Evaluation of Facade Performance, in Terms of Thermal Comfort for Health Center Building, EMU

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ABSTRACT

Nowadays, because of lack of traditional sources of energy and high maintenance cost, building as a one of the major energy consumer and its problems in hot and humid regions become one of the main concerns of architects and designers. Also, there is a growing global interest in the impact of human activities on the environment in respect to global warming. The increment of energy demand in the developing world and global warming issues define the need for buildings with fewer problems. With regards to built environment, the primary concern is sustainability in the developments of the building industry and building energy consumption (Djongyang, Tchinda, & Njomo, 2010). This implies consideration of the impact of the climate and environment on the building and ultimately the effect of the building's condition on the occupants. This awareness has initiated many studies related to climatic design to maximize indoor comfort with minimum and efficient use of the energy. Understanding the local weather climatology and learning a reliable prediction process is essential for an architect before designing the building. Today mostly used by the developed countries and it is still an emerging technology (Chou, Chua, & Ho, 2009).

Therefore, in this study, aim is to analyze building facade in terms of to find out how the design qualities of the building, supply indoor thermal comfort. Health center of "E.M.U" has selected as a case study. This research focused on thermal comfort of that building which calculation of thermal comfort factor has been analyzed by TAS software application. This method was explained and used in order to estimate the existing temperature to the highest efficiency effect and reduce the carbon footprint of the building.

Key Words: Facade, Double Skin Facade, Chimney, Thermal Comfort, Natural Ventilation

ÖZ

Günümüzde geneleksel enerji yetersizliğinden dolayı, mimarlar ve tasarımcıların sıcak ve nemli ülkelerde en önemli endişelerini oluşturmaktadır. İnsanların ilgisi, küresel ısınmadan kaynaklanan çevresel anlamda aktiviteleri giderek artmaktadır. Gelişen dünyada giderek artan enerji ihtiyacı ve küresel ısınmadan oluşan sorunlar, bugünkü yapıların daha az problemli olmasını arz eder. Yapılı çevreyi göz ardında bulundurarak, inşa alanlarındaki en büyük kaygı, inşaat sektörleindeki enerji sarfıyatı ve tüketimin gelişmesidir. Yerel iklim ve klimatalojiyi öğrenmek mimarlar için güvenilir bir ön sezgi metotu tasarımda oluşturmuştur. Yeni mimari yapılardaki tasarım çift ön cephe sistemi güncel mimarlığın bir parçası olarak şehir ve çevreyi etkiler. Günümüzde çoğunlukla gelişmiş ve gelişmekte olan ülkelerde teknoloji olarak üremekte rağbet görmektedir. Dolayısıyla, bu çalışma ve araştırmanın amacı, iç ortam sıcaklığı termal rahatlık sağlamak amaçlı ön cephe yapılarının analizidir. Kuzey Kıbrıs Türk Cumhuriyeti'nde, Doğu Akdeniz Üniversitesi Sağlık Merkezi araştırmaya konu olarak seçilmiştir. "TAS" yazılım uygulanması tarafından incelenmiş,tir Bu metot var olan ısıyı tespit etmek ve etkili kullanımı en üst düzeye çıkartmakla binada karbon izinin azalmasını sağlamak tadır.

Anahtar Kelimeler: Chephe, Iki Katmanlı Cephe, Baca, Isıl Konfor ve Doğal Havalandırma

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LIST OF SYMBOLS AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineer
HVAC	Heating, Ventilation and Air-Conditioning
(m2)	Meter Square
(Max)	Maximum
(Min)	Minimum
(%)	Percent
(kg/s)	Kilogram/ Second
(m/s)	Meter/ Second
(l\s)	Liters/ Second
(W)	Watt
(°C)	Centigrade

Chapter 1

INTRODUCTION

1.1 Research Background

The current world population is around 7 billion people, who are always rushing toward a better and more comfortable life, going ahead in the shadow of technology. Buildings are not unaffected by the modern technology, hence they have to provide comfortable environments for their users by regulating temperature, humidity, odors and contaminants in the air. It seems that the best index to measure this comfort and peace is the mental and physical healthiness of human bodies. In this area of research, achievements in medical sciences (especially in diagnosis and treatment sections) and medical engineering play critical roles. Designing a healthcare place is very complicated and requires a lot of specialty and considerations. Healthcare area design should be performed with complete accuracy as well as a crucial plan and enough budget so that the construction and operation of equipment be done without any delay. Moreover, specific additional information must be gathered so to start-up the hospital on time. Thus, regarding the population growth, constructing a health center is a priority in urban planning. If it takes a long time from the beginning to the starting-up period of a hospital construction, it may impact the environment negatively.

Nowadays, as a result of global warming and high use of fossil fuels, architects and designers put more attention to the environment than before. Since buildings are big consumers of energy, achieving sustainability in buildings while being in harmony with the environment are of the main concerns in the developing countries. In other words, climate and environment are two impressive factors on buildings and their users (Serra, Zanghirella, & Perino, 2010). A climatic design can exploit a maximum indoor comfort with minimum use of energy. To achieve an energy efficient design, different factors have to be combined and considered carefully. Orientation and location of the building, and the type of building envelope and materials are some important factors which affect building thermal performance (Parsons, 2006).

In this respect, the awareness about the usage of renewable energy sources provides the possibility to exploit the precious natural resources such as wind, water and solar energy. It has been proven that sustainable architectural buildings reduce the energy consumption of buildings; moreover, the level of hospital staffs' services increase and, as a result, the duration of patients' treatment would decrease.

1.2 Statement of the Problem

The first aim of any building is to protect the occupants from unfavorable outdoor situations, such as cold or hot conditions, wind and rain. In order to create a comfortable indoor environment, architects need to pay attention to all human comfort senses while designing the building. In hot and humid climates, temperature directly affects the comfort level of the indoor environment for occupants. Now a days, researchers believe that controlling the air circulation between patients' rooms is an important issue, added to a bad microclimate which can also be harmful to a patient's health because it possibly will provide an appropriate condition for growing airborne bacteria or viruses such as fungi and tuberculosis.

1.3 Aim and Objectives of the Research

This master thesis contributes to the energy performance evaluation of double skin facade, by means of experiments and simulations. Achieving a suitable indoor environment condition, while declining energy utilization, is one of the most difficult strategies in hot humid climates. Heating, cooling, ventilation and also indoor temperature level play important roles in each climate. Thermal comfort in health care buildings is a significant factor which architects have to consider carefully. Researchers and designers try to find out effective strategies so to provide a proper indoor environment for the occupants. The use of simulation tools during the design period can help the designer to improve building performance; moreover, simulations can be used to predict the indoor climate and the energy use of an existing building. Therefore, the aim of this study is to examine the thermal comfort performance of double skin facade in health care area and find a solution for hot humid climate.

The current study tries to achieve these main objectives:

1) To understand the problem of thermal comfort in hot humid climate
2) To find out effective strategies so to provide a healthy environment
3) To understand how environmental conditions may affect the therapy to speed up
4) To evaluate the thermal comfort of health space through thermal standards (via ASHRAE standard)
5) To find out the advantages and disadvantages of double skin facades

Consequently, the general purpose of this study is to figure out building problems and try to suggest an appropriate solution by focusing on hot-humid climate conditions as well as finding out some solutions to enhance comfort conditions in buildings along with reducing energy consumption.

1.4 Research Scope and Limitation

In this study, the aim is to analyze internal thermal comfort and to evaluate facade performance in terms of design principles, so to find out how the design quality is able to change the indoor environment in the Health Center Building located in the campus of the Eastern Mediterranean University in Famagusta, Northern Cyprus, in 2013-2014. Hence the research focuses on thermal comfort separately in each zone. The focus of the study is then on double skin facade integrated with the chimney to achieve the optimum thermal performance in the health center building, and analyzing the building via TAS software.

1.5 Research Methodology

The methodology which was used in the previous literature is the combination of theoretical issues with empirical examination in collecting data. In the theoretical part, data has been entirely collected from books, articles, scientific journals and previous researches regarding the specific topic. After data collection process, evaluation of the data took place to find out the building's problems in hot humid climate conditions and health-related buildings. Obtained data from the theoretical part was then analyzed in the practical part through measurements and observations.

To calculate the existing temperature and compare it to the thermal performance of the case study, TAS software was used: several simulations were made with various parameters in different seasons. TAS software is one of the powerful energy simulation programs which is used in this thesis to estimate the thermal performance of the selected building.

1.6 Organization of the Thesis

The current study contains four chapters; first chapter presents, research background, statement of the problem, aim and objectives of research, research scope and limitation, research methodology and organization of the thesis. In second chapter, the background information related to the subject chosen was gathered, and a general approach was given to achieve thermal comfort in buildings with regard to sustainability, energy consumption and energy saving. Pointing out several factors which affect the thermal comfort in a building, plus double skin facade thermal performance in hot and humid climate areas in the literature section. In the third chapter, the Health Center building as the case study was analyzed regarding its thermal comfort by the help of TAS simulations and comparison of the simulations with each other. Finally, chapter four includes the conclusion of this study, summarizing the findings in the literature review and the simulations results. The obtained data furthermore illustrates and suggests some solutions for future studies.

Chapter 2

FACADE PERFORMANCE IN THE BUILDING

2.1 Introduction

Facade is an important element in buildings, so energy efficient building designers have started to develop their researches based on this matter. Today, energy usage in buildings have became an important factor due to the limited energy sources, hence, building construction materials and techniques should be considered accordingly in the design period. The main function of the facade of a building is to protect and distinct the interior from the exterior environment conditions (Wigginton & Harris, 2002).

Architects do not see the building envelope as an isolated building component but rather they see it as an integral element with considerable importance in terms of building’s appearance. Building envelope hence is a part of an integral design concept. It should include some functions such as solidity, passive or active environmental control, and special creative expressions. Facade is the main element when observing a building from outside and has effects on the inner part of the building too. Lighting, ventilation, view, and user comfort are all tasks the facade may need to address.

Modern building systems consist of structural, service and envelope components that can be compared to the bones, organs and skin of the human body correspondingly.

Skin protects the body from harmful exterior environments and maintains comfortable conditions for the body. In the same manner, building envelope aims to regulate indoor environmental conditions for human use or occupancy.

Clothing has been especially designed to assist the skin so to protect the body more effectively. In the building envelope industry, new products that control one or more aspects of envelope performance are being introduced every year.

The differences between exterior environment and what constitutes comfortable interior conditions, generate environmental loads on the building envelope. Controlling interior conditions dependends on both envelope and mechanical systems - the latter is usually referred to as heating, ventilating, air conditioning or HVAC - which require energy input.

2.2 Facade Performance

Finding appropriate envelope systems for each building type, usage, and climatic region can dramatically reduce the overall energy input to the mechanical systems. Hence, better envelope designs can improve performance along with reducing energy consumption. A building envelope separates the interior environment from the exterior one. Differences in the two environments generate environmental loads. The most important of these environmental loads can be categorized as: temperature, moisture, and air pressure. Temperature load is generated by both exterior temperature factors [i.e. exterior air temperature, solar radiation, and wind], and interior temperature factors [i.e. occupant activities, ventilation, and heating equipment] (Wigginton, Harris, 2002).

- **Solar Radiation**

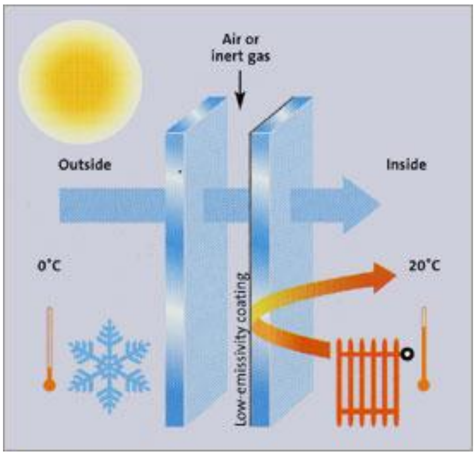
Solar radiation influences building envelope considerably. It induces high surface temperatures, which cause high drying rates, and inward vapor flows, in building envelopes. Radiation travels in a straight line between two surfaces. This fact facilitates the prediction of location, period, and intensity of solar radiation based on sun path and building orientation.

- **Wind**

Most building envelope designs are based on average long term wind pressure data; however, to justify short-duration random wind gusts, gust factor can also be employed. Gust factor is the ratio of maximum wind pressure to mean wind pressure, and is most often used to estimate the accidental moisture gains due to windblown rain.

2.2.1 Types and Materials of Facade

The function and form of current facades and wall constructions are the result of a long process of development, which is related to the history of human shelter. Solid walls were built by available building materials such as naturally occurring stones, wood and early soil bricks while openings were made in the walls to remove the smoke from inside the dwellings. At later times in the development stage, openings were made larger to let the light in. After the development of glass as a building material, ancient people filled their openings in the walls with single panes of glass. This material provided natural lighting inside the building and also allowed the people inside to view out. Development of glass technology made it possible to build much larger windows and transparent panes. The next step was the invention of box window, or double glazing, which consists of two glass panes, joined together with an insulating layer of air or gas which enters in between (Figure 1). After several experiments with different methods of glass material, nowadays, the pane of glass is a usual material which is used in building facades (Knaack, Klein, Bilow & Auer, 2007).



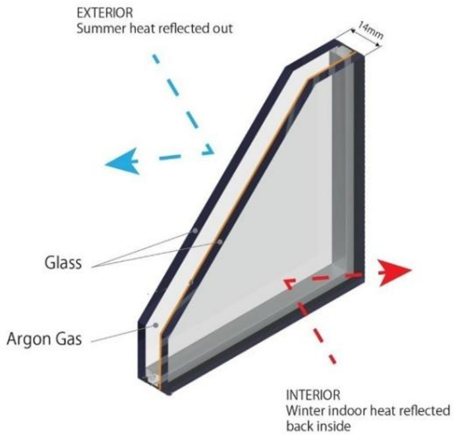


Figure 1: Double Glazing Window.
(Knaack, Klein, Bilow and Auer, 2007)

2.2.1.1 Glass Material

The history of glass can be a traced back to over 7,000 years ago. First proper glass was made in Egypt. At that time glass was used in mosaics form in buildings, but later, after the invention of glass blowing, probably in Sidon (Lebanon), in the 1^{st} century BC, the production of transparent glass was expended.

After the Byzantine and Graeco-Roman periods, glass mosaics were used mostly in the great glass openings of Gothic cathedrals (Cever, 1997). The enormous rise of glass use happened in the 1920s, when glass and steel skeleton were the key elements in modern architecture to achieve transparency, and increase natural daylight, health and social well-being. Also in 1970s, global energy crisis convinced the glass industry to improve their energy-saving policies which would as a result decrease both cooling and heating loads in buildings (Krewinkel, 1998).

A typical glass material is transparent and brittle, and is composed of silicon dioxide (SiO2), sodium oxide (Na2O), lime (CaO), and some minor additives. Glass material allows indoor spaces to get isolated and protected from different weather conditions, while permitting the light, air, sunshine. Nowadays, architectural research conducted on glass material is mostly about optimizing energy and indoor climate performances (Figure 2), (Cever, 1997).

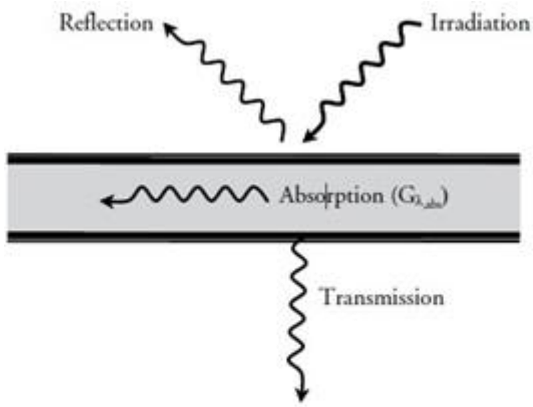


Figure 2: Reflection, Absorption and Transmission of Solar Radiation of Glass (Poirazis, 2008)

The glass surface temperature impacts the thermal comfort of an occupant who stays near the window; during the winter, the glass surface temperature is often lower than the other surfaces, and in summer period, the glass surface temperature is higher than the other surface areas (Hamza, 2008).

Building envelopes should respond to the requirements of the building in different climate. In each climate facade insulation is necessary facture such as, control heat flow and air flow, control water vapor flow and rain penetration, control noise and fire, control light, solar and other radition, be durable, aesthetically pleasing and be economical. From 15 years before until now, facades have become increasingly complex ‘intelligent’ facades, for example, adapt to changing climate and lighting conditions. The intelligent facade are being developed with the aim to increases the user’s comfort level (Knaack, Klein, Bilow, Auer, 2007).

Currently there is a growing attention on using glazed facades in buildings. The implementation of double skin facade system is a useful measure in order to improve the building’s performance and is an attractive solution to solve energy problem.

Double skin facade compared with single skin facade has some advantages such as protecting shading devices, improving the acoustic insulation, and providing natural ventilation (Poirazis, Blomsterberg, and Wall 2008). Particularly this can be a good solution for buildings which are affected by great number of external factors such as daylight, different outdoor temperatures during summer and winter, noise pollution and etc.

2.2.1.2 Double Skin Facade

The architectural design of an office building has an important impact on providing thermal comfort for the occupants as well as reducing the usage of energy. Nowadays, different types of transparent facade are erected in new structures, especially in office buildings. These facades, which are called “Double Skin Facade”, are generally composed of an interior and exterior glazing. The aim of this facade type is to increase internal comfort and decrease energy consumption. A building’s shape and location, integration of passive or active solar systems in it, and the facade’s orientation, are some elements that affect the energy consumption levels in the building.

According to Poirazis (2004), the first example of a double skin curtain wall seems to be used in 1903 in Germany. At the end of the 1920s, this kind of facade was improved with other priorities (Poirazis, 2004). It is evident that glazed office building was initiated and used in 2003 for Swedish climate. Currently, double skin facades are mostly used in contemporary architectural designs in different climate zones.

Double skin facade, as a building envelope system, consists of a pair of transparent surfaces, separated by an air corridor called cavity or intermediate space. The outer glazing is usually a hardened single glazing, and insulating double glazed unit is used for the interior one; solar-control glazing and clear low-E coating can also be used. The extra skin can decrease both heating demand in winter and cooling demand in summer (Alibaba & Ozdeniz, 2011). The width of this corridor is between 20 cm to several meters; it can change according to the function of the applied concept, and is naturally or mechanically ventilated, or fan supported. Solar radiation enters through the external skin on the south face and heats the air in the cavity (Figure 3). During the heating period (in winter), solar radiation will be absorbed, the temperature inside of the cavity will start to increase, and the preheated air will provide good indoor climate inside the building. Double skin facade further decreases heat losses within the cavity. On the other hand, during summer time, overheating problem appears when the facade is poorly ventilated. Due to the stack effect, around 25% of the heat can be ejected by natural air circulation, and the heat can be drawn off through the exterior skin by mechanical or natural ventilation systems. Double skin efficiency depends on many factors such as building orientation, its type and use, level of insulation, operating mode of the double skin, the proportion of opaque and glazed surfaces of the inside skin, and position and type of shading devices (Harris, 2006).

The importance of proper design of double skin facade has been recognized by the Solar Heating and Cooling (SHC), International Energy Agency (IEA), Community Systems, and Energy Conservation Buildings Programmers (ECBCS).

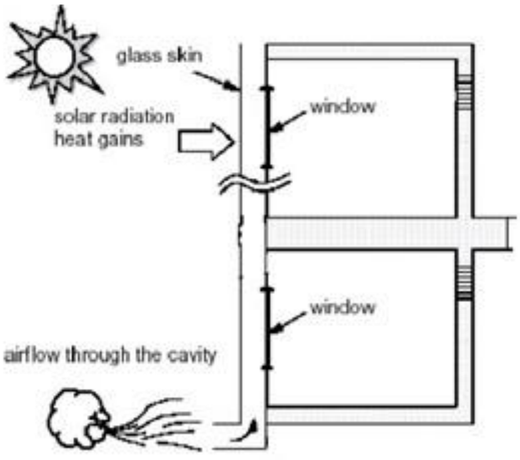


Figure 3: Heating, Ventilation and Air Flow of the Double Skin Facade
(Poirazis, 2008)

2.2.1.2.1 Classification of Double Skin Facade

Based on the cavity being divided along the facade, construction systems can be categorized as follows: shaft box window, corridor façade and multi-storey facade.

- **Shaft Box Window**

If air space be divided into vertical compartments along the height of the facade, it constructs a shaft box window. Continuous vertical shafts extend over a number of stories to create a stack effect consist of an alternation of box windows and vertical shaft segments (Figure 4).

Figure 4: Shaft Box Window
(Schulze, Eicker, 2013)

Vertical shafts are linked with the adjoining box window on every storey with a bypass opening. The air from the box window is drawn by the stack effect into the vertical shafts and up to the top. Smaller size external openings are also required so to provide higher levels of sound insulation. These types of facade are suitable for buildings located in high noise areas where a high level of sound insulation is required inside the building (Harris, 2006).

- **Corridor Facade**

The intermediate space in corridor facades is closed at the level of each floor. Divisions are only made along the horizontal length where acoustic, fire protection and ventilation is needed. Air-intake and extract openings should be located near floor and ceiling, usually in staggered forms (Figure 5). They are mostly used for ventilation and also sound insulation between rooms (Knaack, Klein, Bilow, Auer, 2007).

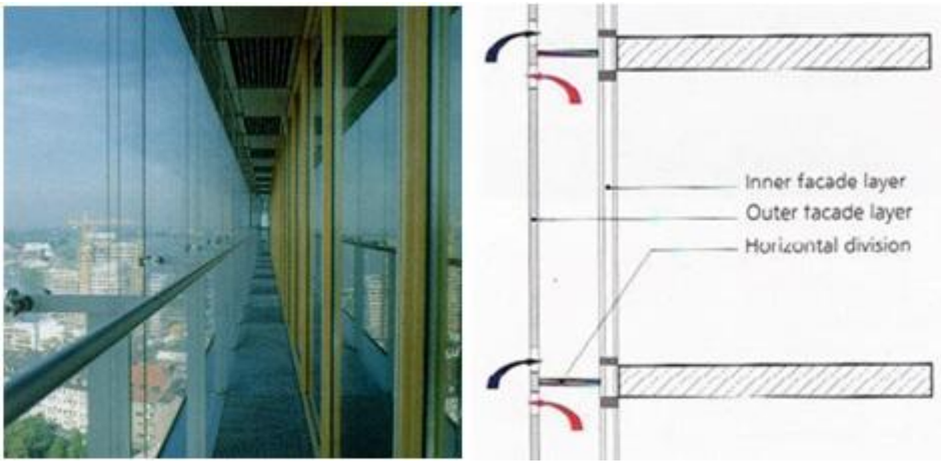


Figure 5: Corridor Facade
(Schulze, Eicker, 2013)

- **Multy- Storey Facade**

The intermediate space is linked vertically and horizontally by several rooms. Sometimes the space can extend to be placed around the entire building. Ventilation takes place only near the ground floor and the roof. When heating is needed, openings can be closed. These openings are useful when external noise levels are very high. The rooms behind the facade usually have to be mechanically ventilated. Facade is then used for a joint air duct. This kind of double skin facade is most commonly used in short buildings (Figure 6).

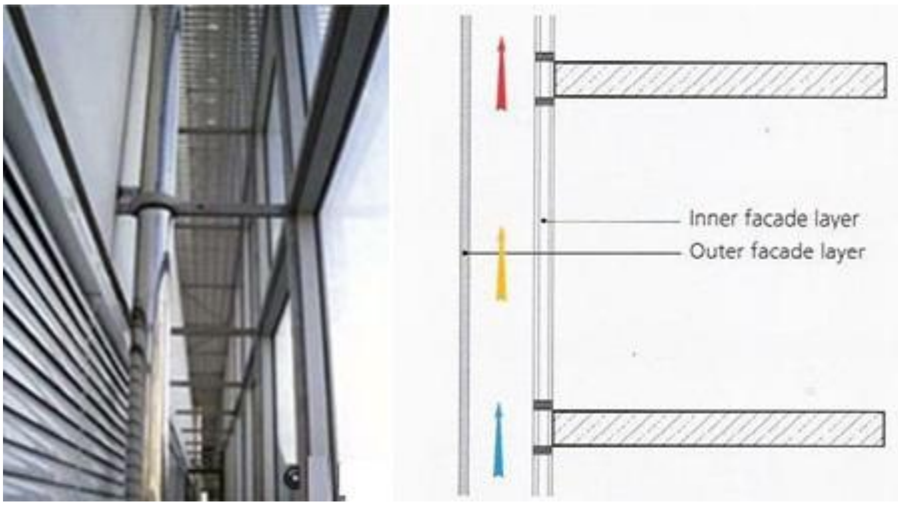


Figure 6: Multi-Storey Facade
(Schulze, Eicker, 2013)

To improve the function of this kind of facade during summer, it is suggested to integrate the facade with a chimney for better air circulation between cavity and inner part of the building. By use of this strategy, the air is brought into the cavity and exhausted by the stack effect and wind pressure, which as a result generates natural ventilation inside the building. The DSF then significantly improves the building's energy behavior (Schulze & Eicker 2013).

2.2.1.2.2 Some Advantages and Disadvantages of Double Skin Facade

Advantages:

- Thermal comfort and thermal insulation
- Natural ventilation and increase ventilation quality (Figure 7)
- Acceptable internal surface temperatures during the summer and winter
- Reduce of heating request in winter and cooling request in summer
- Visual comfort and acoustic insulation
- Energy efficiency and reduce of environmental impacts and lower construction cost
- Transparenty, architectural design

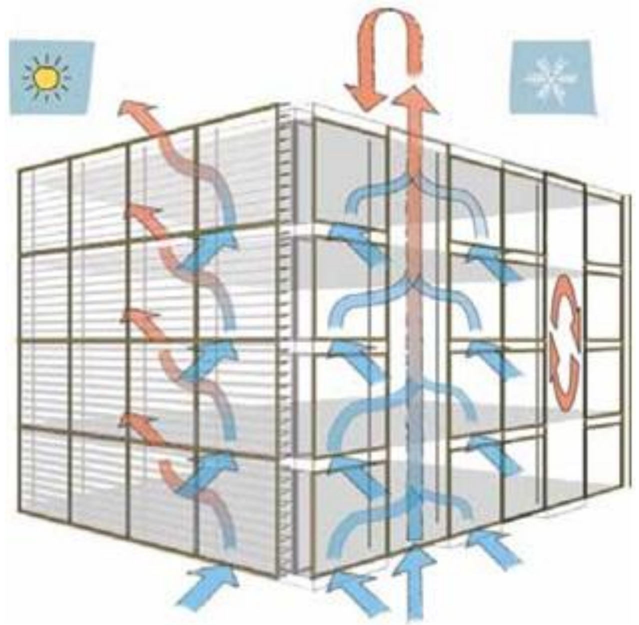


Figure 7: Double Skin Facade and Wind Circulation
(Poirazis, 2004)

Disadvantages:

- Inside acoustic insulation (sound transmission room to room or floor to floor, if the facade isn't designed properly)
- Overheating during the hot period (if it designed without ventilation)
- Fire protection
- Reduction of rentable office space (the loss of useful space by width of the intermediate cavity)

There are various models of DSF which is separated by:

- Type of DSF (shaft box window, corridor and multi-storey facade)
- Geometry of the facade (width of the openings, height and width of the cavity and etc)
- Type of panes (clear glass, solar control glass)
- Combination of shading devises by panes (venetian blinds, louvers and etc)
- Heating, ventilation and air-conditioning strategy (natural and mechanical)
- Air flow direction (to the top or to the bottom)

2.3 Thermal Comfort

Thermal comfort refers to the reaction which humans show toward heat and coldness in a place (via ASHRAE standard). The following factors affect the thermal comfort: four physical variables (air velocity, air temperature, mean radiant temperature, and relative humidity), (Figure 8), and three personal variables (clothing insulation, activity level and body metabolic rate) plus several other secondary factors which can have effects on comfort such as gender, season and circadian rhythms, day-to-day variations, adaption and age. In order to create a comfortable condition for humans in terms of temperature, an important issue which should be considered is providing thermal comfort (Fanger, 1970).

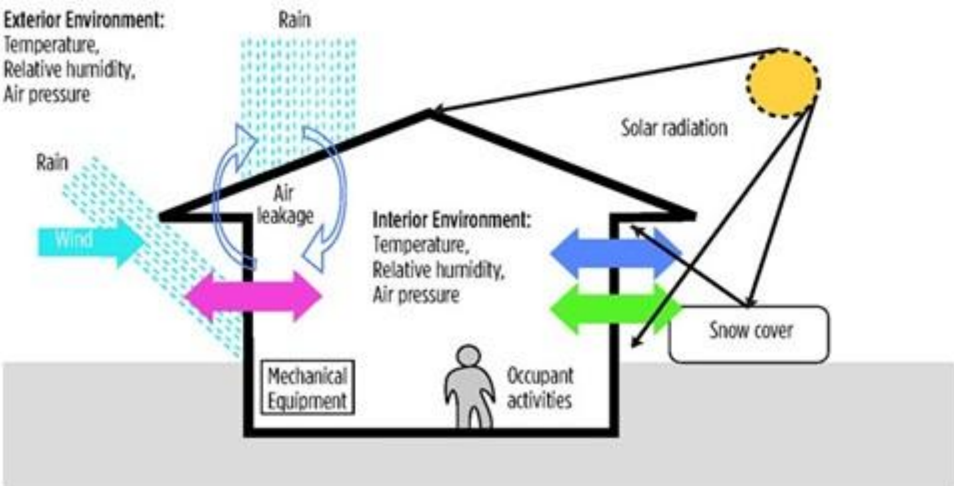


Figure 8: Physical Variables
(Kleiven, 2003)

Indeed the climate in each country with different climate zones varies in relative humidity, air temperature, global temperature and air velocity; therefore, comfort zone can have different values. According to ASHRAE (2009) there is no difference between inside thermal conditions for comfort during summer and winter periods. However, the preference of an inhabitant for thermal comfort may change during the day. The body has a lower temperature rhythm in the early morning hours and a higher one in the late afternoon. There are also specific thermal comfort standards in air-conditioned buildings. Thermal comfort temperature is 26°C, with 60% relative humidity and 0.2 m/s air velocity (Fanger, 1970).

Conversely to winter time when the body temperature decreases, in summer time, it will increase. These issues affect thermal comfort level for the building occupants; it can be combined with excessive moisture content (relative humidity), which is another important factor that can provide an uncomfortable thermal environment

(Figure 9). There is no real absolute standard for thermal comfort of the humans, however, the standards used are usually 4-6 air changes per hour when using heating or cooling mechanical systems, while the minimum outside air ventilation per person, for any kind of space, is 8 l\s. The number of air changes can reduce when the room is vacant. In hospitals and health centers, for patient rooms, labor and recovery air changes reduce to 4 with heating or cooling mechanical systems (Krewinkel, 1998).

