Energy-efficient building design guide:
Design strategies for office buildings in a temperate-dry climate.

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Abstract

Building sector has been accounted for 40% of total energy consumption in the European Union and the United States. Accordingly, building companies and governments are responding to make new buildings self-sufficient and to become "nearly zero-energy buildings". Implementing passive environmental design strategies, local resources, and sustainability principles have become a must to enhance building's efficiency. Indeed, buildings' performance change according to the climatic zones. Considering vernacular architecture principles while designing, constructing, and orienting buildings would help reducing energy consumption, enhance indoor and workspace quality. HVAC systems and artificial lighting are taking the biggest share of energy consumption in office buildings. Hence, heating, ventilating and indoor lighting are among the most issues that could arise during design process to tackle. This paper will draw on sustainability principles referencing from vernacular architecture to discuss offices buildings' design strategies in temperate dry climate. The paper also aims to review design process from the settlement stage to envelope implementation. Finally, it will consider climate adaptation, and spaces usage to reduce energy consumption ,minimize the impact on the environment, and respect the surrounding nature to achieve sustainable architecture goals.

Keywords: Energy-efficient buildings, office buildings, temperate-dry climate, sustainable architecture, passive design.

1.Introduction

The urgent need to enhance building performance, reduce energy consumption and to implement renewable green energy, has made the European Union comply with Kyoto protocol, the council has decided that after 2020 new buildings will be nearly zero-energy buildings. In addition, the council is aiming to reduce greenhouse gases, in reaction to climate change (EU, 2010).Accordingly, stimulate efforts from the governments and architects to rethink design process, energy consumption and to enhance the built environment. Moreover, avoiding high emitting technologies, and using green renewable energy instead of fossil fuels are part of energy efficient buildings principles.

The recent energy-efficient designs are referencing from vernacular architecture and learning to build upon climate-responsive concept, since thermal comfort and using renewable energy were the main concerns of vernacular designs (Fathy, 1986) after the increasing awareness of the negative impact of the built environment and its carbon emissions on climate change(Konis, Gamas, & Kensek, 2016).In Europe, Offices buildings are accounting for 26% of non-residential buildings share (BU, 2019)(figure1). Hence, improving passive heating and cooling systems since HVAC systems are accounting for the largest share 55% of energy consumption in buildings (Liu, 2012),also replacing artificial lighting with natural light became a necessity (figure 2).Indeed, orientation, materials, building geometry, thermal management, and building envelope are supporting pieces to achieve zero-energy buildings concept.

Having highlighted the need to reduce energy consumption in building sector and depend on climatically responsive designs, the following sections will guide to build energy-efficient offices buildings in temperate dry climate.

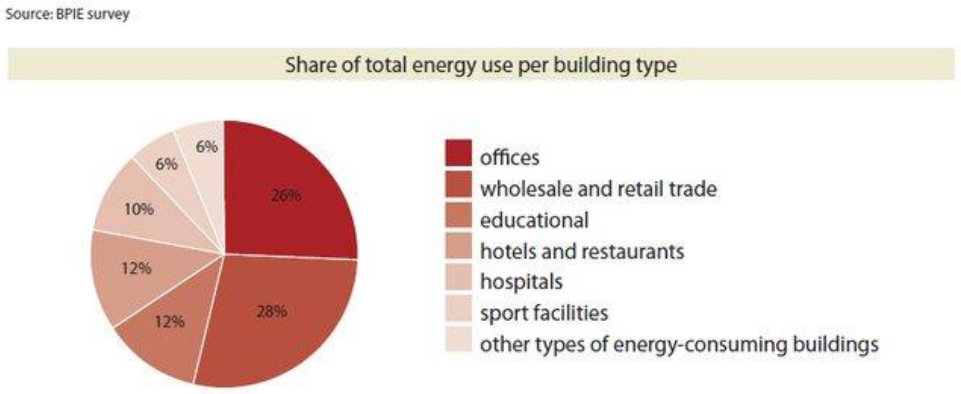


Figure1: non-residential buildings energy consumption. Source: https://www.researchgate.net/profile/Paolo_Negro/publication/260434512/figure

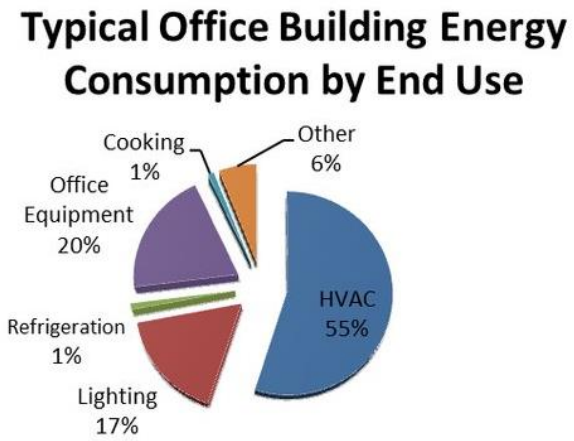


Figure2:Energy consumption shares by use in offices buildings. Source: https://www.researchgate.net/publication/333671816_

2.Temperate -dry Climate, main considerations

Temperate dry climate is widespread in the Mediterranean region, especially in the Anatolian plateau in Turkey, (Ankara, Afyon, Konya, Eskisehir, Kayseri, Malatya…) are the main provinces with this type of climate (figure3). The temperature differences significantly between summer and winter, day and night. Winters are cold and snowy while Summers are hot and dry. Moreover, temperatures could drop below comfort level and summers could be intense (Karagoz, 2016), Average temperatures vary between (-5 and +30) (Incecik, Toros, & U.Sertan, 2013).

In addition, this type of climate is considered as the most complex one according to architects, since buildings should satisfy different types of climates in one building (Gut & Ackerknecht, 2011). Building's thermal demands vary according to many climatic and topographic factors. As a consequence, design solutions should compromise between the conflicting needs (Gut & Ackerknecht, 2011), site analysis is highly required to find the balance and to design climate-responsive building.

