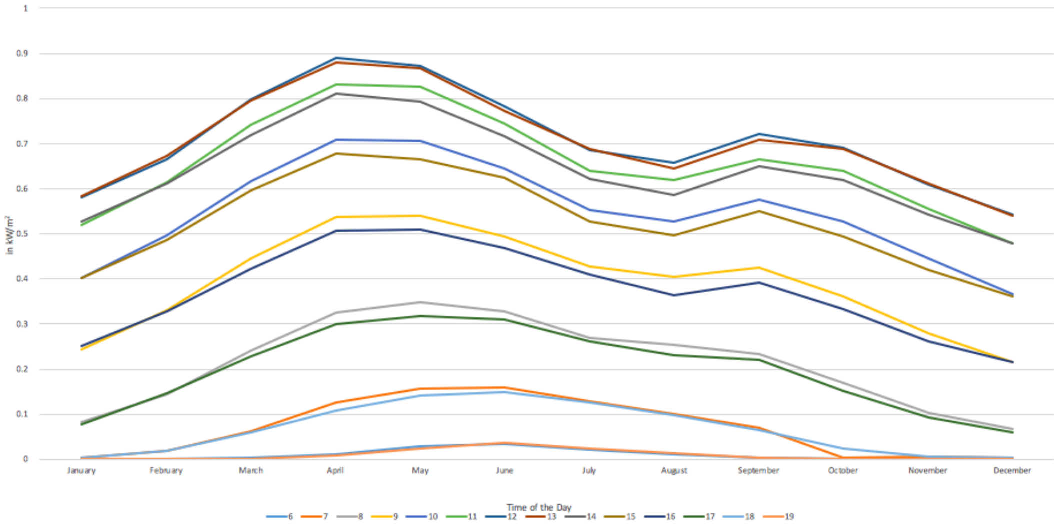
The variation of mean daily duration of sunshine hours with the months of the year is plotted. It shows an anomaly that the maximum average sunshine hours occur in the month of October, which being a month in the winter season, should have lesser amount of sunshine. This variation also shows that Delhi receives approximately 9 hours of sunshine daily, which is sufficient for the utilization of solar devices. The trend line shows a decreasing trend towards the latter months of the year, which shows lesser solar radiation during the winter months.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018



Graph 3: Monthly Variation of Mean Daily Duration of Sunshine Hours

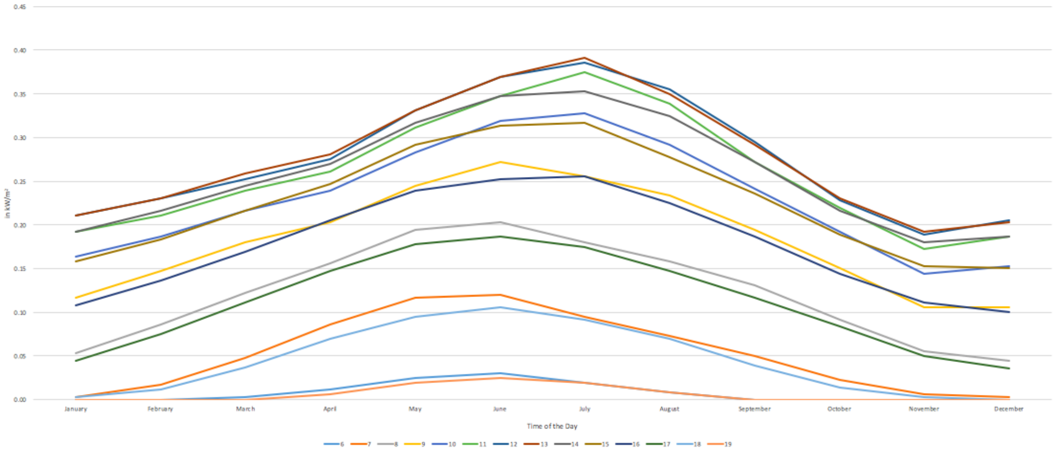
The variation of hourly solar radiation with the time of the day shows that the maximum radiation falls at 12 noon and 1 in the afternoon. As per experience, the data shows that the amount of solar radiation falling in summer months is more than that in the winter months.



Graph 4: Variation of Hourly Global Solar Radiation Exposure at Delhi

The variation of hourly diffuse solar radiation is plotted. It shows that the maximum diffuse radiation occurs in the months of June and July at 12 noon and 1 in the afternoon. The trend of hourly global radiance and diffuse radiation differs due to the presence of clouds and moisture in the atmosphere.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018



Graph 5: Variation of Hourly Diffuse Solar Radiation at Delhi

V. CASE STUDY

A) ITC Hotel, New Delhi

Fig 4: ITC Maurya, Delhi

ITC Maurya has implemented solar thermal technology to generate hot water used for laundry. The Concentrated Solar Project was implemented in the year 2010 and has utilized the solar concentrated heat of 8 Scheffler dishes, each of area 16 m^2, to generate hot water. The supplier for the same was Thermax Limited, Pune. The project was set up at a cost of Rs. 35 Lakhs with a grant of Rs. 5 Lakhs available from the Ministry of New and Renewable Energy (MNRE).