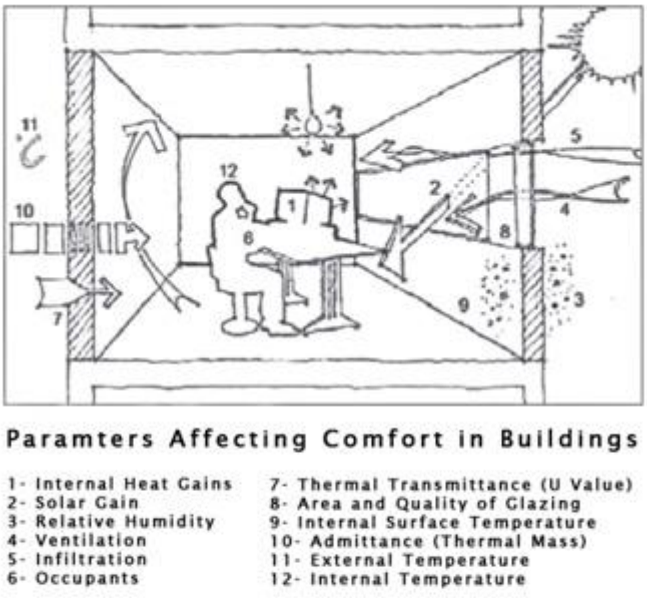


Figure 9 : Parameters Affecting Comfort in Buildings
(Allard, 1988)

Thermal indoor environment and ventilation are of important issues in a health center in order to achieve human thermal comfort, health or improved productivity. The need for a special design and indoor thermal environment is of the concerns of both engineers and inhabitants (Verderber, 2010). It is noticeable that patients need a warmer indoor environment than lusty people. Medical care and medicines affect patients' metabolism. A cold environment creates an uncomfortable sensation that can increase aggravate pain, restlessness, inattentiveness, shivering, muscular and joint tension, and as a result, low satisfaction for patients (Kaushal, Saini, & Gupta, 2004).

A suitable thermal comfort, in general, can be achieved by the temperature being between 24°C and 26°C. In a healthcare area, indoor air temperature, according to the international standards for medical conditions and activities, is between 20–24°C. Body skin temperature, while in a sedentary activity, is 33°C to 34°C and less; whereas internal temperatures increase with activity. A temperature more than 45°C can cause irreversible brain damage and less than 18°C can also lead to serious cardiac arrhythmia and death. Therefore, careful controlling of body temperature is crucial for comfort and health (Fathy, 1986).

2.3.1 Thermal Comfort Problems in Hot Climates

In a hot climate, high heat loss during winter and high heat gain during the summer period can affect the thermal comfort level; hence, these should be considered as the main issues in providing cool indoor environment and generating thermal comfort conditions by increasing air movement (Yilmaz, 2007).

In hot humid climate zone, buildings normally face three main factors with respect to the thermal comfort principles:

- Excessive heat gain in summer
- Excessive heat loss in winter
- High relative humidity level

In such climate zones, large amounts of energy are used in buildings, therefore, high financial costs are generated which require high amounts of money to be spent so to provide thermal comfort for residents (Nicol, Humphreys, & Roaf, 2012). In addition to the immoderate loss and gain of the heat, controlling moisture is another important factor which has to be considered through air ventilation (Fanger, 1970).

To achieve the previously mentioned aim of the research, architects as building designers have to evaluate some aspects in the design stage such as the building orientation and envelope details (opening, solar control, shape, insulation) in order to control the sustainability and thermal performance (Baker & Steemers, 2000).

2.3.2 Factors, Which Influence Thermal Comfort in Hot Climate

Normally when air is heated, it moves up and replaces the cooler air; thus a wind flow occurs. This can be used as a strategy for achieving acceptable indoor air quality and thermal comfort with reduced energy consumption. Natural ventilation works based on two issues: wind and buoyancy. Along the building envelope, the difference in wind pressure and also the difference between outdoor and indoor temperatures generate natural air exchange between outdoor and indoor spaces. Passive natural cooling generates energy by the usage of outside air flow, cooling it out and ventilating it to the building, without using fans or any other powered mechanical systems. Passive cooling systems are typically used in designing the new buildings, but there are also some cases where existing buildings were able to benefit from using the same principles.

Wind flow can create comfortable conditions: when dry-bulb temperature blows the body temperature, wind can cause a favorable cooling. In contrast, when relative humidity or temperature is very low, body will lose too much heat and it will suffer from the ventilation; or even if the dry-bulb temperature is above the skin temperature, the air circulation causes unpleasant and discomfort situation. In hot-humid and high temperature-humid climates, during the times when the temperature is highly effective, there should be an effort for receiving the winds in and around the buildings (Schulze, Eicker, 2013).

Windows, on the other hand, can cause localized discomfort environment due to cold radiations in winter, or solar gains in summer. Nowadays, we can control the ventilation by opening and closing the aperture with an advanced technology in adjusting windows, both to provide ventilation in warm conditions, and to completely stop the ventilation in cold climates. A well-designed and positioned window should allow adequate ventilation on breezy or warm days, without causing uncomfortable draughts (Alloccaa, Chenb, & Glicksma, 2003). Producing natural ventilation has been the main challenge in a hot humid region for a long time in order to keep the thermal comfort inside buildings. Natural ventilation can also be used as an energy-conserving design strategy to reduce building cooling loads by removing the heat stored in the buildings' thermal mass. Evaporation reduces humidity and makes the environment cool, so by the usage of wind and generating natural ventilation, the saturated air is removed, increasing the rate of evaporation and supply of fresh air to the space and removing unhealthy air. This is the main strategy used for reducing heat and humidity in hot humid climates.

Natural ventilation has useful measure to:

- Improve energy consumption in buildings
- Increase the indoor air quality
- Access higher level of day light

"Natural ventilation as a strategy for achieving acceptable indoor air quality is essentially based on the supply of fresh air to a space and dilution of the indoor pollution concentration (Santamouris& Asimakopoulos, 1995).

There are two major categories for ventilation: using natural air flow and ventilation by means of mechanical devices. Natural or passive cooling includes cross ventilation and passive stack ventilation.

2.3.2.1 Cross Ventilation

Cross ventilation can be achieved by opening windows on both sides of a room, causing airflow across the space. Positive pressure on the windward and vacuum on the lee side of a building causes air movement across the room (Figure 10).

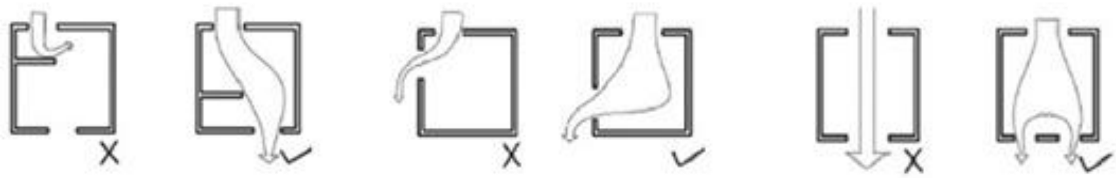


Figure 10: Keep Partition Away from Window, Outlet Larger than Inlet, Distribute Air throughout the Room
(Emmerich, Dols & Alexy, 2001)

Generally, a smaller window size should be located in windward side of the building, and comparatively, the bigger one, which is in leeward direction, improves the air circulation (Figure 11). In addition, night ventilation is one of the most effective passive cooling techniques .This strategy can decrease cooling load by 40% and daily temperature up to 1.5°C (Santamouris, 2007).

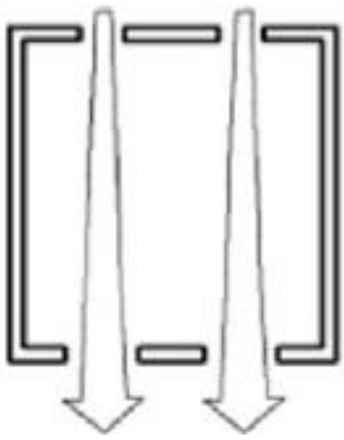


Figure 11: Local Window Position for Distributing Air
(Emmerich, Dols & Alexy, 2001)

2.3.2.2 Passive Stack Ventilation

Ventilation can be achieved by utilizing the ‘stack effect’ plus the driving force of the wind (Figure 12). This system brings fresh air into the building and removes stale warm air from high level openings; exploiting the fact that as warm air rises, the air pressure within the space decreases, thus more cool air would be drawn in as the room air is displaced.

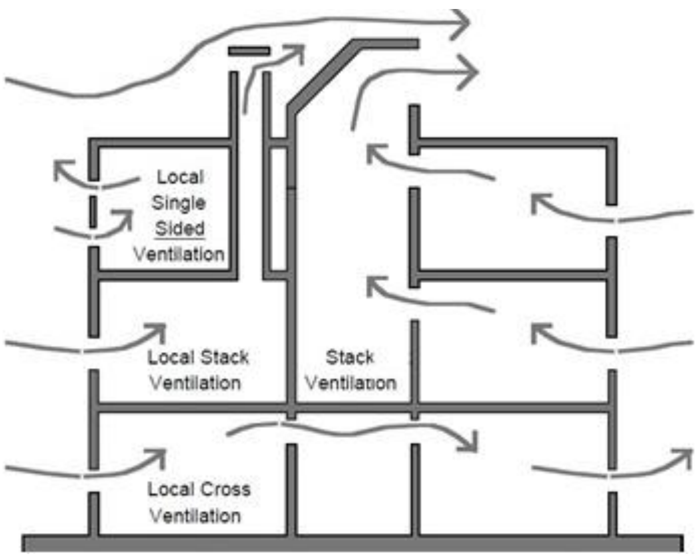


Figure 12: Stack Effect
(Brown, Mark, 2000)

This strategy is used often at the top of a chimney or atrium. A solar chimney uses the sun's heat to provide cooling, by the help of stack effect. Solar heat gain warms a column of air, which then rises, pulling new outside air through the building. Solar chimney is also called thermal chimneys or thermosyphons.

Advanced solar chimneys can involve Trombe walls or other means of absorbing and storing heat in the structure so to maximize the sun's effect, and keep the process working even after the sunset. Unlike a Trombe wall, solar chimneys are generally in their best situation when insulated from occupied spaces; so they do not transfer the sun's heat to those spaces but only they provide cooling (Figure 13),(Brown, Mark, 2000).

If the top exterior vents are closed, the heated air is not exhausted out from the top; at the same time, if high interior vents are opened to let the heated air into occupied spaces, it will provide convective air heating.

This strategy works even on cold and relatively cloudy days. It can be useful for locations with hot summers and cold winters, switching between cooling and heating by adjusting the specific vents to be opened or closed (Brown, Mark, 2000).

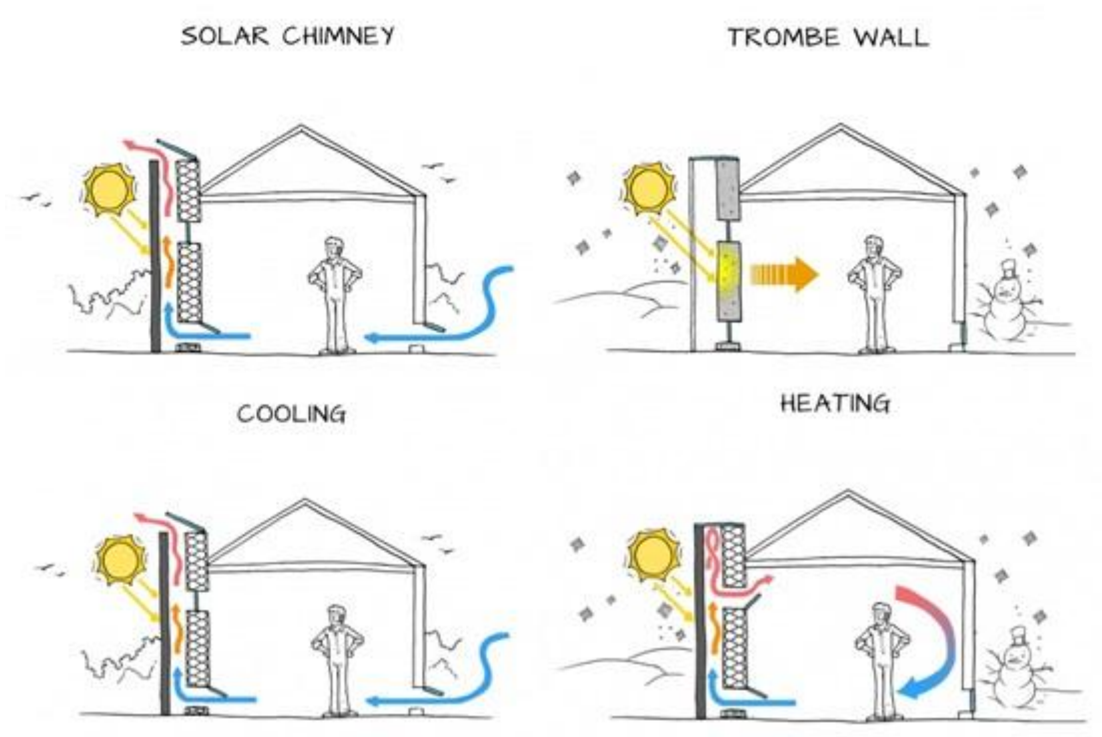


Figure 13: Solar Chimney
(Brown, Mark, 2000)

2.3.2.3 Wind Control

Wind flow effect is an important factor that should be controlled. It affects the external elements and increases the loss of heat in winter times. In order to control wind, we need to know how it moves around the building and what its effects are. According to the considered field study, principles of wind flow in Gazimağusa, Northern Cyprus, which is surrounded by the Mediterranean Sea, can be mentioned as follows:

- **Wind Caused Around Coastal Area**

Daytime wind flow in coastal area moves from the sea to the land. Solar energy heats the land to be warmer than the sea surface in daytime, and transmitted heat to the air above causes the air density to decrease, and as a result of which a natural upward trend of air circulation occurs, thus the wind flows from the sea to the coast and replaces with the warmed-air (Figure 14), (Emmerich, Dols, & Alexy, 2001).

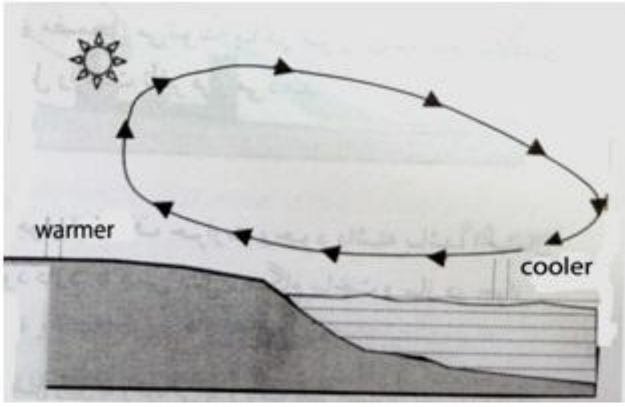


Figure 14: Wind Flow from Sea to Land
(Emmerich, Dols, & Alexy, (2001)

At night time, wind flow in coastal area moves from the land to the sea. At nights, the warmed-land loses its heat, so the sea surface temperature would be higher than the coastal land; thus the air above the sea rises because of lower air density and the coastal cooler air flows to the sea (Figure 15). Natural wind flow from the land to the sea then takes place at night (Emmerich, Dols, & Alexy, 2001).

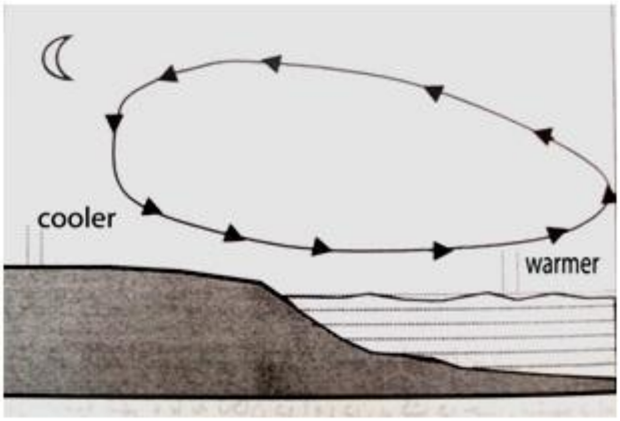


Figure 15: Wind Flow from Land to Sea
(Emmerich, Dols, & Alexy, (2001)

■ **Height of the Building**

Height of the building is an important factor for using natural wind flows (Figure 16). The buildings cooled by natural ventilation should face to windward orientation (Fordham, 2000).

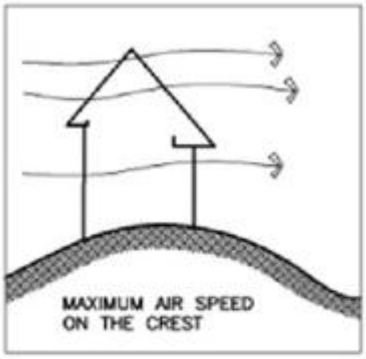


Figure 16: Maximum Air Speed on the High Level
(Fordham, M, 2000)

■ **Building Direction**

Both sun rays and wind flow in cities can cause comfort situations for residents. A north-south direction for the building should be selected for blocking sun radiation, preventing excessive heating during late mornings and early afternoons in the street, and utilization of natural wind flow in the street spaces needs to be oriented parallel to the prevailing wind (Fordham, 2000).

■ **Open Spaces and Built Form**

Open spaces and built form in hot-humid climates have important roles. Buildings with a narrow plan in west-east direction, facing prevailing wind, can improve the ventilation. In the hot humid climate, as was the case of the considered field study, green areas are used as shading, which cools the building environment and assists in energy saving, as one of the most effective strategies. It was proved that implanting a sole tree in a house can cause 12% to 24% energy saving for cooling. Moreover, 17%

to 57% reduction in energy consumption levels can be achieved by adding three trees (Figure 17) (Fordham, 2000).

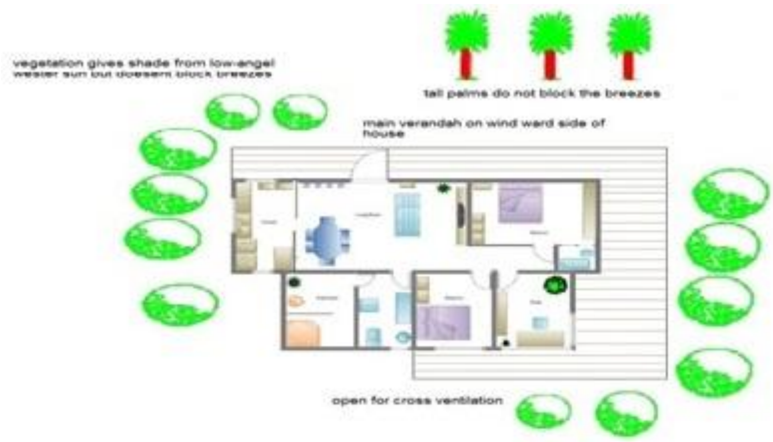


Figure 17: Building Plan in Hot and Humid Climate
(Fordham, 2000)

- **Opening**

Windows as the most important opening elements in buildings do bring illumination to the rooms, daylight, and natural ventilation in spaces. Both direction and size of the windows have important effects on improving natural ventilation and reducing energy consumption by air conditioners (Geros, Santamouris, Karatasou, Tsangrassoulis, & Papanikolaou, 2005).

Even an small window can generate natural ventilation in any climate, making the space cool or warm. Natural ventilation can be achieved through the windows openings on opposing walls, which is called cross ventilation (Figure 18). The picture below exemplifies how air movement within a room can be circulated (Brown & Dekay, 2000).

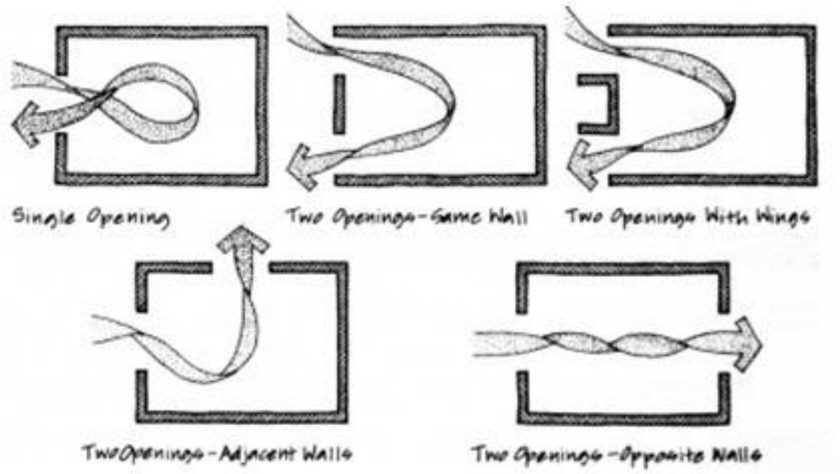


Figure 18: Cross Ventilation
(Brown, Mark, 2000)

Traditional architecture has achieved a relativity successful climate, but nowadays the lessons from those patterns are forgotten by most of the building designers. Furthermore, most of the new constructions are designed depending on fossil fuel energies to achieve comfort environment. With a suitable passive design based on the local climate, designers can achieve less energy consumption by fossil fuels. Correct design improves the indoor condition and increases airflow inside buildings (Montazeri, 2011).

Climate in each region and different zones varies, therefore, comfort zone can have a singular value. In general, there are standards for thermal comfort temperatures in buildings, having 60% relative humidity, 26°C indoor temperature, and 0.2 m/s air velocity (ASHRAE Handbook, 2009).

In hot humid regions, actually natural ventilation is the most important key factor while wind is the main part to generate natural ventilation and air circulation. To achieve the air flow and remove the unhealthy air, apertures should be located in the facades which face to the dominant summer wind, so to attract fresh air.

"When streets are parallel to the wind direction and the buildings along them face the street, the ventilation potential of the buildings is compromised" (Givoni, 1998).

These days, air-conditioning systems (mechanical ventilation) are used in most offices and residential buildings. These types of air conditioning systems cannot control relative humidity and temperature at stable levels. Consequently, another device is needed to reduce or increase humidity so to save energy costs.

Mechanical fans create mechanical ventilation, which nowadays is supplied in indoor area, however mechanical ventilation system also has problems such as:

- High financial cost of money
- Harmful for natural environment
- Consumption of natural resources fuel
- Poor maintenance , poor design or utility service interruption

Currently there is a substantial volume of literature conducted on thermal comfort studies of healthcare and hospitals buildings. In healthcare areas, ventilation plays an important role in supplying fresh air from outdoors with respect to the temperature so to control the disease. Good indoor air quality affects the infection control and can be used as a part of treatment. Engineers should understand completely the patients' thermal requirements in hospital environments. Necessity for the design of HVAC (health, ventilation, and air conditioning) systems in health center was published in 1949. Hygiene and safety are the main factors privilaged to establish hospital standards. Control of the air flow between the spaces in healthcare areas is the most important factor which can prevent pollution diffusion. In the World Health Organization (WHO), natural ventilation is an acceptable method of ventilation in the hospital area (Ormandy, Ezratty, 2012). Natural ventilation in health center facilities is a significant issue; ventilation by replacing the air in any area can control temperature or remove unpleasant air and heat in addition to resupplying fresh air and oxygen; it can be useful to lower energy consumption in spaces and time as well as decreasing environment problems (Atkinson, Chartier, Pessoa-Silva, Jensen, seto).

In most places, ventilation is used for comfort, but in the health center building, the rate of ventilation can help and be useful for disinfection of air and odour control, for in this area, airflow can directly affect patient care. Ventilation design system should supply air movement, which is generally directed from clean to less clean areas, and air from contamination areas shall also be guided toward outside, not arriving at other areas. Air flow inside the building can control the spread of humidity and make the temperature rise, increasing the growth of fogs and bacteria, making the viruses active or deactivate in the hospital area. As a variable of thermal comfort conditions, air movement inside the building can spread or control diseases in hospitals. It is good to point out that protecting patients against infection, and supplying a good indoor air quality, are the main concerns of heathcare places (Figure 19).

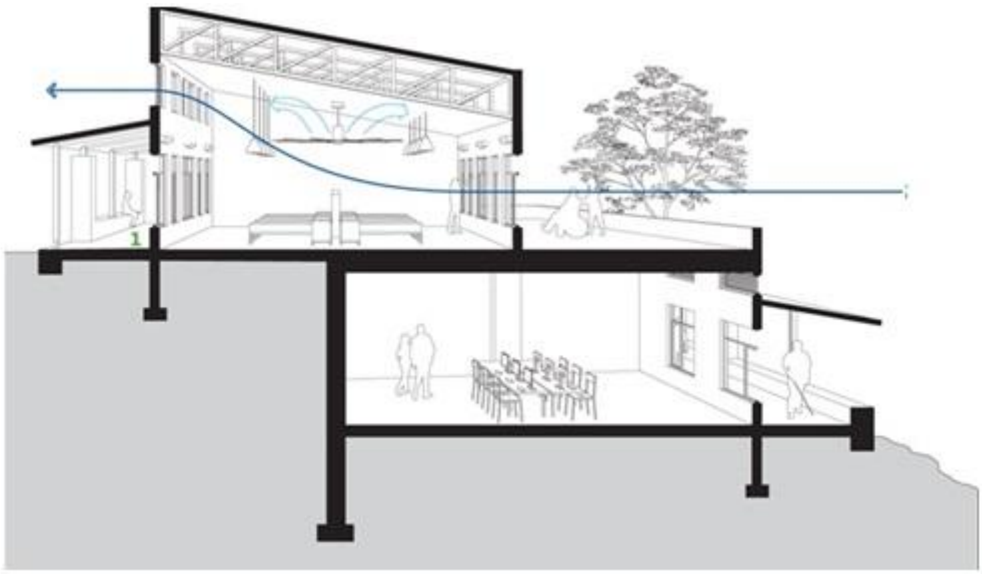


Figure 19: Natural Ventilation in Health Center Building
(Ormandy, Ezratty, 2012)

The design of buildings depends on human comfort, especially in hospital buildings. Patients, personnel and other relevant persons are under the risk of contagion through germs, bacteria, virus. Moreover, relative humidity should remain less than 50%, not going over 60%., cause its raise can rear the distribution rate of influenza virus. Hence, comfortable thermal environment is important for peoples' health in hospitals and is helpful in stabilizing moods of staff, and assisting the patients (Brager , Dear, 1998).

According to UK hospitals, over 40% of energy consumption stands for space conditioning. The UK department of health technical accepts natural ventilation as a satisfying method of ventilation for healthcare places. Approved air is gained when it changes six times per hour, so it is called an acceptable air circulation (Adamu, Price, & Cook, 2012).

However, a good indoor air quality affects the infection control which can be a part of treatment, but preparing a comfortable thermal situation helps to stabilize the emotional moods of the ill person, helping them in their healing process (Khodakarami, Nasrollahi, 2012).

The quick development in constructions around the world has created poor and costly indoor environments. Most of the buildings are constructed without considering local climate conditions, therefore, there was a quick increase in the use of cooling systems and electronic ventilation systems instead of natural ventilation. Hence, these kinds of buildings can bring about excessive, unnecessary energy consumptions. Alternative natural ventilation strategies have operational costs, as well as lower carbon in comparison to mechanical ventilation. Since most of the people spend 90% of their time inside buildings, ventilation in this area is necessary for everybody. Indoor area with a thermal comfort means a place where 80% of all inside residents can approve the environment condition.

According to the high summer heat and also high cost of electric energy in hot-humid regions, natural ventilation can be a solution to answer these problems. In the design section of buildings, both the positive and negative points of the local climate should be considered. Building orientation, solar energy, the appropriate use of heat, light, air circulation and local wind around the building, play important roles in these climate (Clements-Croome, 2003). In contemporary buildings, by use of chimney and vertical ventilation element building achieve the natural ventilation and increases the indoor thermal comfort situation.

2.3.2.4 Chimney and Wind Catcher

Sustainable architecture seeks to be in harmony with nature and environment emphasizing the global environment and local ecosystem. In one word, the harmony with environment is the aim for preserving the sources for the afterward generations, but in the past they erected their constructions in adaption with their environment and climates by means of architectural elements. Wind catcher as a natural ventilation construction is increasingly used in contemporary buildings to reduce the consumption of non-renewable energy and minimize the harmful emissions, and suggests different solutions for adapting with environment's potentials, by using natural energy such as wind by supply wind catcher and chimney, which create air flow without any mechanical methods. Wind is a powerful force that should be harnessed and harvested to maximize its potential positive contribution to the indoor environment and also it is an effective solution to improve indoor air quality (Mikhail, El Damatty, 1999). Height, place and the number of openings and cross section of the air passages are the main issues which affect the ventilation performance of a chimney structure (Figure 20).

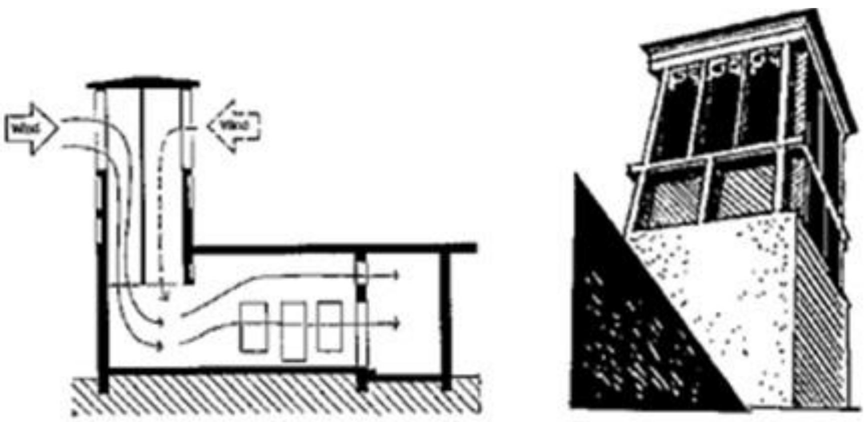


Figure 20: Vertical Ventilation Increases the Thermal Comfort Situation
(Mahmoudi, 2009)

Advancing the knowledge and technology mechanical methods helped architecture to make comfort condition. By passing the time and population growth and urban progress requirement of energy and raw material increased; raw materials and energy which most of them roots in fossil fuel, causes environment pollution, is limited it is not too far to be depleted thus usage trend have to be changed. The more passing time the more problem emerged and architects force to adopt themselves with environment much more than previous. Green architecture seeks to be in harmony with environment emphasizing both in local ecosystem and global environment. In one word, being harmony with nature is a goal for preserving the sources for the next generations in these days but in the past they built their constructions in adaption with their climates by means of architectural elements (Mahmoudi, 2009).

2.3.2.4.1 Chimney in Ancient Architecture

Usually Chimney can be found in traditional Iran and Egypt architecture, which affected throughout the Middle East structures; including in Afghanistan, Pakistan and the Persian Gulf states (Figure 21, 22). Architecture suggests various solutions for adapting with environment's potentials. They could make a comfort condition by using local materials. Wind and solar energies and their creative architectural elements; such as roofs shape, using huge and thicken walls, utilizing handy materials such as mud, mud brick, stone, brick, mortar, lime and wood. With a glance at ancient buildings in desert, it can be easily seen that the building was constructed with most adaption with their situation in a simple way. Green architecture which seeking to lessen the negative effects on environment and erecting buildings adapted with environment is used in a simple way in Iran historical architecture.