Figure3: Climatic zones in Turkey. Source: https://slideplayer.com/slide/10395990/

3.Settlement standards

3.1. Topographical location

Considering climatic type and zone when choosing a proper land to settle is a must, because topography, sun's path, humidity and wind direction play an important role in designing process. In temperate-dry climate, the most proper topographical lands for settlement are middle or lower middle of the slope. Moreover, south and southeast slopping are preferred (Gut & Ackerknecht, 2011) (figure4). In Ankara case, the capital of Turkey people have applied the mentioned principles while settling (figure5).

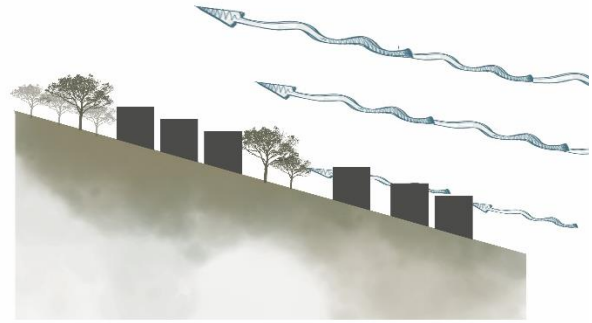


Figure4: preferred topography for temperate-dry climate

Figure5: Cankaya neighborhood/Ankara. Source: https://tr.pinterest.com/anatoliatours/ankara-06/

3.2 Orientation

As mentioned earlier, temperate climate is the most difficult type of climate to tackle while designing. Indeed, determining orientation in such climate should consider an accurate analysis (Givoni, 1998). Site analysis and orientation should consider two types of regions upland region, and lowland region.

In upland region: passive heating measures are more important than cooling. Thus, proper orientation to shelter buildings against the wind and gain solar radiation are to be considered to ensure thermal comfort (Gut & Ackerknecht, 2011).

In lowland region: passive ventilation and cooling are to be considered. Allowing buildings to be exposed to summer breezes ,and to be sheltered from direct sun in summer are the main requirements for this region while in winter vice versa (Gut & Ackerknecht, 2011).

The best orientation for temperate-dry climate to gain proper sunlight is the southern direction facing 27^{o} degrees southeast (Figure6).

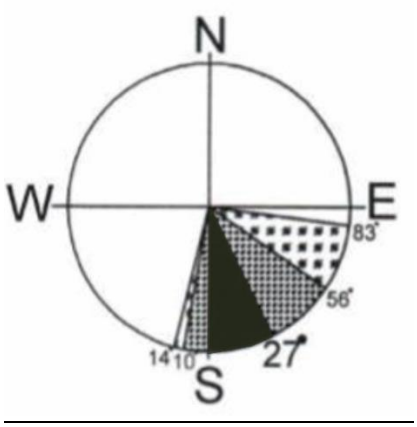


Figure6: Temperate-dry climate preferred orientation.
Source: (Orhan et al., 1988)

3.3 Urban forms, Settlement pattern

Urban form or planning plays an important role to determine the energy efficiency and sustainability of cities, since successful contemporary cities should balance between social, economic and environmental aspects. Indeed, insuring (water and electricity) security and efficiency among the urgent needs of sustainable contemporary cities (Khalil, 2009). Proper orientation (heat gaining) in winter, sheltering against the wind and allowing summer breezes are the main standards to consider while designing for temperate-dry cities' layout. hence, Compact or semi-compact patterns are the best options to consider (Gut & Ackerknecht, 2011).Compact patterns help reducing heat loss and shelter buildings from winter winds and intense summer sun .Moreover, streets should be implemented in the direction of summer breezes and avoid winter's wind direction.

When it comes to buildings ensuring climatic comfort is the main goal to achieve, sufficient distance between buildings should be considered (2H-3H) in north-south direction (Karagoz, 2016), or buildings row could be implemented along the west-east axis (Gut & Ackerknecht, 2011). Enhancing life quality is part of architecture role, hence, healthy, proper public spaces should be insured and should be efficiently used. Balancing between open and closed spaces, shaded spaces for summer and sunny spaces for winter. Accordingly, open spaces like urban squares should consider windbreakers towards wind direction, and trees row for proper shading.

2.4 Landscaping

Green spaces are not only good with reducing greenhouse gases and improving mental health (Engemann, 2019). It also helps enhancing the climate, moisturize the air and reduce energy consumption since trees work as a natural sun shading and windshield (Givoni, 1998). Moreover, the exterior of the building plays an important part to achieve thermal comfort within the interiors (Szoboszlai, 2015). There are three main kinds of plants and trees that should be considered for temperate-dry climate: Deciduous trees, Windbreak trees and bushes (Gut & Ackerknecht, 2011).

Deciduous trees: this type is an excellent medium to provide partly shaded areas and partly sunny. In summer the trees' leaves shade the building, while in winter the leaves fall allowing sunlight to access the building (Maddex, 1981).Hence, it should be planted in south and west (figure7).

Windbreak trees: help preventing fast temperature dropping, it should be planted in northwest direction to shelter the building from winter wind as an extra exterior shield (Karagoz, 2016) (figure8).

Shrubs and bushes: it should be planted against the building's exterior walls to provide moisturized fresh breeze in the building (table1).

