Energy-efficient, site-specific planning

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Building energetics is the complex analysis of energies entering the building (energy gain), the energy consumption to produce the necessary comfort level inside the building, and energies leaving the building (energy loss).

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Abstract

Currently 40% of the energy consumption and 36% of CO2 emission in the European Union is on account of to the operation of buildings, a low extent efficiency improvement could already result in significant economic savings.

Building energy dimensioning today in Hungary happens by the existing regulation and its sections. The fundamental aim of the regulation is to make buildings comparable regarding energetics. By reason of comparability it makes buildings comply with building energy requirements using projected average data from over the country.

To get a more precise prediction about the buildings’ energy consumption, we have to take into account that the inhabitants’ demands and the environmental effects impacting the building do change both in time and space.

In response to the previous thoughts, the Residential Building Design Department of the Budapest University of Technology and Economics started a research. The result was a patented invention, a newly designed measuring equipment and software system, called: DROID. By measuring site-specific environmental effects the developed
Introduction

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Dear Readers!

Building energetics is the complex analysis of energies entering the building (energy gain), the energy consumption to produce the necessary comfort level inside the building, and energies leaving the building (energy loss).

Building energy dimensioning today in Hungary happens by the existing regulation TNM 7/2006. (V.24.) and its sections. The fundamental aim of the regulation is to make buildings comparable regarding energetics. By reason of comparability it makes buildings comply with building energy requirements using projected average data from over the country.

In the course of the calculation, the regulation determines the value of outside temperature without reference to the local circumstances, using a projected average data.
Planning and constructing economical buildings in respect of energetics is becoming more and more important. In its 2020 strategy the EU has set the target to reduce its energy consumption by 20%. Since 40% of the energy consumption and 36% of CO2 emission is on account of the operation of buildings, a low extent efficiency improvement could already result in significant economic savings.

By using the current dimensioning system we end up getting a fake image about the buildings’ energy consumption. Standardized data used by the regulation, can result in great differences on local levels. To get a more precise prediction about the buildings’ energy consumption, we have to take into account that the inhabitants’ demands and the environmental effects impacting the building do change both in time and space.

In response to the previous thoughts, the Residential Building Design Department of the Budapest University of Technology and Economics started a research, connecting to the BUTE program called „Development of quality-oriented and harmonized R+D+I strategy and functional model at BME” (Project ID: TÁMOP-4.2.1/B-09/1/KMR-2010-0002), supported by project New Széchenyi Plan. The result of this research was a patented invention, a newly designed measuring equipment and software system, called: DROID. By measuring the site-specific environmental effects the developed unit creates location and building geometry-specific data and organizes them into databases. The research clearly demonstrated, that the energy balance of a building is significantly affected by local environmental effects.

Chapter 1. Energetics and function

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   1.4. Determination of the expected subjective heat sensation
   1.5. Local discomfort factors
   1.6. The interior air quality
   1.7. The „Sick Building Syndrome”

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To approach the topic of this curriculum – energy-efficient, site-specific planning - it is imperative to understand the basics of building energetics and comfort theory. Building energetics is the complex analysis of energies entering the building (energy gain), the energy consumption to produce the necessary comfort level inside the building, and energies leaving the building (energy loss). Several well useable curricula and textbooks were made in the subject by the BUTE Faculty of Architecture Department of Building Energetics and Building Services, therefore this study does not discuss these particularly – it leans on them.


Human needs on residential environments are considered to be satisfied, when the residential environment ensures comfort of its inhabitants. Comfort is a subjective relation between a person and the surrounding closed space. Amongst others, building energetics deals with the human needs on residential environments, which studies the energy consumption to produce the necessary comfort level inside the building, besides studying the energies entering the building, and the energies leaving the building.

The factors primarily affecting the comfort level – the temperature, the humidity, the motion of air, the noise and the lighting – all have direct effect on humans. The moderately influential factors of comfort level are sun radiation, ionization and vibrations, that occur less and more periodic. The human organism’s conformation to a specific environment is a complex process, the single factors apply combined as well as in interference, and the human organism reacts to this collective effect.