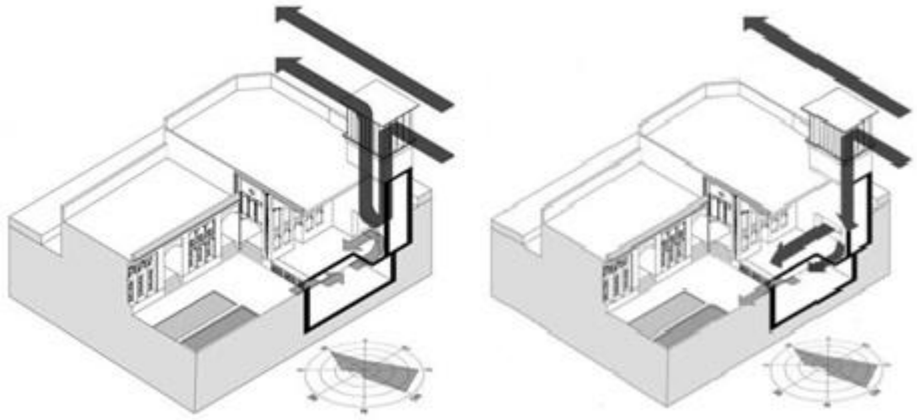


Figure 21: Diagram of Operation of Chimney in Iran
(Mahmoudi, 2009)

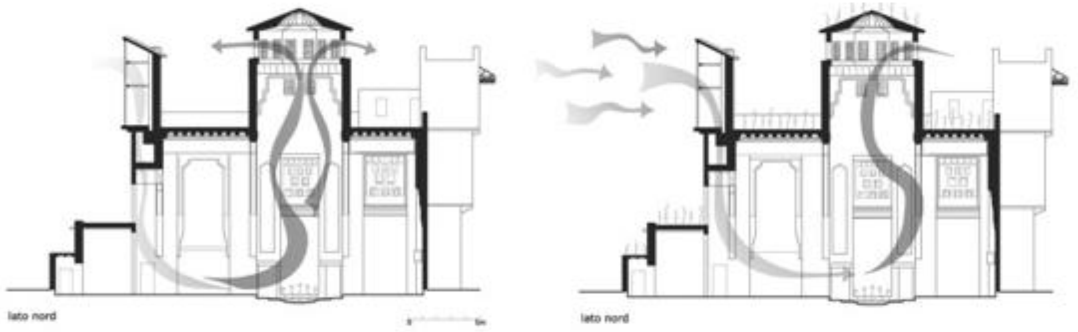


Figure 22: Diagram of Operation of Chimney in Egypt
(Ficarelli, 2009)

Wind catcher and chimney erected around the 10th century; they were applied in buildings in the Middle East and used in warm, dry and hot humid climate. The wind catcher effects on their local architecture, which has been used as a refrigerating device and considered as an inseparable part of building forms in any hot, dry and hot humid area. It plays an effective role in modifying heat and adjusting a temperature of interior living spaces in regard to thermal comfort it is used as the convection created by a wind flow and natural pure energy, which exists in nature of dry and hot humid climate (Hamzanlui Moghaddama, Amindeldarb, & Beshar, 2011).

Wind catcher, made by a kind of large chimney vertically slit in its upper part by several brick baffles. During the night time, the tower cools off; the air transferring within the chimney contacts with the tower also cools off; the air enters the side of the tower exposed to the wind, goes down through the building and goes out from the doors that face the central hall or the basement. The pressure created by the cool air pushed hot air through the doors and windows. When further cooling is needed, this existing can applied to suck in the building the fresh air of the night. Wind direction has fluctuation seasonal basis and even during the days.

The chimney often used in combination with curved roofs or domes, which comprise other elements of environmental comfort during the summer heat. In these areas, hot air tends to rise above the living area. Although a curved roof receives the same amount of radiation as a flat roof, but curved roof can transfer heat to the exterior during night time be meant of greater surface in compared of a flat roof. In the upper section of the dome placed a circular hole which further improves the circulation of the air.

The most efficient natural cooling systems found in traditional architecture combined with water; these systems exploit the cooling effect caused by the evaporation of water (Figure 23). Warm air when blown over a water surface, transfers part of its heat to the water and cause a partial evaporation. This cooling effect is achieved by the Iranians through various means; sometimes they use the natural humidity of the underground portion of the wind tower, or of the underground ducts were traditionally used for food conservation before the coming of modern refrigerators. A fountain and water basin placed in the basement of the wind tower or in the room connected to the duct coming from the tower can supply more cooling by evaporation.

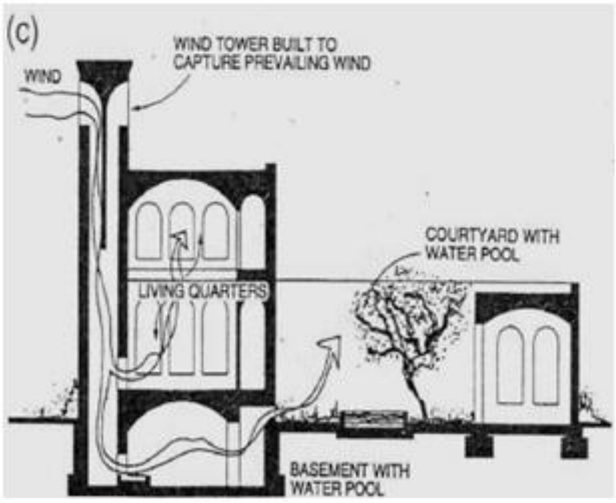


Figure 23: Way of Chimney Function for Provided Humidity
(Azami, Yasrebi & Salehipoor, 2005)

The positive and negative pressure produced by the wind in varying over the time. Air flow moves from the positive-pressure zones to the negative. The openings of wind catcher work based on the pressure and may hence change from a positive pressure to a negative pressure from one day (or season) to the next (Hughes, Calautit, 2012).

2.3.2.4.2 Chimney in Contemporary Architecture

In contemporary buildings, these principles can be followed and recognized to achieve the natural ventilation. The success of a natural ventilation system relies upon the design, vertical ventilation of wind catcher increases the thermal comfort situation, and application of chimney and vertical placement of windows are two ways to achieve vertical ventilation.

The chimney approach has recently been utilized in contemporary architecture in different climate zones. In most countries such as, UK, Greece, Taiwan, Malaysia and etc apply the chimney to generate the wind flow and daylight.

- **De Montfort University Building**

There are several buildings in UK which, the air is circulating and ventilating by natural forces. Queen's Building, De Montfort University, located in UK, the building constructed by heavy conventional structure and illuminates by natural light and ventilates by natural wind flow (the air is circulating by natural forces by means of some chimneys). This case as one of the first example of "green architecture" was designed to be Europe's largest naturally ventilated building at the time (Figure 24). In Queen's Building illuminated by means of natural light penetrates to atrium-like compartment and using the chimney for getting positive and negative pressure of wind flows for air circulation.

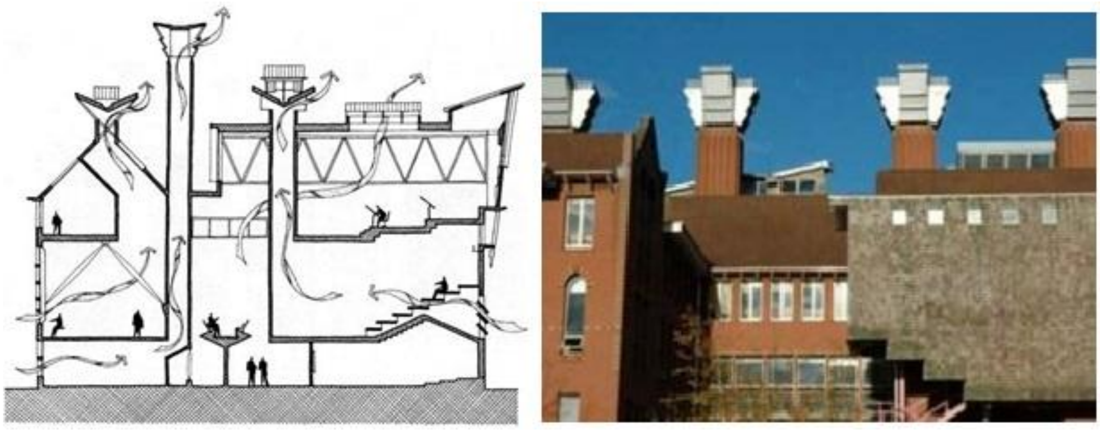


Figure 24: Ventilation by Natural Wind Flow
(Kleiven, 2003)

In this building, air is exhausted via 20 perimeter stacks, which connect the lower three floors, and a central atrium. The top-floor stacks are separated from the lower three floors to prevent unfavorable air circulation. This strategy had been used in the traditional architectural elements in Iran. By opening around the sunken garden, the surrounded spaces are illuminated. The mentioned buildings have circulated the air without machine using and by means of the same architectural elements, chimney (Figure 25).

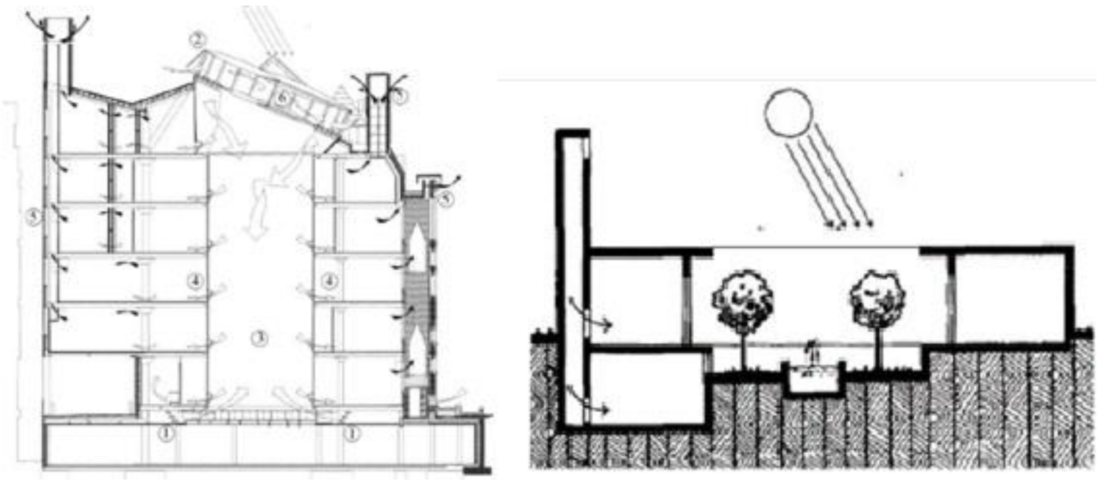


Figure 25: Natural Ventilation and Daylight in Contemporary and Traditional Buildings
(Azami, Yasrebi & Salehipoor, 2005)

- **Architecture & Asian Music Building**

Architecture & Asian Music, National Tainan University of Arts in Taiwan, is an another new building example, which has environmental design by using natural air flow and daylight, to maximize the beneficial use of nature. Apply chimney to catch the wind and Double shell and double roof for passive solar ventilation. The wind catcher is the chimney to get the north east wind in the afternoon in summer and the thermal chimney in the morning in summer (Figure 26). Wind catcher integrated with vertical planting wall is incorporated at the south-eastern to receive the prevailing summer breeze and the central void providing daylight at different levels.

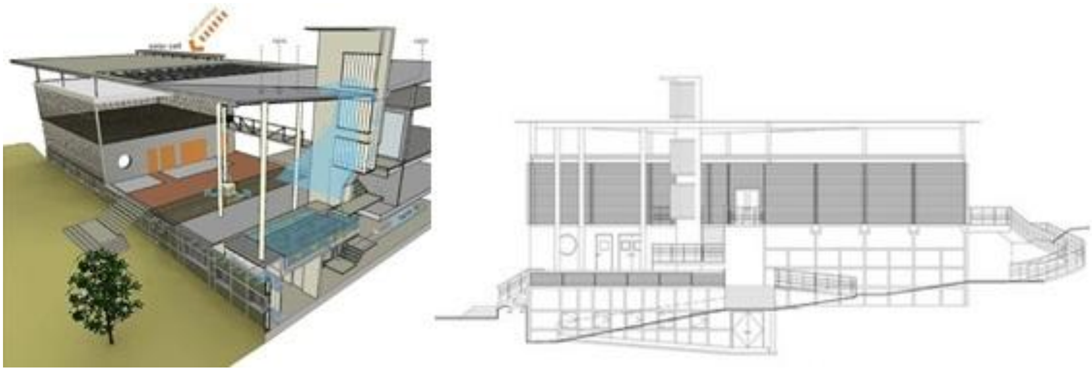


Figure 26: Natural Ventilation
(Hasse, Marques Da Silva, 2009)

Nowadays designer invented which, the integration of DSF and wind tower improves airflow, and achieve more ventilation inside the cavity during the hot season, therefore generate acceptable thermal comfort within the buildings. In this kind of system, the cavity in double skin facade is ventilated naturally, reduces the requirement for mechanical ventilation and provides environmental friendly atmosphere. To improve the function of building envelope during the summer, it is suggested to integrate the chimney with the double skin facade, to increase air circulation between cavity and indoor climate. In this system, for natural ventilation, the air is brought into the channel and exhausted by two reasons: the stack effect and wind pressure. Wind pressure generally dominates the airflow rate (Poirazis, 2004).

If designed correctly, wind blowing over the facade can produce pressure differences between the inlet and outlet inducing air motion. Air will move into the inlet and out the outlet while ejecting the heat (Figure 27).

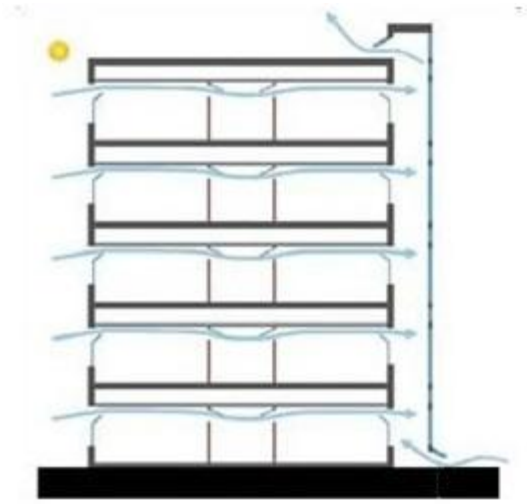


Figure 27: Stack Effect and Wind Pressure
(Gratia, Herde, 2004)

During the cooling periods, open the cavity and chimney window’s for extracting the heat from the channel, and close it during the winter for increasing of indoor temperature. Cavity can still ventilate without wind, due to the stack effect but during the summer, the solar heat gain within the facade cavity will increase the cavity temperature, which produces a burst of hot air in summer (Figure 28).

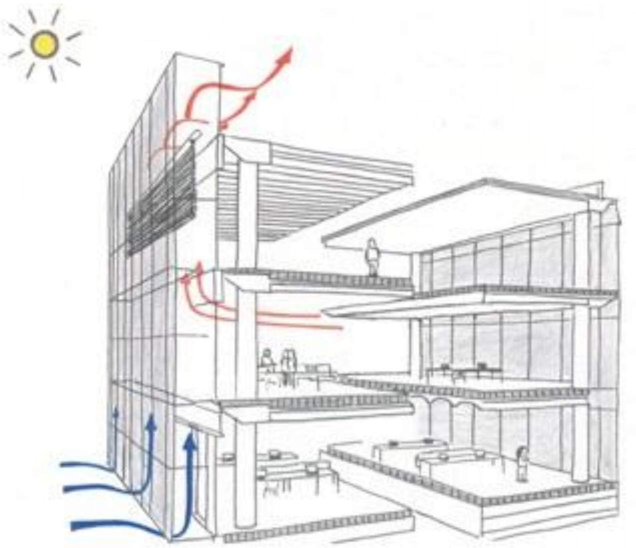


Figure 28: Double Skin Facade and Chimney
(Poirazis, 2008)

Chapter 3

ANALYSIS OF HEALTH CENTER BUILDING, EMU AND RESULTS

3.1 Methodology

A health center is a public institution that was created to protect human bodies against diseases, returning them to healthiness. Therefore, the history of hospitals is mixed with the history of medical sciences, and their development depends on the growing of medical knowledge and technology. Admission and treatment of patients in the right time and cooperation in public health are two important functions of health centers. The progress in the technology of hospital buildings as well as providing more adequate ventilation happened in the 19^{th} century. The technique of pre-fabricated was proposed and performed in several health center buildings.

According to the importance of indoor environment in the health care area, this chapter of thesis reports the analyzed results of the selected case study, (Health Center building at Eastern Mediterranean University's campus) and explains created simulations via EDSL TAS software. In this regards, due to the climate and weather conditions in Gazimagusa, the thermal comfort zones for occupants of Health Center building were analyzed and the thermal behavior and energy efficiency strategy were found out by examination of double skin facade and chimney in the building. To reach these objectives, local climate and some other parameters were examined such as, doors and windows size (height and width), their materials, opening percentage and existing building facade material, so to contribute to a better design of facade in the health center building in hot climate (TAS- Software, 2012).

3.1.1 TAS Software

TAS is a software program for thermal analysis in buildings which include a 3D modeler, a system/control and thermal energy analysis module. It uses global radiation (W), wind speed (m/s), ambient air temperature (°C), wind direction (°), cloud cover (0-1) and relative humidity (%) as climate parameters of the TAS simulations. TAS software is a complete tool for thermal simulation of a building aimed at optimization of buildings environmental, energy and comfort performances. To be able to use this software, Gazimagusa weather file was bought from meteorological station of TRNC.

3.2 Case: Health Center Building, EMU, Gazimagusa

3.2.1 General Physical Characteristics of the Health Center Building, EMU

Health Center building is located at EMU Campus to serve the university staff and students. The building was constructed in 1996, has two stories and a rectangular shape. It is not surrounded by any other buildings, has an open and cell plan type and is 1370.97 m2, composed of 42 zones (Figure 29). Offices aligned on two facades (East and West) are separated by a central corridor which divides the zones (Figure 30, 31). The building is being used during the week, between 7:30 am and 17:00 pm. The lighting system is only used during the open period of the building.

Each level has a main entrance in east and west side of the building. Each zone such as offices, information, rest room, emergency room and etc, has various door and windows sizes (Table 1).

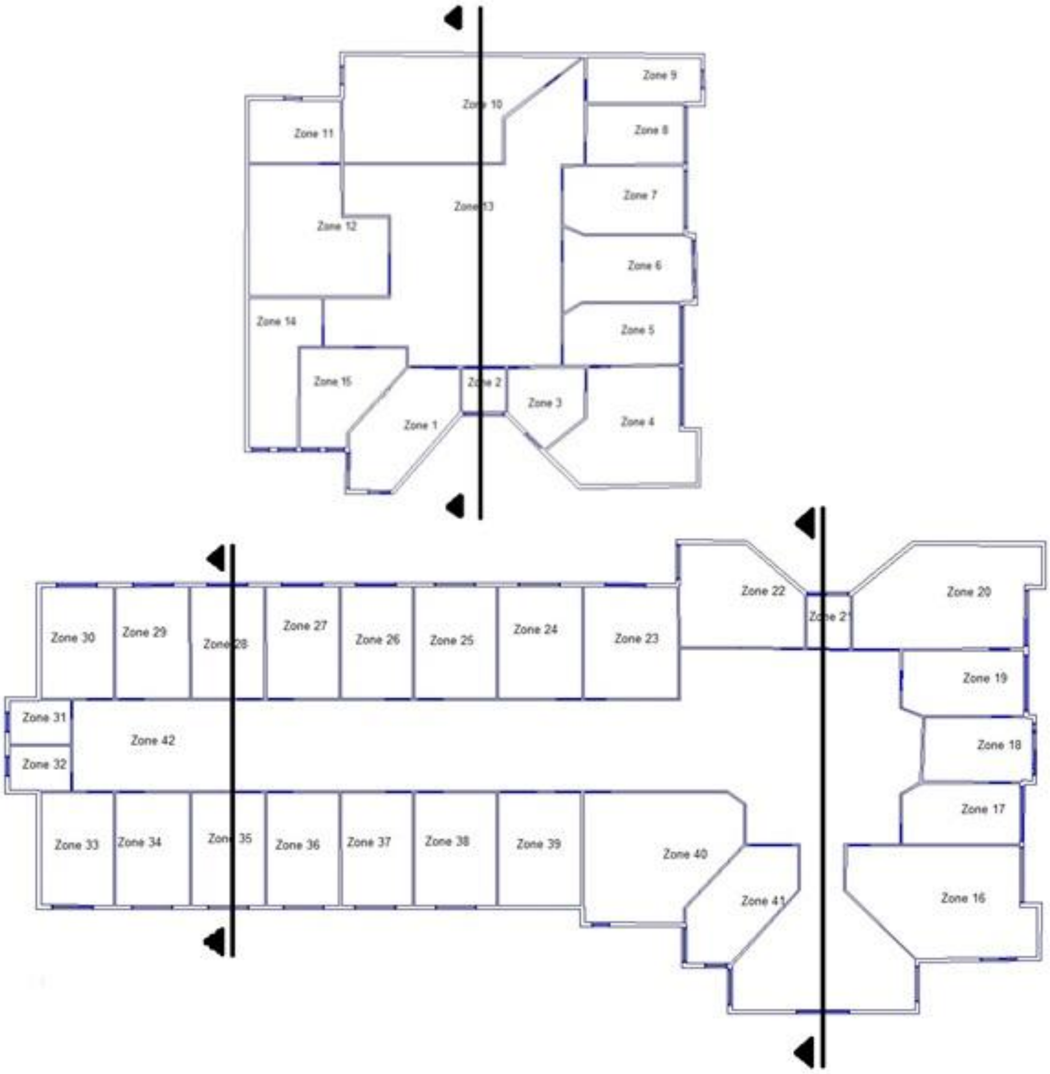
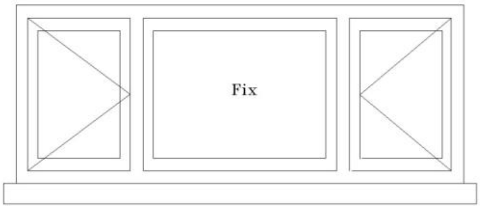
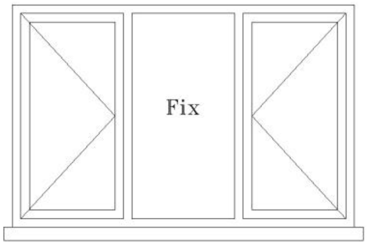
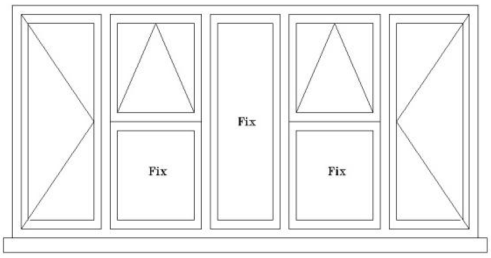
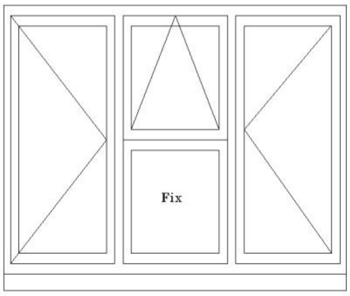
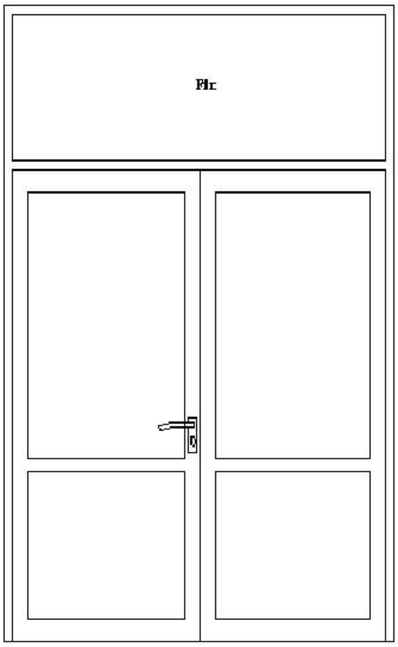
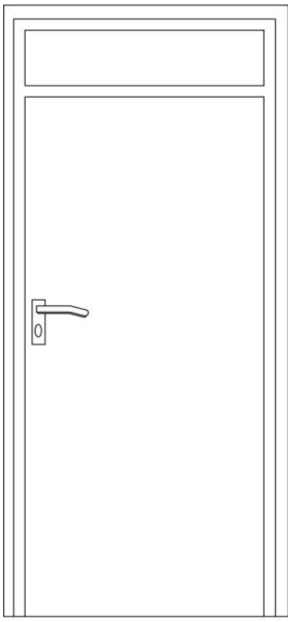


Figure 29: Health Center Zones in TAS Software (Underground and Ground Floor Plan
(Drawn by author, through the given plans by Architecture Department, 2013)

Table 1: Various Windows and Doors
(Drawn by author, through the given plans by Architecture Department, 2013)

 Window 175*70 cm (Glass and Aluminium)	 Window 200*130 cm (Glass and Aluminium)
 Window 260*120 cm (Glass and	 Window 165*130 cm (Glass and
 Door 200*130 cm (Glass and Aluminium)	 Door 100*220 cm (Glass and Wood)

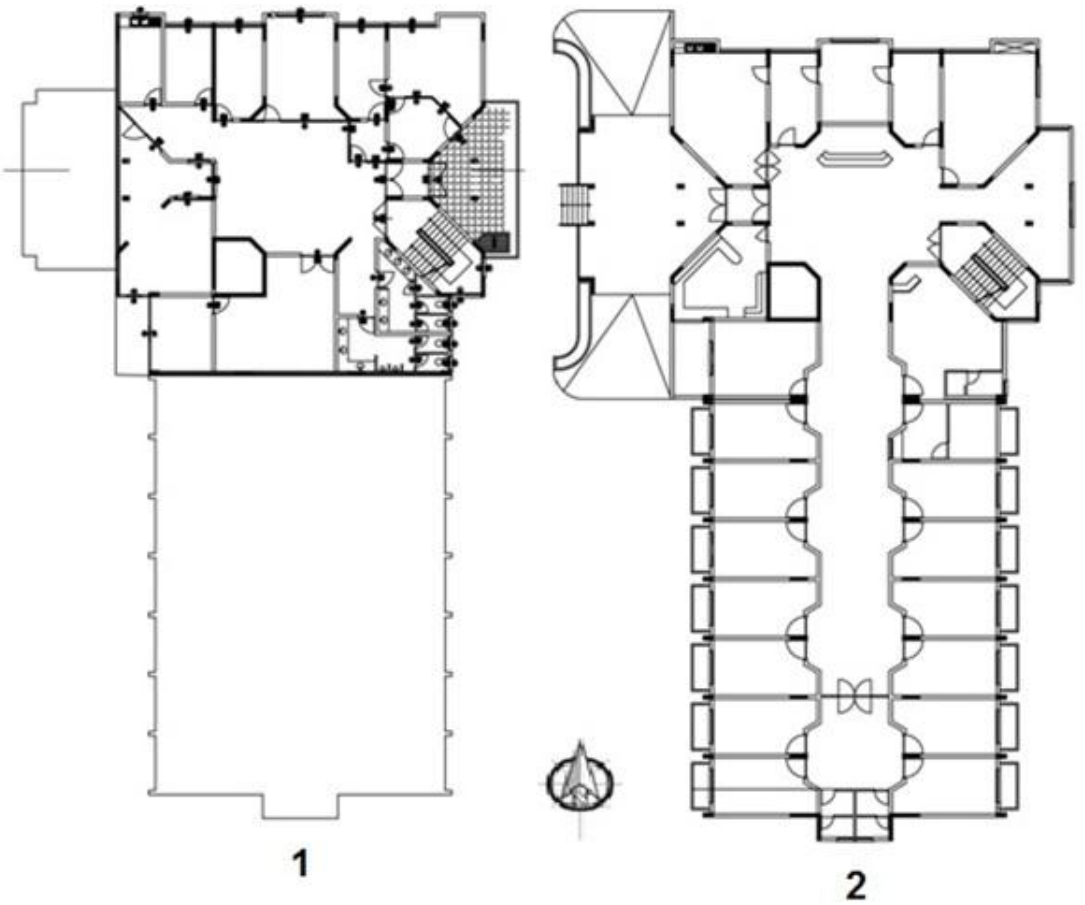


Figure 30: Underground, 2 Ground Floor Plan of the Health Center Building
(Drawn by author, through the given plans by Architecture Department, 2013)

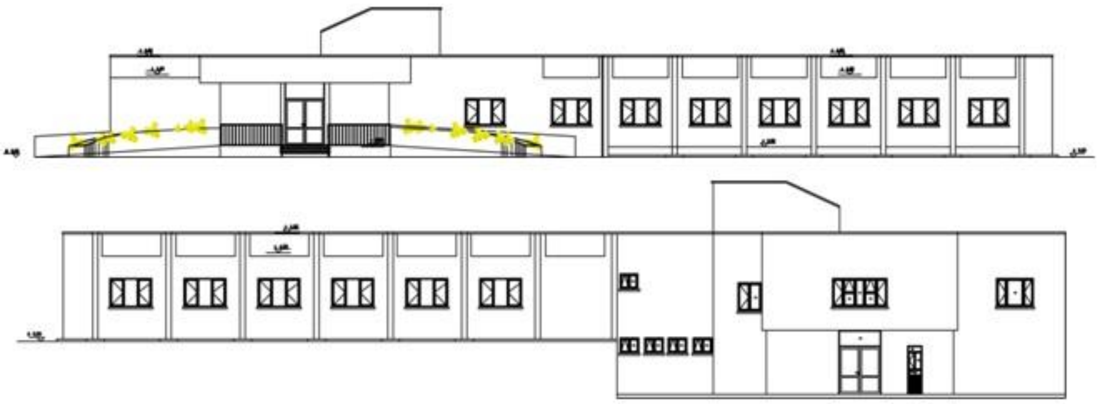


Figure 31: East and West Elevations
(Drawn by author, through the given plans by architecture department, 2013)

In TAS simulations from second simulation attached multi storey double skin facade around the building with a distance of 50 cm and from third simulation add chimney which by using stack effect catch more wind flow through the building. Building elements are the same for all simulations which is constructed by:

- Internal Walls: constructed 1cm thick plasterboard layer, 2 cm thick lime plaster layer, brick wall with 20 cm thick and internal layer 1 cm thick .with plasterboard. The function of internal wall is divided zones or areas from each others for the simulation (Figure 32).
- **Facade:** 20 cm thick brick wall and 1.5cm thick, lightweight lime plaster (Figure 33)
- **Floor:** the inner layer composed by two 3 cm plasterboard and lime plaster.
- **Roof: 0.**3 cm thick asphalt ,6 cm concrete screed, 20 cm thick compacted hardcore, 0.5 cm, plaster for inner layer
- **Doors:** 0.5 cm thick wood, 0.5 cm thick wood composed by single clear glazing, 0.5 cm thick aluminum composed by single clear glazing
- **Windows:** 0.4 cm thick single clear glazing
- **Aperture Frame:** Aluminum with 0.5 cm thick and wood with 0.7 cm thickness

Figure 32: Interior Material of the Health Center Building
(Taken by author, 2013)

Figure 33: Exterior Material of the Health Center Building
(Taken by author, 2013)

3.2.1.1 Gazimağusa, Cyprus Climate

Cyprus, as the third largest island in the Mediterranean Sea, is located at the north-eastern side of the sea, and the city, Gazimagusa (Famagusta), is located on its eastern coast. According to proximity to the sea and topographical values, Cyprus has hot–arid or hot–humid climate or a composite of both climates. Hot summers (high heat in daytime), moderately cold winters (intense coldness at night) and very high summer dryness with minimal yearly rainfall (Oktay, 2002) are of characteristics of its climate. During summer, the temperatures range between 37°C and 40°C and in winter, they range from 9°C to 12°C, in each day (Alibaba, 2013).

3.3 Analysis of TAS Simulations for Health Center Building

Based on the TAS simulations, the evaluation of the health-center building thermal performance which will be divided to two seasons, summer and winter time, the selected months were 21 of March as spring season, June as summer season, September as autumn season and December as winter time, three times during the day, at 7:00 am as early morning, 12:00 as noon time and 19:00 pm as afternoon time, 0.0% means all the openings are closed; 0.1% means apertures were open around 10 percent and 100% means they were open completely whole the day.

3.3.1 TAS Simulations

In the following parts, each simulation is evaluated by different modifications. The first simulation is the existing situation of Health Center building. All opening such as doors and windows are considered as 10%. The second simulation is Existing building with double skin facade, multi-storey model and the third one, existing building integrated with multi storey double skin facade and chimney (Table 2) .In all simulations shading devices aren't considered. From the second simulation the double Skin facade is added for each simulation and description. Each of the simulations are considered different percentage of opening, 10%, 50% and 100%. The general weather file of Gazimağusa, will be presented in table 3 (http://kktc meteor.org, 2013).