Landscape Elements	Temperate Climate
Ground cover or grass	South
Paving	Shaded if on South
Shrubs against house wall	East, West, North
Deciduous shade trees	South and West
Evergreen trees	East and West
Windbreak (trees, fences)	Sides exposed to winter winds
Windbreak to funnel wind	Sides exposed to summer winds

Table1: preferred landscaping types for temperate-dry climate. Source: (Maddex, 1981)

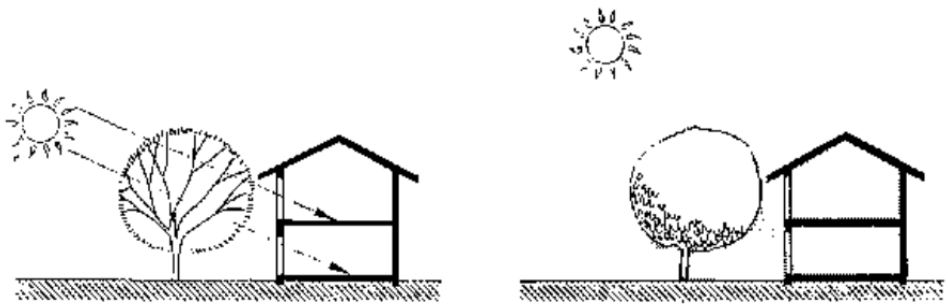


Figure7: Deciduous trees natural shading in summer, and it allows sunlight in winter.
Source: (Gut & Ackerknecht, 2011)

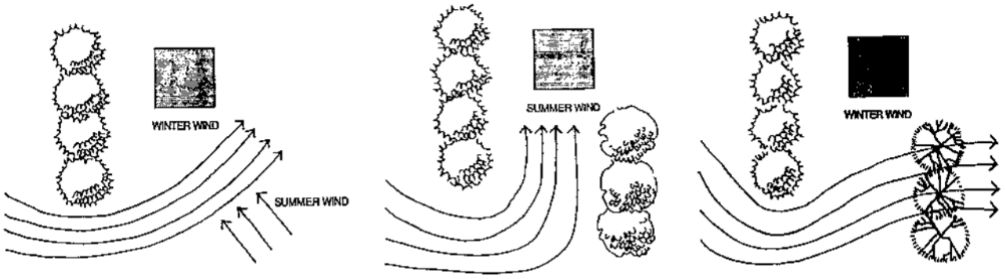


figure8: ventilation regulation and usage of natural wind shelters.
Source: (Gut & Ackerknecht, 2011)

4.Energy-efficient Offices building guide

Offices buildings have spread on a wide range since the mid of 20th century, the rise of universal policies and economies had a huge impact to spread High-rise buildings, and office spaces among cities. Nowadays, offices buildings or spaces are among the most widespread buildings after residential. Moreover, office buildings are the second

energy consumers after the residential buildings (Liu, 2012).As we spend half of our daily life basis in workspaces architects should work hard to enhance office buildings and reduce emitting materials and energy consumption.

Recently, countries are more concerned with workplaces to become more efficient and healthier. like for instance, in Europe, natural ventilation is required in offices buildings. Moreover, energy cost is approximately six times the cost in the U.S to encourage passive designs in offices buildings sector (Kohn & Katz, 2002). Indeed, orientation measures, interior arrangements, materials and passive design strategies are the main principles to design energy-efficient office buildings.

4.1 Building's geometry

Buildings shape and form affect the building's performance and its energy consumption directly since bigger spaces require more artificial lighting and air-conditioning (Hisarligil & Karaaslan, 2013). Increasing the building's area will increase heat loss which is not preferred in our case. Compact, intensive and bulk forms are preferred to reduce heat loss (Karagoz, 2016).Moreover, square or rectangular shapes would preserve heating and also make natural light and ventilation circulations easier within the building.

Temperate-dry climate requires a bonded relationship with nature and the surrounding (Gut & Ackerknecht, 2011). Hence, implementing inner garden and atrium would help gain more natural ventilation, light and enhance indoor air quality. Moreover, multi-functional spaces are preferred to minimize space loss in office spaces and make the interiors more compact, proper circulations also should be considered.

4.2 planning process

"Recognizing the need is the primary condition for design." Charles Eames

A successful plan should include an accurate analysis of the users' movements and their requirements. Moreover, spaces should be designed according to users' needs and the building's main function. Hence, a table which includes approximate spaces area, using hours and number of users would make designing process easier for architects, and help them frame their designing decisions and strategies accordingly.

The importance of spaces in offices buildings could be determined according to the previously mentioned aspects and to:

Using hours: working hours and break times.

Number of users: it could be decided according to the space type

- Private spaces (private offices, storage, security…)
- Public spaces (Café, Lobby…)
- Shared spaces (Creative open office, Staff lounge.)

The following tables will propose a possible architectural program to consider for an office building:

Number	Space Type	Approximate area	Using hours	Number of users
1	Car parking		12 h	20 cars
1	Mechanical room	30 m^2	-	-
1	Technical room	24 m^2	-	-
1	Storage	24 m^2	-	-

Table 2: Basement's space organization. Source: Author's own

Number	Space Type	Approximate area	Using hours	Number of users
1	lobby +exhibition	100 m^2	9 h	30
1	Security room	15 m^2	+12 h	1
1	Reception office	24 m^2	9 h	2
1	Café+ kitchen	50 m^2	9 h	20
2	Sales offices	24 m^2	9 h	1
1	Accounting office	35 m^2	9 h	2
5	W.C	-	-	2 men, 2 women, 1 disabled.

Table 3: Ground floor space organization. Source: Author's own

Number	Space Type	Approximate area	Using hours	Number of users
1	creative open office	100 m^2	9 h	10
1	Printing room	15 m^2	9 h	1
4	Private offices	24 m^2	9 h	1
1	Semi open terrace	40 m^2	9 h	10
1	Staff lounge	24 m^2	9 h	5
5	W.C	-	-	2 men, 2 women, 1 disabled.

Table 4: first and second floors space organization. Source: Author's own

Number	Space Type	Approximate area	Using hours	Number of users
1	Private gallery	-	9 h	10
1	Reception desk	15 m^2	9 h	1
1	Achieve	24 m^2	9 h	1
1	Semi open terrace	40 m^2	9 h	10
1	HR office	24 m^2	9 h	1
1	Secretary	24 m^2	9 h	1
1	Manager's office	35 m^2	9 h	1
1	Meetings room	35 m^2	-	8
5	W.C	-	-	2 men, 2 women, 1 disabled.

