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INFLUENCE OF CLIMATIC CONDITIONS AND TECHNICAL SOLUTIONS ON THE ENERGY PERFORMANCE OF A COMMERCIAL BUILDING IN TURKEY

The paper presents the energy modelling results for a commercial building located in different climatic zones of Turkey using different normative U-values for respective locations. The analysis includes the calculation of heating and cooling load, as well as annual energy consumption for heating, cooling, lighting, equipment and hot water preparation depending on building envelope specifications and climatic conditions. Since the analysis has been performed with the use of simplified HVAC systems modelling approach the next step will be more detailed investigation of technical systems options.

Key words: building energy performance, building energy modelling, building envelope, climatic zones, heating load, cooling load

Introduction. In the framework of this study, building modeling was carried out in order to evaluate the current situation and to bring logical energy efficiency design solutions for a commercial building in Turkey. Energy modeling is the process of building computer modeling in order to analyze its thermal state and energy performance indicators. Such models often employ scenario analysis to investigate different assumptions about the technical and economic conditions. Outputs may include the system feasibility, greenhouse gas emissions, cumulative financial costs, natural resource use, and energy efficiency of the system under investigation. A wide range of techniques are employed, ranging from broadly economic to broadly engineering [1].

Purpose and objectives of the research. The objective of the paper is to analyze the building energy performance indicators, such as heating/cooling loads and final energy consumption, for a commercial building in Turkey depending on climatic conditions and normative building envelope specifications. This analysis is essential for the further investigation of technical systems options.

Research materials and results.

In order to assess building energy performance indicators building energy modelling using specialized software has been performed. Building geometry has been created in DesignBuilder [2], a graphical interface for EnergyPlus software [3]. EnergyPlus is one of the most sophisticated and widely used software used for building energy modelling. It is capable both to perform heating and cooling design calculations and to model the whole year energy need and energy consumption for different end uses, e.g. heating, cooling, service hot water, lighting, interior and exterior equipment, fans and pumps.

In order to use dynamic energy modelling in Turkey, three different cities and their respective normative U-values are selected. These cities are located in three different climate zones of Turkey in order to see the difference between the models more easily. These cities are: Ankara (3rd zone), Istanbul (2nd zone) and Izmir (1st zone). Distribution of climatic zones can be seen on the Figure 1.

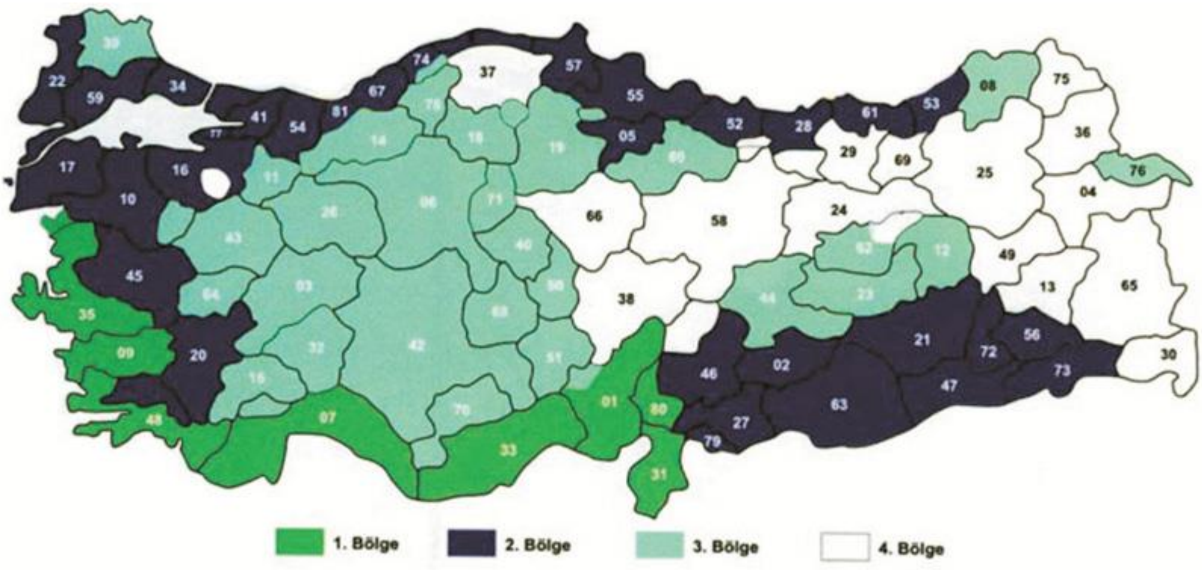


Figure 1 – Climate zones in Turkey [4]