Table 2: Simulations of the Health Center Building
(Drawn by author, on TAS Software data, 2013)

Simulation 1	Existing Building	All Door and Windows open 10%
Simulation 2	Existing Building with Double Skin Facade	All Door and Windows open 50%
Simulation 3	Existing Building with Double Skin Facade and Chimney with Consideration of Cross Ventilation	All Door and Windows open 10%, Chimney 100%

As demonstrated in table 3, the less external temperature was 10.90 °C at night in 21 December among the four evaluated. The highest external temperature was in noon time at 21 September, 29.20 °C. The relative humidity in 21th March was reached to 89% in 7 am, and it decreased to 48% in 21 September at 12 o'clock. The highest solar radiation was 993.20 W, at 12 o'clock in 21 June reduced to 0.00 from noon to night. The wind speed maximum speed to 6.90 m/s.

Weather parameters data of the Health Center Building has been obtained in table 3. It is shown the external temperatures, relative humidity, global radiation, wind speed and direction, and cloud cover in 21 of March, June, September and December, three times during the day, at 7:00 am, 12:00 and 19:00pm. The general climate data of Gazimağusa, North Cyprus, will be presented in table 4 (Alibaba, 2013).

Table 3: Weather Parameters
(Drawn by author, on TAS Software data, 2013)

Date	Time (h)	External Temperature (°C)	Relative Humidity (%)	Global Radiation (W)	Wind Speed (m/s)	Wind Direction (°)	Cloud Cover
21th March	7:00	16.10	89	315.17	4.50	31	0.03
	12:00	17.80	51	839.69	7.10	60	0.03
	19:00	16.10	76	0.00	1.00	2	0.03
21th June	7:00	26.40	68	532.65	2.80	35	0.00
	12:00	28.90	74	993.20	3.70	96	0.00
	19:00	28.30	72	0.00	1.90	212	0.00
21th September	7:00	21.90	59	369.83	2.50	254	0.21
	12:00	29.20	48	833.87	3.70	131	0.21
	19:00	24.20	68	0.00	2.60	214	0.21
21th December	7:00	14.50	62	82.57	6.90	17	0.24
	12:00	14.70	55	519.86	4.30	9	0.24
	19:00	10.90	62	0.00	1.90	296	0.24

Table 4: Climate Data of Gazimağusa, North Cyprus
(Alibaba, 2013)

Months	January	February	March	April	May	June	July	August	September	October	November	December
Sunshine Period (Hour/day)	5.5	6.2	7.0	8.4	10.1	11.8	12.4	11.6	10.2	8.3	6.6	5.1
Cloud Cover	6	5	5	4.5	4	2.5	2	1.5	2	3	4	5.5
Total Solar Radiation (MJ/m2)	7	10	14	18	23	24	24	23	15	14	9	6.5
Max Air Temperature °C	16.4	16.4	18.4	22.2	26.5	30.6	33.1	33.3	31.1	27.2	22.0	17.6
Min Air Temperature °C	6.9	6.5	7.8	10.5	14.2	18.4	21.1	21.4	16.4	15.3	11.0	7.5
Related Humidity %	88	89	84	89	90	88	85	88	86	86	88	87
Predominant Wind Direction	W	W	W	W	W	SW	SW	SW	W	W	W	W

3.3.1.1 Simulation one, Existing Building

The first simulation modeled the current building so to contribute to a better facade design for the health center building concerning a hot humid climate (Figure 34, 35). The building is covered with a 20 cm thick brick wall, plus a 1.5 cm thick and lightweight lime plaster for its outer facade and a single glazing with aluminum frame for windows and doors. In the present simulation, all openings such as doors and windows were 10% open. The selected dates and times were 21st of March, June 21st, September 21st and December 21st, at 7:00 am, 12:00 pm and 19:00 (Appendix A).

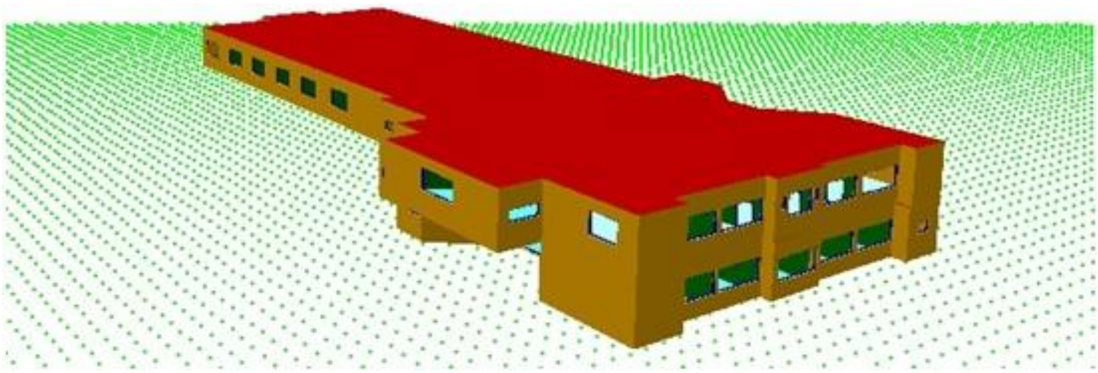


Figure 34: Existing Building, TAS Modelling
(Drown by author, base on TAS software data, 2013)

Figure 35: Existing Building Materials
(Taken by author, 2013)

Table 5 illustrates the summarized performance of the EMU health center on 21st of March, June, September and December. With an overall look at the simulations it can be understood that west side of the building (zone 28) on June 21st, 12:00 pm, has the maximum internal temperature of 35.58°C, higher than the other seasons, and the minimum temperature of 18.75°C belongs to zone 21. According to the literature, thermal comfort standard in air-conditioned buildings is 26°C with a 60% relative humidity. During the days June 21st and September 21st, internal temperatures of each zone were approximately 15 degrees higher than March and December. As it can be seen in Appendix A, entrance area (zone 21) had the lowest temperature in December and the highest in June in west side of the office area (zone 35). In bioclimatic chart of Health Center Building, maximum and minimum temperatures in June and December are not in comfort zone, and they need more air flow through the building during summer time and more radiation and heat in the winter time, because the interior thermal environment of the building is far away from comfort zone. Observations also prove that east and south sides receive more solar radiation from morning till noon.

Table 5: Summery Performance of Health Center, Existing Building in EMU Campus (ADSL TAS Software, 2013)

Simulation 1 All doors and windows open 0.1%						
	Season	Value	Unit	Zone	Day	Hour
Max Air Temp	21June	35.58	°C	Zone 28	172	12:00
Max B.H.T	21June	-385.52	%	Zone 28	172	12:00
Max R.H	21June	45.95	W	Zone 28	172	12:00
Max Flow in	21June	0.11	Kg/s	Zone 28	172	12:00
Max Flow out	21June	0.11	Kg/s	Zone 28	172	12:00
Min Air Temp	21 Dec	15.75	°C	Zone 21	355	19:00
Min B.H.T	21 Dec	641.34	%	Zone 21	355	19:00
Min R.H	21 Dec	45.72	W	Zone 21	355	19:00
Min Flow in	21 Dec	0.084	Kg/s	Zone 21	355	19:00
Min Flow out	21 Dec	0.084	Kg/s	Zone 21	355	19:00

- **March 21st, Existing Building**

In this chart (Figure 36) zone 28 and 35 were analysed on March 21st at 12:00 pm, with a section line crossing these zones. The offices located on east and west of the building shown in the chart are located in the comfort zone. That means during this period in March, considered as a cold time, there is no need for cooling or heating (Appendix A).

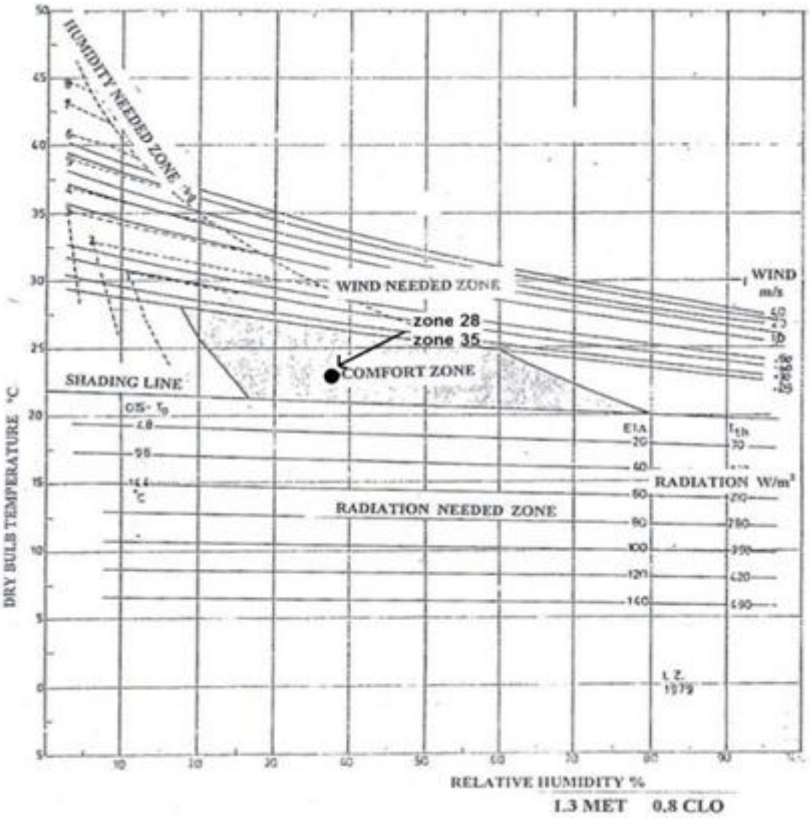


Figure 36: Bioclimatic Chart of Health Center Building in 21 March at 12:00, Zone 28, 35, East and West Office (Modified by author, Based on TAS Software data)

- **June 21st, Existing Building**

Figure 37 demonstrates the analysed results of zone 28 and 35 on June 21st at 12:00 pm. This chart shows that the internal temperature at this period is higher than the other seasons and far away from comfort zone. The building, during summer time, absorbs more sun radiation than winter time and hence the indoor temperature rises. Therefore, more air flow (natural ventilation) should be created during summer time and more heat (solar radiation) should be provided in winter time to achieve comfort zone. In this case, mechanical machines should be used which require much energy usage and hence huge amount of cost both in summer and winter time (Appendix A).

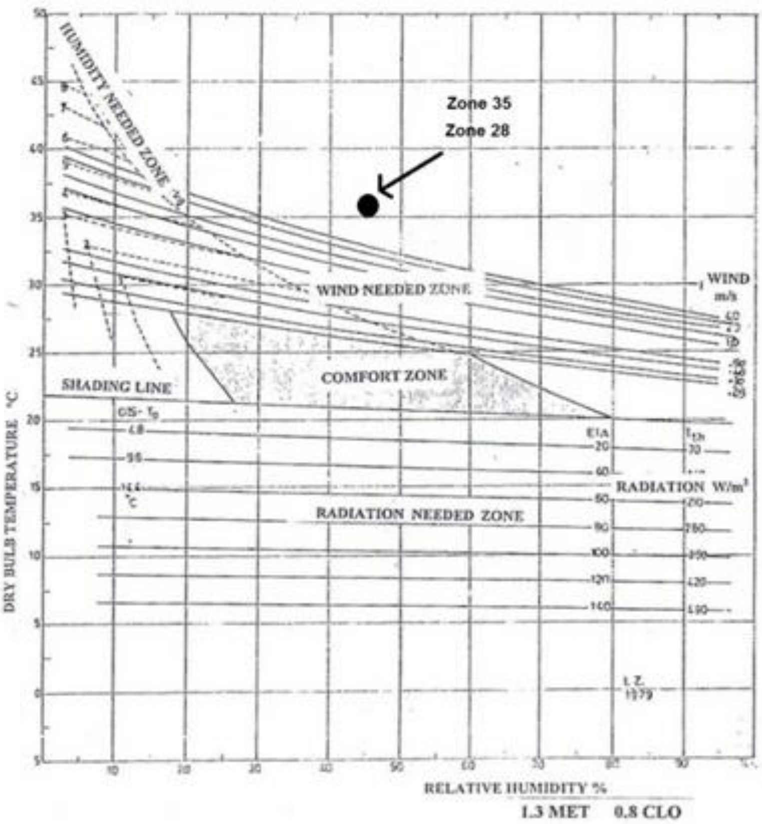


Figure 37: Bioclimatic Chart of Health Center Building
in 21 June at 12:00, Zone 28, 35, East and West Office
(Modified by author, Based on TAS Software data)

- **September 21st, Existing Building**

In this case (Figure 38), zone 28 and 35 are considered on September 21st at 12:00 pm. Internal temperature at this period is close to the comfort zone, hence, they can achieve the comfort environment by more air flow in summer season (Appendix A). A comparison of the existing building's performance in cold and hot season shows that the building suffers from some problems in summer period, from June to September. Moreover, in west side of the building, because of high amount of sun radiation, internal temperature increases during the hot season.

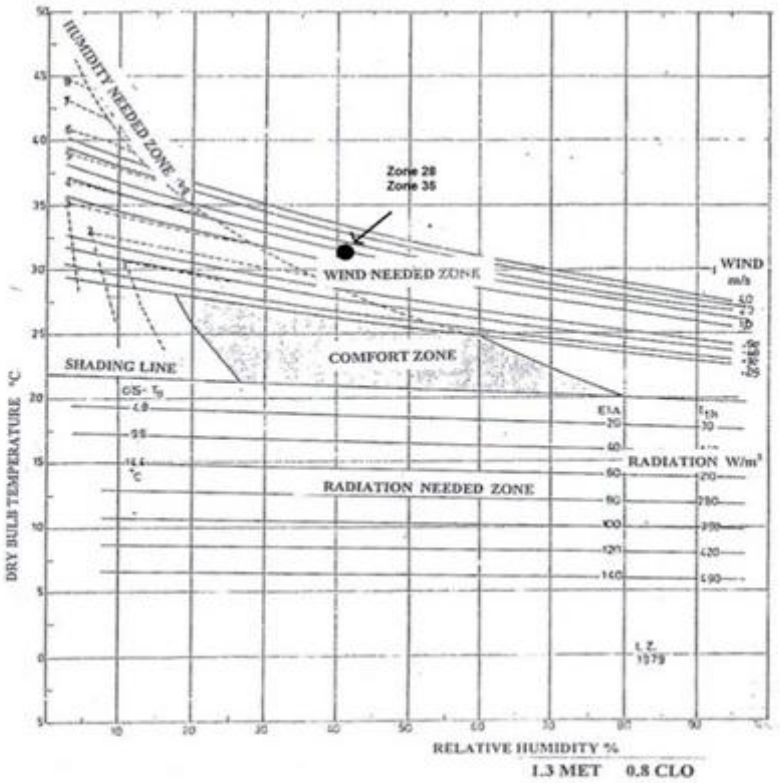


Figure 38: Bioclimatic Chart of Health Center Building
in 21 September at 12:00, Zone 28, 35, East and West Office
(Modified by author, Based on TAS Software data)

- **December 21st, Existing Building**

Looking at this chart, which shows zone 28 and 35 on December 21st at 12:00 pm, demonstrates that indoor temperature in zone 35 is in comfort zone. However, the other zone, which is located at east side, needs more heat to achieve the comfort zone on December 21st. Because of the reason that east side has morning sunshine and south side has the better sun radiation in winter time, east side zones in winter had lower temperatures compared to west side ones (Figure 39) (Appendix A).

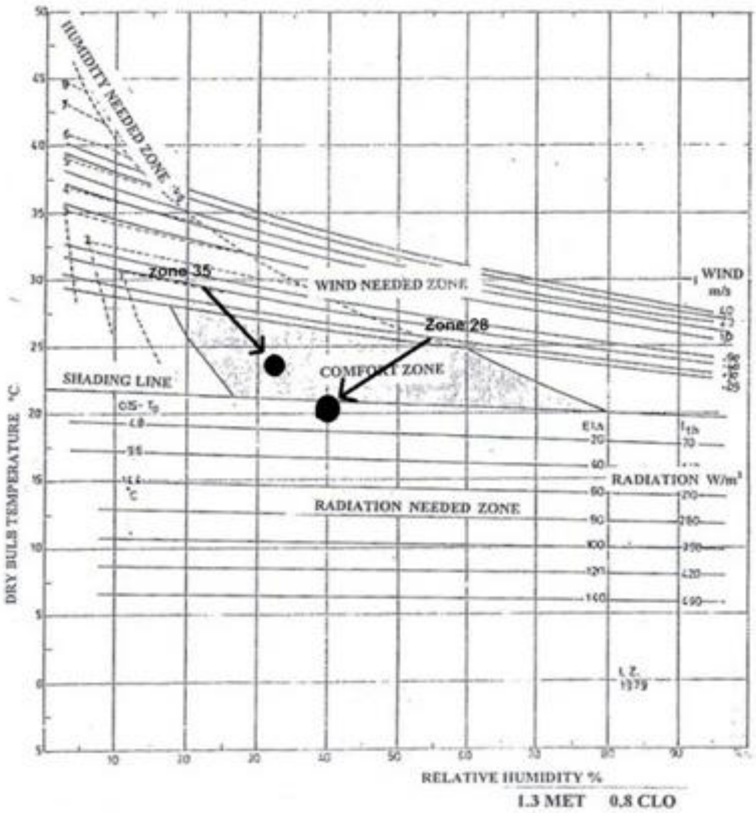


Figure 39: Bioclimatic Chart of Health Center Building
in 21 December at 12:00, Zone 28, 35, East and West Office
(Modified by author, Based on TAS Software data)

3.3.1.2 Simulation Two, Building+ Double Skin Façade

The second simulation was grounded on the first simulation. The second simulation considers multi-storey double skin facade plus the external wall, which mostly is used in short buildings, with a 50 cm cavity composing of double clear glass. The main wall is a 20 cm thick brick wall, a 15mm thick and lightweight lime plaster outer facade, and a single glazing aluminium frame for windows and doors. All openings such as doors and windows were 50% opened. The second TAS model had no difference in comparison to the first one, and could not solve the internal thermal problem. The analyses for summer simulations, selected from June to September, are presented at 7:00 am, 12:00 pm and 07:00 pm (Appendix B).

- **June 21st and September 21st, Building with the Double Skin Facade**

A general view on the charts, on 21st of June and September at 12:00 pm, presents that the inside temperature still was far away from comfort zone, and all documents were very similar to the first simulation. In this case, during the hot time, more air flow was generated by mechanical machines to achieve the thermal comfort (Figure 40).

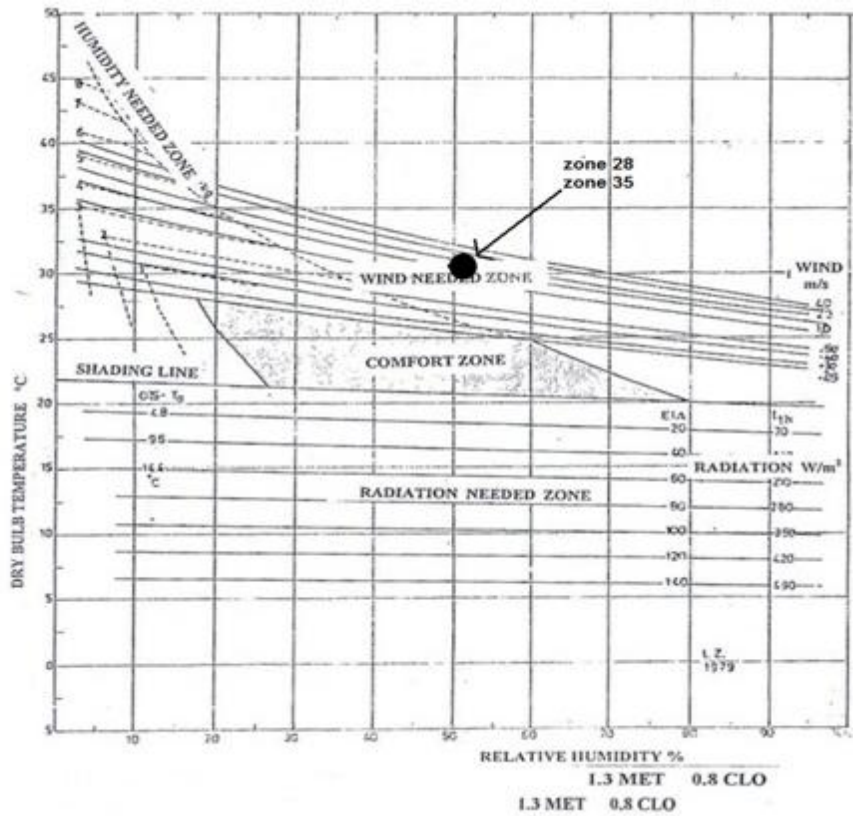


Figure 40: Bioclimatic Chart of Health Center Building+ DSF in 21 June at 12:00, Zone 28, 35, East and West Office (Modified by author, Based on TAS Software data)

With no variation in this simulation, this strategy also did not work and the thermal comfort zone could not be reached. That means another TAS simulation with new variable parameters had to be created and evaluated to find out a better solution for the existing condition (Figure 41) (Appendix. B).

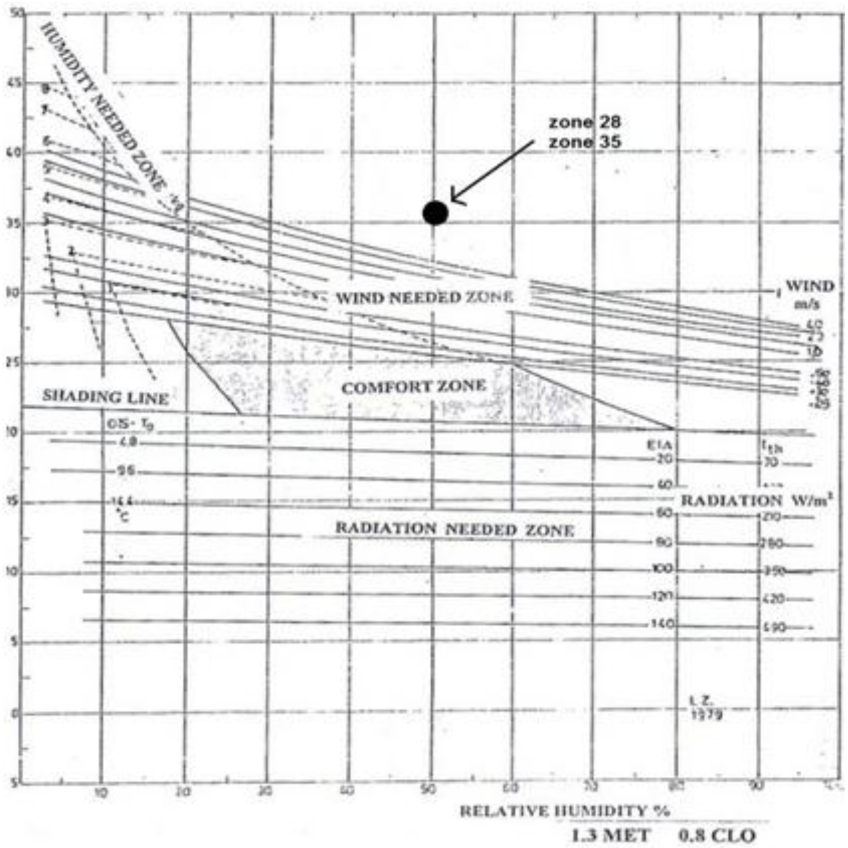


Figure 41: Bioclimatic Chart of Health Center Building+ DSF
in 21 September at 12:00, Zone 28, 35, East and West Office
(Modified by author, Based on TAS Software data)

3.3.1.3 Simulation Three, Building+ Double Skin Facade and Chimney

In this simulation, the main facade of the existing building was covered by a double skin facade in combination with a chimney to load more air flow through the building. In simulation two, double skin facade absorbed heat from the sun, saving it in the cavity, making the inner part warmer than outside. Thus, the chimney was installed around the building to remove the heated air (Appendix C). In this simulation, the used multi-storey double skin facade was constructed by double clear glass and a chimney with a 100 cm height was installed on the top. After the 50 cm cavity, there is the main wall, a 20 cm thick brick wall, a 1.5 cm thick and lightweight lime plaster for the outer facade and a single aluminum frame glazing for windows and doors. In the lower section of the facade, a hole was placed to further improve the circulation of the air when there is need to more cooling; this element can be employed to suck the fresh air inside the building. During summer time, the pressure created by the cool air in the cavity pushed hot air out of the building through the upper hole of the tower. In the present simulation, all openings such as doors and windows were 10% open, with a 100% open tower. The selected periods were 21st of March, June, September and December, and the selected times were 7:00, 12:00 and 19:00 (Figure 42).

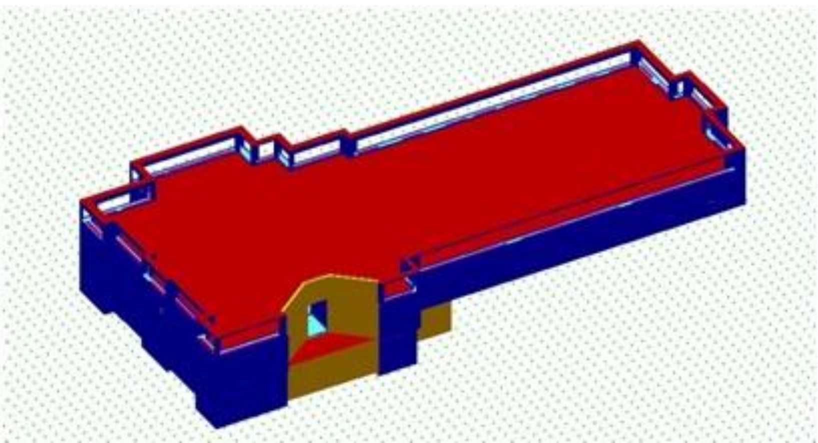


Figure 42: Third Simulation, Modeled with Double Skin Facade and Chimney
(Drawn by author, on TAS Software data, 2013)

Table 6: Summery Performance of Health Center Building+ DSF+ Chimney in EMU Campus
(ADSL TAS software, 2013)

Simulation 3 DSF +Tower +All doors and windows open 0.1%						
	Season	Value	Unit	Zone	Day	Hour
Max Air Temp	21June	30.31	°C	Zone 35	172	12:00
Max B.H.T	21June	-10.45	%	Zone 28	172	12:00
Max R.H	21June	52.47	W	Zone 28	172	12:00
Max Flow in	21June	0.044	Kg/s	Zone 28	172	12:00
Max Flow out	21June	0.044	Kg/s	Zone 28	172	12:00
Min Air Temp	21 Dec	17.08	°C	Zone 21	355	19:00
Min B.H.T	21 Dec	258.97	%	Zone 21	355	19:00
Min R.H	21 Dec	62.80	W	Zone 21	355	19:00
Min Flow in	21 Dec	0.00	Kg/s	Zone 21	355	19:00
Min Flow out	21 Dec	0.00	Kg/s	Zone 21	355	19:00

- **March 21st, Building with the Double Skin Facade and Chimney**

This chart (Figure 43) shows the results of analysing zones 28 and 35 on March 21st at 12:00 pm. The results show that the double skin facade incorporated by chimney works better and attracts more air inside the building. Most of the zones were located in the comfort zone and only in some situations more wind was needed. Moreover, in this season, there was no need to use mechanical machines to achieve thermal comfort (Table 6). Chimney reduces the indoor temperature around 5 degrees, so the indoor air measurements of the third simulation had an air temperature near the comfort conditions (Appendix C).

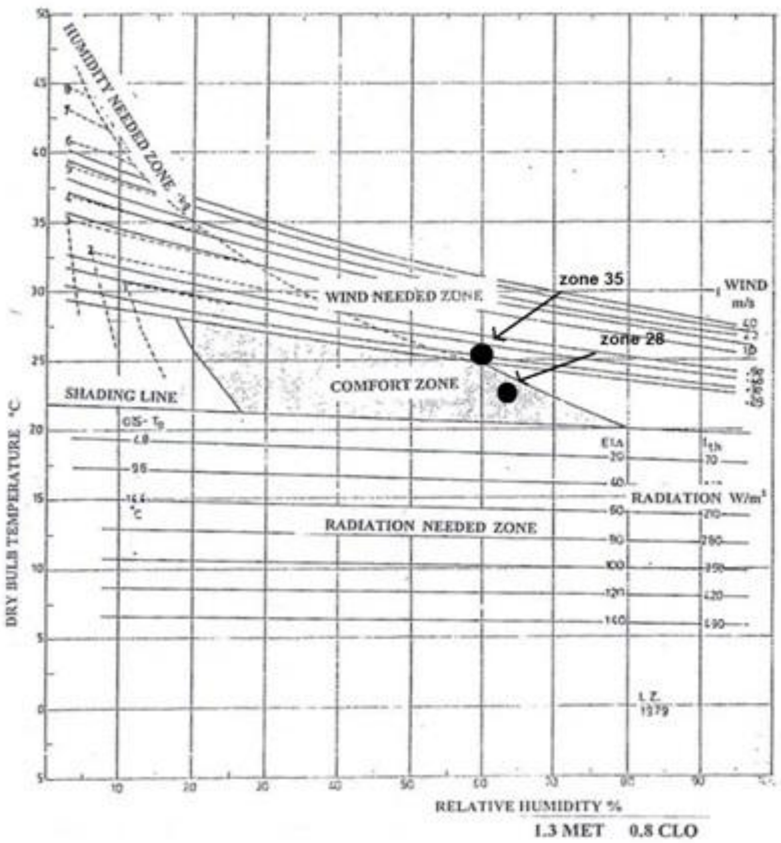


Figure 43 : Bioclimatic Chart of Health Center Building+ DSF+ Chimney in 21 March at 12:00, Zone 28, 35, East and West Office (Modified by author, Based on TAS Software data)

- **June 21st, Building with the Double Skin Facade and Chimney**

In the former chart, it was demonstrated that the indoor temperature was located in the thermal zone on 21st of March. Knowing that June is hottest season in the year in a hot climate, according to prevailing wind direction in this season (south-west), in third simulation a double skin facade was incorporated with a chimney to load more air through the building (Alibaba, 2013). In Table 6, it is shown that the highest indoor temperature was on June 21st, 30.31°C, which was 35.58°C in simulation one. However, in simulation three (Figure 44) indoor thermal of the buildings zones was closer to simulation one and two, by loading more wind (Appendix C).

