Avrupa Bilim ve Teknoloji Dergisi
Sayı 14, S. 17-22, Aralık 2018

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 14, pp. 17-22, December 2018

Research Article

Free Cooling Potential of Turkey for Datacenters

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(First received 27 April 2018 and in final form 4 November 2018)

(DOI: 10.31590/ejosat.419027)

Abstract

Electricity consumption for cooling in data centers is increasing rapidly. The heat released from equipment's in datacenters is discharged into the room and room has to be kept at acceptable temperatures. Free cooling technology is more efficient way instead of using conventional systems in cold regions to reduce the electricity consumption for cooling. It is useful to know the free cooling potential of a location before installing the free cooling system. In this study, free cooling potential of six cities (Ankara, Antalya, İzmir, Erzurum, Konya and Trabzon) located in different regions of Turkey is investigated according to supply air temperatures from 15 ˚C to 21 ˚C. Then Power Usage Effectiveness (PUE) value of a datacenter with a free cooling chiller is calculated for each city by using the electricity consumption measurements of cabinets and free cooling system conducted in a datacenter in Ankara, Turkey. Calculations show that free cooling system is convenient for Erzurum, Ankara and Konya with PUE values 1.23, 1.37 and 1.37 and the potential calculated to be almost 100% for eight, six and six months respectively for different supply air temperatures 17 ˚C to 21 ˚C. In addition to cold climates, free cooling system for Antalya in Tsat=19 ˚C is calculated to save 46% energy on annual basis.

Keywords: Air conditioning, Free cooling, Data Processing Center, Electricity Saving, PUE.

Nomenclature

PUE	Power Usage Effectiveness
EC_{free}	Annual Electricity Consumption in free cooling mode (kWh/year)
EC_{mech}	Annual Electricity Consumption in mechanical mode (kWh/year)
$EC_{partial}$	Annual Electricity Consumption in partial mode (kWh/year)
EC_{fcs}	Annual Electricity Consumption of free cooling system (kWh/year)
EC_m	Power on Mechanical mode (W)
EC_p	Power on Pump (W)
H_T	Number of hours at given temperature interval
T_{oat}	Outside air temperature
T_{sat}	Supply air temperature
T_{rat}	Return air temperature

1. Introduction

Data centers consist of cabinets composed of servers, switch devices, storage arrays and cooling systems. Parallel to the increase in data storage space and server performance demand associated electricity consumption also increases respectively. Datacenters must contain cooling systems to remove the hot air released from equipment and deliver cold air to the server racks for thermal management and keep the system room at a stable temperature. Worldwide electricity consumed in datacenters is increased by about 56% from 2005 to 2010 (1). Furthermore, electricity consumption of datacenters in the USA occupies approximately 2% of total national electricity consumption which makes Information Technology (IT) Sector second most electricity-consuming industry, passed by only the aeronautical industry. Due to these reasons reducing electricity consumption of datacenters has significant effect on total consumption. Electricity is consumed in datacenters for operating the cabinets and cooling system. Cooling is the second largest power consumer in the datacenters after IT equipment. Electricity consumption for cooling system accounts for 30~50% of the final electricity consumption of a datacenter (2).

A significant percent of old datacenters are being cooled by Floor Standing Cooling Systems. However, nowadays there are new technologies introduced to reduce the electricity consumption for cooling of datacenters. The required cooling energy in the most efficient datacenters can be lowered as much as 10% of the total energy consumption, compared to closer to 45% in the air-cooled datacenters (3).

The free cooling system which takes the advantage of cold ambient air is one of these technologies. Free cooling system is based on the benefit from cold outdoor air instead of cooling the indoor air. Free cooling is applicable when the outdoor temperature is lower than supply air temperature. Efficiency of free cooling depends on the number of hours lower than supply air temperature. Consequently colder climate results in higher electricity savings.