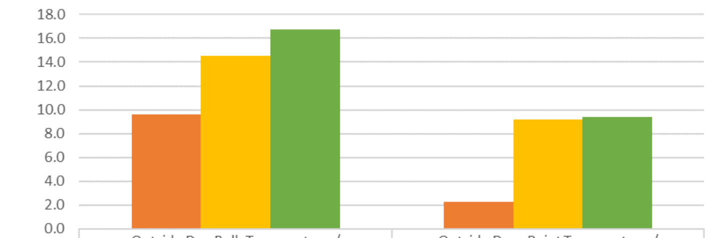
For these climate zones and locations, the following normative U-values are valid:

Table 1 – Normative U-values for building envelope constructions [4]

Regions defined in TS-825	**Walls U_D (W/m²K)**	**Ground floor U_T (W/m²K)**	**Floor U_t (W/m²K)**	**Windows U_P (W/m²K)**
1.Region	0.80	0.50	0.80	2.80
2.Region	0.60	0.40	0.60	2.80
3.Region	0.50	0.30	0.45	2.80
4.Region	0.40	0.25	0.40	2.80

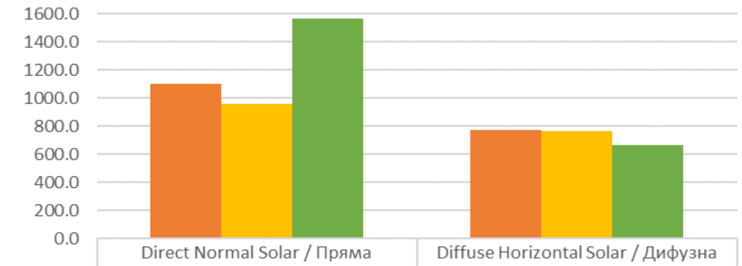
Building energy model takes into account building geometry, building envelope constructions, environmental set-points, exterior climatic conditions, systems types and efficiencies, internal heat gains, work schedules and other parameters. External environmental conditions are accepted based on International Weather for Energy Calculations (IWEC) files for Ankara, Istanbul and Izmir. Profiles of outdoor air temperatures and solar radiation are given on the figures below.

As seen in Figure 2 and Figure 3, cities in 3 different locations and different climatic zones in Turkey were selected. And accordingly, these 3 cities have different U-values. As it can be understood, the coldest of these cities is Ankara (the capital of Turkey), Istanbul is located in the middle, and Izmir is in the hottest climate zone. Although Istanbul and Izmir are located in different climatic zones, since Turkey is not a country with sharp differences between climate zones, these two cities can sometimes provide similar results during the energy modeling. Especially since Ankara is a city located in a continental climate, it is dry and hot in summers and cold and rainy in winters. Figures 2 and 3 confirm this information. On the contrary, Istanbul and Izmir are located in the Mediterranean climate zone. In these seaside cities, the weather is very humid and the winter months are milder.



	Outside Dry-Bulb Temperature / Температура зовнішнього повітря (сухого термометру), °C	Outside Dew-Point Temperature / Температура зовнішнього повітря (мокрого термометру), °C
Ankara	9.6	2.2
Istanbul	14.5	9.2
Izmir	16.7	9.4

Figure 2 – Annual outside air temperature for different locations



	Direct Normal Solar / Пряма нормальна сонячна радіація, kWh	Diffuse Horizontal Solar / Дифузна горизонтальна сонячна радіація, kWh
Ankara	1099.8	774.6
Istanbul	954.8	766.1
Izmir	1561.3	666.2

Figure 3 – Annual data on solar radiation for different locations

Building geometry was based on the actual administrative building located in Kyiv, Ukraine. The model was first calibrated and checked with the use of historical energy consumption. Further, building envelope constructions have been changed according to norms in Turkey for each of the locations. Building envelope thermophysical properties have been modelled for building models for the following constructions: exterior walls, roof, ground floor, windows and doors. Each of the construction materials were characterized by conductivity, specific heat and density, that provides the possibility not only to calculate U-values of building envelope constructions, but to take into account thermal inertial properties as well. 3-D view of the building model and typical floor zoning can be found on the following figures.