In a generic case the first three of the comfort level manipulating factors, the temperature, the humidity and the motion of air are closely related to building energetics. The needs on accommodations shows chosen factors’ specific values based on the present Hungarian people’s general needs on residential environments. Separating an ordinary residential environment into diversely functioning spaces, the differences between the needs may be observed.

Table 1.1. Table No 1.
<table>
<thead>
<tr>
<th>Rooms / Factors effecting comfort level</th>
<th>Winter temperature (°C) / Winter temperature (°C)</th>
<th>Summer temperature (°C) / Summer temperature (°C)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>entrance, hall</td>
<td>18 - 20</td>
<td>26 - 30</td>
<td></td>
</tr>
<tr>
<td>bedroom</td>
<td>18 - 22</td>
<td>22 - 24</td>
<td>30 - 50</td>
</tr>
<tr>
<td>children's room</td>
<td>20 - 23</td>
<td>24 - 28</td>
<td>30 - 50</td>
</tr>
<tr>
<td>study, workroom</td>
<td>18 - 22</td>
<td>24 - 26</td>
<td>30 - 50</td>
</tr>
<tr>
<td>livingroom</td>
<td>20 - 22</td>
<td>24 - 26</td>
<td>30 - 50</td>
</tr>
<tr>
<td>dining room</td>
<td>18 - 22</td>
<td>24 - 26</td>
<td>30 - 50</td>
</tr>
<tr>
<td>kitchen</td>
<td>18 - 20</td>
<td>24 - 26</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>bathroom</td>
<td>22 -26</td>
<td>28 - 30</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>toilet</td>
<td>18 - 20</td>
<td>26 - 30</td>
<td></td>
</tr>
<tr>
<td>indoor storage - pantry</td>
<td>&gt; 10</td>
<td>&lt; 26</td>
<td></td>
</tr>
<tr>
<td>indoor - wardrobe</td>
<td>16 - 22</td>
<td>26 - 28</td>
<td></td>
</tr>
<tr>
<td>outdoor storage - garage</td>
<td>&gt; 0</td>
<td>&lt; 30</td>
<td></td>
</tr>
<tr>
<td>circulation, corridor</td>
<td>16 - 20</td>
<td>26 - 30</td>
<td></td>
</tr>
<tr>
<td>laundry room</td>
<td>18 - 20</td>
<td>26 - 30</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>jacuzzi</td>
<td>29 - 33</td>
<td>26 - 30</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>swimming pool</td>
<td>(tmed + 3) 29 - 33</td>
<td>26 - 30</td>
<td>&lt; 60</td>
</tr>
</tbody>
</table>

Regarding the indoor temperature, there are differences between the values expected in summer and winter (the favorable temperature in summer is an average of 24-26 °C, while in winter it is 20-22°C), therefore they have to be studied apart. The expected level of humidity is described in the table as the relative air humidity. The allowed rate of air motion in dwellings’ interior spaces is 0,2 m/s, but usually it does not even reach 0,1 m/s.

It is important to note, that the level of comfort is a subjective human demand. Therefore the data shown in the table are general values which, in reality vary by person to person. The different needs could be affected by the environment, the cultural background as well as age. For example, the little children and the elderly people feel comfortable in warmer tempered residential spaces than usual and it’s more difficult for them to conform themselves to the changes of air conditions.

### 1.1. Definitions related to comfort level

#### 1.1.1. The concept of heat sensation

The comfort level factor related to environment heat is called heat sensation factor. The emergence of this subjective sensation is mainly affected by the following six parameters:

- air temperature, its distribution and change in space and time,
- radiational temperature of the surrounding surfaces,
- relative humidity of the air, and the partial pressure of steam within the air,
- speed of airflow,
- the human body’s heat production, heat transfer, and heat regulation,
- the heat insulating ability of clothing, its affect on evaporation.

