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Prospects of Solar Powered Air Conditioning Systems in Bangladesh and Comparative Analysis with Conventional Systems

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Abstract

This paper concerns the importance, efficiency and prospects of solar powered air conditioning systems in Bangladesh alongside portrays a comparative analysis of this system with the conventional AC units presently at use. We know that the air conditioning system nowadays is turning out to be a much popular approach to attain low temperature and less humid air. But as desirable as it may seem, it is very costly and also consumes a lot from the power grid that has far reaching effects on the environment as well as the overall energy consumption. Solar powered air conditioning systems provide cool and low humid air by harnessing the renewable energy and the dehydrating power of desiccants causing the whole system to be environment friendly as well as cost efficient. The comparative analysis will show the advantages and drawbacks of both systems and thus contrast the preferable choice according to the economical perspective of Bangladesh.

Keywords: Solar powered AC, Desiccants, Conventional AC.

1. Introduction

Bangladesh, situated in South Asia with a coastline of 710 km on the northern littoral of the Bay of Bengal. Bestriding on the Tropic of Cancer, this country has a tropical monsoon climate which consists of heavy seasonal rainfall, high humidity, and high temperatures [1]. Dhaka, the capital of Bangladesh has an average temperature of 30 degree as of July, 2017 [2]. So due to this high temperature, people are more likely to adopt air conditioners and air cooling systems and being reliant on them day by day. A 2 ton air conditioner consumes about 300 KWh of power every month if kept on for 5 hours every day. Presently the installed generation capacity of Bangladesh is 15,761 MW [3] as of 30 August, 2017. According to this information we can surely estimate the huge share of power that will be taken from the total power generation if the use of conventional air conditioning systems increases. On the other hand, use of air conditioners links to more power usage and more power usage links to production of more green-house gases, so the climate is also affected indirectly. Therefore, if the air cooling and dehumidifying could be done by harnessing the naturally occurring renewable sources then it would obviously lessen the pressure on the overall usage. Solar air conditioning system basically harnesses solar energy directly or indirectly to provide cool and dehumidified air. It is also eco friendly, as it doesn't contribute to green-house gas production. The main aim of this paper is to illuminate the prospect of solar air conditioning systems in Bangladesh and present a comparative analysis with conventional vapor compression air conditioners that will help us find whether using solar powered air conditioners will be suitable for use in Bangladesh based on its efficiency and economic feasibility. Additionally, the representation of the comparative analysis of the economic feasibility, efficiency, power consumption and cooling capacity between the solar powered air conditioning unit and conventional air conditioners is another major objective of this paper.

2. Theoretical Descriptions

Solar conditioning generally refers to the process that uses solar power to drive a system that would cool and condition inner atmosphere of a system. Solar air conditioners are mainly two types [4], namely - solar photovoltaic system and solar thermal system. Solar photovoltaic system, consisting of PV modules, inverter, battery and vapor compression cooling system that can harness solar power and convert it into electricity that later on can drive an air conditioning system. The COP and current efficiency being an important factor, the

present and projected efficiencies of a single crystal silicon PV module is 17% and 21% according to the International Energy Agency. Solar thermal systems are more desirable as they can utilize more of the solar energy than the PV systems because it utilizes the heat coming from the solar radiation as about 65% incident rays are converted into heat and about 35% converts into light energy for generating electricity [4]. The basic parts are a solar collector, a thermal storage tank, thermal air conditioning unit and a heat exchange system. The efficiency of a solar thermal system increases with the ambient temperature. Moreover, we can classify solar thermal systems into categories such as – desiccant based systems, solar sorption systems (absorption and adsorption) [4].

3. Climate Change and Energy Considerations

If we consider the solar thermal technologies then the measure of the relative humidity, average solar insolation and the average temperature throughout the year are some eminent criteria. According to the Bangladesh Meteorological Department [5] two cities with highest monthly normal humidity in Bangladesh are represented in Fig.1. The graph depicts the variation of the relative humidity throughout the year. It is seen that from the months May to September the relative humidity ranged from 75-86% in Rajshahi and 76-83% in Dhaka reaching the yearly maximum and directing the seasons mid of summer and rainy season. On the contrary, from the months November to February the relative humidity ranged from 78-71% in Rajshahi and 73-64% in Dhaka being moderately less than the previous magnitude and directing the winter season. The highest monthly normal humidity of Rajshahi was 88% and that of Dhaka was 83% approximately (Fig 1.).