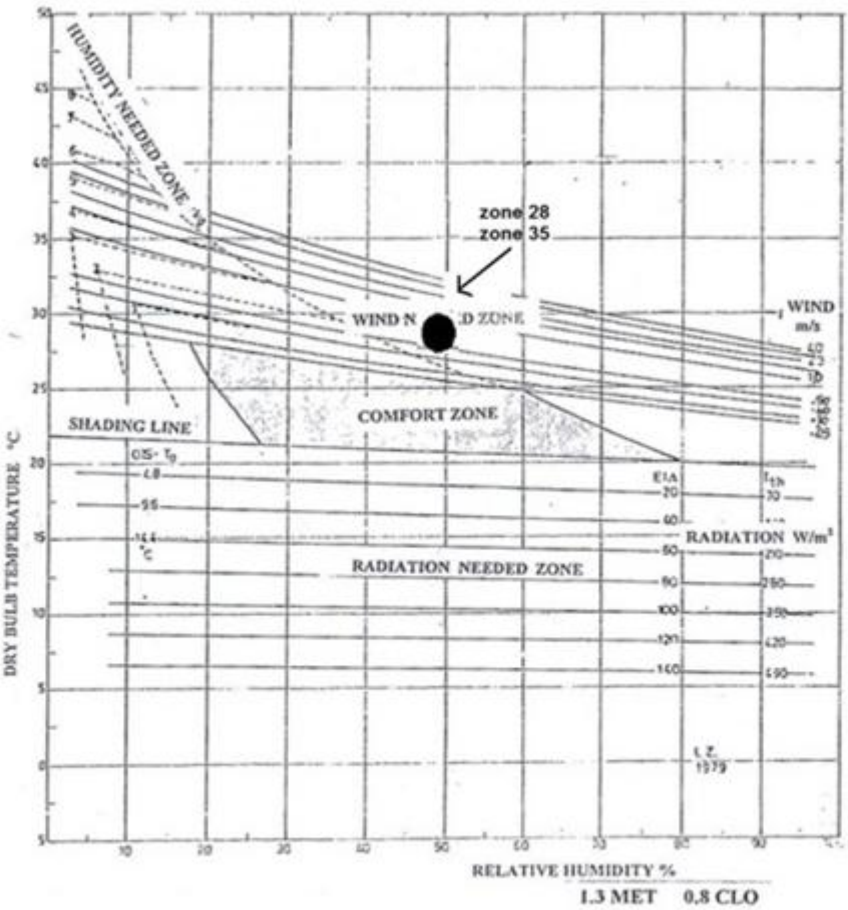


Figure 44: Bioclimatic Chart of Health Center Building+ DSF+ Chimney
in 21 June at 12:00, Zone 28, 35, East and West Office
(Modified by author, Based on TAS Software data)

- **September 21st, Building with the Double Skin Facade and Chimney**

Prevailing wind direction is on the south side in September, and this amount of air flow can ventilate the building. Unfortunately, north side of the building has the least number of windows and misses the air flow during the year, especially in September (Figure 45). According to the below chart, these zones need more wind in September. In hot seasons, that is June and September, by the help of DSF and tower, inside temperature was decreased from 35°C to 30°C (Appendix C).

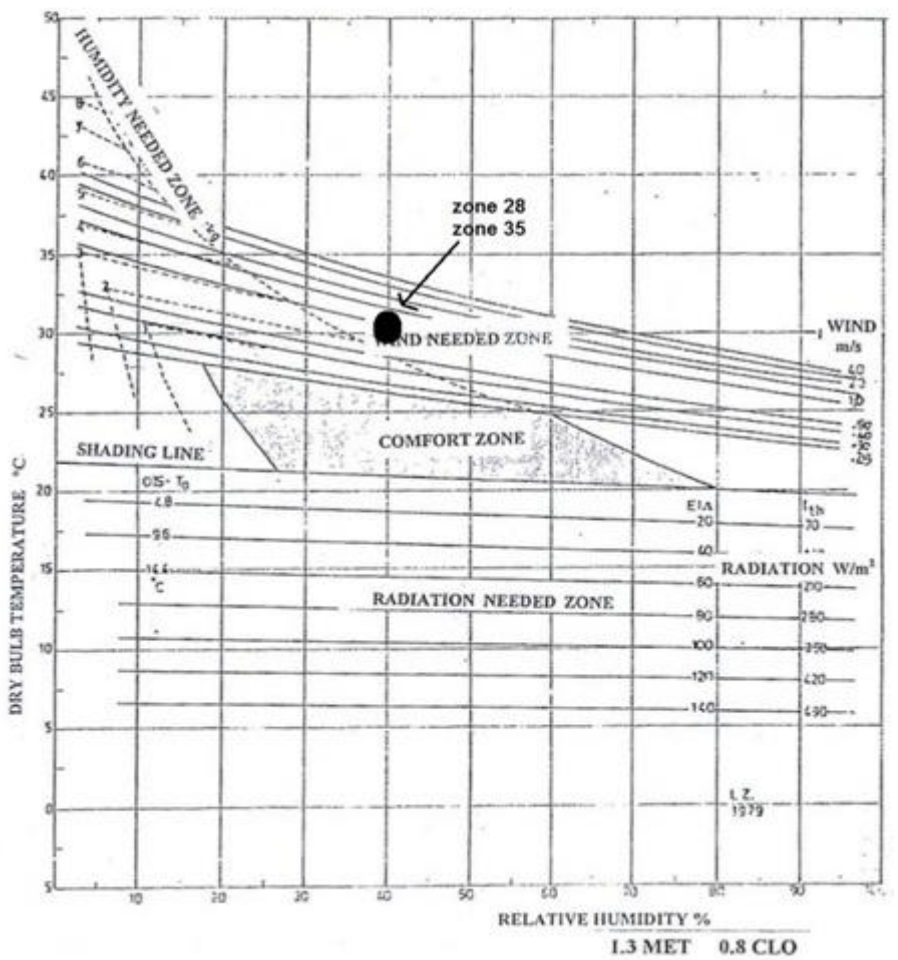


Figure 45: Bioclimatic Chart of Health Center Building+ DSF+ Chimney in 21 September at 12:00, Zone 28, 35, East and West Office (Modified by author, Based on TAS Software data)

- **December 21st, Building with the double skin facade and Tower**

This chart (Figure 46) shows the analysed zone 28 and 35 on June 21st at 12:00 pm. This chart shows that the internal temperature was about 22°C and relative humidity was 58%. In this month, zones were located near the comfort zone, but according to preceding data, comfort environment area is around 24-26 degree in a hospital, for patients have lower body temperatures and hence they need more heating (Appendix. C).

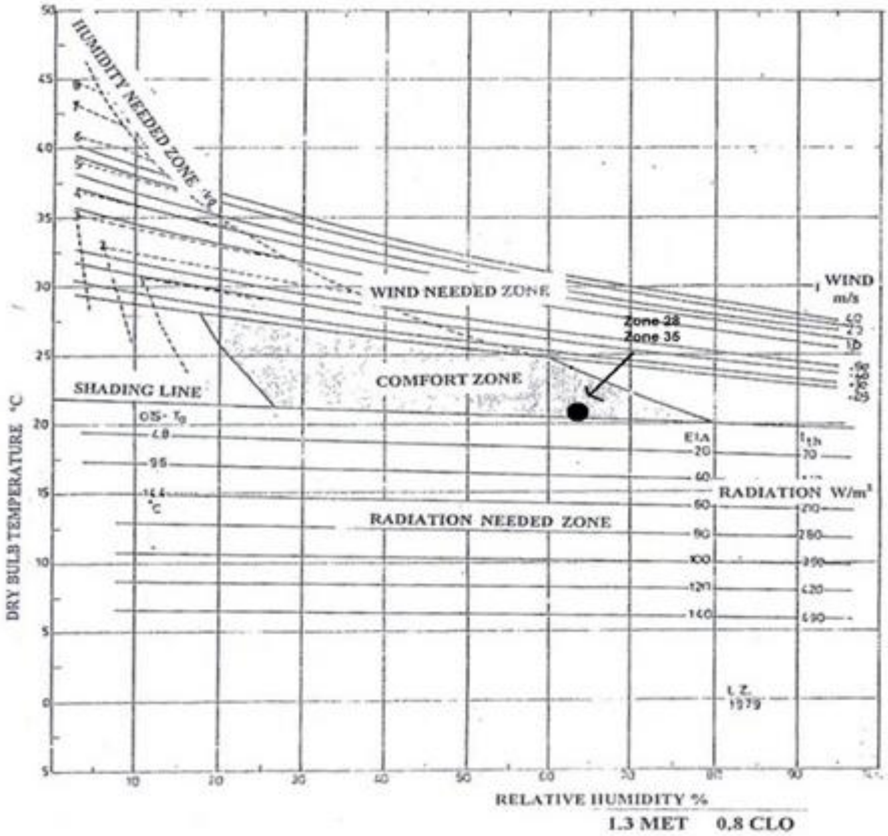


Figure 46: Bioclimatic Chart of Health Center Building+ DSF+ Chimney in 21 December at 12:00, Zone28, 35, East and West Office (Modified by author, Based on TAS Software data)

3.4 Discussion and Results

In general, chapter two presented examinations of three dynamic thermal modeling of the Health Center Building, via TAS software, to find out the thermal comfort condition, based on double skin façade and tower strategies.

According to the TAS simulations results, internal temperature of each zone in the existing building in simulation one were more than 32°C on 21st of June and September which were considered as hot seasons. During the cold seasons, that is on 21st of March and December, indoor thermal condition of the building was around 15°C.

Considering the first simulation, which displayed the existing situation of the Health-Center Building, it was revealed that the building has the worst thermal performance. However, thermal condition in simulation two was near the first one, and DSF without the air flow and ventilation could not work well in this climate. The third simulation had an acceptable thermal condition. In summer time, the indoor temperature of the first simulation was even more than outside, and in winter time, it was near the outside temperature, especially in zone 28, 21 and 10 which were located in west side. Among the examined simulations, simulation two had no positive effect on indoor thermal performance, with 50 percent aperture openings and a double skin facade. In simulation three, the effect of chimney combined with the double skin facade, with a 100 percent open chimney window and 10 percent aperture openings is demonstrated. The results did not work out 100%, achieving the exact thermal comfort, but the strategy has some positive effects and reduces the temperature around 5 degrees in summer time and is located close to the thermal condition in cold time.

Therefore, from the first and second simulation, it was understood that June and December, as a hot and cold seasons, had crucial conditions. The building simulation in March and September, however, had an acceptable situation, located near the comfort zone. Temperature inside the cavity (between the Double Skin Facade and the existing wall) in summer season had increased, so the wind tower considered with DSF could obtain thermal comfort in all building zones. Consequently, it was realized that in the third simulation, by using these strategies, the maximum internal temperature decreased to 30°C with a relative humidity of 50% in summer and was about 22°C with a relative humidity of 58% in cold seasons. Therefore, in simulation three, building condition obtained was able to generate thermal comfort condition and the annexes used can be useful for future design plans.

Chapter4

CONCLUSION

Research has been conducted to find out new approaches so to have better safety requirements and a healthier environment. Investigation was conducted to raise the level of life quality. Nowadays human thermal comfort in buildings is an interesting subject area along with integration and reporting the international standards for human environment such as heating, cooling, lighting and etc. Radiation temperature, air temperature, air movement and humidity are the four basic environmental parameters which affect human thermal environment. As discussed before, using natural sources of energy is the most efficient and cheap alternative to achieve cooling and heating in the building considering energy conservation.

In the 19th century medical center design, ventilation was changed and provided through the hospital and based on each patient's problem, looking after them in separate areas. The important point in ventilation is to pay attention to the building location. The building gets affected by its environment and climate, so these factors have important roles on building form. Recently architects put much attention on the relationship between climate and architecture so to provide comfort condition for the occupants. By performing some strategies such as building orientation, more wind can be attracted in hot-humid climates; open and narrow plans in west-east direction catch more wind for lessening the heat in summer period and absorbing sun radiation from south side in winter. Even any small window can generate ventilation: using cross ventilation, more natural ventilation can be achieved by opening the windows on opposite walls. In respect of the importance of opening in buildings, in the last simulation, windows location and size were changed. With this change, more air entered and the level of air circulation in each zone raised. Application of chimney or vertical placement of windows also increases the thermal condition.

Considering Cyprus climate conditions and the amount of wind demand in its hot season, temperature in the first and second simulation conducted were far away from the comfort zone. In the third simulation, double skin facade in combination with the tower acted like a channel, in summer time. When there was need to further cooling, air flow pushed hot air out of the cavity and fresh air was suck in the building. When double skin façade opening are close during cold season, the glass facade isolated the existing facade from high rate of wind flow and absorbed the solar radiation in winter time.

This study aimed to improve the indoor thermal performance of the Health Center Building, increasing internal thermal comfort quality of the building environment and decreasing energy usage while cooling and heating the building. In this regards, three dynamic thermal modeling of Health Center Building via TAS software were examined to find out the thermal comfort zone based on the double skin facade strategies, without using mechanical systems. Moreover, the influence of double skin facade and chimney around the existing building, solar radiation, internal air circulation, relative humidity, external temperature and apertures opening percentage in thermal performance of the Health Center Building was examined. From ASHRAE point of view, in general, suitable thermal comfort is between 24 - 26°C.

According to the literature review, internal temperature of a health center building, should be around 26°C with a 60% relative humidity.

In simulation one, the current situation of the Health Center Building with 10% opening had been demonstrated. Because of the building direction, heat and sun radiation in winter time are lost and extra heat from east and west side in summer is gained. In summer time, inside temperature of the existing simulation was even more than outside, and in winter time it was the same as the external temperature. One of the influential issues in hot period which effected internal temperature of the Health Center Building was that the north side had the lowest amount of opening. In summer time, inner temperature arrives around 35°C and in winter time, it is 17°C. Therefore, it was understood that in the selected months of March and September there exists an approximately moderate and acceptable condition, while in June and December, the situation is worst both in hot and cold seasons.

In terms of reducing the heating need in winter and cooling need in summer, in simulation 3, the facade was covered by DSF plus the help of a chimney which ejected the heated air by natural air circulation, drowning it off through the exterior skin in summer period. In this regards, DSF helps the building to increase the internal temperature. In winter time, by closing the chimney opening, solar radiation gets absorbed and the inner temperature of the cavity starts to increase so to provide a good indoor climate inside the building. In simulation 3, 10 percent apertures openings and 100 percent opening for the chimney was considered in order to monitor the new effects on internal performance, because the building needed more ventilation to decrease internal temperature based on the former simulations during summer time. The results showed that on March 21st, at 7:00 am, inside temperature was around 20°C with a 69% relative humidity, which is acceptable for the morning temperature. At 12:00 am, west side of the building was located in the comfort zone, being about 25°C and 60% relative humidity, and east side was 2 degrees lower than the west side.

Summer time is a problematic period for reaching the thermal comfort in this kind of climate: on 21st of June and September, at the noon time, temperature arrived around 35-36 degrees and there was a high rate of humidity which was far from comfort zone. According to simulation three, considering DSF and chimney for the Health Center Building, in the morning and afternoon time, temperature was around 24-26°C with 55% humidity and in noon time, compared to simulation one and two, inside temperature was reduced 4-5 degrees, reducing from 36 to around 30°C and 58% humidity. Although 30°C is not in comfort zone, but the natural ventilation load through the building makes occupants to use less hours of mechanical air conditioner.

In March and December which are considered as cold seasons the average range of internal temperature was around 23°C with 63% humidity which in first simulation was around 19 with 55% humidity; that means 4 degrees higher than the existing situation. In this study, finally, the thermal comfort inside the building reached near the comfort zone, through increasing the temperature in December as the cold season, and decreasing it in June.

Consequently, it was understood that in the first simulation, thermal situation in March and September had a moderate and acceptable condition, and in June and December it had a critical condition. In the third simulation, by raising the ventilation quality, an acceptable internal surface temperature was provided, and also heating need in winter and cooling need in summer was reduced. By using these strategies, lower amount of electricity would be needed to heat or cool the building, hence reducing the environmental impacts.

Due to the lack of natural resources and the country being highly dependent on imports of raw materials, energy and goods, these days, the government in this island has developed the use of renewable energy sources, such as solar or wind. Because of critical summer heat situation in Cyprus and the high cost of electricity, natural airflow would be a solution to answer these problems. By use of natural and renewable energy resources such as sunlight, water and wind in buildings, maximum levels of thermal comfort can be reached, reducing the buildings' energy consumption levels.

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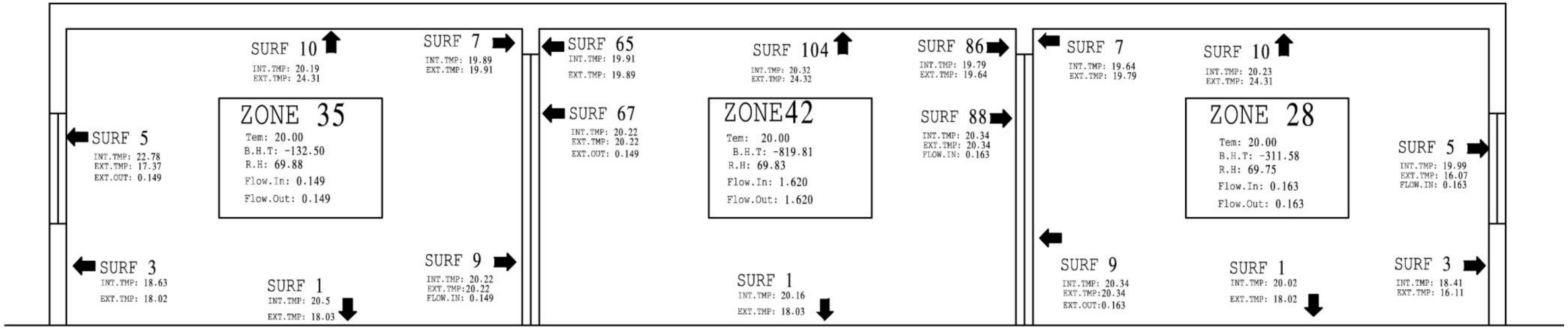
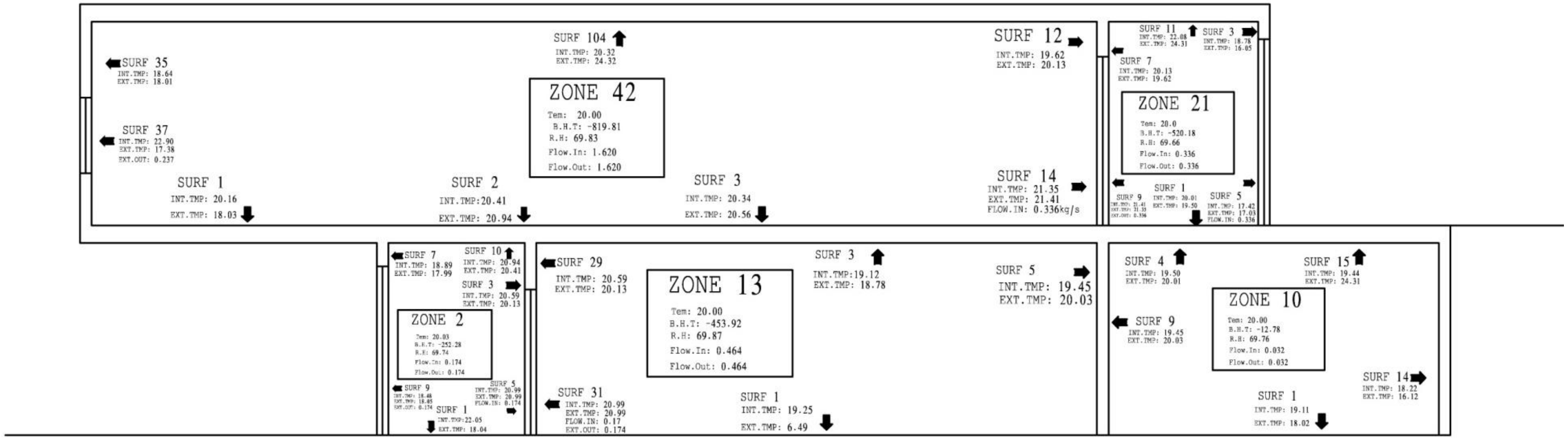
APPENDICES

Appendix A: Simulation 1



Ex.Temp: 16.1 C° Ex.R.H: 89% Ex.G.C.Rad: 315.17(W)

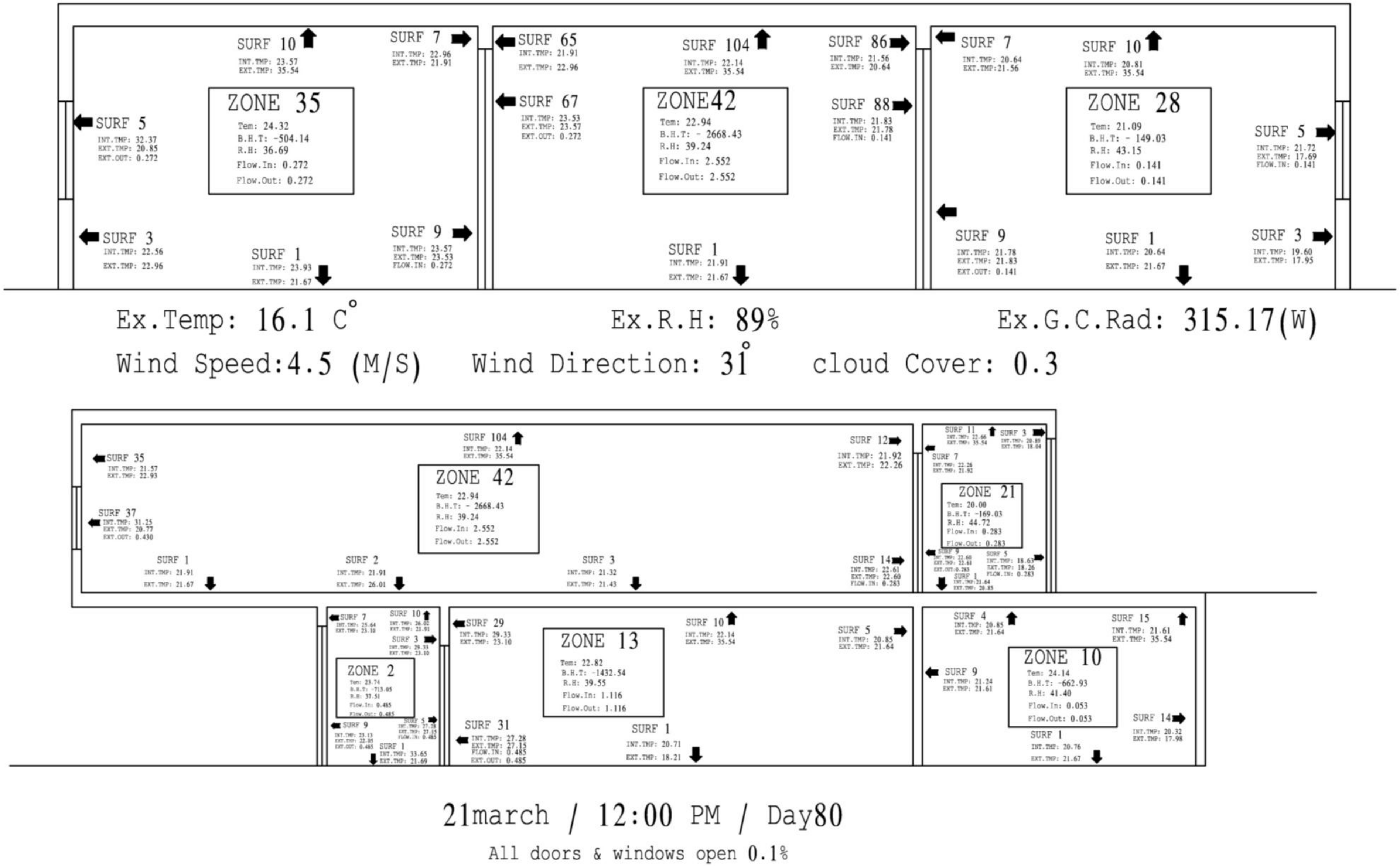
Wind Speed:4.5 (M/S) Wind Direction: 31° cloud Cover: 0.03



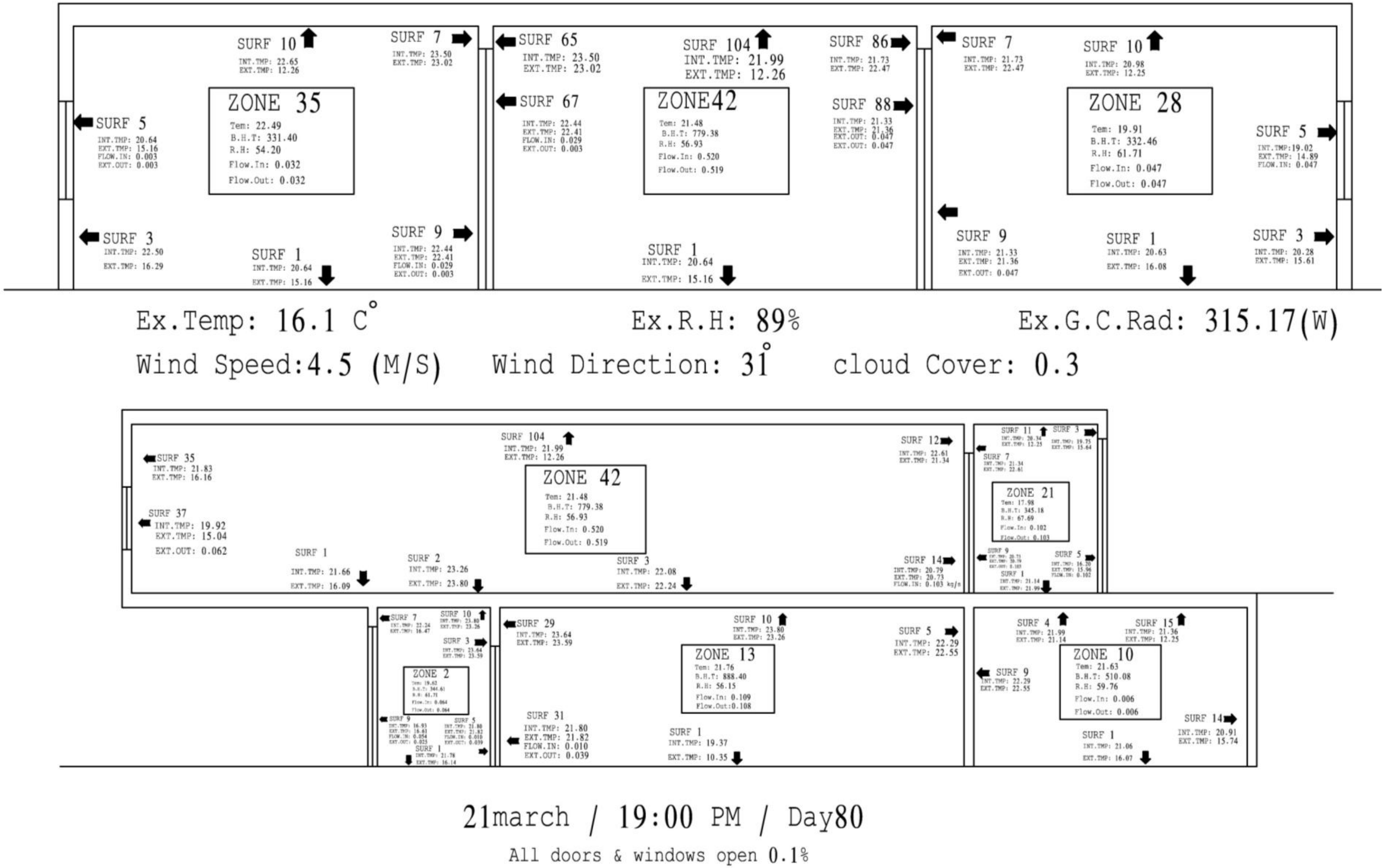
21march / 7:00 AM / Day80

All doors & windows open 0.1%

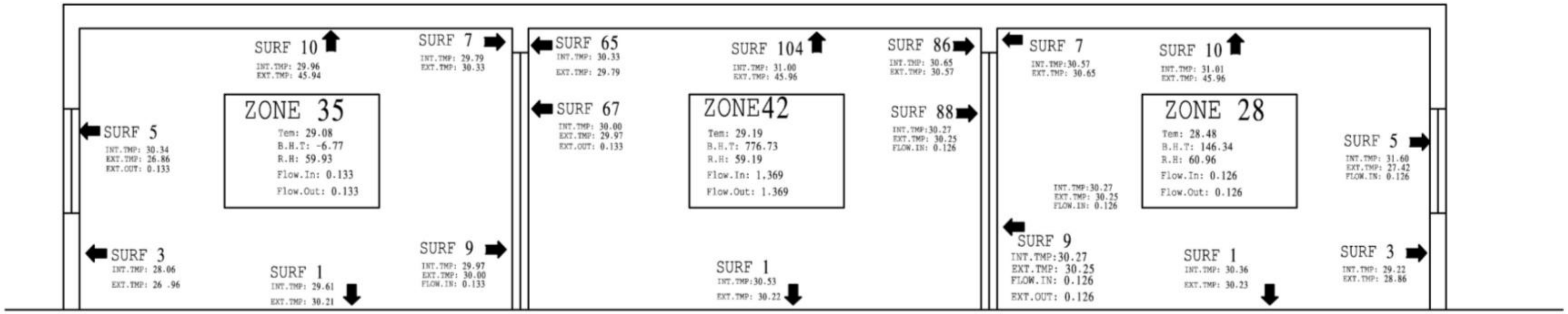
Appendix A: Simulation 1



Appendix A: Simulation 1

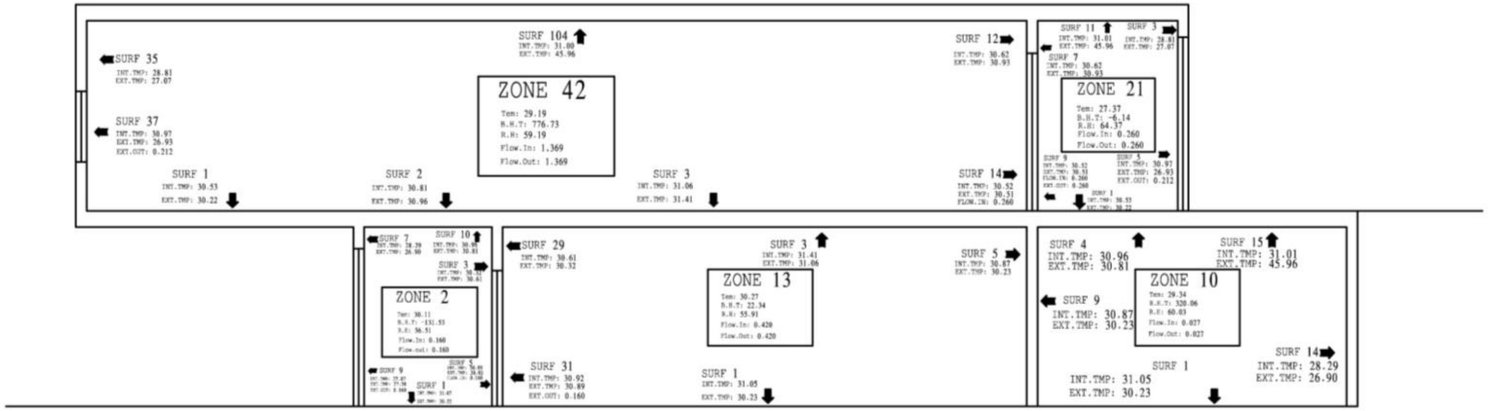


Appendix A: Simulation 1



Ex.Temp: 26.4 C ° Ex.R.H: 68% Ex.G.C.Rad: 532.65(W)

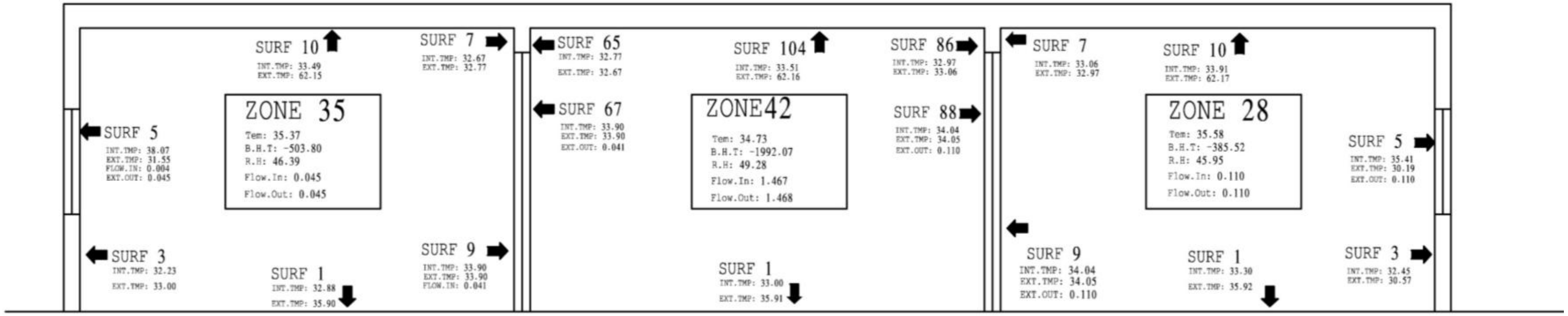
Window Speed:2.8(M/S) Wind Direction: 35° cloud Cover: 0.00