The total available are for solar heat generation application is (16 m^2 x 8 dishes) 128 m^2. ITC has implemented the Scheffler dish based system for steam generation used for laundry purposes. The system runs every day from 9 AM to 4 PM and the steam generated is used for laundry applications while hot water is supplied for bathing purposes. The operating temperature and pressure is 100-120 ^{O}C and 4-8 kg/cm^2. The amount of steam generated by this system is 520 kg/day.

IRR refers to internal rate of return which makes the net present value of all cash flows in a particular project zero. It is called internal as it does not take into account the external factors like inflation or cost of capital. With an IRR of 6.39%, the payback period with subsidy is 15 years and with an IRR of 3.66%, the payback period without subsidy is 25 years.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

B) Gajraj Dry Cleaners, Ahmedabad

Gajraj Dry cleaner was established in 1971. They have a central unit for washing, drying and pressing with seven collection and distribution centers. To reduce labor and distribution costs, they opted for solar based heating technology. The supplier for the same project was Supreme Rays Solar System. The project was commissioned in 2006 at a cost of Rs. 23 Lakhs and has a grant availability from MNRE of Rs. 8.5 Lakhs.

The project has 15 concentrators installed, each of 16 m^2 area. Therefore, the total area available for solar concentration is (15 x 16 m^2) 240 m^2. The system is operated on steam and has been integrated with the existing boiler. It is used on clear sunny days from 11 AM to 4 PM i.e. 5 working hours. The operating temperature and pressure is 180-190 ^{O}C and 7 kg/cm^2 respectively. The fuel which is saved by using solar technology is high speed diesel (HSD) and the amount of fuel saved is about 30 Liters/day. The amount of steam generated per day is 750-870 kg/day.

The plant has IRR without subsidy of 28.42% and a payback period of 3 years and 8 months (about 44 months). With the subsidy, IRR is increased to 39.44% and the payback period is 2 years and 4 months.

VI. ECONOMIC ANALYSIS

Firstly, a single scheffler reflector is considered to calculate the heat output. This heat output is then used to calculate the amount of fuel saved in liters per day and the cost savings involved. This calculation is then extended to a system consisting of 10 scheffler dishes. Estimation of annual savings and the break-even point are done.

Considering only a single Scheffler reflector,

Taking number of sunny days in a year = 300

And the working hours = 8/day

Aperture area = $16\cos(43.23 + {}^{\delta}/_{2})$, Where δ is the seasonal angle deviation

Taking δ as 3^{O},

Therefore, aperture area = $16\cos(43.23 + 1.5)$

Taking direct normal radiation = 5 kWh/m^2/day

Heat output of one scheffler reflector = 11.732 x 5= 58.5 kWh/day= 50448.16 kCal/day

= 211176 kJ/day

= 211.176 MJ/day

Now, calorific value of diesel = 36.9 MJ/liter

Per day fuel saving in liters = $\frac{211.176}{36.9}$

Price of 1 liter of Diesel (as on 28/4/18) = Rs. 65.93

Therefore, per day saving = $211.176/36.9 \times 65.93$ = Rs. 377.31

Annual Savings = Rs. 377.31 × 300 = Rs. 113193.76

Now, for a laundry system, at least 10-12 scheffler reflectors would be required to generate the adequate amount of energy. The annual fuel savings and the payback period are calculated.

Considering a system consisting of 10 Scheffler reflectors,

Cost of 1 Scheffler dish = Rs. 2.5 lakhs

Therefore, cost of 10 Scheffler dishes = Rs. 25 lakhs

Adding on the cost of equipment and other auxiliary systems = Rs. 5 lakhs

Thus, total set-up cost = Rs. 30 lakhs

Heat output of the system = 2111.76 MJ/day

Per day fuel savings in liters =$\frac{2111.76}{36.9}$ = 57.229

Per day cost savings = $2111.76/36.9 \times 65.93$ = Rs. 3773.1

Annual Savings = Rs. 3773.1 x 300 = Rs. 1131937.6

Payback Period = $\frac{(\text{Set} - \text{up Cost})}{1131937.6} = \frac{3000000}{1131937.6}$

= 2.65 years

This calculation shows that with the utilization of scheffler reflector system consisting of 10 scheffler dishes, the set-up cost would be recovered in under 3 years. The only costs that would be involved would be the maintenance and labor. Hence, after approximately 32 months, the savings would start. This would result in savings of both diesel as well as the related costs. This calculation is done without taking into account any subsidy, which would result in further lowering of costs and hence reduction in the break-even time. Subsidies provided to the corporations by the government would help in reduction in set-up costs and would reduce the financial burden due to the higher costs involved.

