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The "All in One" Smart Solar Cooling System

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Abstract: The need for moving away from traditional energy sources and to find alternate energy sources is undoubtedly one of the primary objectives for a sustainable progress to humankind. The design and construction of buildings in hot-humid climates requires high energy consumption typically for air conditioning due to higher thermal loads. In the Gulf Region, there is a rising concern on the current rate of energy consumption due to air conditioning, i.e. two thirds of domestic electrical loads. Considering the wider impacts of carbon emissions on our climate, and the need to reduce these emissions, effective energy efficiency solutions are necessary in order to achieve the overall goal of reducing carbon emissions. This paper presents the performance of the "All in One" fully integrated solar desiccant air conditioning system. The superefficient air conditioning system can provide 1,000 to 2,000 litre/s treated fresh air at supply temperature of 16 °C with 60% reduction in energy consumption compared to conventional systems. The system is locally manufactured and installed.

Key words: Solar cooling, desiccant dehumidification, absorption chillers.

1. Introduction

The Gulf Region countries have extreme climatic conditions and impose a heavy reliance on cooling, mostly electricity-based, and thus a strong and structural dependency of a high energy resource. In Doha-Qatar, the average highest outdoor temperature during a year is 37.0 °C, however, high-temperature values that exceed 46 °C could be observed in summer. As shown in Fig. 1, the temperature exceeds the 40 °C for more than 300 hours, which anticipated to be doubled when considering Doha climate change in 2025 [1-3].

The governments of the GCC countries are facing challenges related to intensifying energy consumption majorly by the air conditioners installed in the buildings. Therefore, energy efficiency initiatives have been taken by the government to establish strict standards and regulations.

Many buildings in the Gulf Region have been constructed following international models that are not fit for the particular conditions imposed by the local context. For instance, the design of modern high-rise buildings, with unfortunate high glazing to wall ratio, increased dramatically the energy consumption due to high solar gains. In addition to insufficiently insulated building skins, a lack of passive design measures for energy consumption control such as glazing and shading features, an excessive proneness to overheating and resultantly an excessive reliance on active indoor climate control. Air conditioning counts for more than 60% of the electricity consumption in Gulf countries [4]. Moreover, this lack of responsiveness to the local climatic conditions also leads to problems of indoor air quality, user comfort and user productivity.

Cooling open spaces, particularly with the use of smart AC (air-conditioning) systems, will help in enticing more tourists to visit Qatar and other neighbouring countries in summer. Despite searing temperatures and high humidity, visitors to Qatar will find it interesting to go to places such as souqs, cultural venues, and other tourist destinations if given "a cool and suitable ambiance. Evaporative cooling often used for outdoors but it will not be enough to relief people's discomfort with the weather during the hot months" [5].