21june / 7:00 AM / Day172

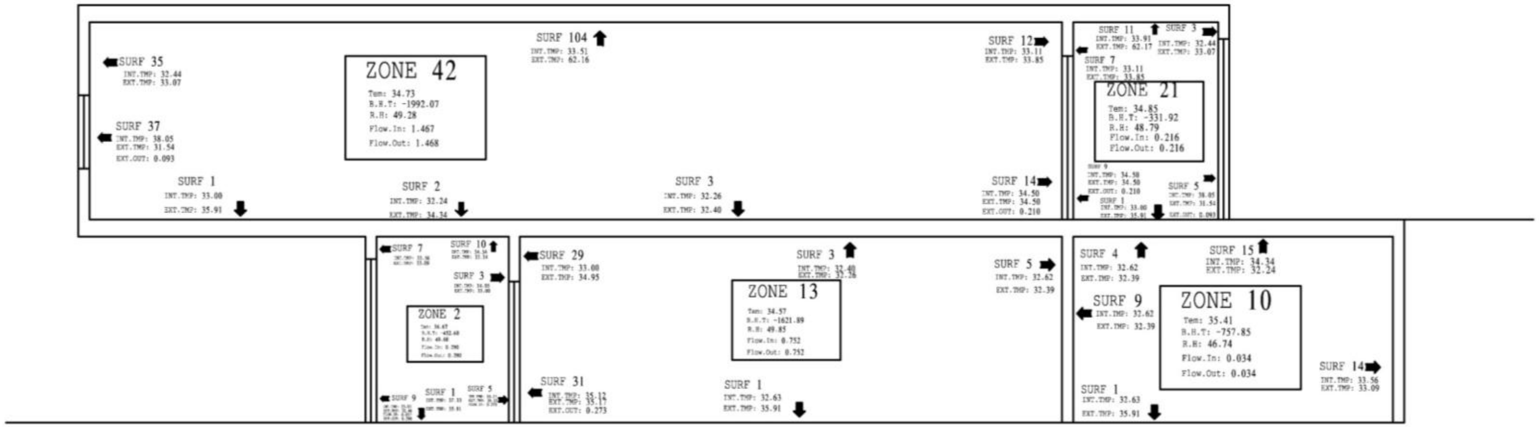
All doors & windows open 0.1%

Appendix A: Simulation 1



Ex.Temp: 28.9 C° Ex.R.H: 74 % Ex.G.C.Rad: 993.20(W)

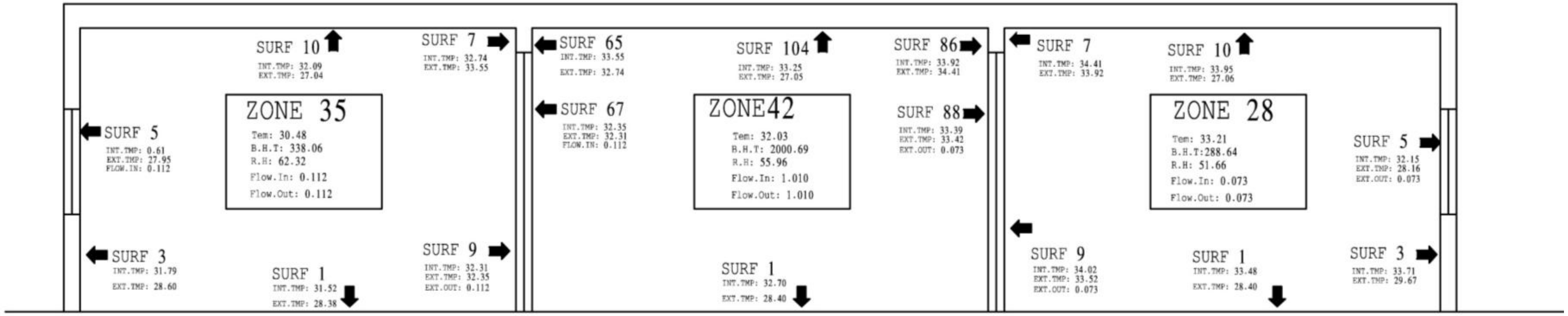
Window Speed:3.70(M/S) Wind Direction: 96° cloud Cover: 0.00



21june / 12:00 PM / Day172

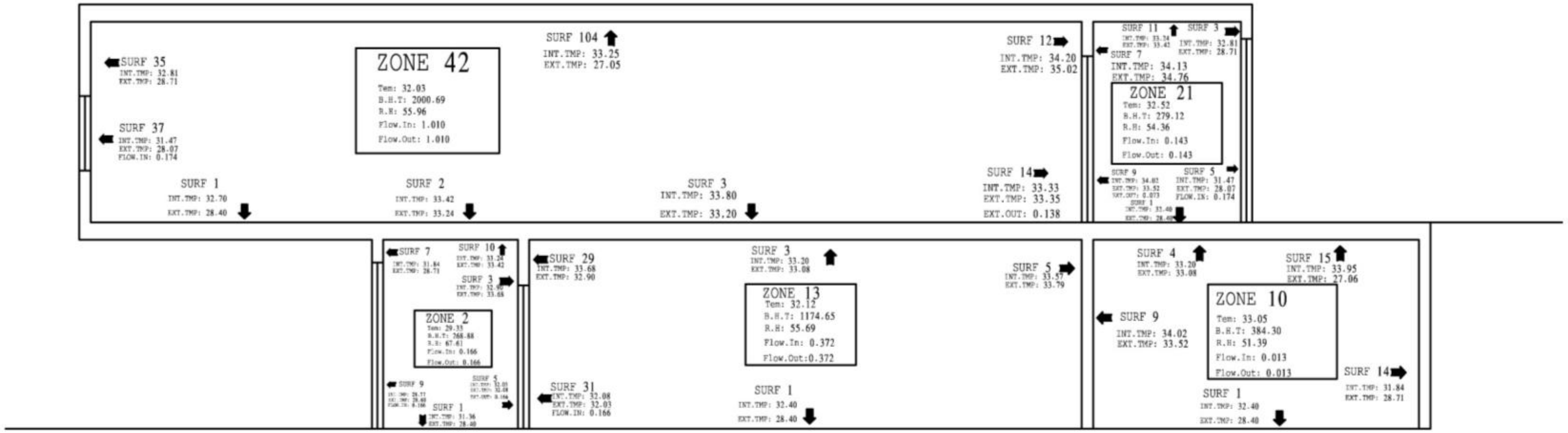
All doors & windows open 0.1%

Appendix A: Simulation 1



Ex.Temp: 28.30 C° Ex.R.H: 72 % Ex.G.C.Rad: 0.00(W)

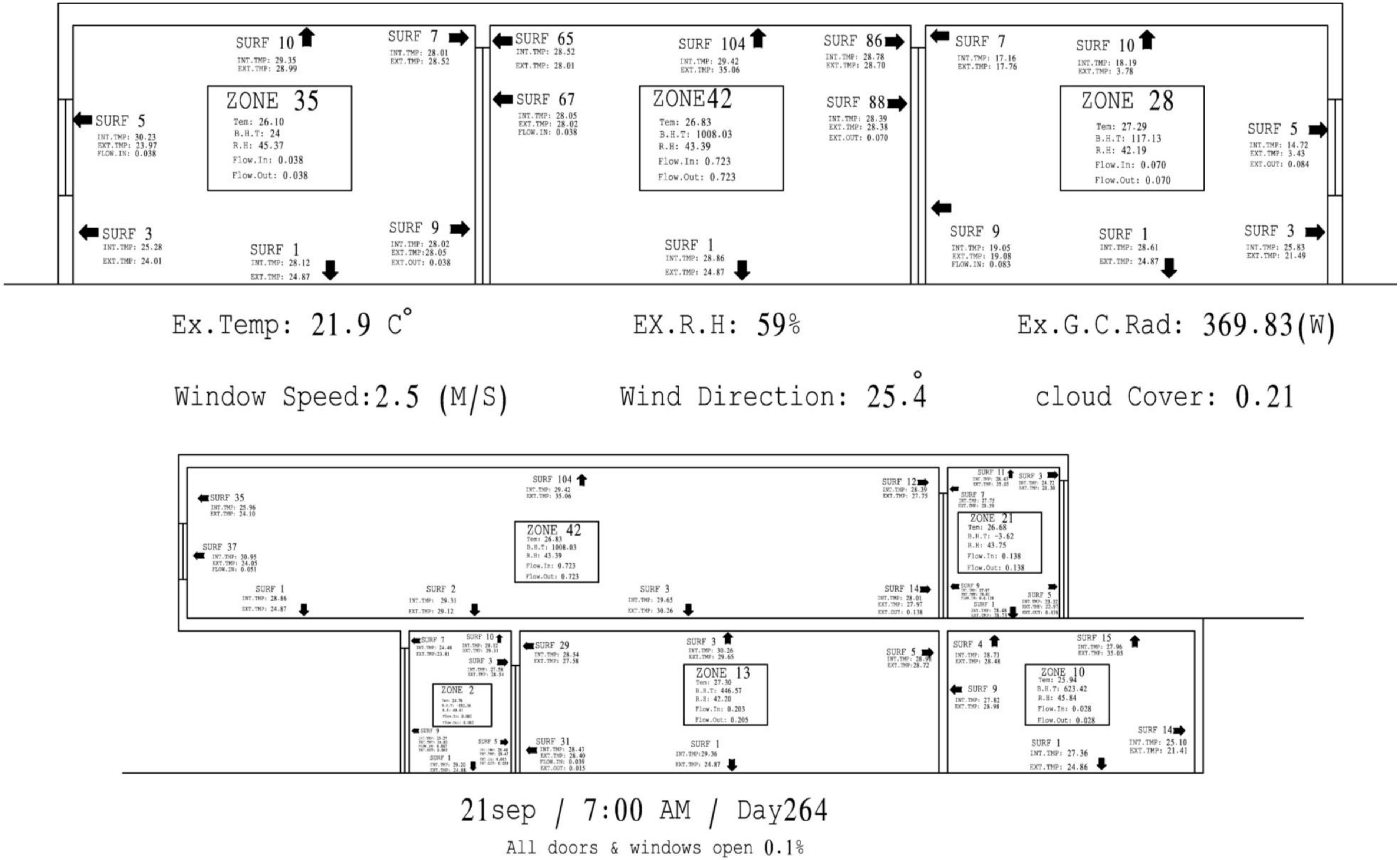
Window Speed:1.9(M/S) Wind Direction: 212° cloud Cover: 0.00



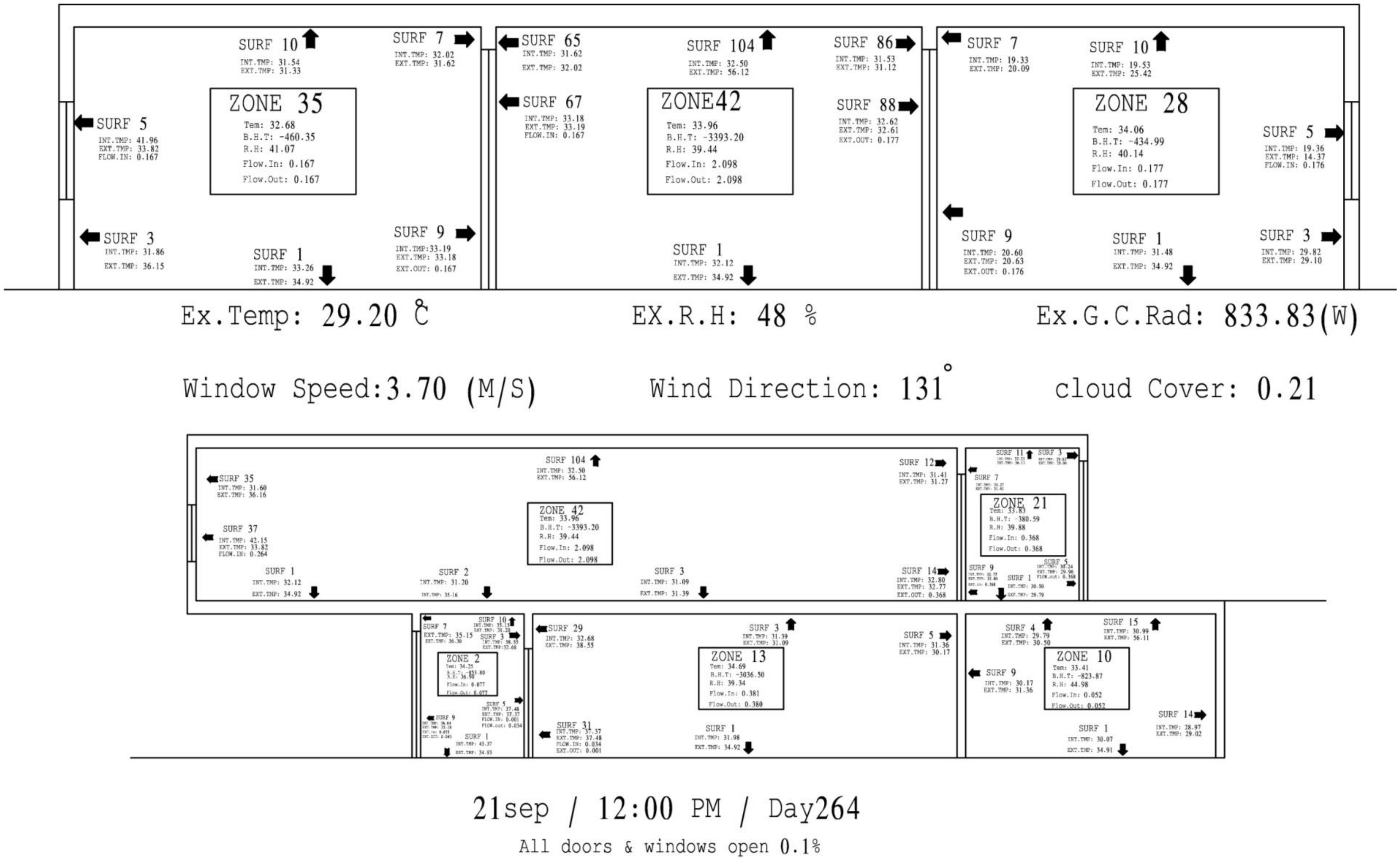
21june / 19:00 PM / Day172

All doors & windows open 0.1%

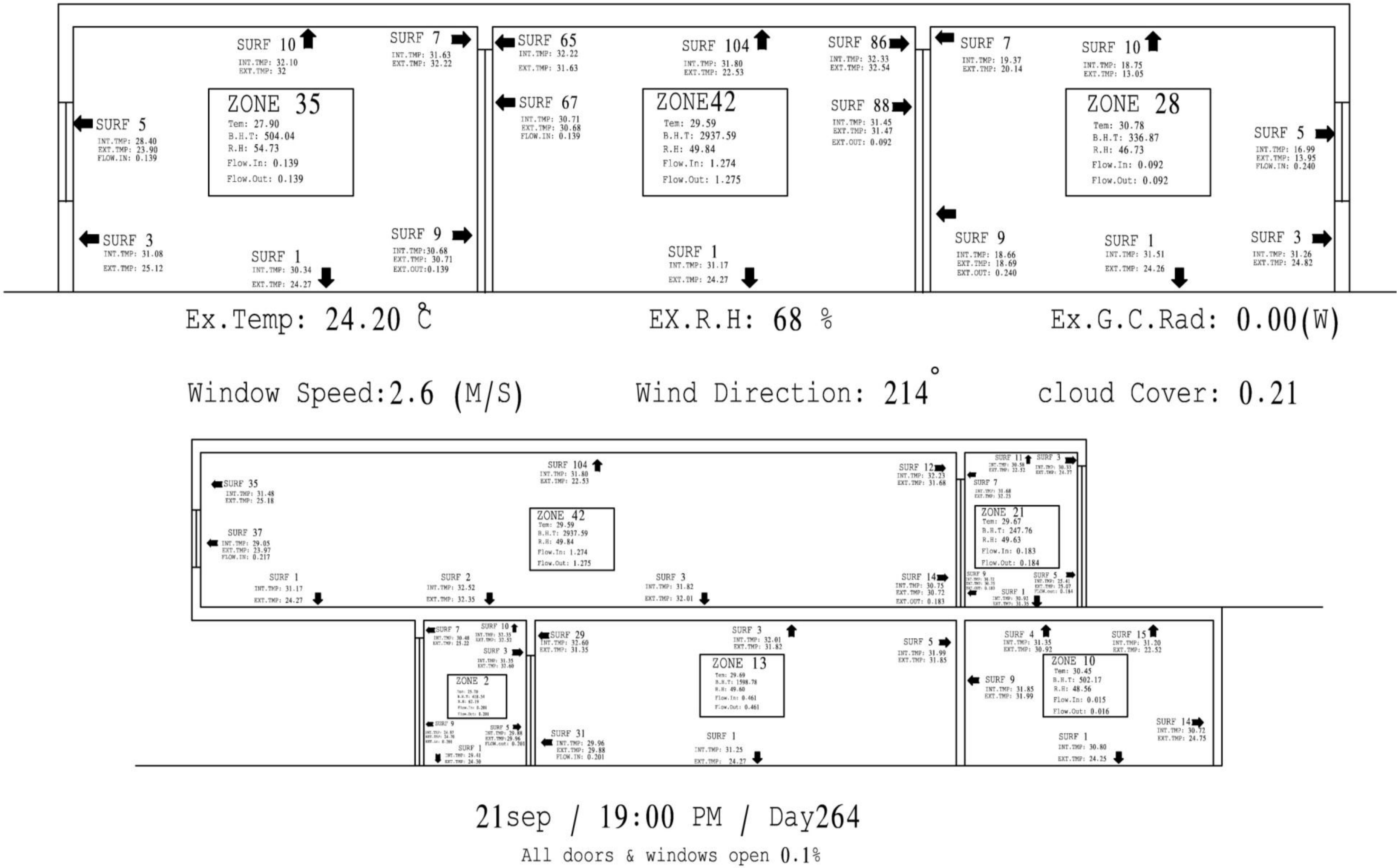
Appendix A: Simulation 1



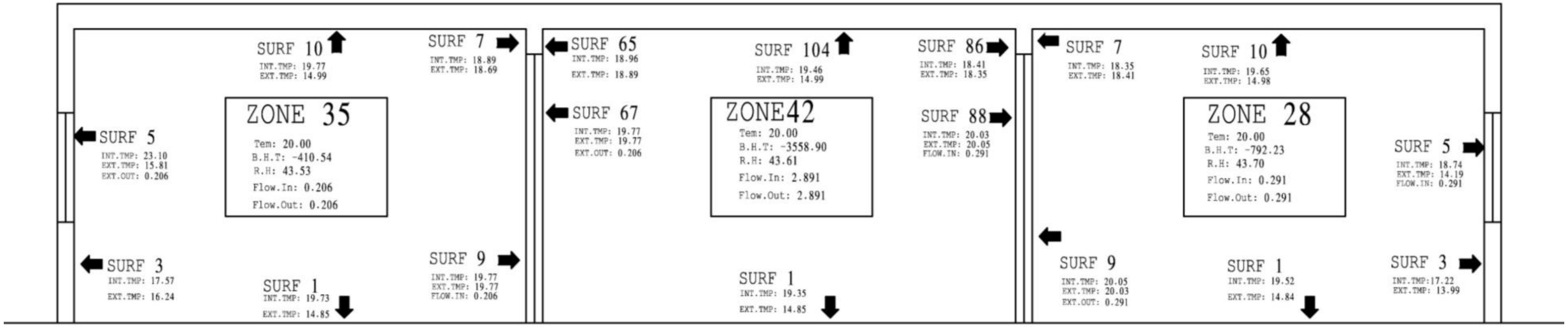
Appendix A: Simulation 1



Appendix A: Simulation 1

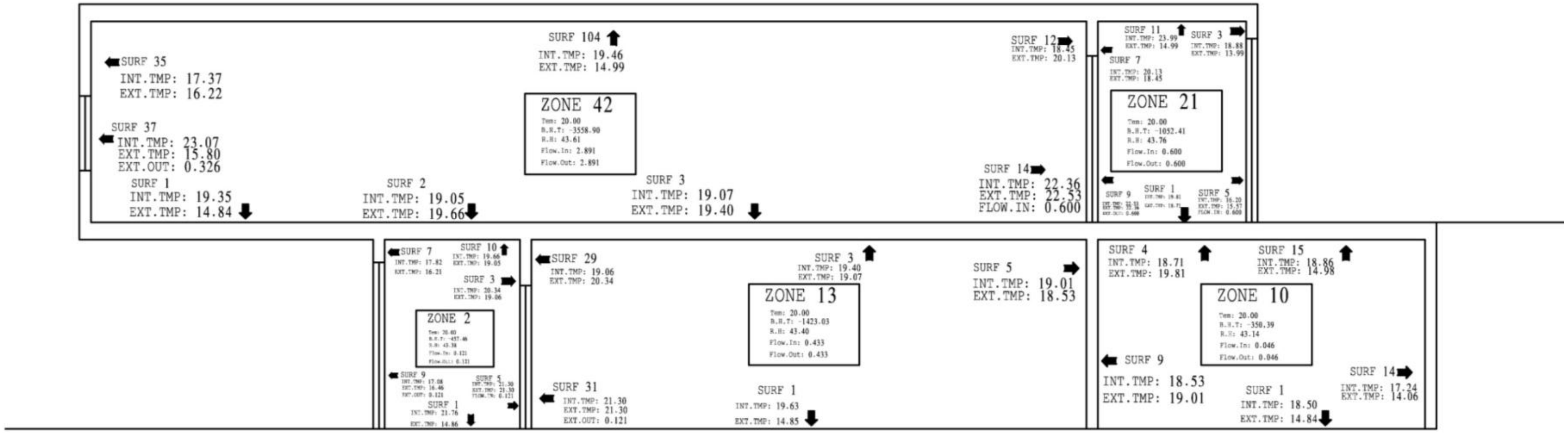


Appendix A: Simulation 1



Ex.Temp: 14.5 C°   EX.R.H: 62%   Ex.G.C.Rad: 82.57(W)

Window Speed:6.9 (M/S)   Wind Direction: 17°   cloud Cover: 0.24



21Dec/ 7:00 AM / Day355

All doors & windows open 0.1%

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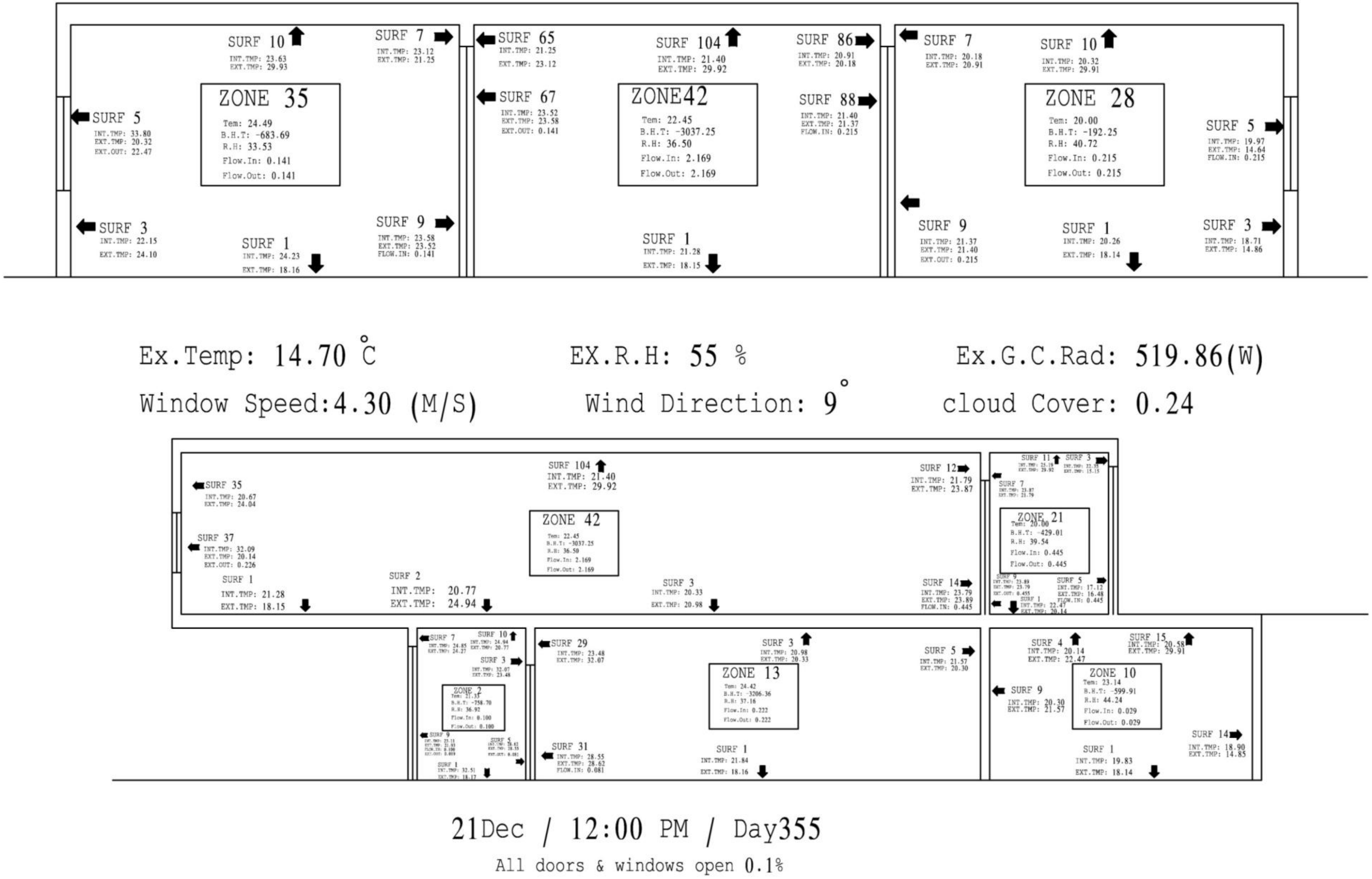
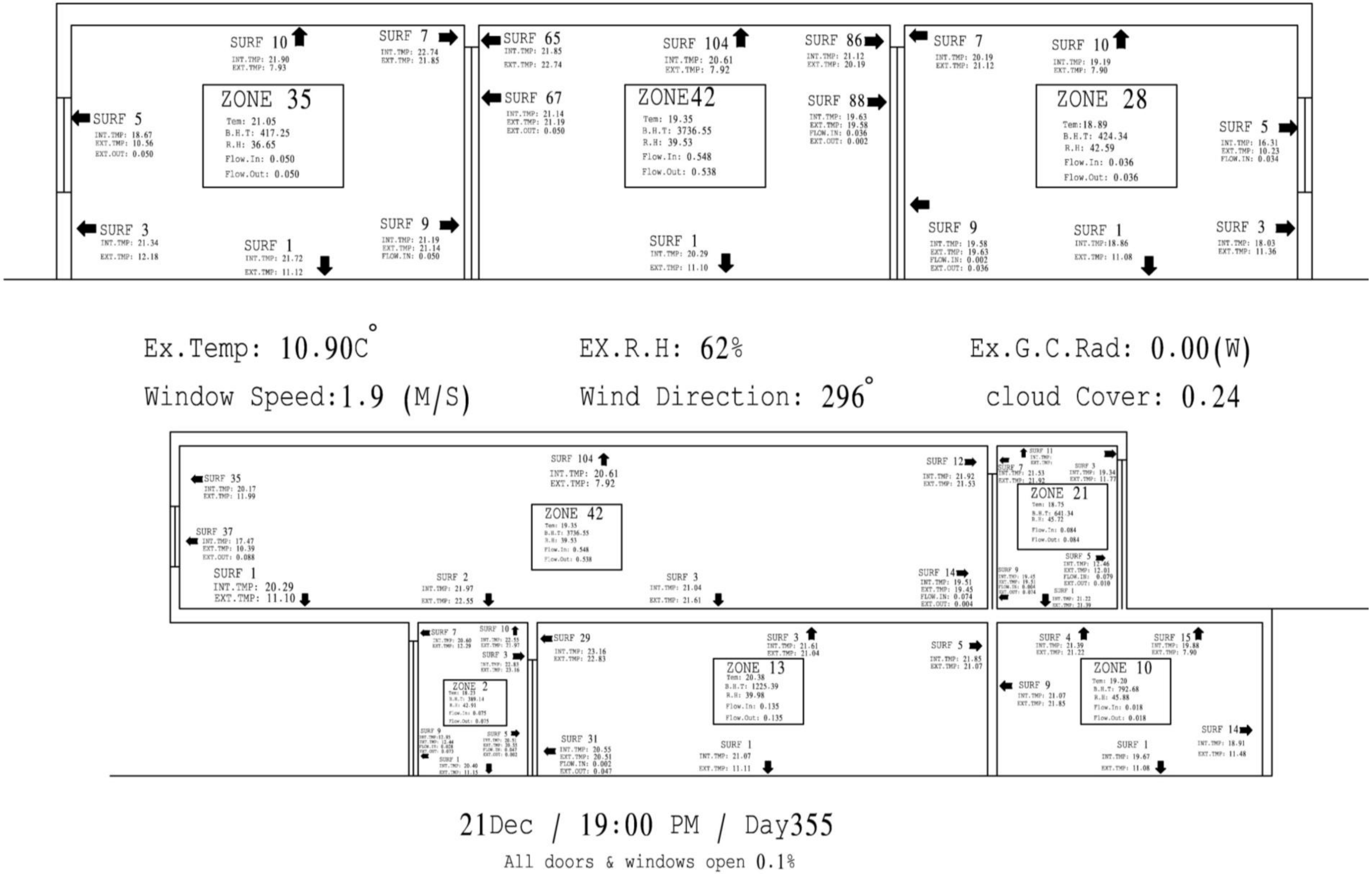
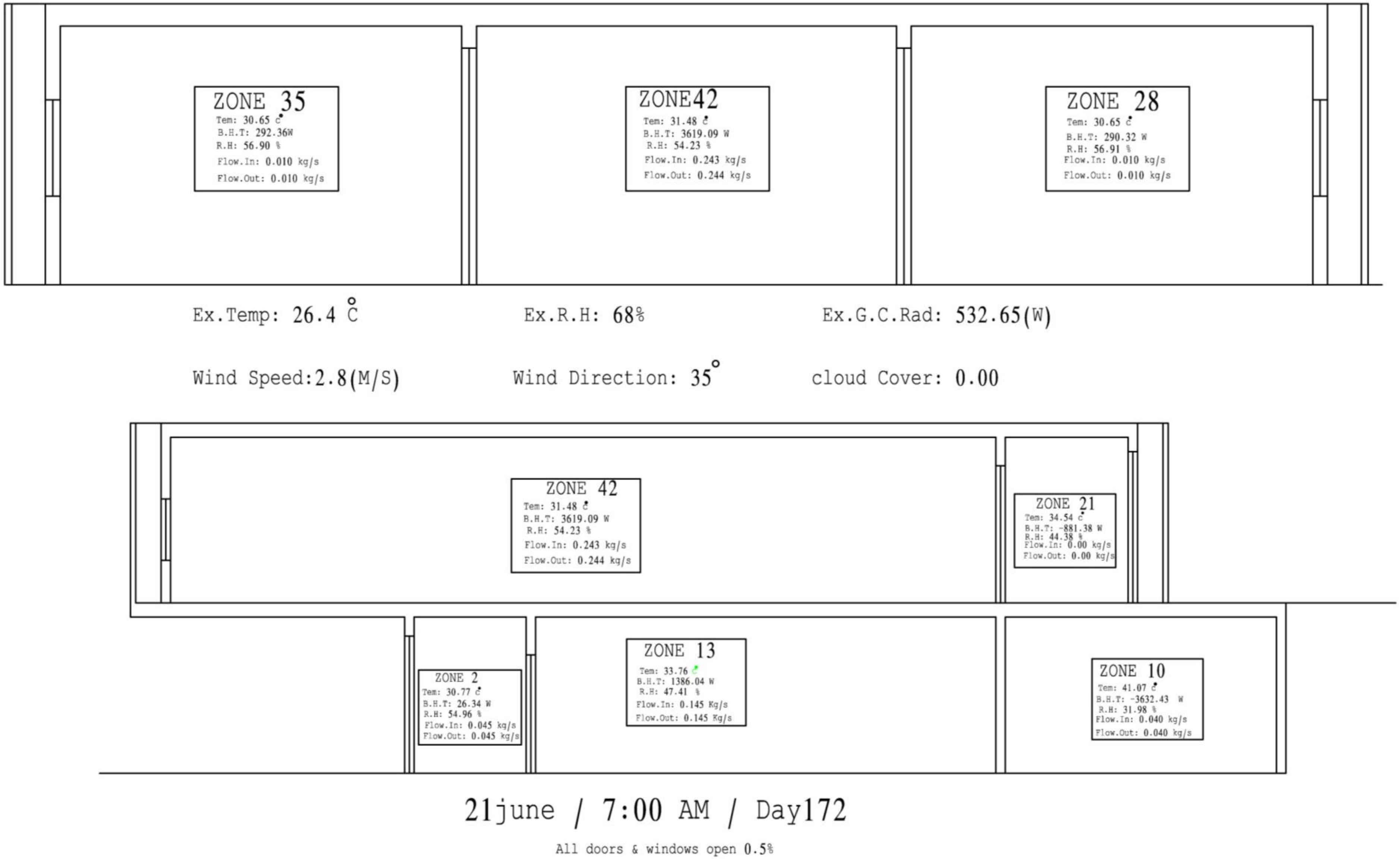