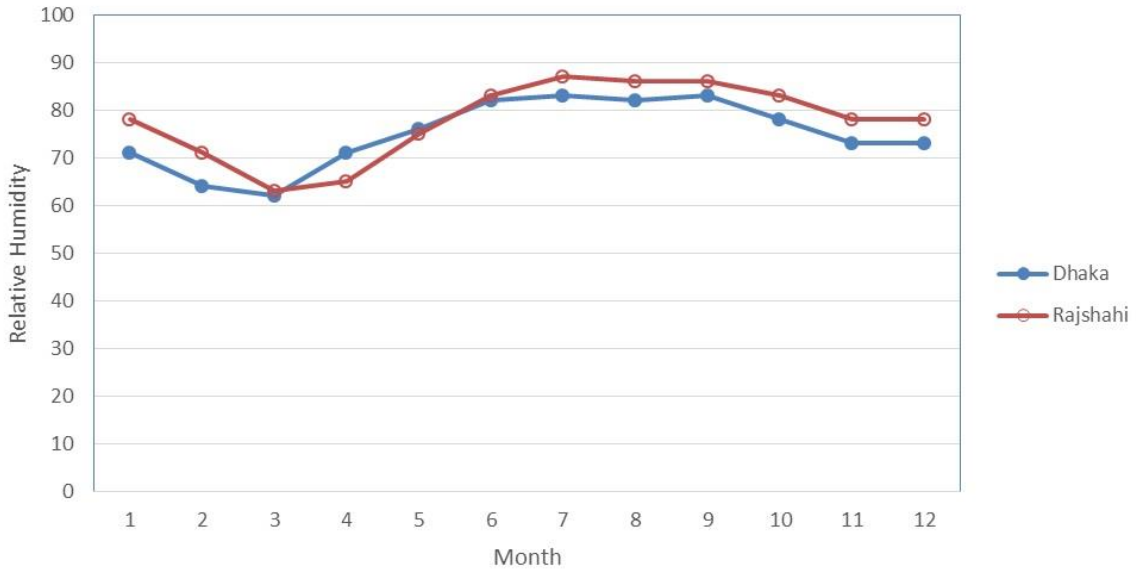

Fig 1. Monthly Normal Humidity of Rajshahi and Dhaka

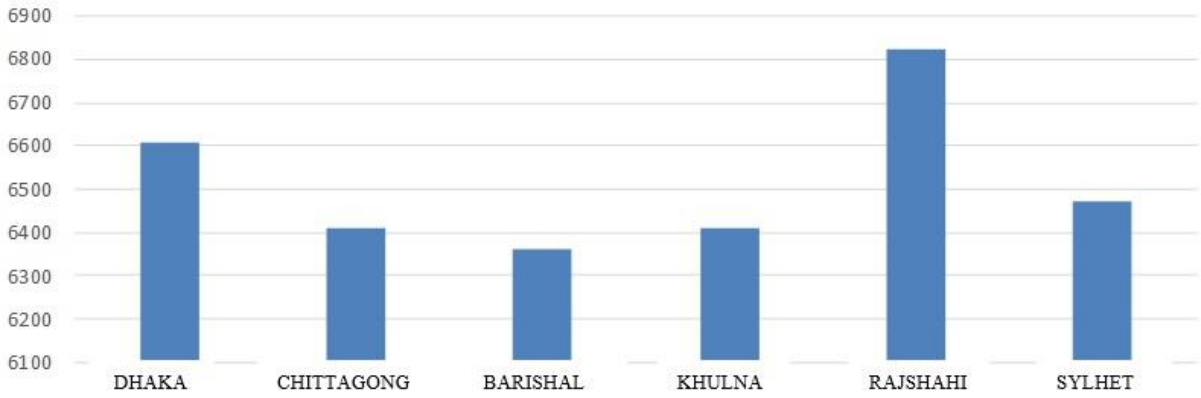

Fig 2. Annual Solar Potential in Bangladesh (MJ/m^2) [6]