Table 5: Third floor space organization. Source: Author's own

4.3 Bubble diagram design

Bubble diagrams are a comprehensive pre-planning process, where architects or designers can meet users' needs with the architectural program. Moreover, this pre-designing process would help analyze the plan on a more actual point of view where

we could consider room arrangements, circulations, orientation…etc. Temperate-dry climate requires considering compact layouts from the city planning stage to buildings' rooms arrangements. Hence, internal compact offices(rooms) arrangements for the building will be preferred (Gut & Ackerknecht, 2011).

The concept of thermal zones: Dividing the plan into thermal zones help reducing heat loss inside the building. Zones are divided according to their function, using hours and heating or cooling demands (Gut & Ackerknecht, 2011).Categorizing the zones according to Temperate-dry climate:

- Warm zone: zones that require high heat demands should be located in the southern area to face the sun (offices, workspaces...)
- Buffer zone: zones with less heat demands in office buildings like: lobbies, entrance, less used spaces or spaces with high number of users could be considered. Accordingly, the spaces should be placed around the warm zone on the west side to provide extra insulation to reduce heat loss.
- Spaces with high humidity like W.C should not be placed next to storages; cross ventilation would help to minimize humidity inside the building.
- Tress belt would also provide extra protection, as mentioned earlier.

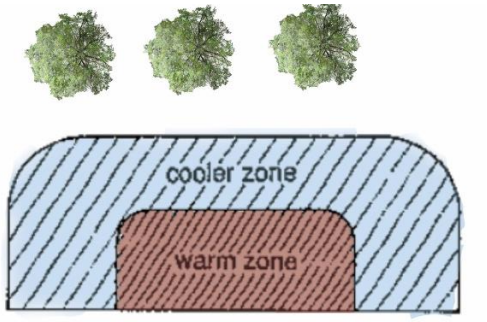


Figure 9: Thermal zones concept. Source: (Gut & Ackerknecht, 2011)

Office building Bubble diagram design

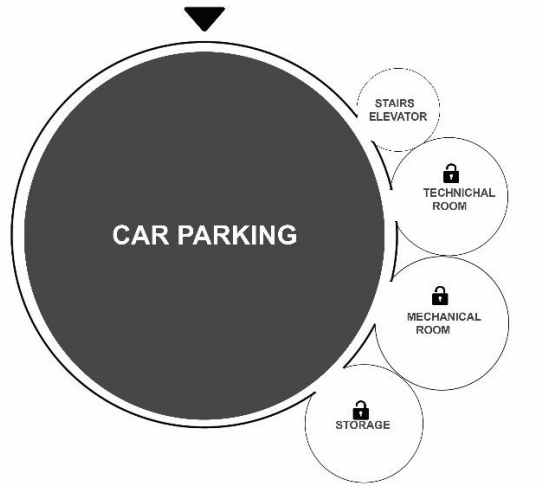


Figure10: Basement design. Source: Author's own

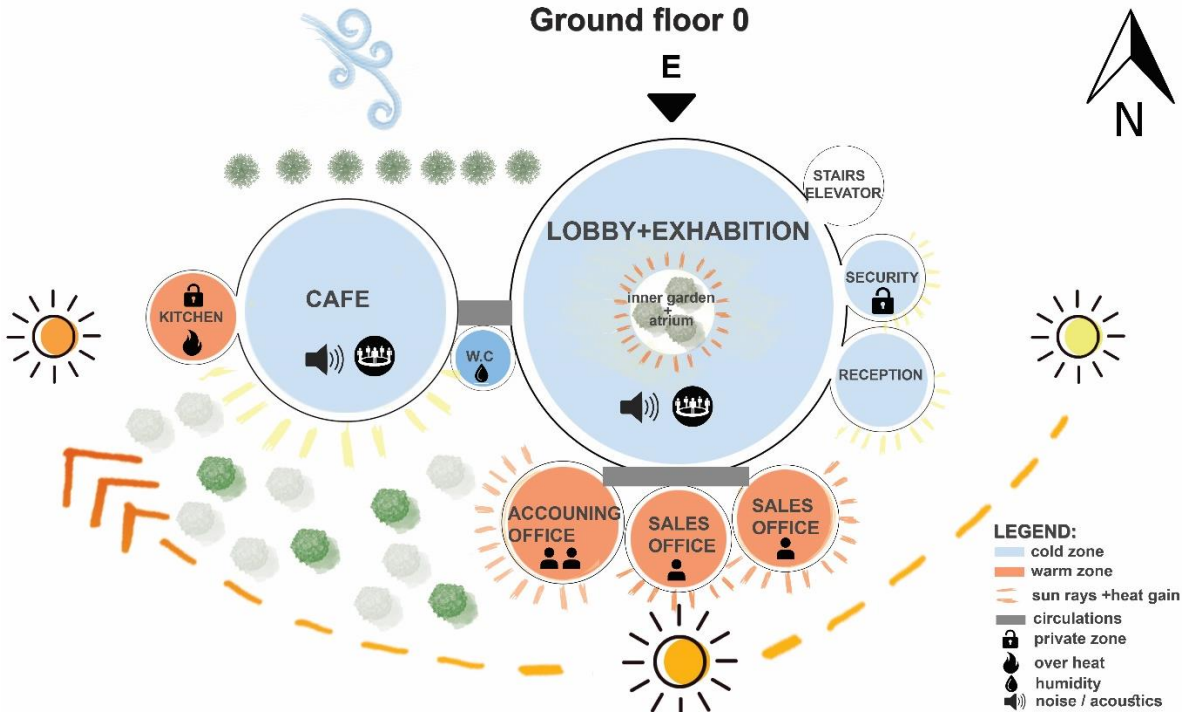


Figure11: proposed ground floor (entrance and public spaces) design. Source: Author's own