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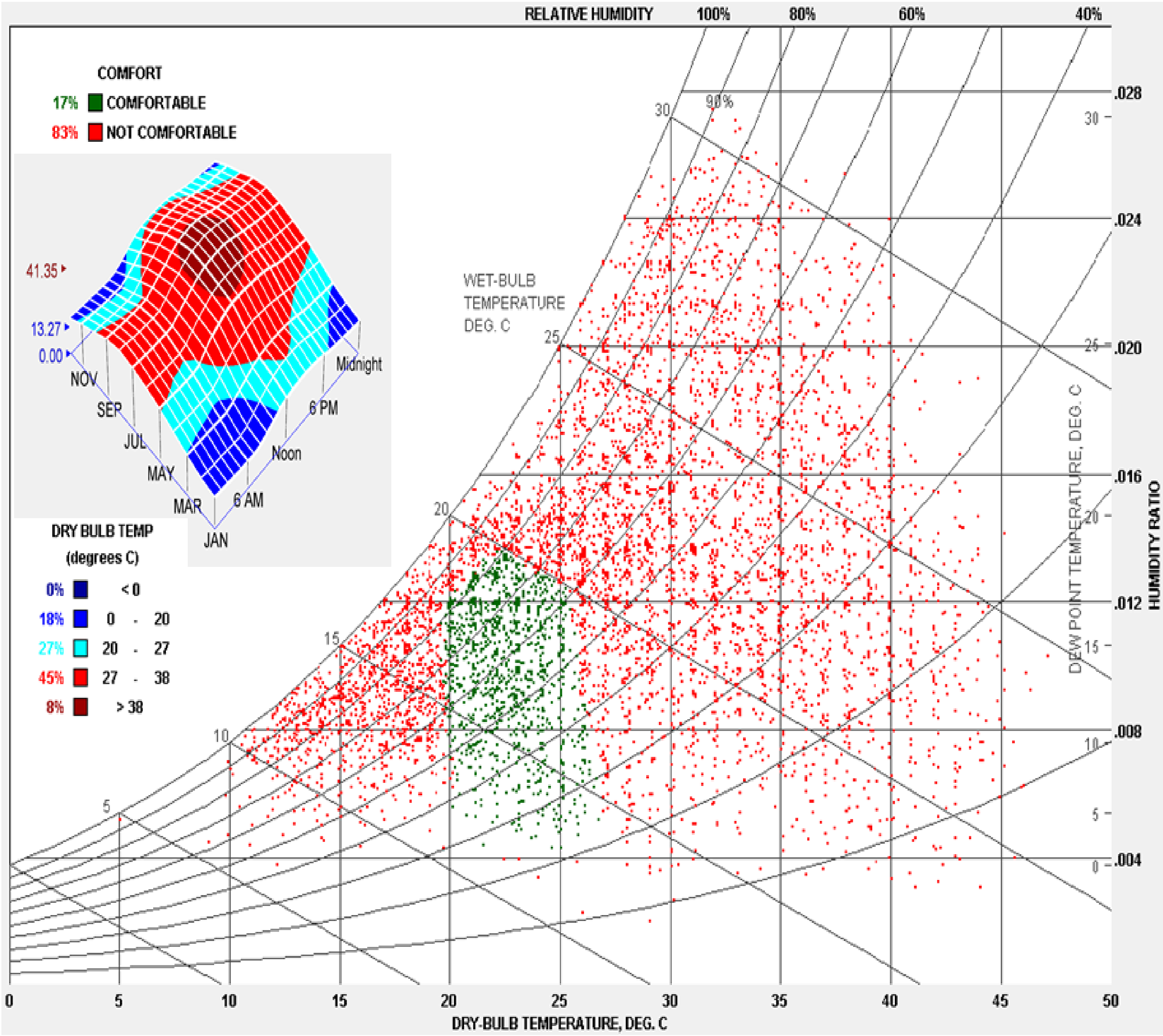

Fig. 1 Extreme weather conditions of Doha City.

In hot climates, it is desirable to reduce the ambient air temperature in order to improve comfort levels; however, in hot and humid climates (as in some Gulf countries), removal of moisture from the air (dehumidification) is almost as important as cooling [6]. Conventional air conditioning systems (for example vapour compression systems) address these issues by cooling air below its dew point such that water vapour condenses on a cooling coil, thus removing moisture from the air. The dehumidified air is then reheated to the desired temperature [7]. This process of deep cooling to dew point and reheating consequently leads to higher energy requirement. Studies have reported that desiccant systems can reduce energy consumption by as much as 40% [8, 9]. In desiccant cooling cycles, the desiccant (brought into contact with air) reduces the humidity of the air by absorbing moisture from the air. Then the air temperature is reduced by conventional cooling coils or other components such as evaporative coolers.

Desiccants are natural or synthetic substances, having a high affinity for water, capable of absorbing water vapour from their immediate vicinity. They are available in both liquid and solid states. Solid desiccants are compact and less corrosive. On the other hand, liquid desiccant offers several benefits, including, lower regeneration temperature, lower pressure drop of air across the desiccant material, suitability for dust removal by filtration, and flexibility in utilisation especially when handling large volumes of air [10].

However, the moisture impregnated desiccants need to be dried in a regenerator, in which the water vapour previously absorbed evaporated out from it by heating. The heat required to regenerate the desiccant can be supplied from low-temperature sources such as waste heat or solar energy [11-13]. Utilising solar energy for this application is particularly interesting because the greatest demand for cooling occurs during times of highest solar insolation. There are different means by which the solar thermal energy can be harnessed for this purpose; examples include conventional solar thermal collectors, solar ponds, and salt works. Besides collecting solar thermal energy, solar ponds have the inherent ability of also storing the thermal energy, and have been widely studied as such.