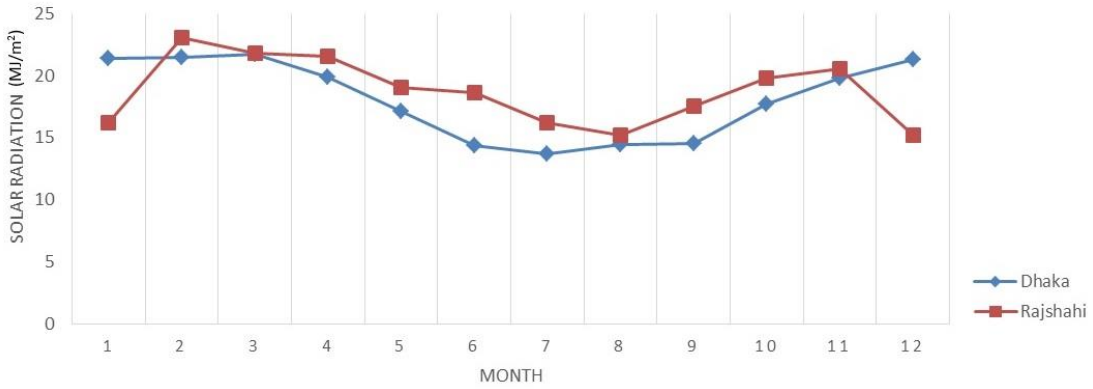

Fig 3. Monthly Average Daily Solar Radiation [6]

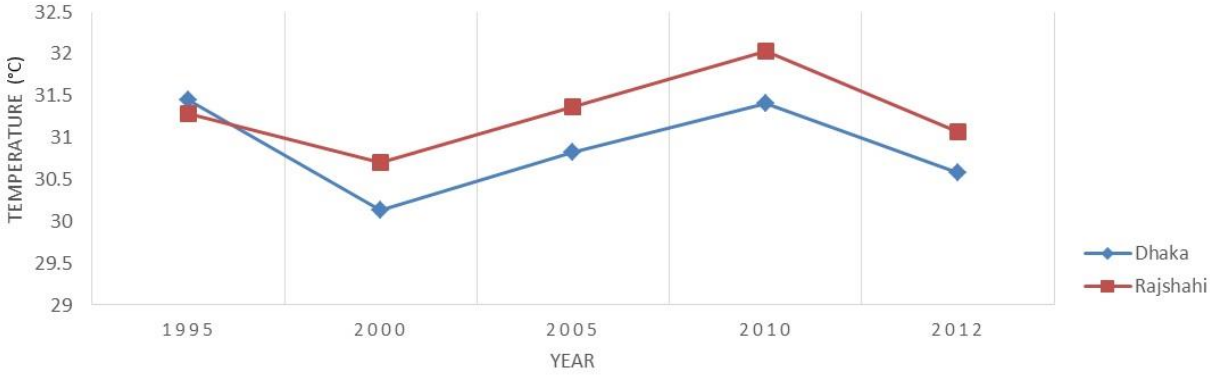

Fig 4. Maximum Average yearly temperature [7]

Fig.2 portrays the annual solar potential in the six divisions of Bangladesh. If we take a look at the annual solar potential then we can see that the maximum annual solar potential in Bangladesh in the Rajshahi division is about 6823 MJ/m^2 and the second maximum is in the Dhaka division which is about 6607 MJ/m^2 [6]. Fig.3. shows the monthly average daily solar radiation of the capital Dhaka and the divisional city Rajshahi, here both the solar global and diffuse radiation is shown. It is worth mentioning that the tilt angle of the solar panel was equal to the latitude of the respective location. Solar radiation being in adequate amount was not or could not be recorded for cloudy conditions owing to rainy seasons in the month of June – September. The monthly average solar radiation are more than adequate to be harnessed in the solar air conditioning technologies. Fig.4 represents the maximum average yearly temperature of the aforementioned two cities. Temperature analysis of past 17 years in 5 years interval and only two year interval from 2010 to 2012 is shown (Fig 4.). We can see that the temperature oscillated among 30°C to 32°C. The results directs us to the dire need of air conditioning systems to enhance efficiency and productivity.