Heat is removed from the environment by using convection principle usually with a water-glycol mixture (4), via the ambient

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air. Free cooler system removes the heat in the warm water by lamellas with extensive area of which the contact surface increases efficiency of the system.

It is of importance to calculate the free cooling potential of a location before installing cooling system. Many studies are conducted in Turkey and worldwide to investigate the free cooling potentials of locations such as Istanbul province (5), Kayseri province (6), Europe (7), Estonia (8), India (9), Australia (10) and Italy (11). After calculating free cooling potential some of the studies also calculated Power Usage Effectiveness (PUE) values of datacenters ((12), (13)). PUE is the most commonly used descriptive of energy efficiency of a data center proposed by the Green Grid initiative. PUE is the ratio of total power required to operate a system (including cooling, power distribution and other overheads) to the power used only by the IT equipment (13).

Main purpose of this study is to investigate the most available location for a datacenter cooled by free cooling system in Turkey. In this study free cooling potentials of six cities that are in dissimilar heating degree day intervals (Ankara, Antalya, Izmir, Erzurum, Konya and Trabzon) are calculated according to supply air temperatures from 15 ˚C to 21 ˚C in order to investigate the free cooling potential of Turkey. Then PUE value of an existing datacenter in Ankara, Turkey is calculated by using electricity consumption measurement values of cabinets and free cooling system. Finally PUE value of this datacenter is calculated in case of being located in Antalya, Izmir, Erzurum, Konya and Trabzon.

2. Methodology

In this study, firstly electricity consumption of free cooling system and cabinets in a datacenter in Ankara is measured and PUE value of this datacenter is calculated. Then PUE value for each city is recalculated by assuming this datacenter being located in six different cities of Turkey. Finally free cooling potential of six cities are determined to decide the degree of conformity of free cooling system by using the meteorological data obtained from General Directorate of Meteorology.

A. Temperature Data

Hourly temperature data of six cities with different heating degree day intervals (Ankara, Antalya, Izmir, Erzurum, Konya and Trabzon) are obtained from General Directorate of Meteorology for 2015 and 2016. In this study average of 2015 and 2016 climate data is used due to the lack of normal climate data for all cities. Average daily temperature data of these cities are given in Figure 1.

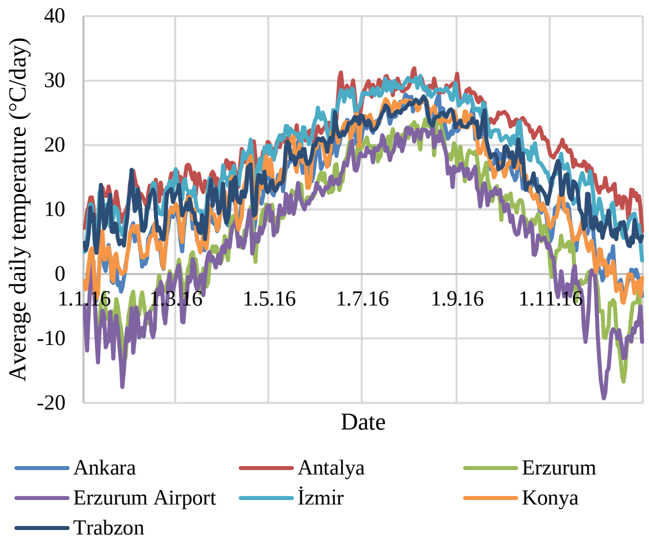

Figure 1 Variation of daily temperature data of Ankara, Antalya, Izmir, Erzurum, Konya and Trabzon (˚C/day)

B. Calculation of free cooling potential

Free cooling potential is calculated by using temperature data and dividing available hours for free cooling to total hours and presented as percentage. Three running modes are described for free cooling system as free cooling mode, partial free cooling mode and mechanical cooling mode. System runs at free cooling mode when outside air temperature (T_{oat}) is lower or equal to desired supply air temperature (T_{sat}). While outdoor air temperature is between T_{sat} and return air temperature (T_{rat}) then cooling system works in partial free cooling mode. When T_{oat} is equal or higher than T_{rat} then cooling demand is supplied only by mechanical cooling. Operating temperatures for cooling modes are shown in Table 1.