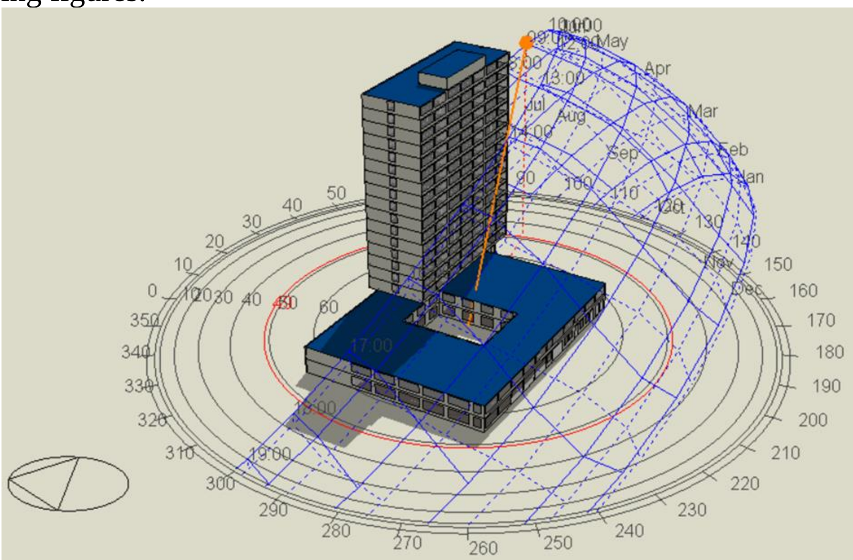


Figure 4 – 3-D model of the commercial building

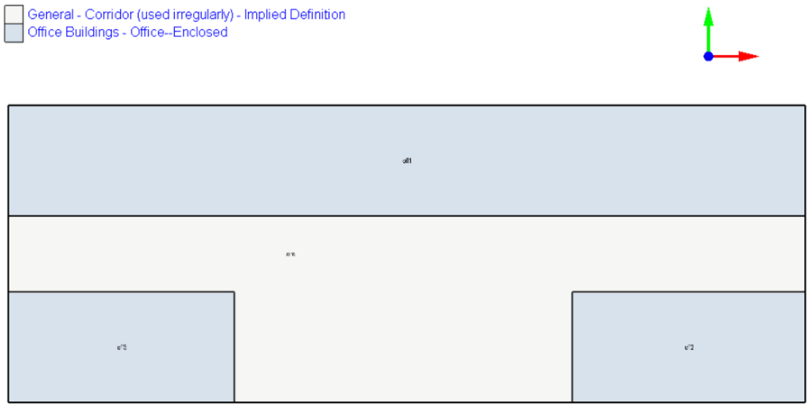


Figure 5 – Typical floor zoning

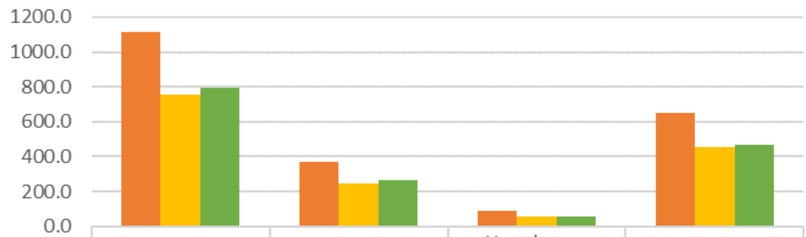
The following input data has been used in the model:

- Gross building area – 16900 sq.m.
- Occupancy density – 10 sq.m. per person
- Lighting power density – 6.5 W per sq.m.
- Equipment power density – 7.5 W per sq.m.
- Ventilation floor rates – 7 l/s per person + 0.7 l/s per sq.m.
- Infiltration – n50 = 1.5 h^{-1}
- Heating set-point / setback – 20/17 °C
- Cooling set-point / setback – 26/32 °C

HVAC system has been modelled with the use of simplified approach and following data:

- HVAC template – fan coil unit + air cooled chiller + natural gas boiler
- Mechanical ventilation – sum per person + per area, energy recovery efficiency – 0.75
- Seasonal heating efficiency – 0.85
- Seasonal cooling efficiency – 1.8
- Seasonal DHW efficiency – 0.85