It has been seen that both machines and human function most efficiently when their local air has a temperature between 20°C and 25°C and not only that, the humidity must also be approximately 50%. If the environment of any confined place in too hot or too cold keeping these conditions as the standard, then the ones inhibiting in the place will feel uncomfortable, resulting less productivity in their operations and in some cases may become ill. Thus solar air conditioning can be taken advantage of in this regard. As solar air conditioning surely contributes to space cooling, space dehumidifying at low energy cost and in a broader sense reduce CO_2 emissions if and only if there is an appropriate and well planned building design [8].

4. Prospect of Solar Air Conditioning in Bangladesh

Air conditioning in Bangladesh is not that popular and surely it needs significant amount of attention. We will take a look at some parameters that will discuss about the prospect of solar powered air conditioning in Bangladesh.

4.1. Cost Analysis

According to a research held in Europe, the main results of the SACE project we can see a price comparison of the cost of different types of solar air conditioning systems. The prices are represented in Euro and Bangladesh currency to show the cost and savings according to Bangladesh's perspective.
The economic comparison of different types of solar AC is shown in Table 1. Based on the SACE project, the cooling capacity was 47 kW and in this paper it was calculated for 1 kW in BDT [9]. Comparison of prices of different types of desiccants are shown in Table 2 [10].

Table 1. Economic comparison of different types of Solar AC

Collector type	**Collector Area (m^2/kW)**	**Chiller type**	**Total annual cost (euro)**	**Total annual cost in (tk.) for capacity 1 kW**
Stationary Concentrating parabolic collector	2.99	ads	14400	29,862
Flat plate collector	2.99	ads	16200	33,594
Evacuated tube collector	2.13	ads	17700	36,705

Table 2. Comparison of prices of different types of desiccants

Desiccants	**Price (tk.) per kg**
Silica gel	2000
Indicating silica gel	2500
Calcium chloride	120
Calcium oxide	120
Calcium sulfate	125
Sodium chloride	70

4.2. Power Saving Capability

We can see the percentage of energy saving is maximum in the STCPC and the ETC which is about 53%. The amount of energy saved and the corresponding value is given in Table.3 [9] basing on the type of collector.

Table 3. Energy saving and corresponding value

Collector type	***Collector Area (m^2/kW)***	***Heat Storage Volume(m^3)***	***Chiller Type***	***Primary Energy saving (%)***	***Value of saved Primary Energy* (euro cent/*kWh)***	***Value of saved Primary Energy (tk/kWh)***
Flat Plate Collector (FPC)	2.99	12.6	Ads	47	19.6	19.1
			Abs	46	14.7	14.33
Stationary		16.8	Abs	52	12.7	12.38
Concentrating		12.6		53	20.3	19.79

Parabolic Collector (StCPC)					
Evacuated Tube	2.13	15	Abs	22.1	21.54
Collector (ETC)		18	Abs	17	16.57

4.3. Annual Coefficient of Performance

The Annual COP is defined as the ratio of the annual cold production (kWh) and the annual heating input (kWh). The available data helps us to project an estimation on how the COP varies for different types of desiccants of the solar powered AC systems. (Fig 5.) [9]. In the above data, absorption-1 is H_2O/LiBr desiccant and absorption-2 is NH_3/H_2O desiccant. We can see that the most enhanced COP in attained by H_2O/LiBr desiccant solar powered air conditioning systems.