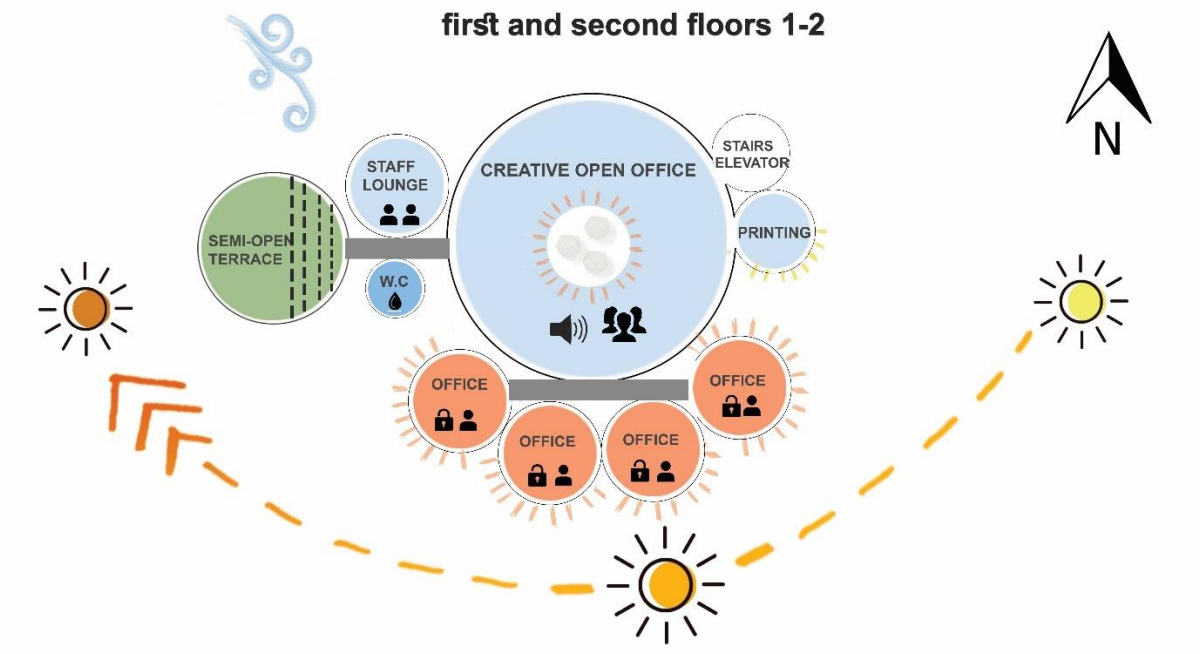


Figure12: proposed first and second (offices floors) design. Source: Author's own

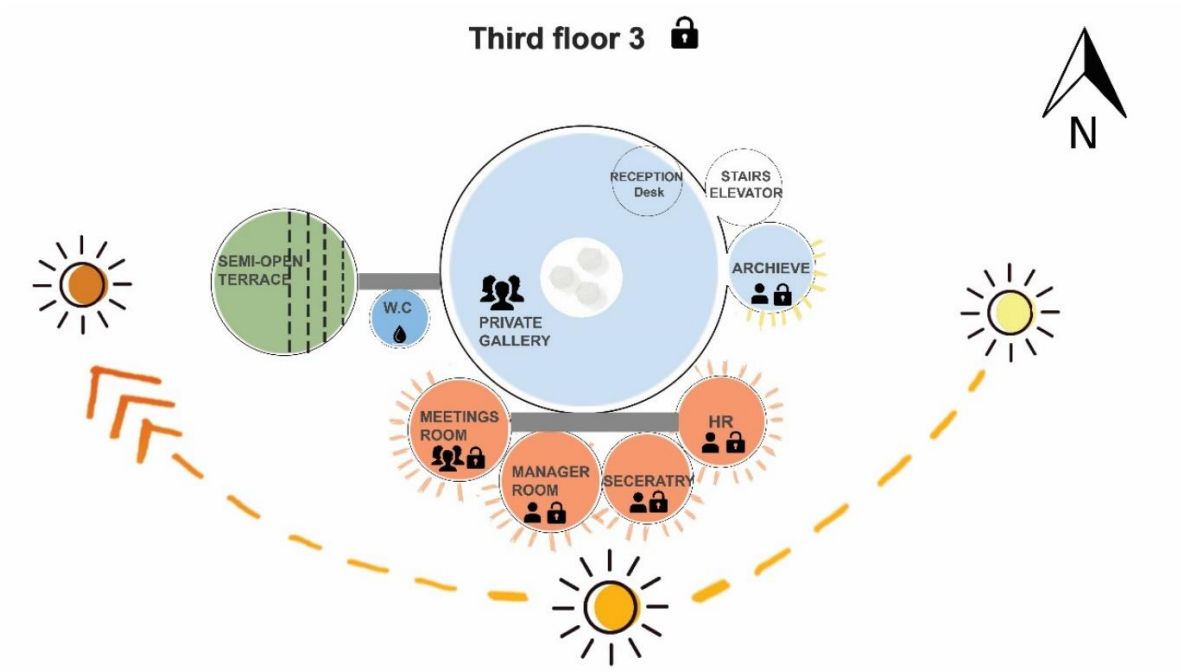


Figure13: proposed third floor (administration unit) design. Source: Author's own

- open office space is located on the northern side, according to the number of users and to the implementation of the inner garden and atrium that could gain solar heat and natural light and ventilation for the building center.
- Semi open-terrace should be located in summer breeze direction to provide fresh air and cross natural ventilation inside the building.
-

5.Climatic-responsive Envelope design

Walls: walls should include both thermal insulation and medium thermal storage to preserve day heat within the building's walls. Airtightness also should be considered to reduce the amount of air inflow in winter (Kodama, 1998). Vernacular buildings used natural local materials like stones and clay for thermal insulation and thermal mass. Hence, adding stones decorations or wallpapers for inner walls for contemporary office buildings, could give extra protection. Moreover, buildings that use local materials have less embodied energy, reduce the emissions of carbon gas since local materials limit delivery transportation and would give a sense of belonging (Moxon, 2010).In addition, Implementing offices with glass inner walls around an atrium would help reducing the usage of artificial lighting.