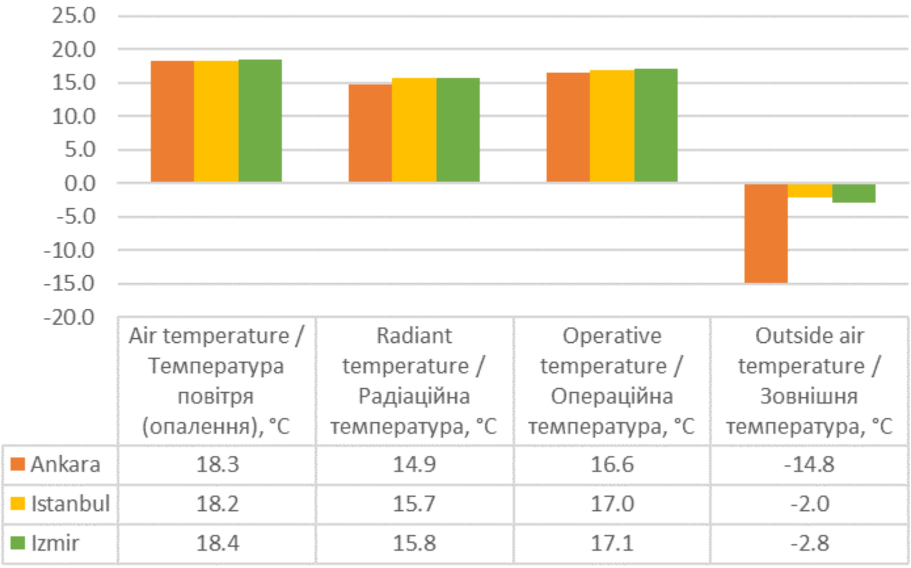
Heating load calculations results for different locations are presented on the figures below.



	Heating load, kW / Навантаження на опалення, кВт	Heat losses (envelope), kW / Тепловтрати через ОК, кВт	Heat losses (infiltration), kW / Тепловтрати через інфільтрацію, кВт	Heat losses (ventilation), kW / Тепловтрати через вентиляцію, кВт
Ankara	1112.0	371.9	86.5	653.7
Istanbul	755.2	242.3	56.6	456.3
Izmir	794.3	267.1	58.5	468.7

Figure 6 – Heating load modeling results

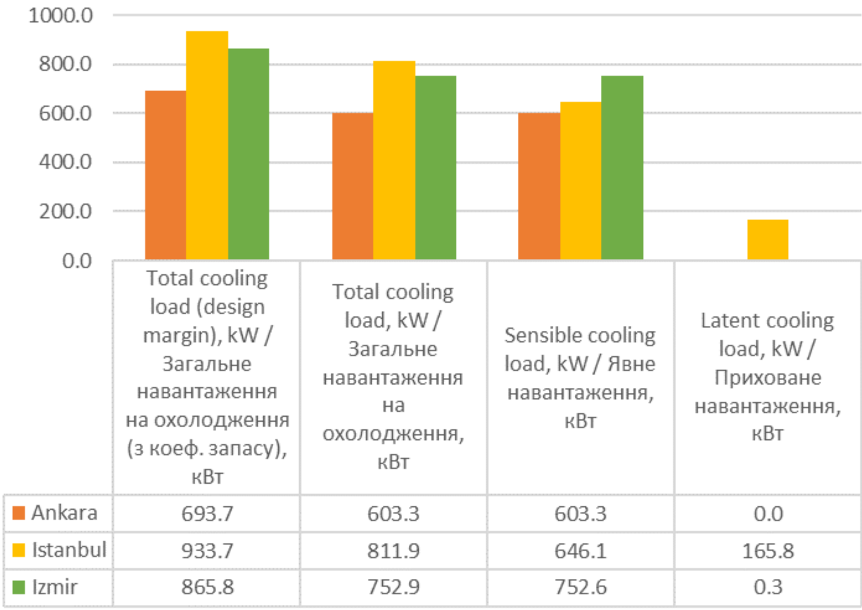
While the heating load shows the highest value in Ankara located in the 3rd climate zone, it is lower than 800.0 kW in the cities of Istanbul and Izmir which are located in the 2nd and 1st regions. However, as it can be seen in the figure ventilation, infiltration, and envelope heat losses in Ankara are 15-20% higher than the other two cities.