Table 1. Operating temperatures for cooling modes

Cooling Mode	Operating Temperature (◦C)
Free cooling	$T_{oat} \leq T_{sat}$
Partial free cooling	$T_{sat} < T_{oat} < T_{rat}$
Mechanical cooling	$T_{oat} \geq T_{rat}$

Number of hours for supply air dry bulb temperature T_{sat}=15 ˚C and return air temperature T_{rat}= 22 ˚C are given for six cities in Table 2.

Table 2. Number of hours for temperature range (T_{sat}=15 ˚C, T_{rat}= 22 ˚C)

	Number of hours in one year (h/year)		
	T<=15	15<T<22	T>=22
Ankara	4904	1983	1873
Antalya	2508	2702	3550
İzmir	3391	2157	3212
Erzurum	6381	1644	735
Erzurum Airport	6694	1473	593
Konya	4808	1945	2007
Konya Airport	4951	2015	1794
Trabzon	4454	2081	2225
Trabzon Airport	4475	1996	2289

C. PUE Value

The Power Usage Effectiveness (PUE) was introduced by the Green Grid Association which shows the electricity efficiency in data centers (14). PUE is a metric that shows the ratio of total electricity consumption in a datacenter to the electricity consumed by the IT equipment. In order to calculate PUE value, electricity consumption of cabinets and cooling system should be measured. In this study to calculate PUE values, electricity consumption of a datacenter located in Ankara Turkey is measured. The data processing center is located at the Department of Data Processing of the General Directorate of Land Registry and Cadaster in Ankara. The cabinet room of the data processing center has 100 m^2 area and contains 18 cabinets. In addition, there are two UPS rooms with a total area of 18 m^2. The working area of the IT staff has an area of approximately 300 m^2 and the area is cooled by two 60000 BTU duct type air conditioners. The cabinets are cooled by free cooling system with two chiller units. The measured power of free cooling system is given in Table 3.

Table 3. Electricity consumption of free cooling system in each mode

Mode	Power (W)
Free Cooling Mode	1709
Mechanical Mode	39444
Pump Power	1512

Electricity consumption of free cooling system is measured only once and annual electricity consumption is calculated by the measurement values and temperature data of each city. Annual electricity consumed in free cooling mode, partial free cooling mode and mechanical cooling mode are calculated separately. In order to calculate final electricity consumption, electricity consumed in each mode is summed.

Electricity consumption in free cooling mode is calculated by using (1).

$$\mathrm{EC_{free}} = (\mathrm{EC_f} + \mathrm{EC_p}) \times \mathrm{H_{T<Tsat}}/1000 \quad (1)$$

where EC_{free} is annual electricity consumption in free cooling mode (kWh/year), EC_f (W) is power of free cooling mode and EC_p (W) is power of pump which are given in Table 3, $H_{T<Tsat}$ (hour/year) is number of hours with temperature smaller than supply air temperature T_{sat}.

Annual electricity consumed in mechanical mode is calculated by using (2).

$$\mathrm{EC_{mech}} = (\mathrm{EC_c} \times 0.7 + \mathrm{EC_p}) \times \mathrm{H_{T\geq Trat}}/1000 \quad (2)$$

where EC_{mech} is annual electricity consumption in mechanical mode (kWh/year), EC_m (W) is power of mechanical mode, EC_p (W) is power of pump, $H_{T \geq Trat}$ (hour/year) is number of hours of which has temperature equal to or higher than return air temperature (T_{rat}).

Electricity consumption of the system is measured in free cooling mode and mechanical modes. The results of the measurements show that the system operated in mechanical mode for a period of 70% of the time and only the pumps are operated in the remaining 30% of time. Due to this reason, energy consumption in full mechanical mode is multiplied by 0.7 and it is assumed to be constant during one year.