Desiccant materials play a crucial role in the development of desiccant air conditioning. The characteristics of the desiccant material being utilised impact the performance of the desiccant air conditioning systems significantly [14]. The equipment used for the different components of a desiccant system is air-contacting equipment for liquid air interactions designed for enhanced heat and mass transfer for handling the low liquid flow and large process air flow rates, with minimal air pressure drop, while providing the desired large contact surface area [11, 13, 15].

This paper reveals and discusses the integration of the super-efficient A/C system that has been regionally designed, manufactured and tested to reduce the need of vapor compression cycles.

2. System Description

As shown in Fig. 2, the system consists of a desiccant evaporative cooling heat exchanger coupled with absorption chiller. The solar absorption chiller has cooling capacity of 21 kW which varies according to the inlet hot water temperature (70 to 90 °C). The absorption chiller container includes 1,000 litres hot water and 500 litres storage tanks. The system is fully driven by solar energy using 40 kW flat plate collecters.

Low grade heat from the thermal store is used to regenerate the desiccant system. The desiccant used is seawater bittern the desiccant regeneration temperature range (45 to 55 °C). The seawater bittern desiccant has a storage capacity of 1,000 litres.

The hot and humid air is cooled and dehumidified in the first stage and indirectly evaporatively cooled in the second stage. The air is further cooled by the absorption chiller cooling coil.

3. Results and Discussion

The monthly space cooling thermal demand is shown in Fig. 3. The total annual cooling coil load is 94 MWh. The most commonly used cooling system is the DX split and packaged system.

The use of indirect-direct evaporative cooling coupled with a desiccant system will reduce the cooling electrical loads by 55% without compromising the thermal comfort, see Figs. 4 and 5. Such savings could be much higher if a new comfort zone is defined.

As shown in Figs. 6 and 7, the use of low grade heat 5 TR (17.6 kW) SAC (solar absorption chiller) of solar water heater will reduce the cooling electrical load by further 15%. The total annual electrical load is reduced by 70% compared to the conventional DX systems.