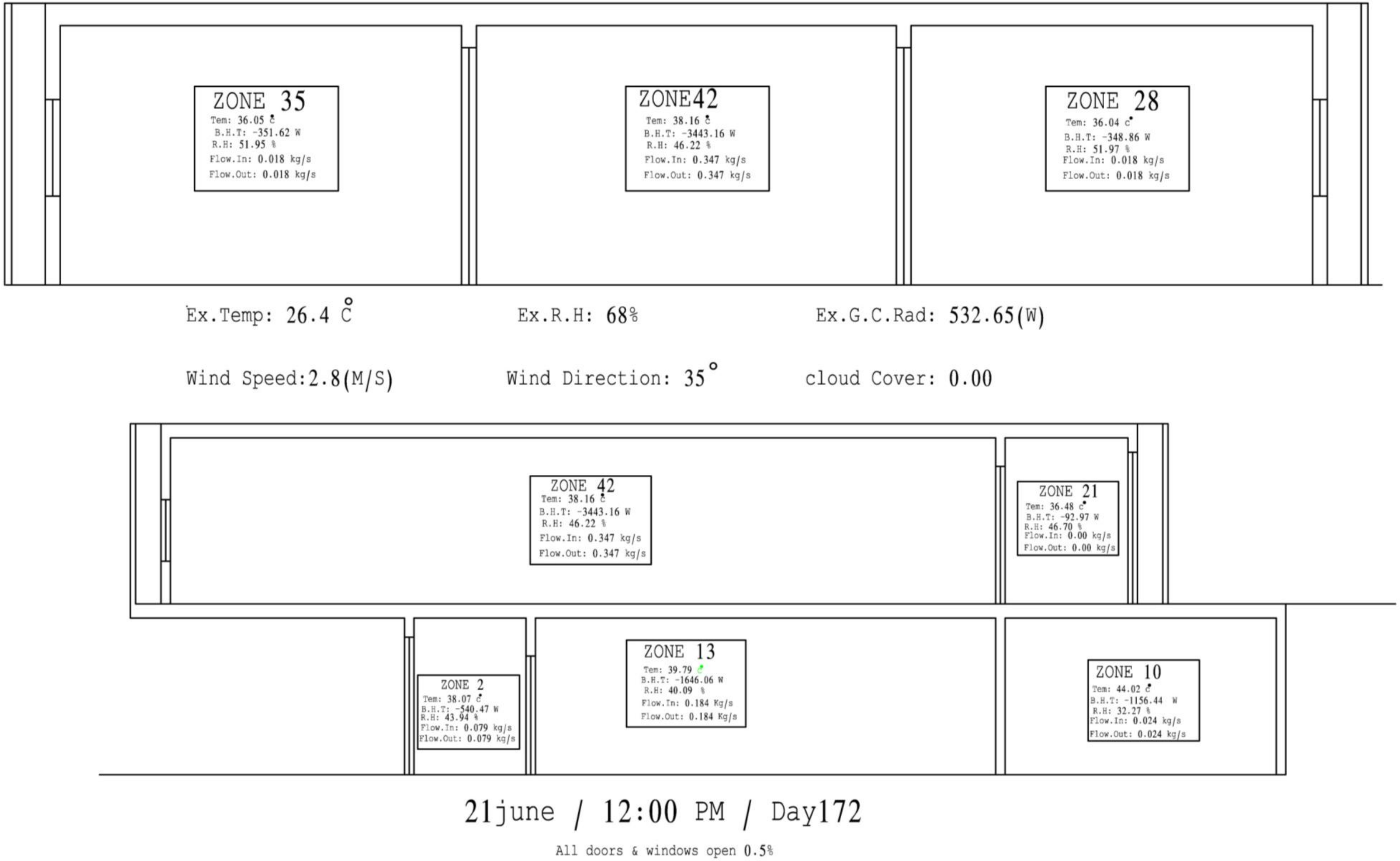
Appendix A: Simulation 1



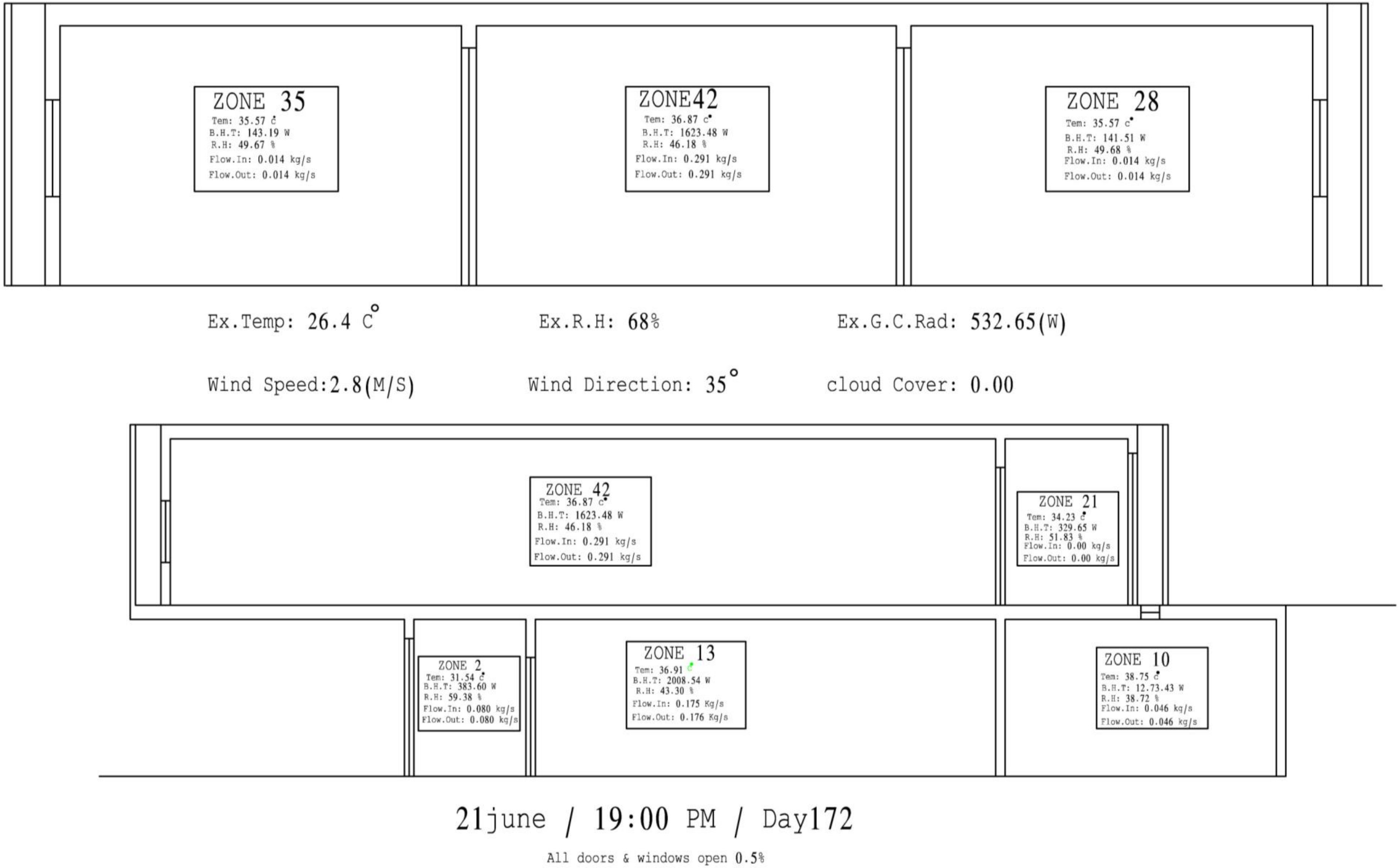
Appendix B: Simulation 2



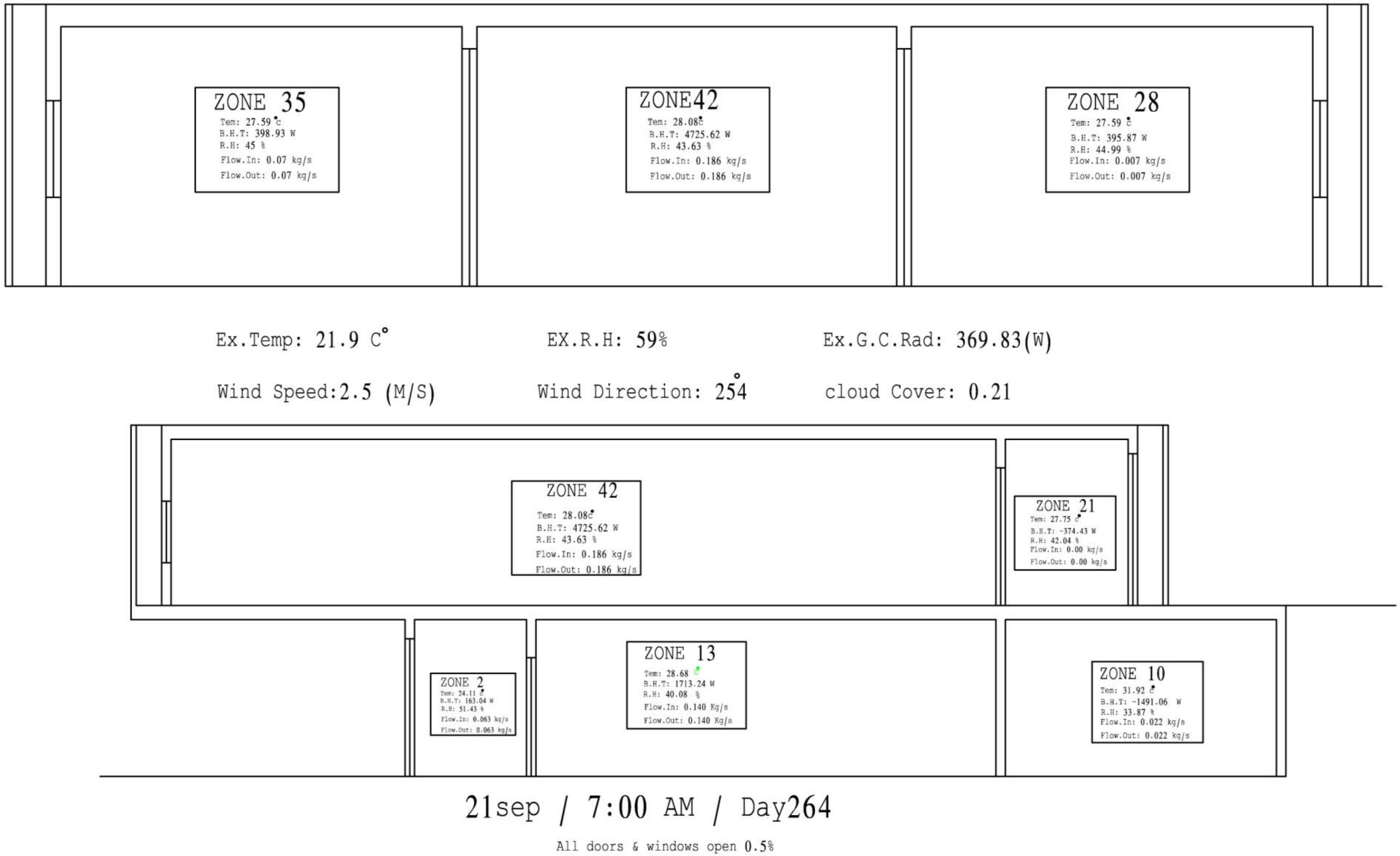
Appendix B: Simulation 2



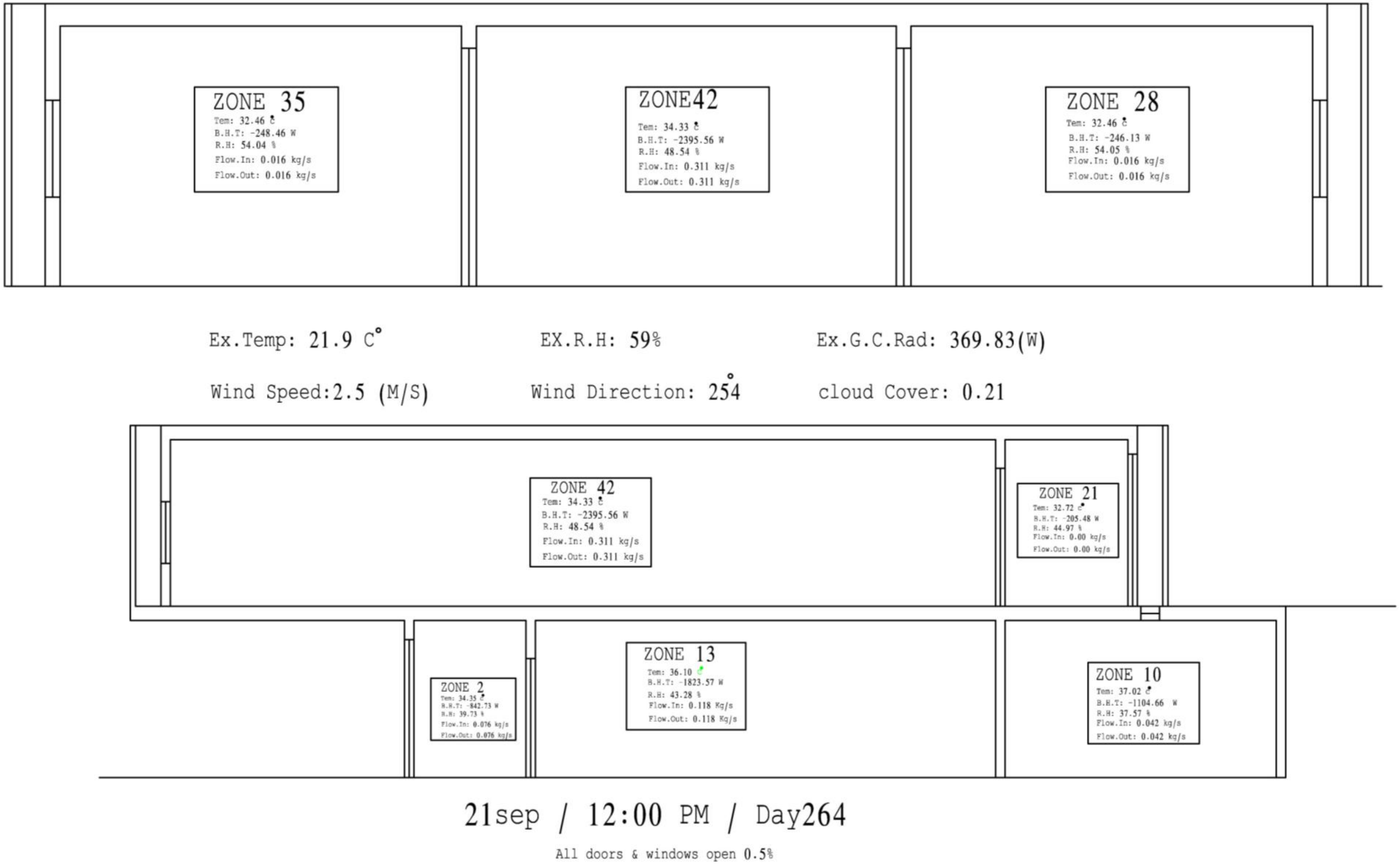
Appendix B: Simulation 2



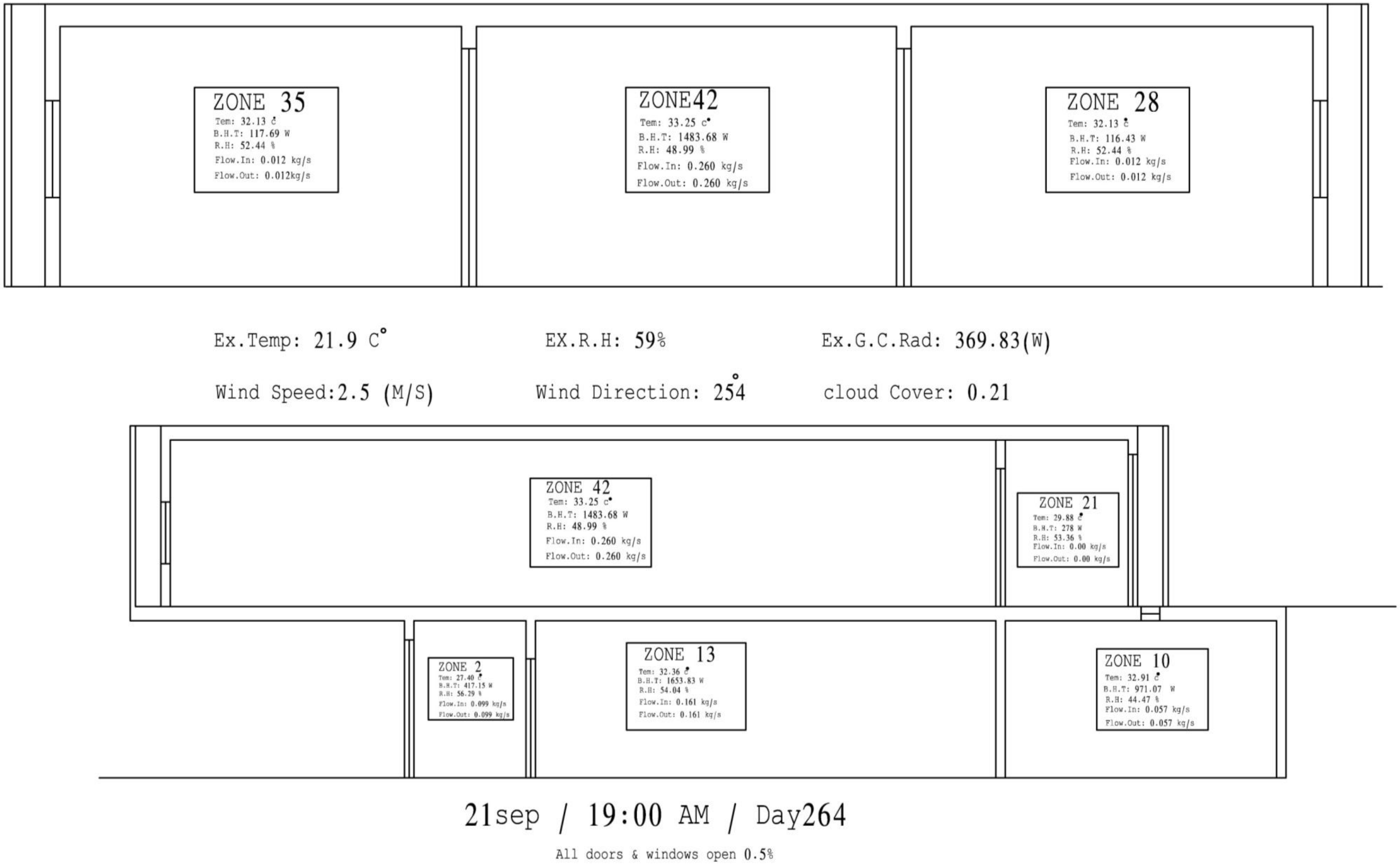
Appendix A: Simulation 2



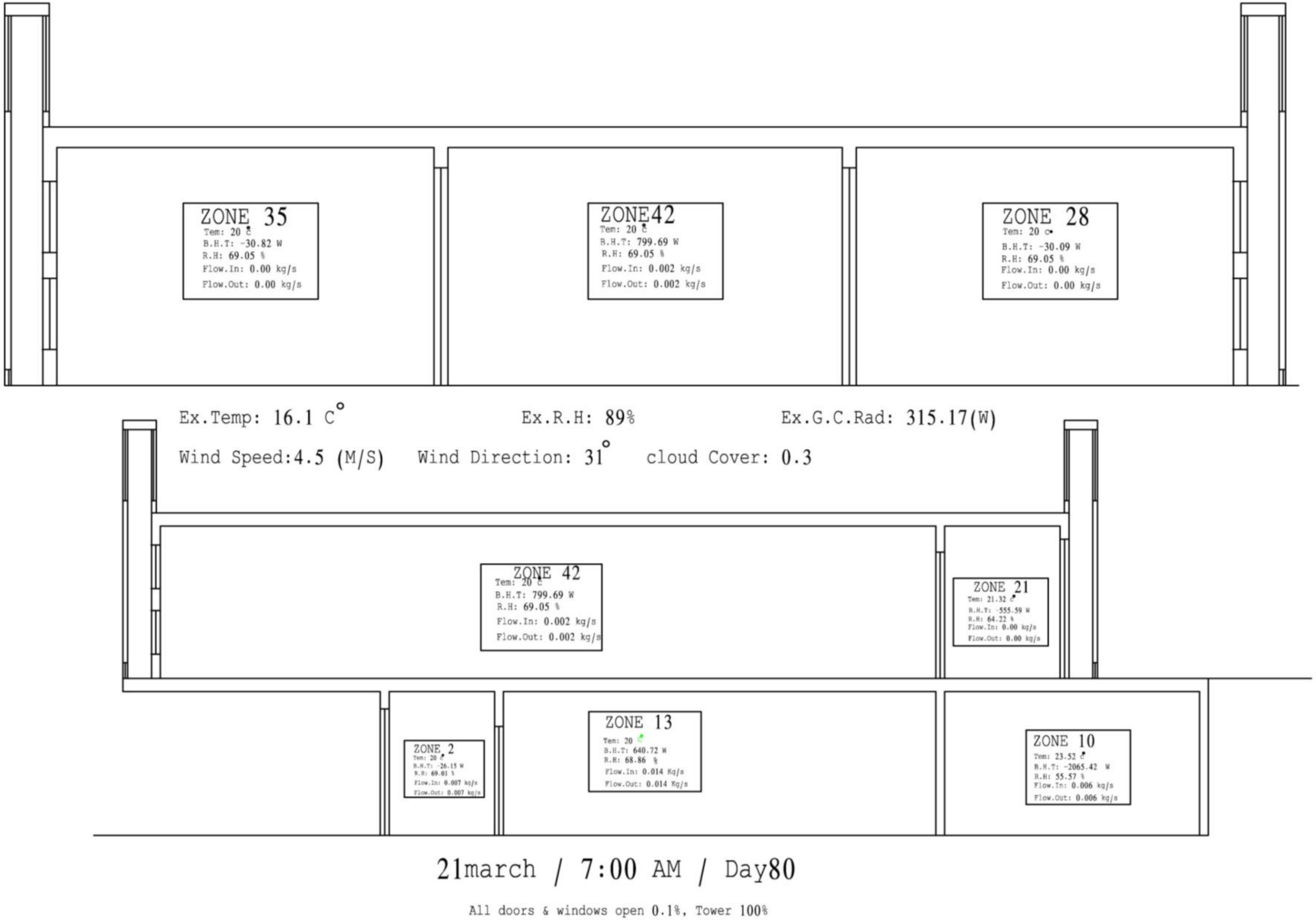
Appendix B: Simulation 2



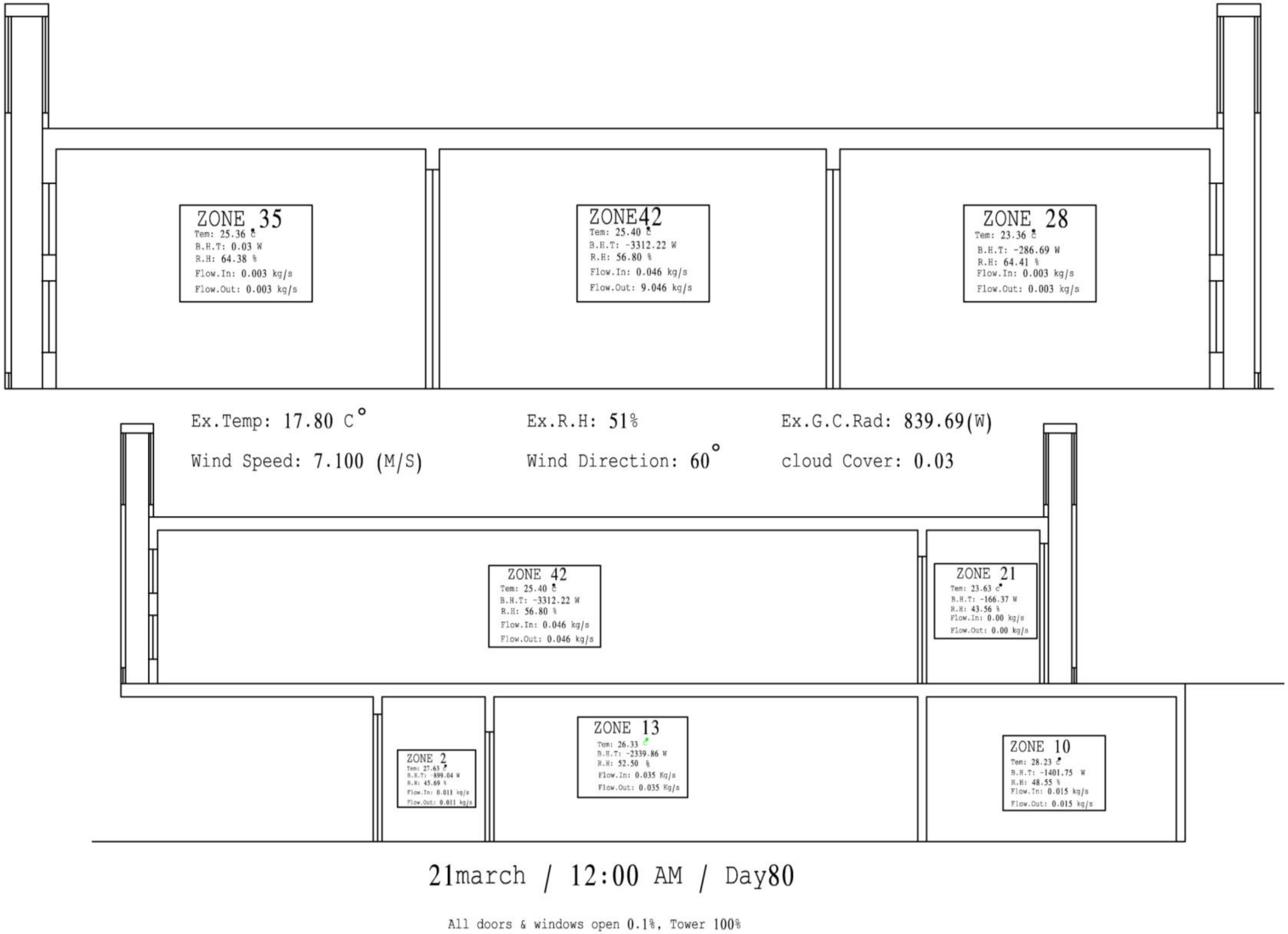
Appendix B: Simulation 2



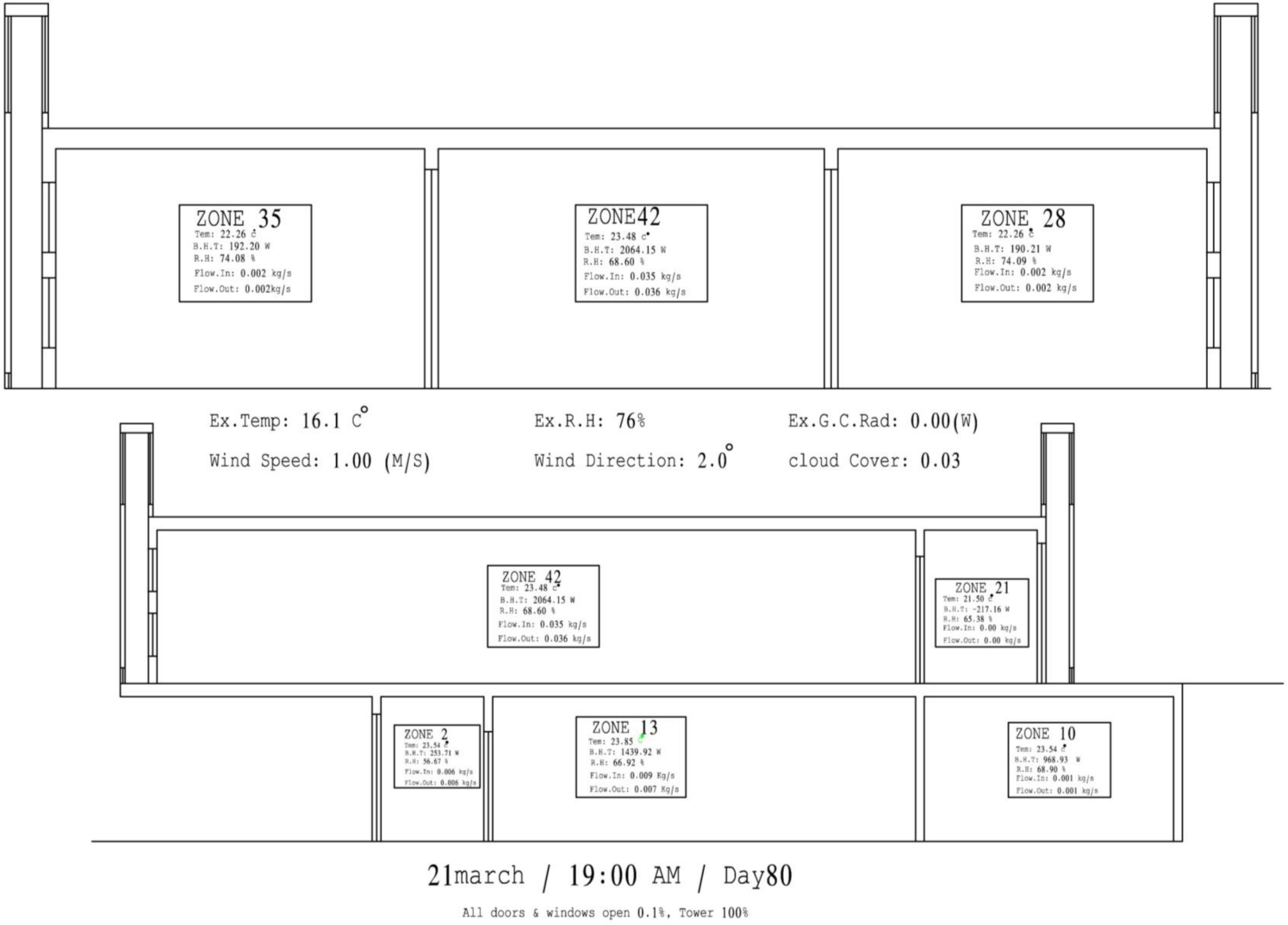
Appendix C: Simulation 3



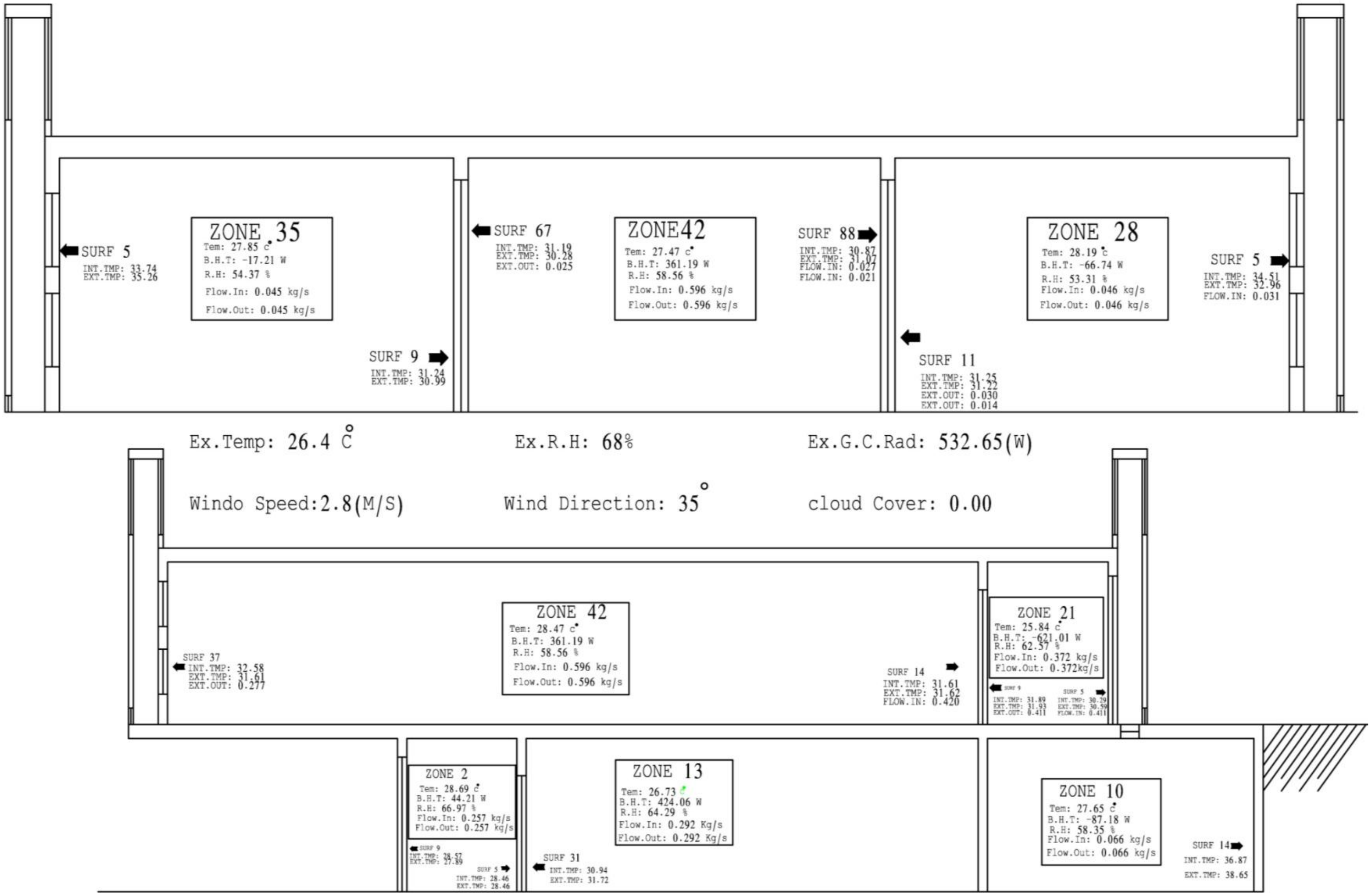
Appendix C: Simulation 3



Appendix C: Simulation 3



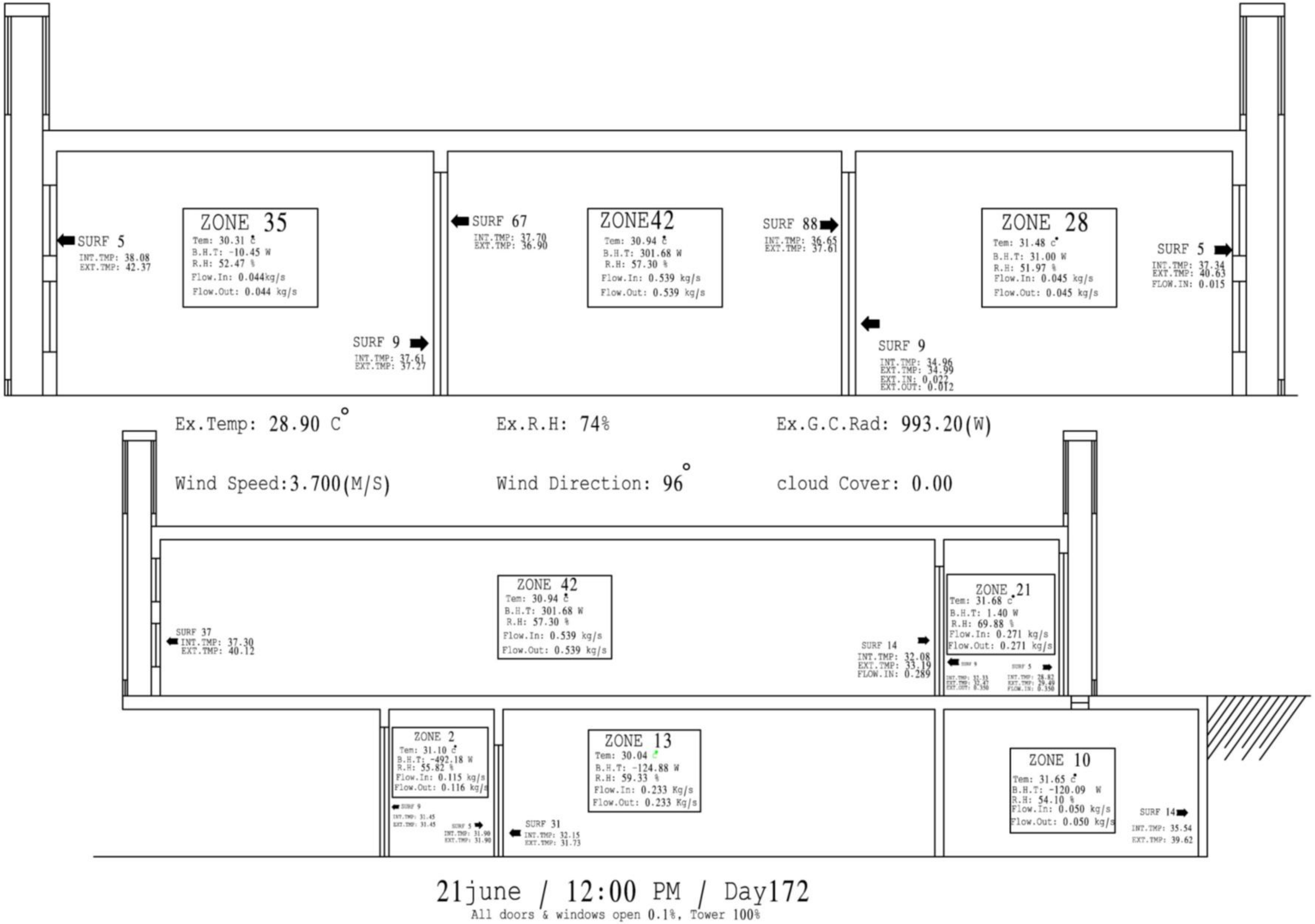