Partial free cooling mode is active when temperature is between T_{sat} and T_{rat}. Electricity consumption in this mode is the average of free cooling and mechanical modes and calculated by using (3).

$$\mathrm{EC_{partial}} = \left(\frac{\mathrm{EC_m} \times 0.7 + \mathrm{EC_f}}{2} + \mathrm{EC_p}\right) \times (\mathrm{H_{Tsat \leq \mathit{T} < Trat}}) / 1000 \quad (3)$$

where $EC_{partial}$ is annual electricity consumption in partial cooling mode (kWh/year), EC_m (W) is power of mechanical mode, EC_p (W) is power of pump, EC_f (W) is power in free cooling mode, $H_{Tsat \leq T < Trat}$ (hour/year) is number of hours equal to or bigger than T_{sat} and smaller T_{rat}.

Finally annual electricity consumption of total free cooling system is calculated by using (4).

$$\mathrm{EC_{fcs}} = (\mathrm{EC_{free}} + \mathrm{EC_{partial}} + \mathrm{EC_{mech}}) \quad \ldots\ (4)$$

where EC_{fcs} is annual total electricity consumption (kWh/year) of free cooling system.

In order to calculate PUE valur total energy consumed in datacenter should be calculated. Electricity consumption of cabinets in existing datacenter is measured hourly by using Rittal Software (15). Then PUE value is calculated by using (5).

$$\mathrm{PUE} = \frac{\text{Total Energy Consumed in Data Center}}{\text{Energy Consumed by IT Equipment}} = \frac{\text{Cooling System+Cabinets}}{\text{Cabinets}} = \frac{\text{Cooling System}}{\text{Cabinets}} + 1 \quad (5)$$

3. Results and Discussion

In this section firstly the results of the cooling potential of six cities are given. Then free cooling potential of Ankara and Erzurum are investigated in detail due to their highest free cooling potential. Finally results of PUE value calculations for each city with supply air temperatures Tsat= 15 ˚C to 21 ° are given.

A. Free cooling potential-All Cities

Return air temperature control is the best known and also the most widespread type of control in data centers provided by setting a setpoint for the return air temperature. If the return air setpoint is set to 33 ˚C and the data center air conditioning system is designed for a temperature difference of 15 ˚C, under full load the supply air temperature would be 18 ˚C. Instead of full load a partial load of 40 % to 60 % is common in datacenters (16). Due to this reason free cooling potential is calculated by using the temperature data of six cities for supply air temperature T_{sat}=19 ˚C and result is shown in Figure 2.

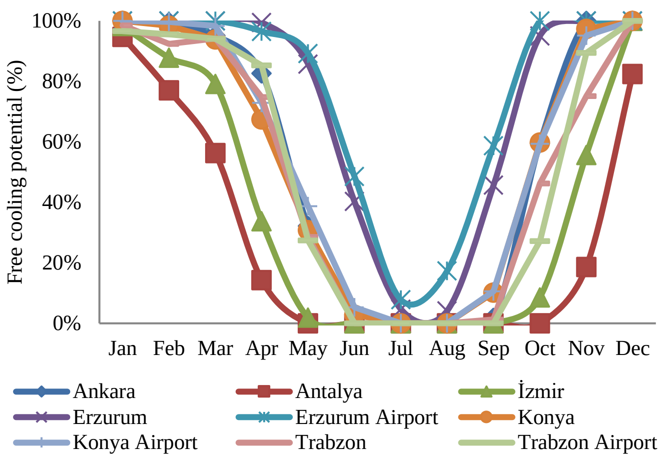

Figure 2 Free cooling potential of six cities (%)

It is clear from Figure 2 that free cooling potential is almost 100% from November to March at supply air temperature T_{sat}=19˚C in Ankara, Konya and Erzurum which are the cities with cold dry climate. However Antalya, İzmir and Trabzon which are the cities with hot and humid climate do not seem to have enough free cooling potential for datacenters. Therefore free cooling potential of Ankara and Erzurum are investigated in detail in following sections.