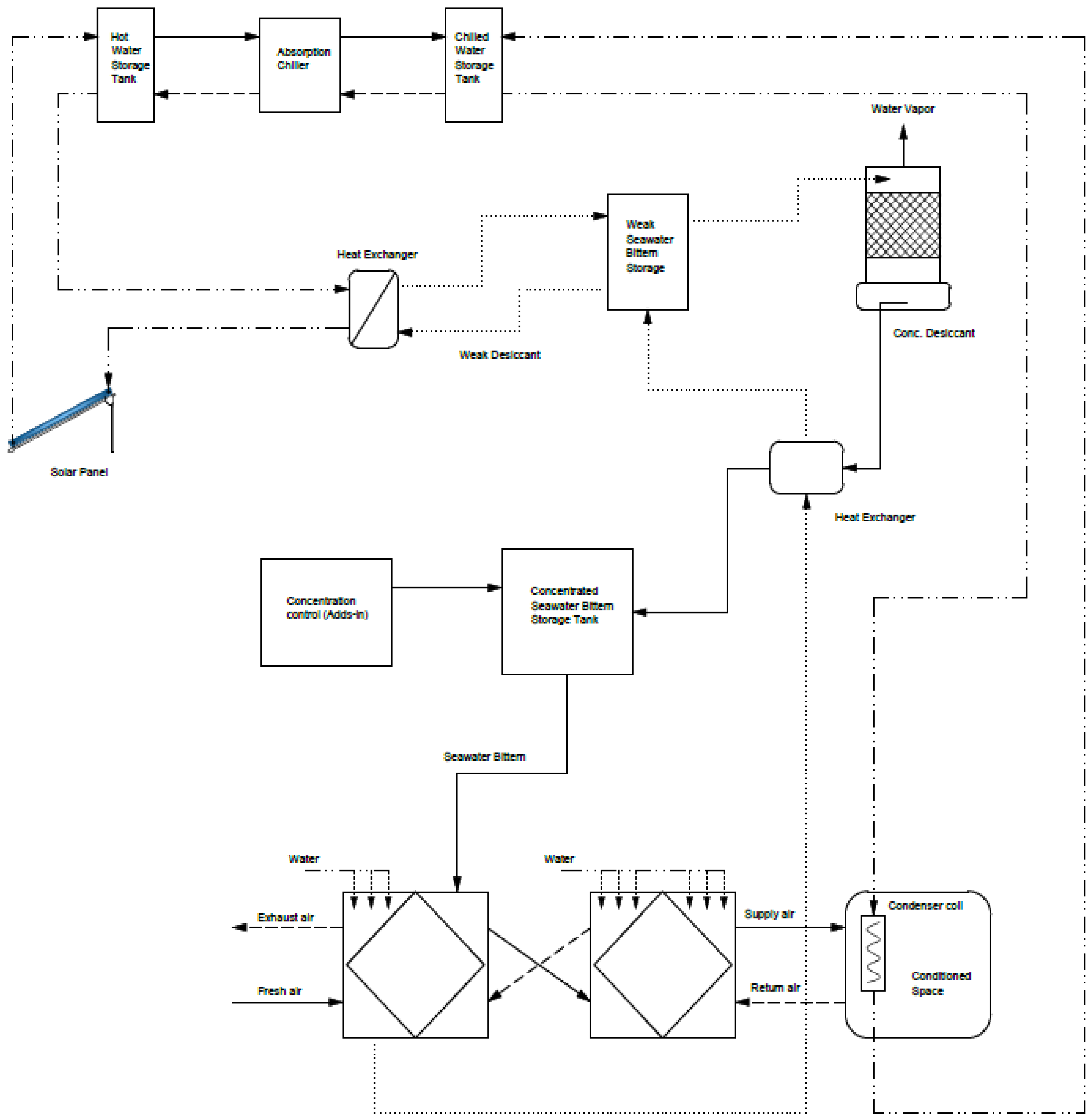

Fig. 2 **The "All in One" solar desiccant system.**

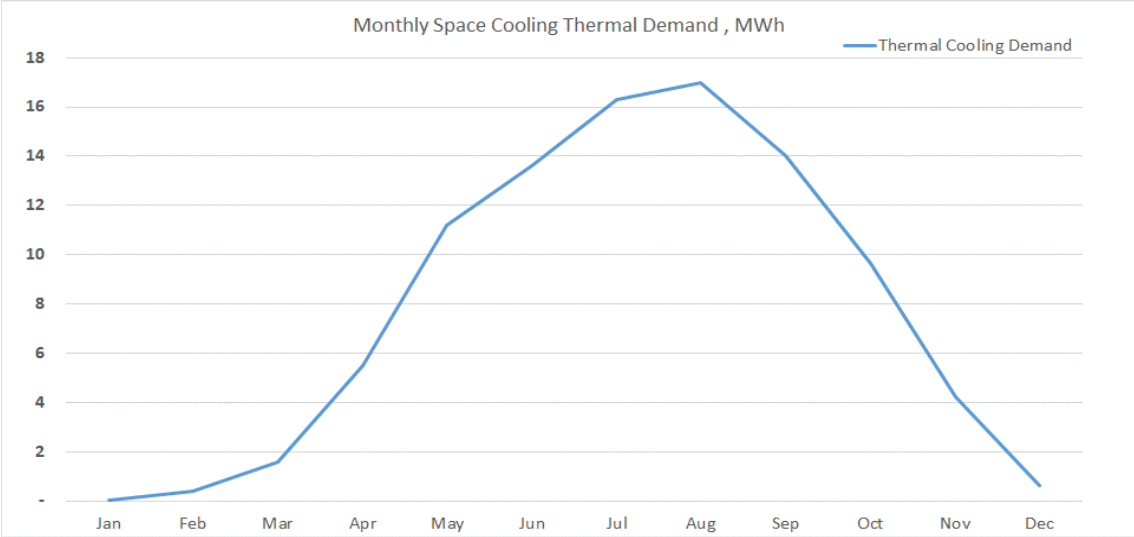