VII. CONCLUSIONS AND RECOMMENDATIONS FOR SOLAR POWERED LAUNDRY SYSTEM

The cost of single 16 m^2 scheffler dish is between Rs. 2.5- 3 Lakhs. The cost of implementation of solar heating system at ITC Maura is more than that of Gajraj Drycleaners even though the number is dishes used at ITC hotel is less and it was integrated at a later time. This can be explained as the ITC system was a completely new system and was not integrated into the existing system. Also, the addition of auxiliary boiler and a thermal storage system further increased the costs of the project.

The initial investment for a solar based heating system is quite steep but it is expected to reduce in the coming years due to adoption of solar concentrating technologies on a large scale. The major disadvantage of solar technology is that it is weather dependent and can only be used on days which are bright and sunny. This can be mitigated somewhat by integration of solar concentrating technology into the existing technology. This can further improved by integrating auxiliary technologies into the system so that when the weather is unfavorable, the system can be reverted back to the old technology or the auxiliary system can come into play.

The implementation of solar heating system has a small payback period, which leads to early return of investment and reduced costs. The long life of the product, about 25-30 years can provide years of service with very little bills and increased profits after the payback period is complete. The costs associated with fuel, labor and distribution can be reduced. Also, the maintenance costs associated with solar heating system is far less than the typical heat-generation methods used in the laundry industry. The implementation of solar based heating system leads to reduction in environmental pollution and less emission of greenhouse gases due to reduction in the running time of boilers. With the increase in the adoption of solar heating technology, the prices of concentrators will reduce which will lead to lower investments costs and more adoption. Also, with continuous improvement in the technology, the integration of nanotechnology can lead to reduction in the size of the concentrators and can increase the effectiveness by double or triple.

For companies investing in laundry industry, the use of solar-powered laundry system would be highly beneficial. Although the initial investment would be quite steep, the amount of savings done over the long period of service would result in huge benefits. The amount of fuel saved and the subsequent elimination of fuel costs would lead to increased profits over-time. Also, the well-being of the environment would be maintained as emission of greenhouse gases would be reduced. Laundry industry can implement concentrating solar technology as:

1. For laundry purposes, concentrating solar technology can be used easily as the existing boiler system requires large area of land which makes it viable to implement solar collectors.
2. With the proliferation of start-ups in this industry and large investments being made, the implementation of solar concentrating technology can be borne.
3. The high costs of diesel charged from this industry would be reduced as solar technology would provide energy at very cheap prices.

REFERENCES

[1] Ministry of New and Renewable Energy MNRE
Available: www.mnre.gov.in.
[2] https://www.entrepreneur.com/article/295606
[3] ITC Hotels, India
Available: www.itchotels.in
[4] http://www.cshindia.in
[5] Dhiresh C.Desale, Sachin Jain, P.K. Sharma, “Performance Analysis of Scheffler Reflector Using Approximate Generalized Method”, International Journal of Emerging Trends in Engineering and Development, ISSN 2249-6149, Issue 4, Vol. 6
[6] Swati Bhasme, Dr. A.G. Thosar, “Performance Analysis of Scheffler Reflector used for Solar Dry Cleaning”, International Journal of Engineering Innovation & Research, ISSN 2277-5668, Issue 4, Vol. 4
[7] A.M. Akhade, Dr. R.J. Patil, “Design, Fabrication and Performance of Scheffler Reflector”, International Engineering Research Journal, ISSN 2395-1621, pg. 2842-2844
[8] Hardik Naik, Prashant Baredar, Anil Kumar, “Medium temperature application of solar thermal technology: Indian perspective”, Renewable and sustainable energy reviews 76.
[9] Wolfgang Scheffler, Solare Breucke, Graf von Werdenbergstr, “Introduction to the Revolutionary Design of Scheffler reflectors”
[10] Matthew Damon Mercer, “Design, fabrication and analysis of thermal storage solar cooker prototype for use in Rajasthan, India”, MS Thesis, University of Iowa, 2014
[11] Simone Alberti, “Analysis and Optimization of the scheffler solar concentrator”, Thesis, California Polytechnic State University
[12] Anita A. Nene, S. Suyabazhahan, “Thermal efficiency optimization applied to scheffler solar concentrator”, CSPE

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 5, Issue 5 , May 2018

[13] Žanis Jesko, "Classification of Solar Collectors", Latvia University of Agriculture
[14] https://mnre.gov.in/file-manager/UserFiles/solar_radiant_energy_over_India.pdf
[15] Vanita Thakur, Ankush Doshi, Akshay Kumar Rana, "Performance Analysis Methodology for Parabolic Dish Solar Concentrators for Process Heating using Thermic Fluid", IOSR Journal for Mechanical and Civil Engineering
[16] Vishal R. Dafle, N.N. Shinde, "Design, Development and Performance Evaluation of Concentrating Monoaxial Scheffler technology for water heating and low temperature industrial steam application", International Journal of Engineering Research and Application