	Air temperature / Температура повітря (опалення), °C	Radiant temperature / Радіаційна температура, °C	Operative temperature / Операційна температура, °C	Outside air temperature / Зовнішня температура, °C
Ankara	18.3	14.9	16.6	-14.8
Istanbul	18.2	15.7	17.0	-2.0
Izmir	18.4	15.8	17.1	-2.8

Figure 7 – Comfort and site data for heating load calculations

Cooling load calculations results for different locations are presented on the figures below.



	Total cooling load (design margin), kW / Загальне навантаження на охолодження (з коеф. запасу), кВт	Total cooling load, kW / Загальне навантаження на охолодження, кВт	Sensible cooling load, kW / Явне навантаження, кВт	Latent cooling load, kW / Приховане навантаження, кВт
Ankara	693.7	603.3	603.3	0.0
Istanbul	933.7	811.9	646.1	165.8
Izmir	865.8	752.9	752.6	0.3

Figure 8 – Cooling load calculation results

The cooling load shows the highest value in Istanbul (933.7 kWh) located in the 2nd climate zone, it is 865.8 kWh in the city of Izmir (1st zone) and 693.7 kWh in the city Ankara (3rd zone). In addition to this, since Istanbul is a densely populated city and consequently, it is a city where commercial buildings are used more frequently, the cooling load is higher than in the other cities.

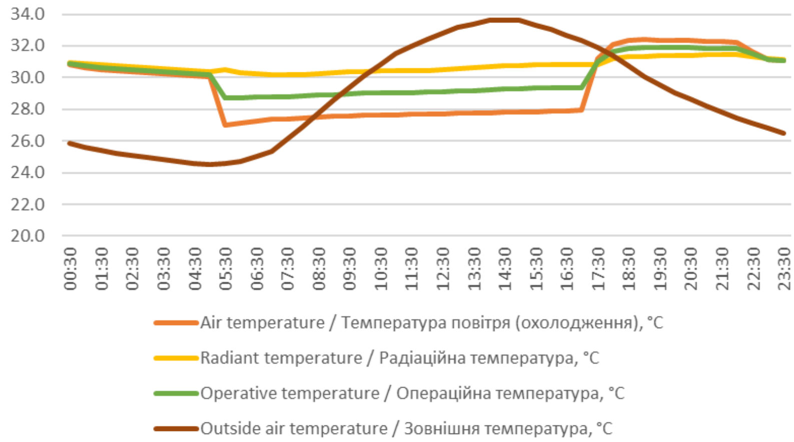


Figure 9 – Comfort and site data for cooling load calculations (Istanbul)

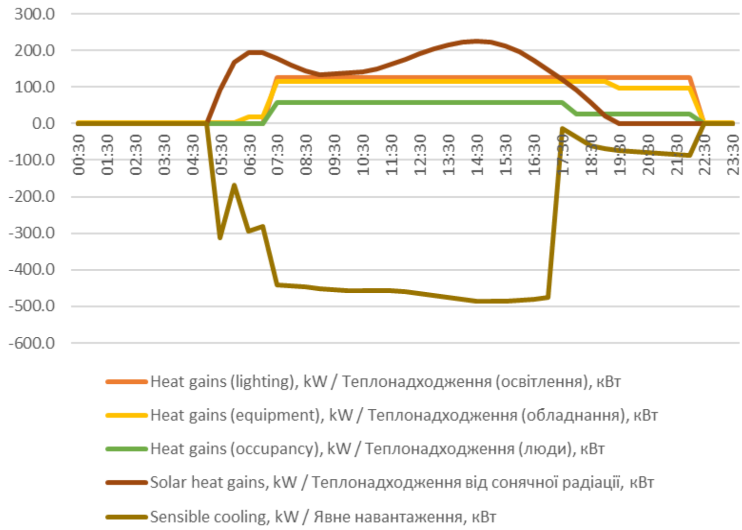


Figure 10 – Heat gains contribution for sensible cooling load calculation (Istanbul)

Annual modelling results include the data on final energy consumption for heating, cooling, lighting, equipment and DHW, comfort and site data for different locations in Turkey.