Colors: Medium colors are preferred for outer walls it helps gain a sufficient amount of heat, Dark colors could be applied for less sun-exposed walls (Gut & Ackerknecht, 2011).Vernacular architecture in (Ankara, Konya, in Malatya…etc.) used the same color pallet for their houses and buildings (figure 14,15).

Figure14: Traditional housing in Ankara
Source: https://www.alamy.com/stock-photo/traditional-turkish-houses.html

Figure15: Vernacular buildings in Malatya
Source: https://www.shutterstock.com/search/kernek

Floorings: Building floorings should include medium insulation and thermal storage capacity (Gut & Ackerknecht, 2011). Cemental or wooden floorings could be considered.

Windows: windows are very important elements in office building design, since offices are used in day time. Hence, architects should consider it as the main source of natural ventilation, passive heat and light gaining to reduce the usage of HVAC systems and artificial light. In Europe, every worker must be near a window (Kohn & Katz, 2002). In temperate-dry climate, windows resistance should be high double-glazed windows could be considered. Indeed, Southern façade windows should be the largest in the building, while openings in northern facades are not preferred. Medium windows size is the best for this climate (Gut & Ackerknecht, 2011).

Roof: winters are intense in this type of climate it may snow many times in the year. Hence, the building's roof should include high thermal insulation, prevent snow accumulation and be well waterproofed.

6.Passive and active energy-efficiency strategies for office buildings

Passive design is the simplest and the most cost-efficient strategy that architects could implement to reduce energy consumption and to enhance thermal comfort and building performance (Moxon, 2010). The previously mentioned strategies (orientation, shape, envelope…) considered the main passive design strategies, yet this section will propose passive design strategies and active technologies to consider in temperate-dry climate offices building design.

6.1 Passive cooling strategies

passive cooling design should consider shading devices and natural ventilation strategies.

1.Sun shading devices: sun shading devices should be highly considered to prevent over-heat and glare in summer since we are using thermal storage strategies for winter (Gut & Ackerknecht, 2011).

- Movable shading devices should be considered to prevent summer sun and allow solar radiation in winter. Hence, automatic movable louvers (figure16) or overhangs (figure 17). could be considered, proper analysis considering sun's path around the site and heating demand should be made to decide shading device type (Moxon, 2010).
- Deciduous trees in southern facades could be considered as a natural shading (Gut & Ackerknecht, 2011).