Appendix C: Simulation 3



21june / 7:00 AM / Day172

All doors & windows open 0.1%, Tower 100%

Appendix C: Simulation 3



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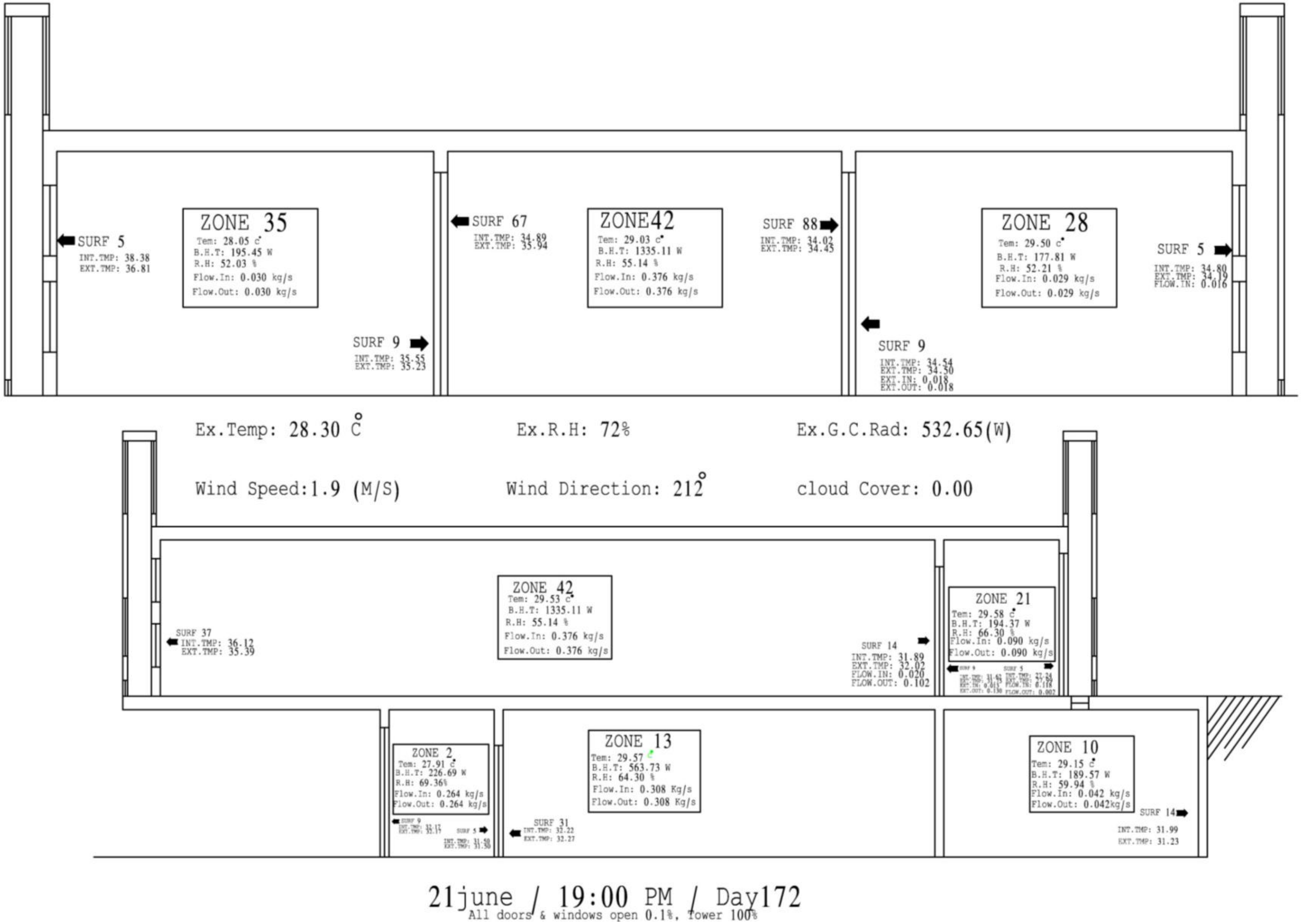
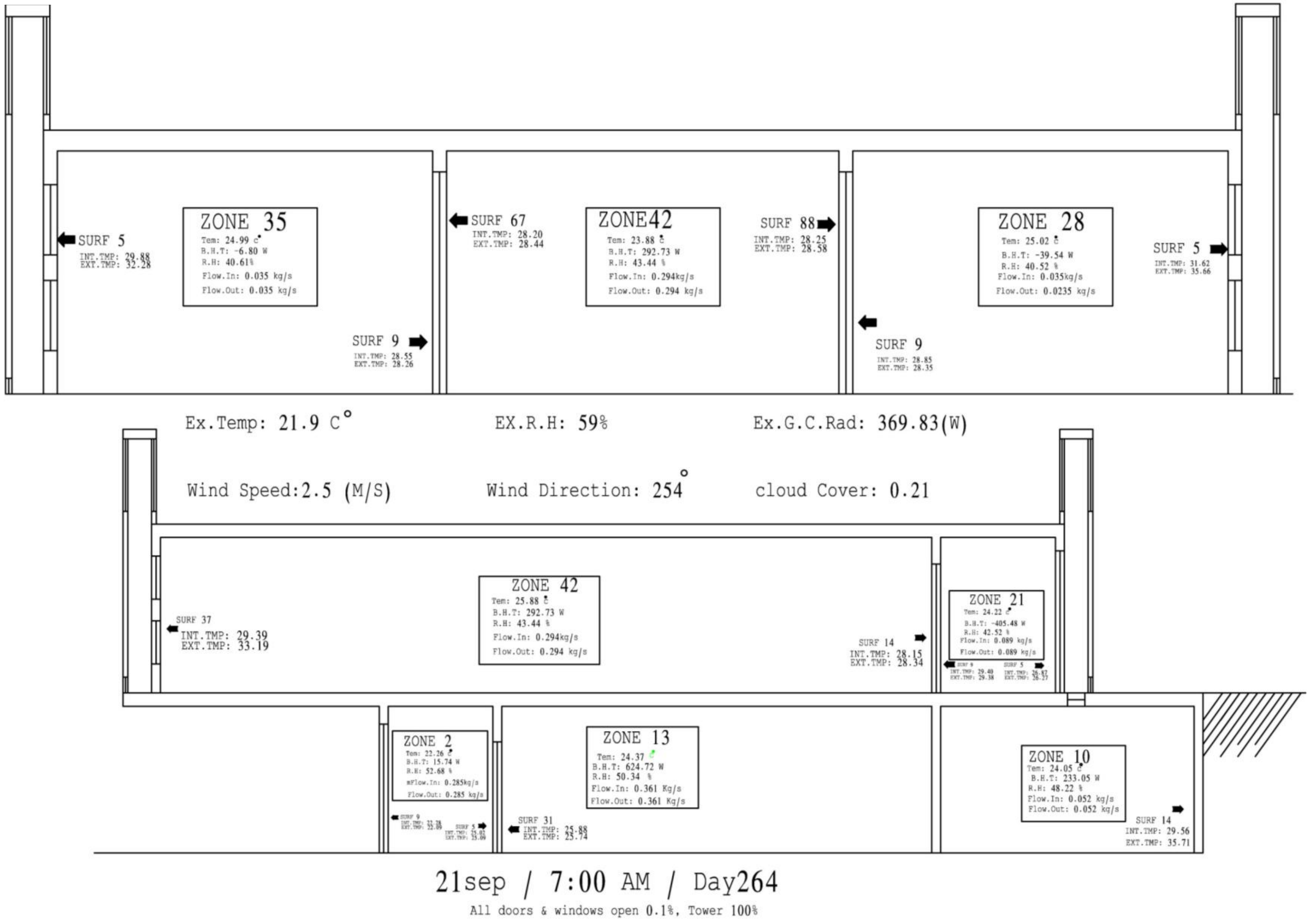
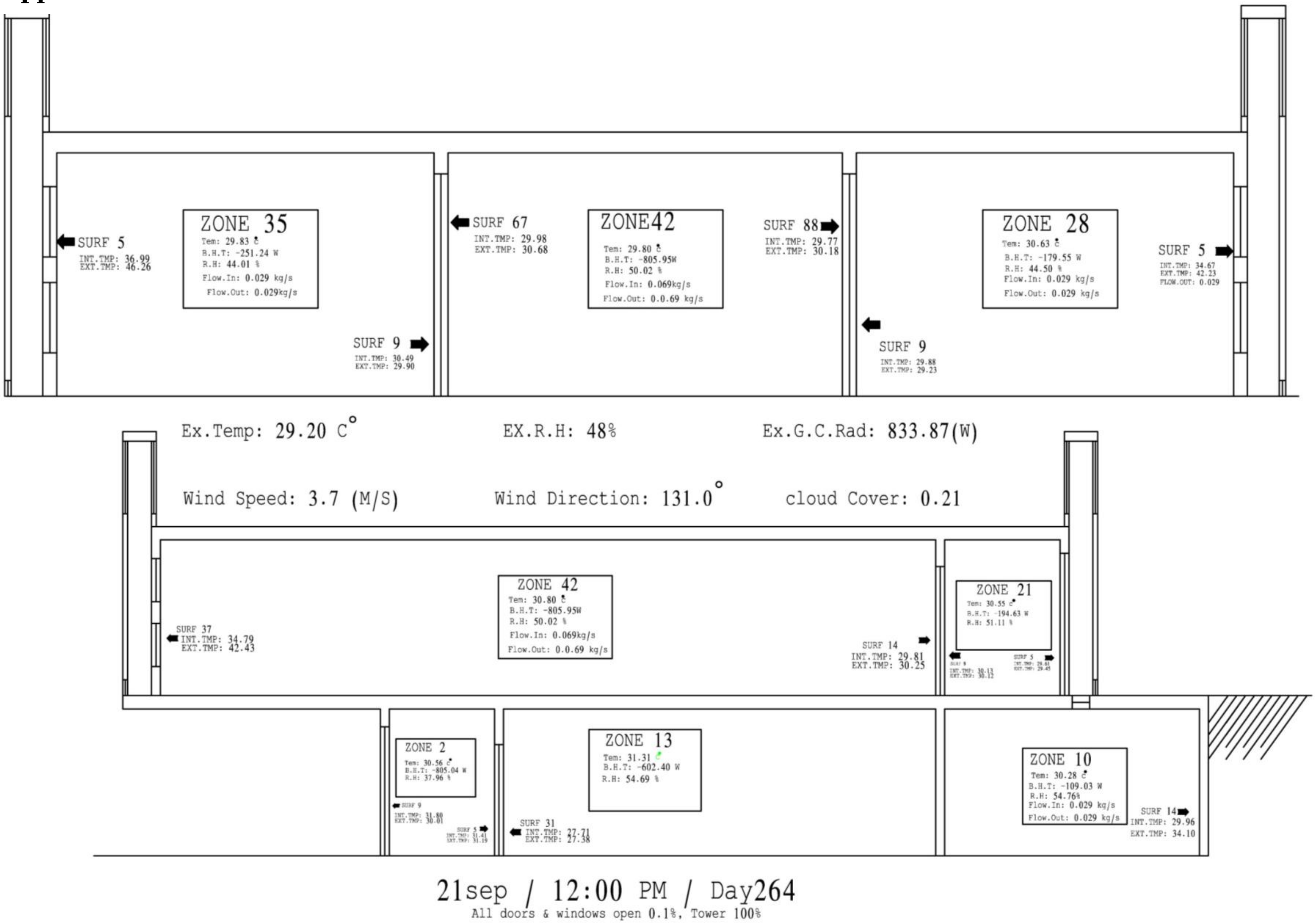


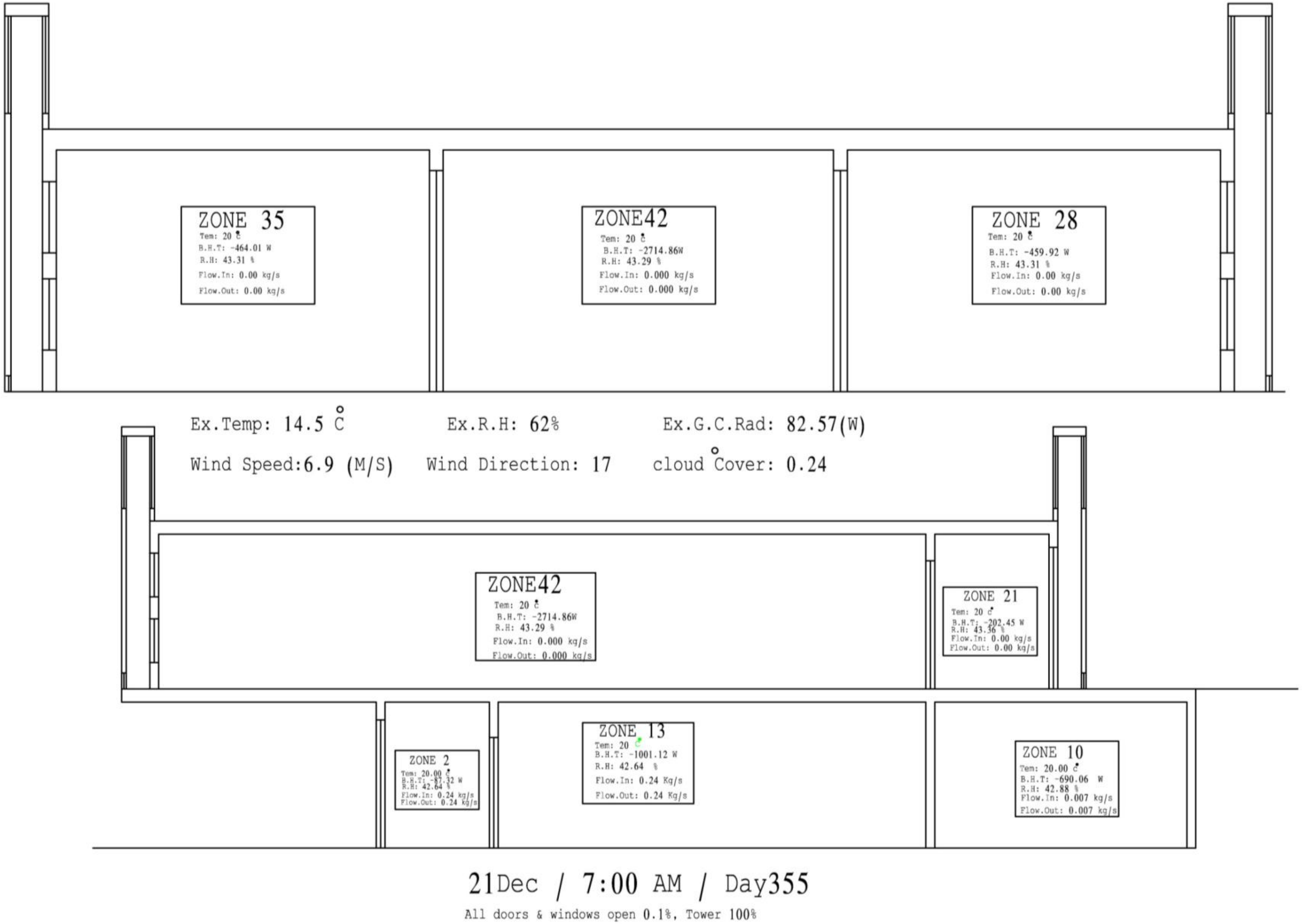
Appendix C: Simulation 3



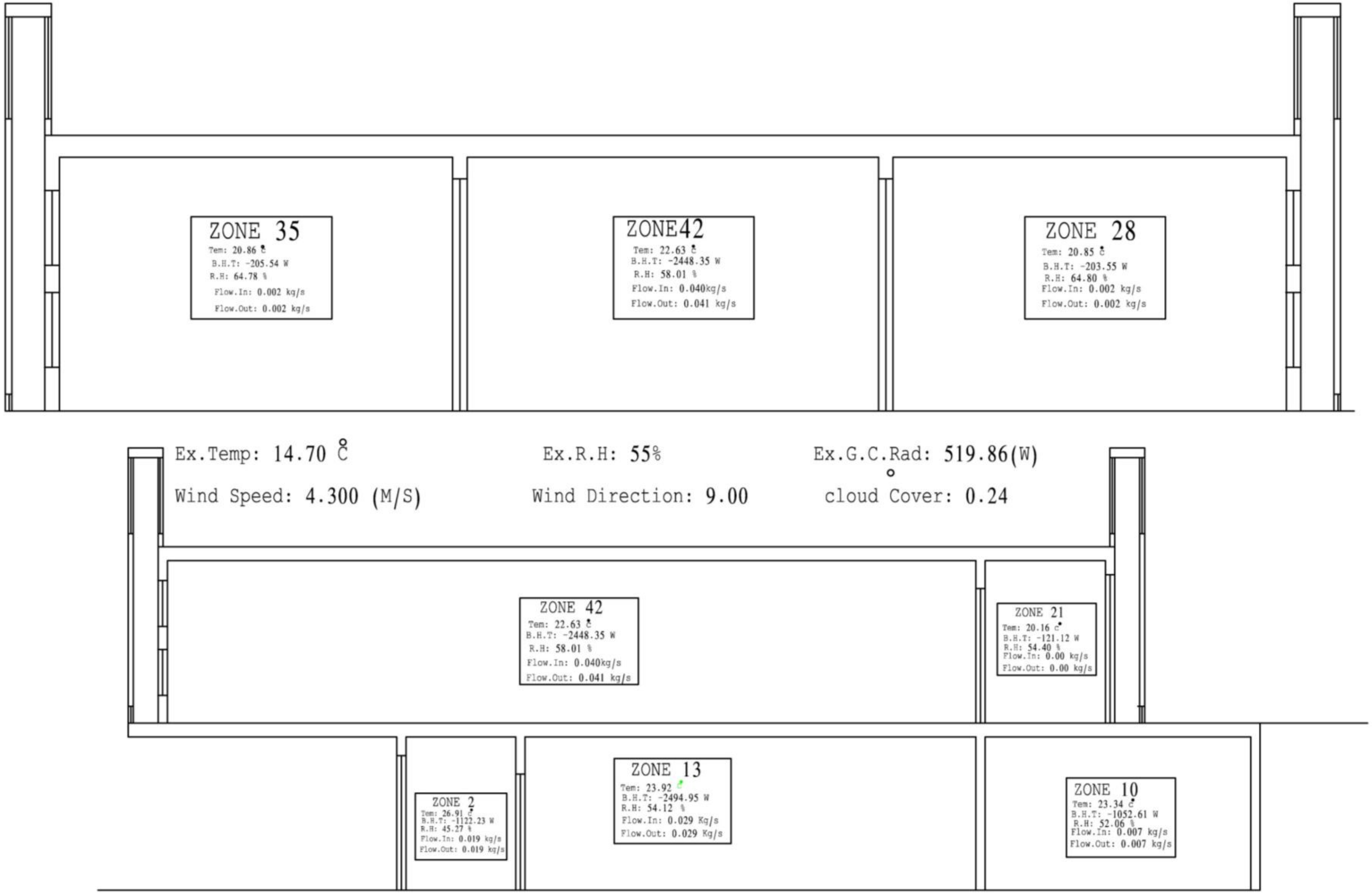
Appendix C: Simulation 3



Appendix C: Simulation 3



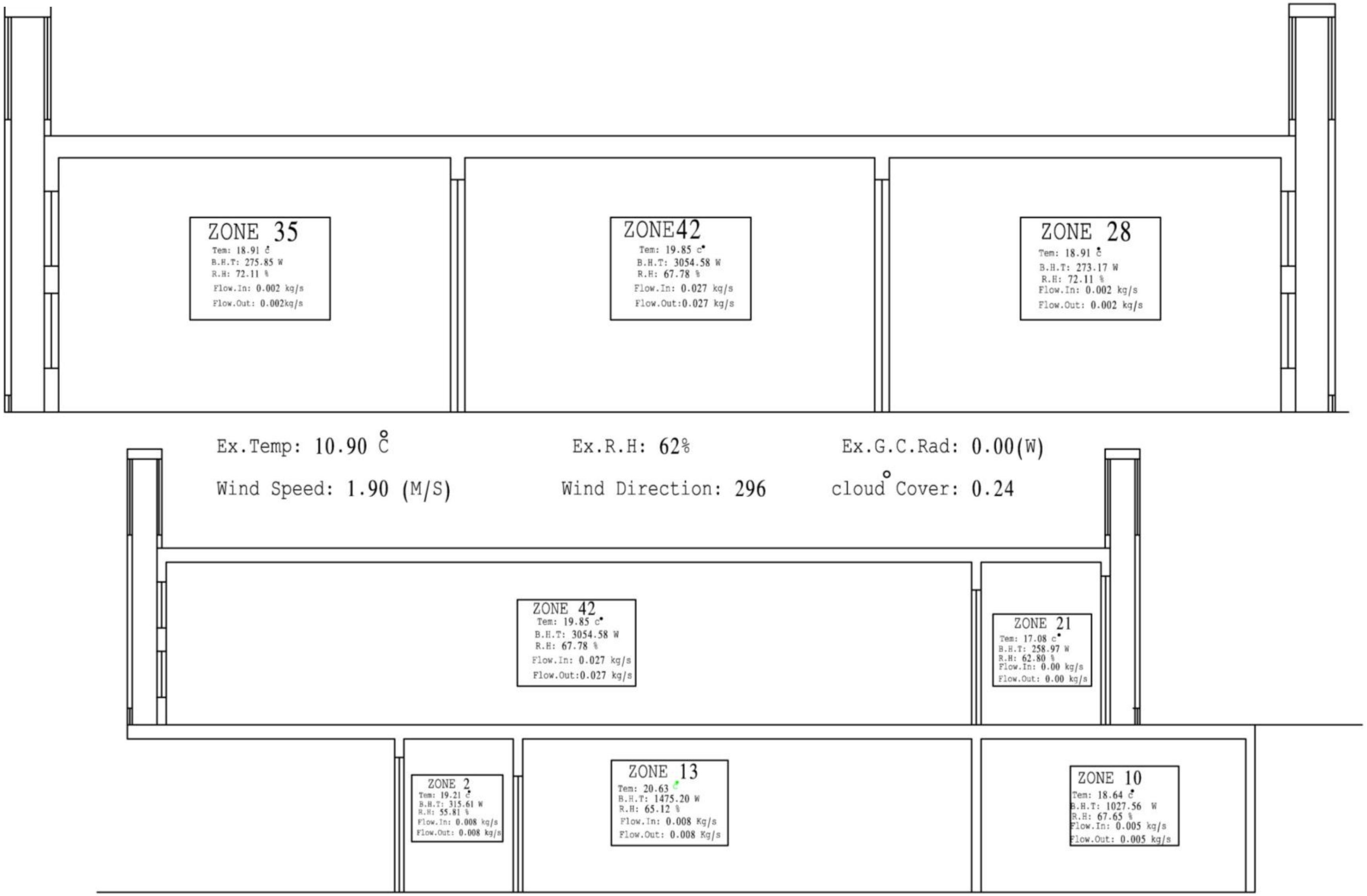
Appendix C: Simulation 3



21Dec / 12:00 PM / Day355

All doors & windows open 0.1%, Tower 100%

Appendix C: Simulation 3



21Dec / 19:00 PM / Day355

All doors & windows open 0.1%, Tower 100%