Fig. 3 **Monthly space cooling load (thermal, MWh).**

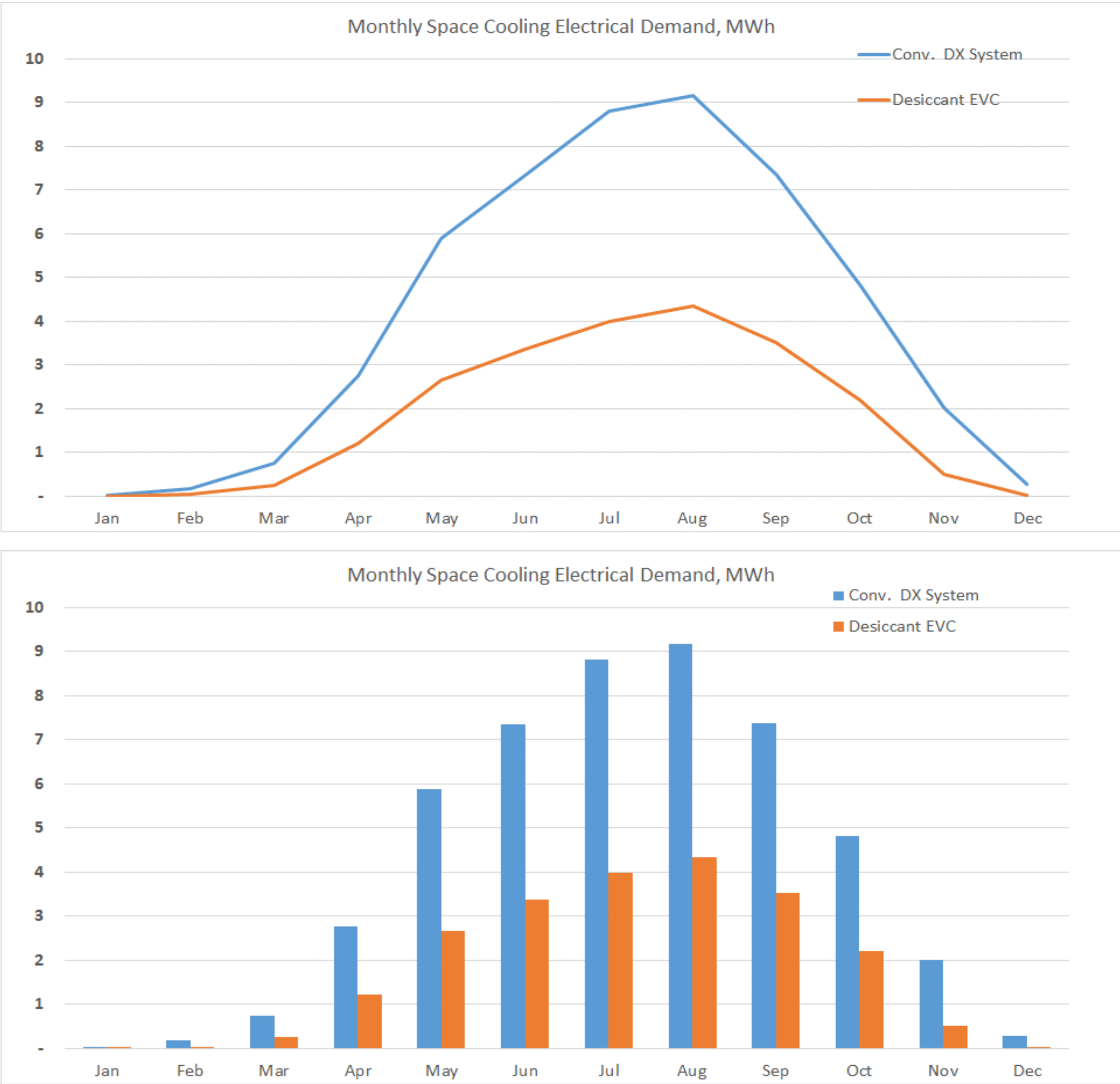

Fig. 4 **DX vs. solar desiccant: monthly and annual cooling load (electrical, MWh).**