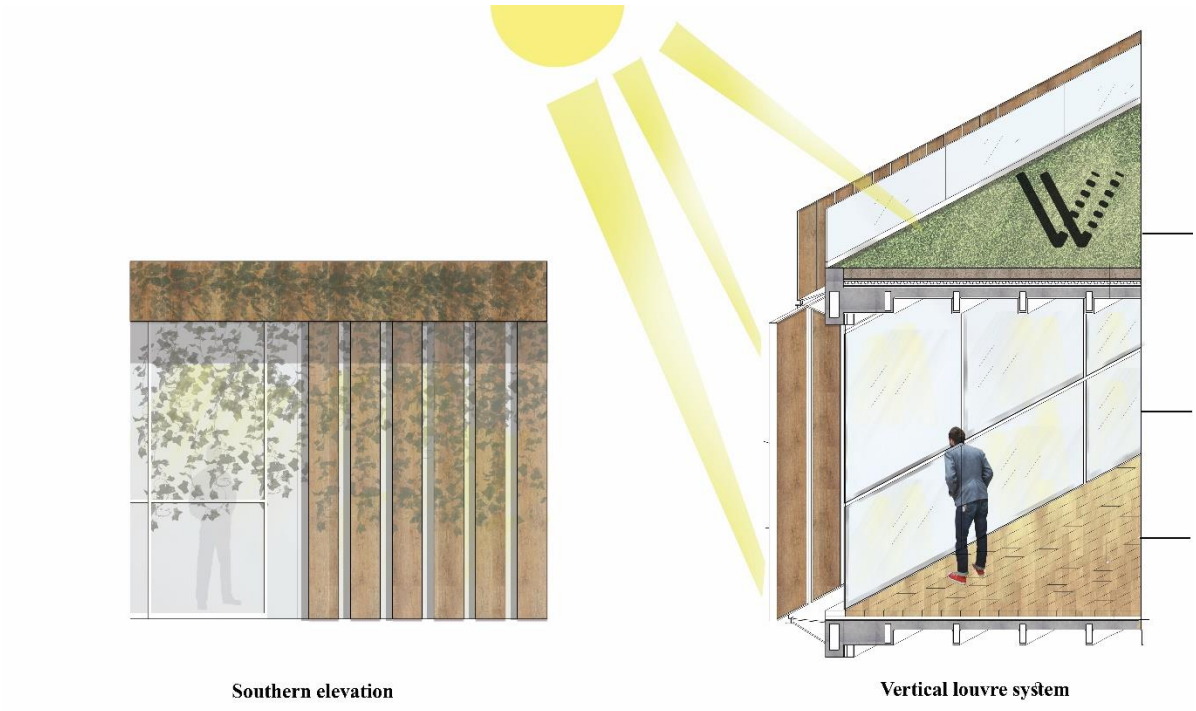


Figure 16: vertical movable louvre system design.
Source: Author's own

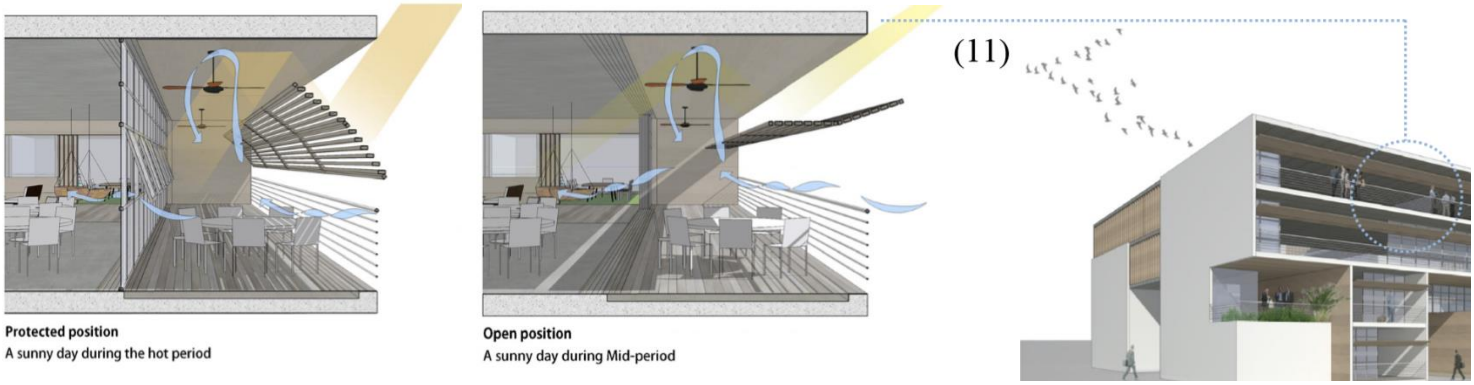


Figure17: Movable overhang. Source: https://www.academia.edu/33896329/The_Open_Air_Office_Climatic_adaptation_of_the_office_building_typology_in_the_Mediterranean

2.Natural ventilation strategies:

- Cross ventilation regulations should be considered to let summer breeze in and out (figure17), to reduce using air conditioning in summer and control humidity inside the building.
- Summer breeze in temperate-dry climate is dry. Hence, locating water surfaces against buildings opening will moisturize the air.
- Atrium stack ventilation could be considered figure 18.
- Fans could be used.

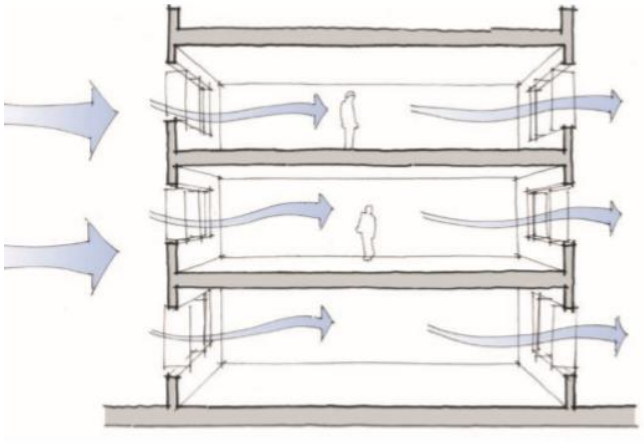


figure17: Cross ventilation.
Source: (Moxon, 2010)

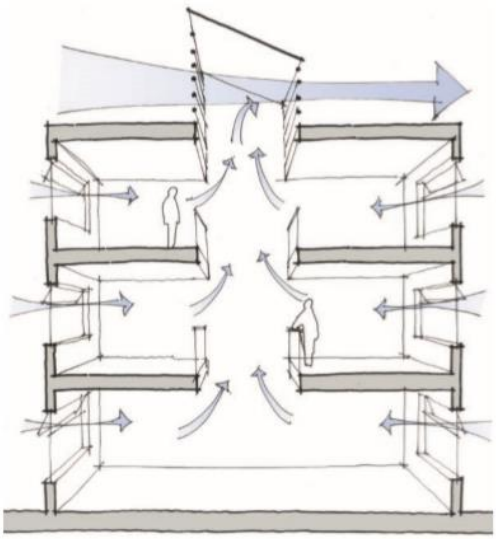


figure18: stack ventilation.
Source: (Moxon, 2010)

6.2 Passive heating strategies

passive heating should be highly considered since winters could be intense and temperature may drop below comfort level.

1.Direct solar gain: solar radiation heat gain through southern façade openings (windows) (Gut & Ackerknecht, 2011).

2.Thermal mass: dense materials with high heat storage capacity are used as a thermal mass (figure 20). Materials will behave like sponge it will absorb heat radiation in morning time, preserve it then it will release heat when temperature drops at night (figure 21). Thick masonry, concrete, stone, clay… have good thermal storage capacity (Moxon, 2010).

- Floors and southern facades could act as a thermal mass.
- Medium heat storage is required to prevent overheating.
- Shading devices should be also implemented with this type of passive heating.

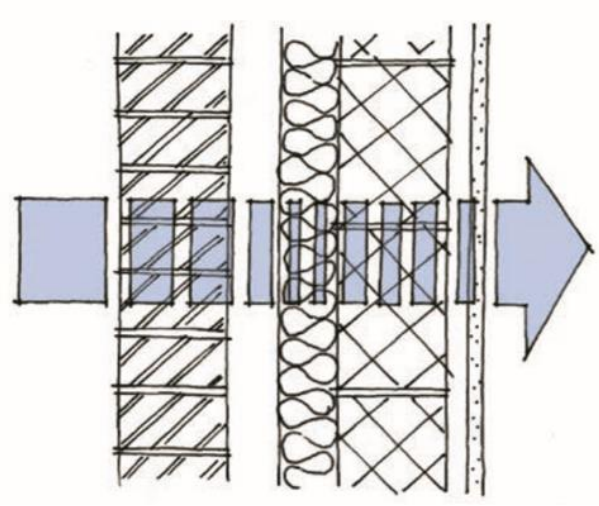


Figure 20: section showing thermal mass work.
Source: (Moxon, 2010)

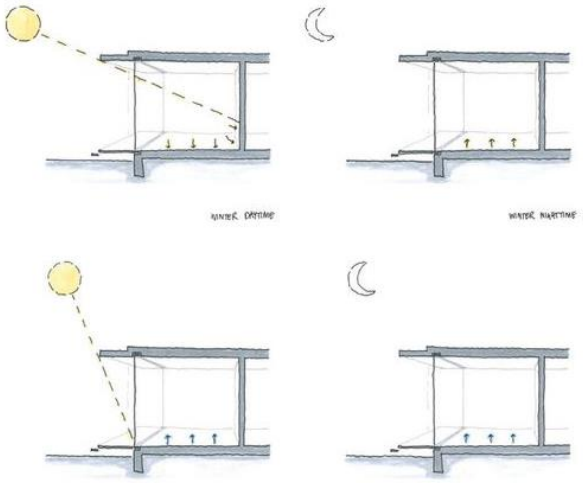


Figure 21: Thermal mass behavior in winter and summer
Source:https://www.heidimerglarchitect.com

3.Tromb walls: tromb wall has a massive dark surface that is located behind glass surface. the dark surface of the wall absorbs solar heat then releases it slowly inside the building. A small opening between the dark wall and the glazed surface should be considered. Moreover, implementing shading device should be considered (figure 22).