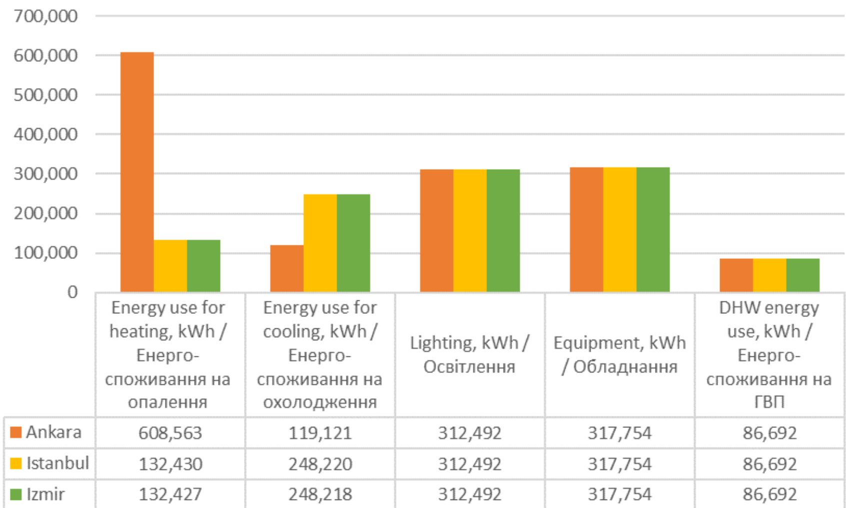


Figure 11 – Annual energy consumption for different locations in Turkey

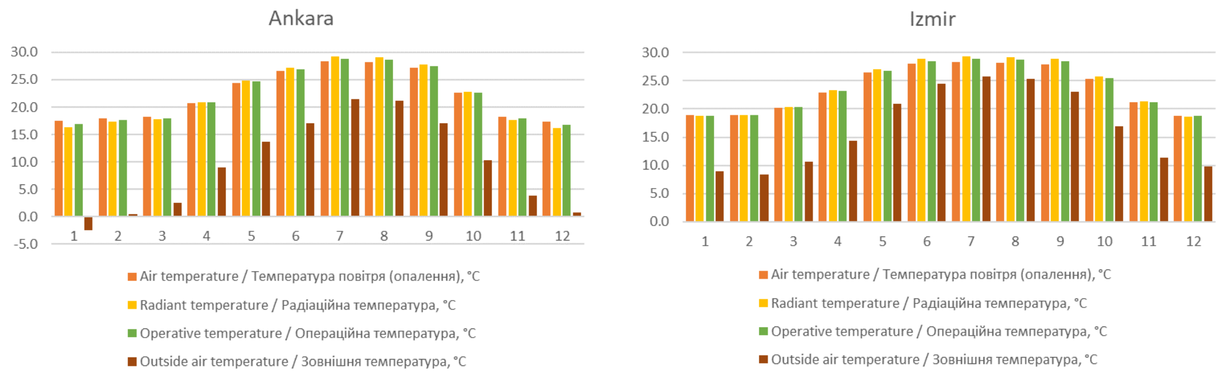


Figure 12 – Annual modelling results for comfort and site data

Conclusion. In the light of the performed analysis, the numerical values known in theory were simulated by modeling and comparison was made for different results under different conditions. During modeling, IWEC data, Turkish Republic standards and European standards were taken as reference. As a result of this analysis performed with the use of different U-values and different climatic conditions, it was determined that Izmir and Istanbul are locations where the heat load and heat losses are lower, on the contrary, the cooling load and outside dew-point/dry-bulb temperature are higher. Ankara, on the other hand, is like a city with continental climate characteristics, with hot and dry summers and cold and rainy winters. And the analysis / modeling results also proved that when these data were brought together, the heating load and heat loss were very high, on the contrary the cooling load and outside dew-point/dry-bulb temperature were very low. Similar results have been obtained for annual energy use for heating, cooling, lighting, equipment and DHW. However, in Ankara, energy consumption for heating is higher and the energy consumption for cooling is lower compared to Istanbul and Izmir.

Next steps will include the detailed HVAC modelling for the following types of systems:

- VRF with heat recovery and dedicated outdoor air system (DOAS)
- FCUs – Air cooled chiller + HW heating + DOAS
- FCUs – Water cooled chiller with fluid cooler + HW heating + DOAS
- FCUs – Water cooled chiller with cooling tower + HW heating + DOAS

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