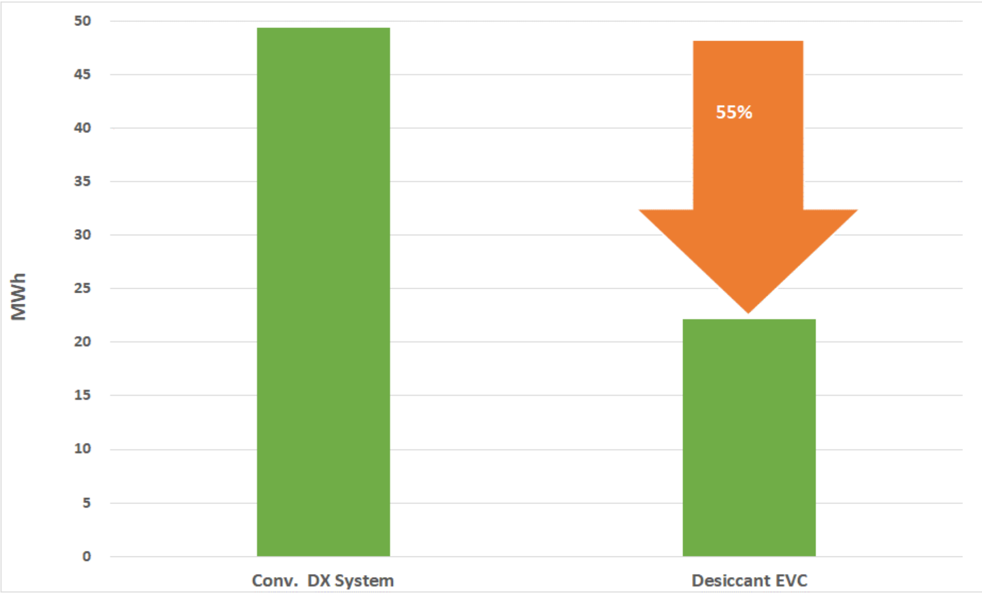

Fig. 5 DX vs. desiccant evc annual cooling load (electrical, kWh).