- Southern façades are the best to gain sufficient heat.
- Adobe, Clay and bricks are cost-efficient and work efficiently.

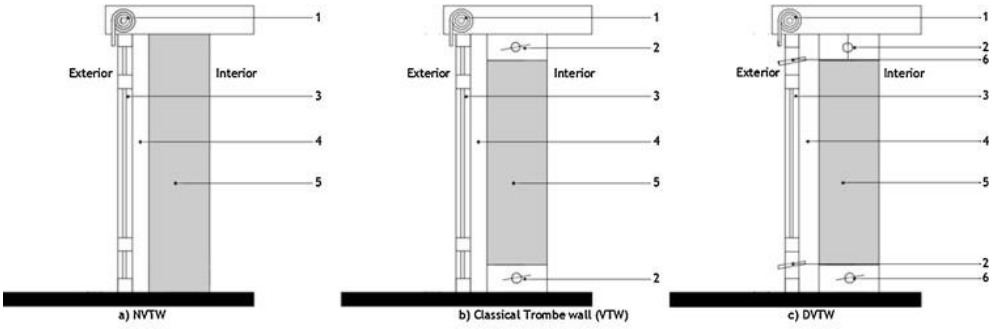


figure22: Tromb walls types. Source: https://www.sciencedirect.com/science/article/pii/S0378778816320850

4. Geothermal wells: This type is highly recommended to make office buildings more sustainable. Geothermal wells are a sustainable replacement of fossil fuels, it preserves snow and rainwater and reduces energy consumption since it uses water pumps to heat the floors (Mock, Tester, & Wright, 1997). This type is gaining popularity among office buildings, Bullitt Center in USA is a good example to check in the sense.

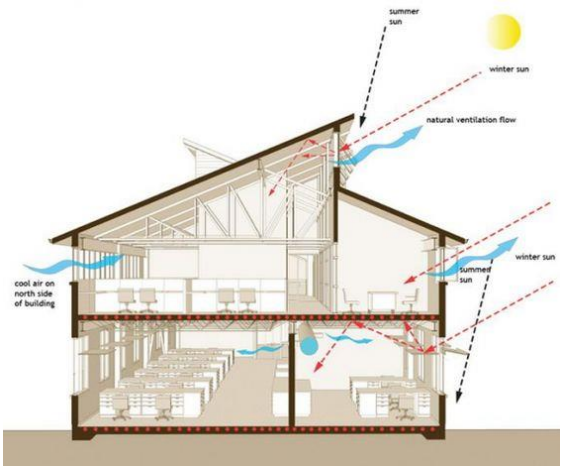
6.3 Passive Lighting strategies

1.windows: they are the main source to gain natural light inside offices.

2.Skylights and atriums: Implementing skylight or atrium in the middle of the building help gain more natural light for building's center where it usually has lack in natural lighting.

3.Clerestories: should be located above eye level. Hence it gains light with minimum heat gain (Gullotti, 2020)(figure23).

- 4.Light shelves: The shelf above the window works like an overhanging shade. Hence, it reduces glare, overheat and reflects direct sunlight (Gullotti, 2020)(figure 24).



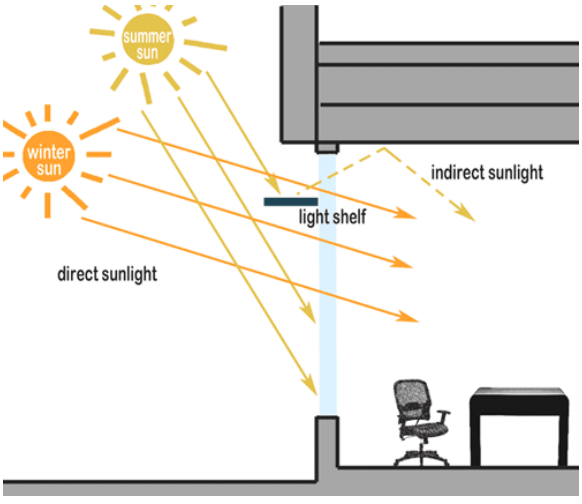


Figure23: Clerestories implementation. Source: http://www.superhomes.org.uk/resources/energy-efficient-windows/

Figure24: Light shelves implementation. Source:

Indeed, implementing photovoltaic cells on the building roof would help gain green energy since sunlight could be converted into electricity. Green renewable energy reduces carbon footprint and buildings' impact on climate change.

7.Conclusion

Having discussed the importance of reducing energy consumption in office buildings sector, implementing renewable energy, passive design, and enhancing buildings performance. It could be deduced that, achieving the European Union plan of making new buildings nearly zero-energy buildings could work when architects study the impact of their designs on the environment. Hence, considering sustainability principles, respecting the environment, the structural culture of the place and using natural local materials in contemporary offices buildings would make the building more energy-efficient and will blend more with the surrounding. Moreover, using natural resources and eliminating carbon gas rates inside the building would enhance employees' productivity and creativity. Finally, designing energy-efficient office buildings became a necessity especially after the emergence of COVID-19, and witnessing significant dropping rates of air pollution in shutdowns times. Hence, enhancing indoor and outdoor air quality, and designing healthy spaces will become among the most important tasks for architects to tackle.

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