Antalya is warm climate region. Free cooling of Antalya is also presented to show that free cooling system also results in decrease in energy consumption hot climates.

B. Free cooling potential-Erzurum

Figure 2 shows that Erzurum is the city with highest free cooling potential. Free cooling potential of Erzurum is given for supply air temperatures from 15 ˚C to 21 ˚C in Figure 3.

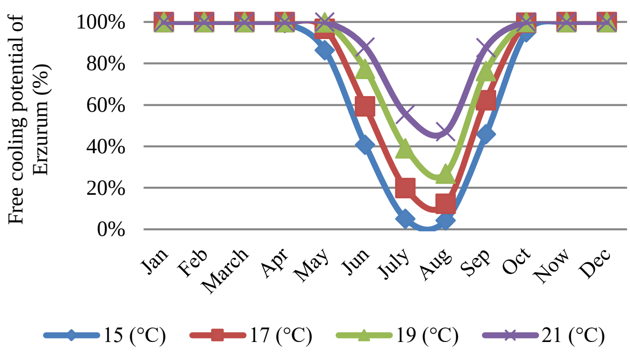

Figure 3 Free cooling potential of Erzurum for supply air temperatures from 15 ˚C to 21 ˚C

Figure 3 shows that Erzurum has nearly 100% free cooling potential during eight months (for T_{sat}=15 ˚C to19 ˚C) from the beginning of October to the end of April which means nearly zero electricity consumption during eight months. Cooling system modes that should be run in Erzurum climate for supply air temperature T_{sat}=19 ˚C is given in Figure 4.

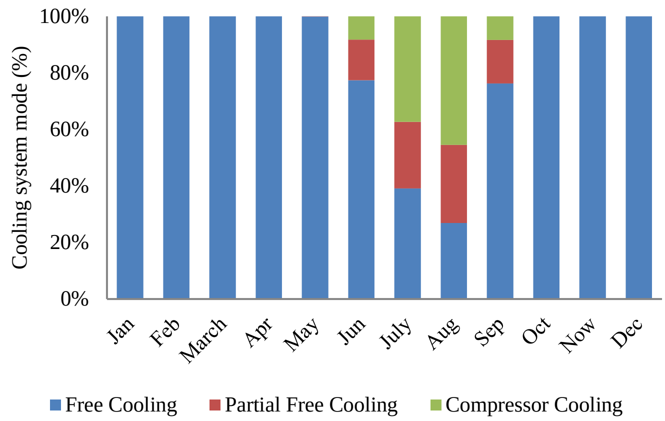

Figure 4 Cooling system modes that should be run in Erzurum climate for Tsat=19 ˚C

Figure 4 demonstrates high free cooling potential of Erzurum for T_{sat}=19 ˚C. The highest percentage of mechanical mode running is 37% and 45% during July and August, respectively. Therefore in case of assuming running duration of mechanical mode as zero during ten months, 37% and 45% during two months, system is calculated to work on mechanical mode only 7% of one year, free cooling and partial free cooling mode 93% of same year.

Erzurum has enough free cooling potential however its transportability from Ankara and Istanbul in where many of the datacenters are located decreases the convenience of Erzurum for datacenters. Due to the difficult access to Erzurum, the transfer of data centers to Erzurum will only be possible if there is enough professional management team to reside in Erzurum.

C. Free cooling potential-Ankara

Free cooling potential of Ankara and Konya are close to each other according to Figure 2. Potential of Ankara is given for supply air temperatures from 15 ˚C to 21 ˚C in Figure 5.