The first four are physical parameters, while the latter two are related to the human organism’s adaptability. The subjective heat sensation is fixed by standards in some countries, namely the so called comfortable heat sensation, which, according to ASHRAE (1981) 55-81 standard is the following:

The comfortable heat sensation is the mental condition, which expresses the satisfaction related to thermal environment. The question is how this „comfortably subjective“ sensation could become quantified, generally applicable. For this, the so called subjective heat sensation scales are applied, the following 7 point scale is the most widespread today:

- hot +3
- warm +2
- comfortably warm +1
- neutral 0
- comfortably cold -1
- cool -2
- cold -3

Within this scale, the +1, 0, -1 range is the so called comfortable zone. The subjective heat sensation scale shows, that in an ordinary Hungarian person’s living room, decreasing the 21°C winter time temperature expected by them with 2°C causes a cold heat sensation while leaving the comfortable zone.

#### 1.1.2. The human body’s heat transfer, heat exchange and the effecting factors

The human body can transfer the heat developing inside it in four ways:
through radiation
through convection
through evaporation
through conducting

In engineering practice and during the calculations, in the range of comfort parameters out of the total heat transfer:

- the radiational heat transfer is 42-44%
- the conventional heat transfer is 32-35%
- the evaporative heat transfer is 21-26%

The change of atmospheric conditions reviewed before cause greatly differing deviations of values, and determines which kind of heat transfer predominates. The air temperature decreases due to an increase of the speed of airflow. Since the general rules of thermodynamics also apply in the human body – the rate of conventional heat transfer increases, over 30-34°C and the organism takes on heat with convection. Sweating starts at 28-29°C environmental temperature. Over the 34°C value, the evaporation and the sweating are the only possible kind of heat transfer of the organism. With the decrease of the terminal surfaces’ temperature, according to the radiational heat exchange law, the transfer of radiational heat rises. But if the air is more humid, it absolves relatively more from the body’s radiation. The measure of evaporative heat transfer depends on the relative humidity.

1.1.3. The thermal equilibrium of the human body

The heat generated in the human body, and the heat emitted or absorbed in different ways moves towards a equilibrium state. This state is the state of thermal equilibrium, that is affected by various conditions.

It is clear, that the human body’s heat exchange conditions are affected by clothing, and its heat insulation ability. To determine the clothing’s heat insulation ability, the so called „clo” unit is used:

\[1\, \text{clo} = 0,155 \, \text{m}^2\text{C}/\text{W}^9.\]
Specific clothes „clo” values (ASHRAE 1985)

- long sleeved shirt 0,22
- thick trousers 0,32
- pullover 0,37
- light skirt 0,1
- vest 0,06
- jacket 0,49
- blouse 0,20
- stockings 0,01

The clothing has an impact on the comfort level, because it effects the thermal equilibrium, therefore it can effect the performance. Some work places by periodically loosening on their dress code – for example they do not require stockings or ties on hot summer days – increase on the comfort level of employees’ comfort sensation and therefore on their performance.

1.1.4. Determination of the expected subjective heat sensation

P. Ole Fanger worked out a principle, or rather practical method, according to which by knowing several parameters, a predicted mean vote could be determined in specific points of a closed space. This is the so called PMV value, the Predicted Mean Vote, and the PPD value, which is the Predicted Percentage of Dissatisfied. Knowing about the concept of these two indicators is essential.

1.1.5. Local discomfort factors

In recent years it has become evident, that there can be discrete points inside closed places dimensioned with the most up-to-date methods, where a person being there has heat comfort complaints. These are called local discomfort factors, because of the nature of their occurrence. By this notion we mean those parameters, which:

- only shows up on specific points of a closed place,
- their effect does usually not refer to the whole human body, but only to certain parts of it.

From the aspect of subjective heat sensation, and the human heat exchange, we currently track two kinds:
asymmetric radiation and
the draft effect.