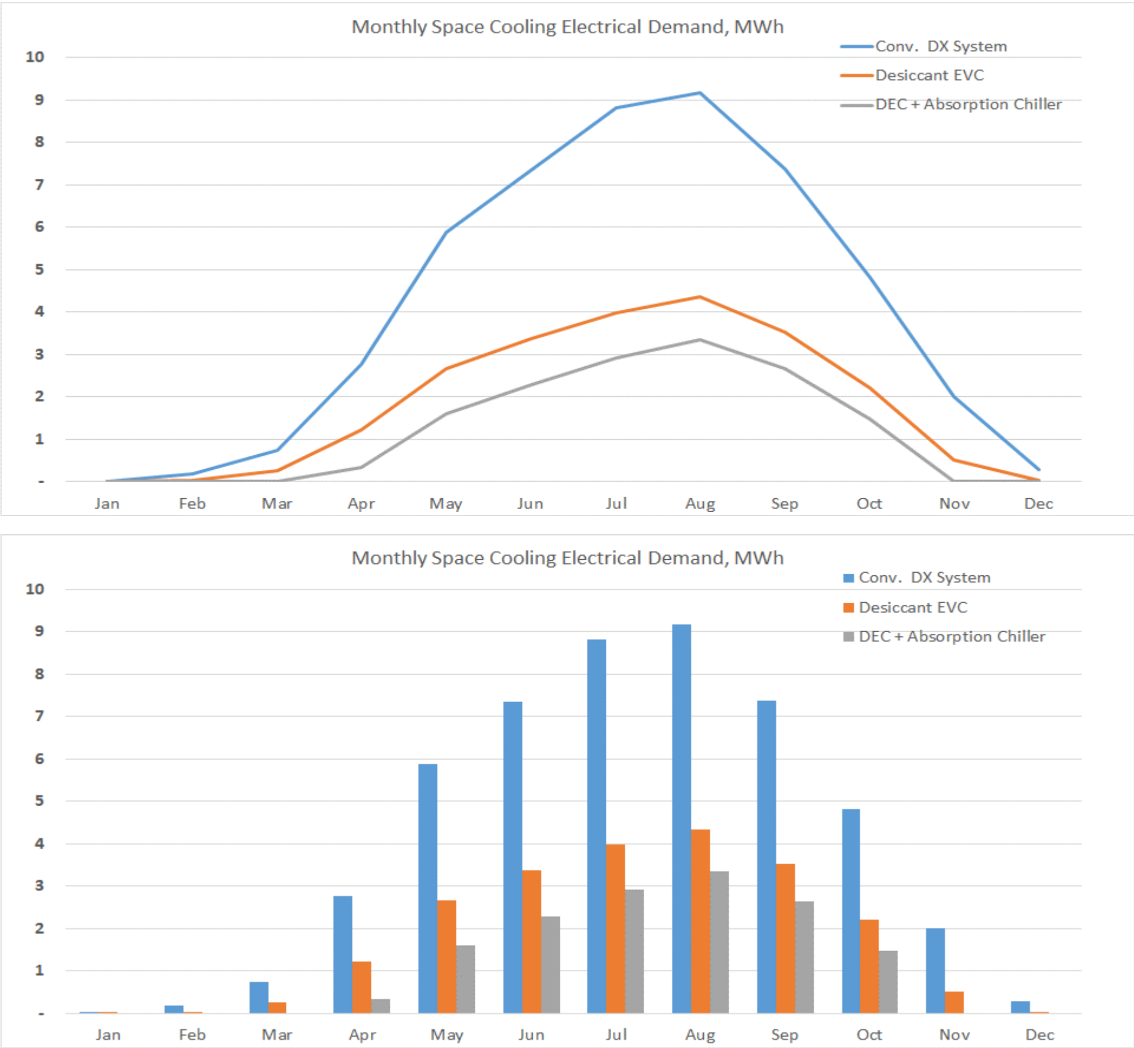

Fig. 6 DX vs. solar desiccant & absorption cooling: monthly and annual cooling load (electrical, MWh).

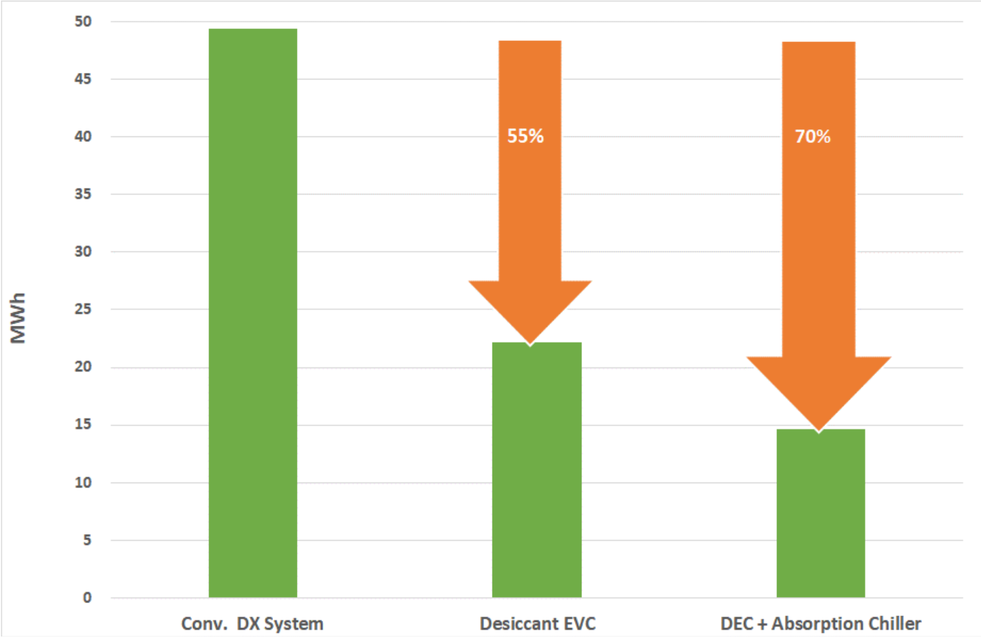

Fig. 7 DX vs. Solar desiccant & absorption cooling: annual electrical cooling load (kWh).

4. Conclusions

This paper presents the clean and renewable integrated technologies. The “All in One” cooling technology will reduce significantly the cooling electrical demands. In this study, the use of seawater bittern as a desiccant source coupled with indirect-direct evaporative cooling reduced the electrical demand by 55%. A 21 kW solar absorption chiller is used to offset the cooling loads. The overall energy reduction is found to be 75%. Such integrated system could be fully driven by renewables by incorporating photovoltaic to offset the balance of the load.

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