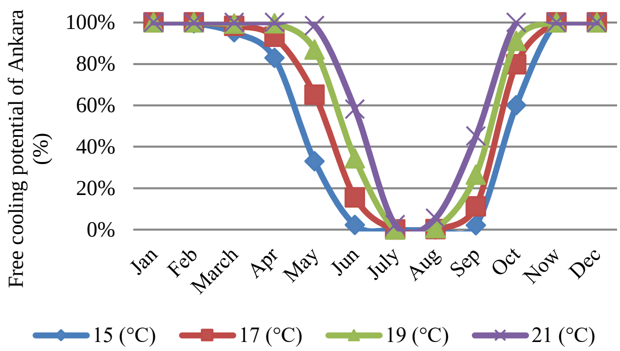

Figure 5 Free cooling potential of Ankara for supply air temperatures from 15 ˚C to 21 ˚C

Figure 5 shows that Ankara has 100% free cooling potential during six months (for T_{sat} =17 ˚C to 21 ˚C) from the beginning of November to the end of March which means nearly zero electricity consumption. Cooling system modes of Ankara climate for supply air temperature T_{sat}=19 ˚C is given in Figure 6.

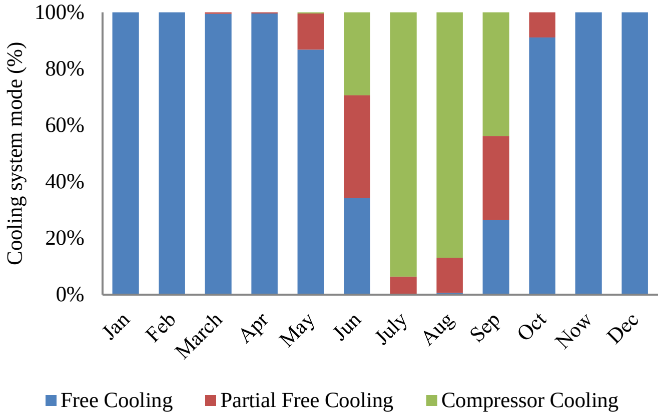

Figure 6 Cooling system modes that should be run in Ankara climate for Tsat=19 ˚C

D. Free cooling potential-Antalya

Free cooling potential of Antalya is given for supply air temperatures from 15 ˚C to 21 ˚C in Figure 7.

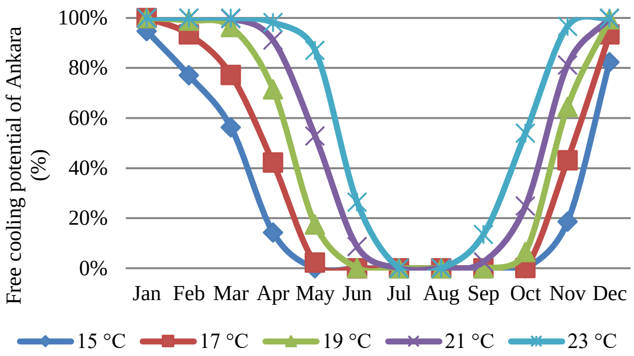

Figure 7 Free cooling potential of Antalya for supply air temperatures from 15 ˚C to 21 ˚C

Figure 7 shows that Antalya has nearly 100% free cooling potential during four months (for Tsat =19 ˚C and 21 ˚C). Cooling system modes of Antalya climate for supply air temperature Tsat=19 ˚C is given in Figure 8.

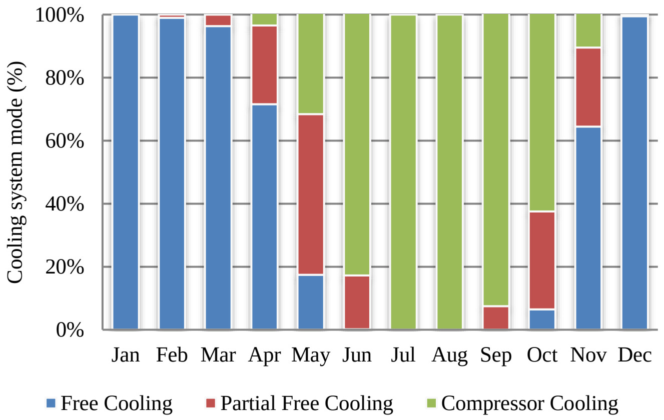

Figure 8 Cooling system modes that should be run in Antalya climate for Tsat=19 ˚C

Figure 8 demonstrates free cooling potential of Antalya for T_{sat}=19 ˚C. During one year 46% of time system is calculated to run on free cooling mood which shows that cost of energy consumption for cooling may be cut in half. In addition to datacenters free cooling may be used in cooling of agriculture crop cold storage rooms in Antalya.