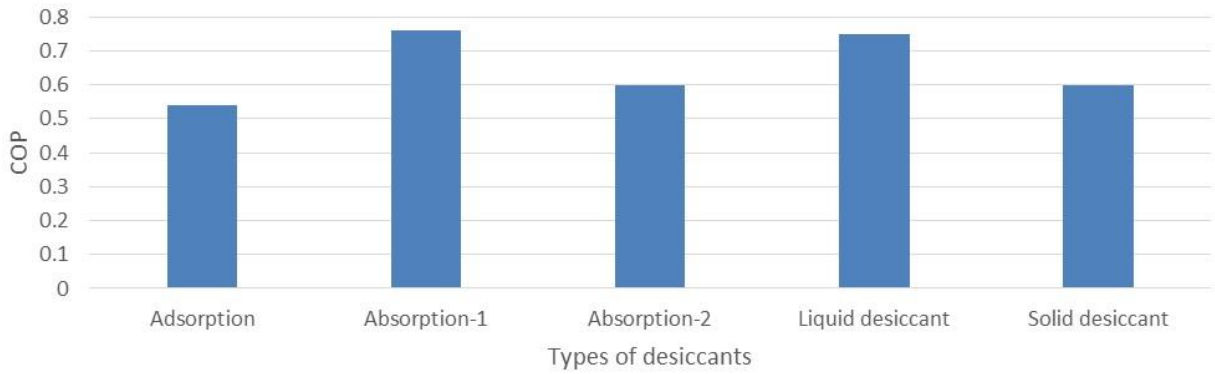

Fig 5. Annual Thermal COP

4.4. Efficiency and Cost Analysis of Conventional Air Conditioners

The market analysis of some conventional air conditioners shows us the scenario of the cooling capacity and the price structures [10].

Table 4. Cost and cooling capacity of Conventional AC units

Brand	Size	Price(tk.)	Cooling capacity(kW)
Sample no. 1	0.75 ton	31500	2.5-2.6
Sample no. 2	1 ton	36000	3.4-3.5
Sample no. 3	1 ton	40000	3.5-3.6
Sample no. 4	1.5 ton	48200	5.1-5.5
Sample no. 5	1.5 ton	55000	5.2-5.4
Sample no. 6	2 ton	57600	6.3-6.6
Sample no. 7	2 ton	65000	6.9-7.0

5. Results and Discussion

According to the above study we can come to some decisions. Such as, the temperature of Bangladesh is more than the human comfort level and so is the relative humidity, and the data analysis shows that Rajshahi and Dhaka has the most temperature among the other cities. Moreover the solar radiation is also significant in these areas and thus it can be efficiently utilized in solar powered air conditioning systems. We also identified several efficient solar plate collectors and a cost analysis of multiple desiccants facilitated the selection of the efficient one among them based on Bangladesh's perspective. Although we observed numerous advantages of using solar air conditioning systems but this system has some drawbacks as well. The solar air conditioning system mainly works based on the amount of solar heat collected by the solar collectors. In moderate temperature its efficiency

will be low and thus in seasons except summer we would not be able to use it efficiently. Another point that can be taken into consideration is that the rate of renewables are generally discontinuous and this could cause variance in the performance in the air conditioning system. If the limitations can be taken care of by research based study for increasing the efficiency of the collectors, then the potential of solar air conditioning system is enormous.

6. Conclusions

We analyzed and came to the conclusion that the climate of Bangladesh is prone to reasonably high temperatures that can be solved by air conditioning systems for increased human comfort and productivity. Then a comparative analysis was operated taking in mind the parameters namely- cost analysis of conventional and solar air conditioning systems, comparison of prices of different types of desiccants, power saving capability of solar air conditioners having different types of collectors, efficiency of conventional air conditioners and annual COP of solar air conditioners having different types of desiccants. After our comparative study we can come to a conclusion that though the objective of both types of air conditioning systems are the same, but they do differ in certain criterion such as- power saving capacity, environment friendliness. Our study further directs us to the fact that the cost difference of the two types of systems is not that much, the solar system's cost being a bit low than conventional systems. Adopting solar air conditioning systems would be cost friendly, energy saving and environment friendly. We should exploit our opportunities and natural blessings in the field of solar power and imply it on solar powered systems to attain a green and sustainable future. Moreover being dependent on the renewable resources would effect on less CO_2 emission. So implying renewable energies especially solar energy in air conditioning systems could be a beginning for Bangladesh in a path of sustainability.

7. References

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