E. PUE Values

PUE values are calculated by using equation (4), equation (5) and electricity consumption of cabinets. Electricity consumption of cabinets in this datacenter is measured hourly by using Rittal Software (15) and average electricity consumption of cabinets is found as 274,248 kWh/year. Firstly electricity consumption of free cooling system in each city is calculated. Then by using the electricity consumption of cabinets PUE values are calculated and results are shown in Figure 9.

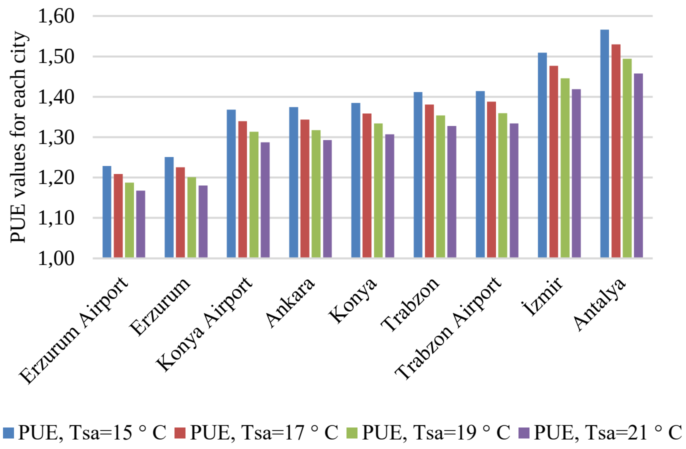

Figure 9 PUE values for each city for supply air temperatures Tsat= 15 ˚C to 21 °

PUE value of the data center in Ankara is calculated as 1.32 for supply air temperature 19˚C which is nearly the same with the PUE value of Konya and Konya Airport at T_{sat}=19 ˚C. Highest PUE value is obtained for Antalya. PUE value of Antalya is calculated to be 0.2 higher than Ankara at each supply air temperature which means 20% more electricity consumption for cooling.

4. Conclusion

This study is conducted to investigate the free cooling potential of six main cities of Turkey with different heating degree day intervals. Free cooling potentials of these cities are calculated for supply air temperatures from 15 ˚C to 21 ˚C. Then electricity consumption of a datacenter chilled with free cooling system in Ankara is obtained. PUE value of existing datacenter is calculated for Ankara climate and in case of being located in remaining five cities. Free cooling potential of Erzurum, Ankara and Konya are calculated to be almost 100% for eight, six and six months respectively for different supply air temperatures 17 ˚C to 21 ˚C.

However Antalya, İzmir and Trabzon are the cities with hot and humid climate. However in these cities using free cooling system will still decrease cooling demand in annual basis by 46%. In addition to datacenters free cooling may be used in cooling of agriculture crop cold storage rooms in Antalya and Trabzon on where wide agricultural lands exist in.

PUE value of the data center in Ankara is calculated as 1.37 for supply air temperature 15 ˚C as in Konya. Lowest and highest PUE values are obtained for Erzurum and Antalya. PUE value of

Antalya is calculated to be 0.2 higher than Ankara, 0.32 higher than Erzurum at each supply air temperature which means 20% and 32% more electricity consumption for cooling.

5. Acknowledgment

I am grateful to Data Processing Center of General Directorate of Land Registry and Cadaster of Turkey for their support and assistance for the electricity consumption measurements of cabinets and free cooling system.

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