By asymmetric radiation we understand the phenomenon when a person being in a closed space has radiation heat exchange between his specific body parts and it is at relatively higher or lower tempered surfaces, so the body part is effected by heat radiation, or radiative heat transfer is toward these surfaces.

A human’s sensibility to air motion depends on the air temperature and the effects of the air flow. Illustration 2. - Permissible airflow speed values based on environmental temperature shows the values of permissible air speed based on the values of environmental temperature. It must be concluded, that in point A of the curve at a 25°C temperature, the airflow speed of around 0,3 m/s is still comfortable, while in point B at 18°C, 0,1 m/s is already disturbing. Body parts sensible to draft are neck and ankle.

Figure 1.2.

1.1.6. The interior air quality

By the interior air quality (IAQ) we mean every non thermal characteristics of the comfort spaces’ air, which effect a human’s welfare.

The contaminations affecting interior air quality:
- gas and steam
- odor substances
- aerosols
- viruses
- bacteria and their spores Illustration 3. - Sources of the interior air quality contaminations

Figure 1.3.

Fanger, based on his researches, worked out the method of rating the interior air quality. He invented a new unit for rating the air quality and determining the source intensity of contaminations. For reference he chose the human.

The unit of the contamination’s source intensity is: 1 olf. According to the definition, 1 olf is the contamination source strength of an average human in a sitting position, in the physical state of rest, in an environment with heat balanced comfortable, with average personal hygiene conditions.

The unit of sensible air quality is: 1 decipol. According to the definition, the air quality is 1 decipol in case of a perfect blend in the comfort zone, when 1 olf is the source intensity of the contamination and the ventilating air’s volumetric stream is 10 l/sec, or an equal 36 m³/h.

1.1.7. The „Sick Building Syndrome”

In recent decades the building technology, the building materials, just as the building service engineering systems have changed, and improved by much. Primarily the changes were brought by the increase in the number of office buildings, shopping centers with air conditioning. Modern architecture is now unimaginable without large outer glass surfaces and air conditioning systems.

The „sick building syndrome” (SBS) contains the complaints of the people working in modern buildings. The most common complaints:
- feeling draft
- feeling drought
- tiredness
- headaches
- noise
- rheumatic complaints
- complaints related to air quality

It ensues from the non complete list, that the study of the problem concerns medical, medical hygienical, building service engineering etc. specialities. In recent years a lot of researchers have dealt with this subject. The studies contained subjective and objective measuring and researching methods. The subject has a wide international
Chapter 2. Historical review of air conditions of living spaces

The inhabitants’ comfort demands for the interior spaces of residential buildings are constantly changing. This chapter presents the differing air conditions on typical residential examples from the different periods of Hungarian history, organized into the Table 2. - Change of the Air Conditions in Historical Living Spaces. Throughout the history until the mid-20th century people only controlled temperature out of the possible characteristic features of interior air conditions, therefore the table only contains data on the interior air temperature in summer and winter.

Table 2.1. Table No 2.

<table>
<thead>
<tr>
<th>Name of period</th>
<th>Period of time</th>
<th>Architectural characteristics, structures uses</th>
<th>Characteristic buildings from the period</th>
<th>The analysed building</th>
<th>The structures of the analysed building</th>
<th>Heating and cooling system of the analysed building</th>
<th>Inside condition of air in winter</th>
<th>Inside condition of air in summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture of Prehistoric Age and Bronze Age</td>
<td>before the 1st century</td>
<td>primarily caves, primitive tents and huts - habitations must provide from rain, snow and wind - controlled use of fire</td>
<td>Szeleta Cave (in the Bükk Mountains); Baradla Cave (Cave of Aggtelek Karst); Vérteszőlős &quot;Basin houses&quot;</td>
<td>pit holes with a diameter of 8-9 meters; in the middle the a clear area provides the possibility of escape from enemies or predators; surrounded by lime tuff cliffs (a loose and porous material, good heat insulation)</td>
<td>fireplaces (diameter: 40-60 centimeters); fueled by wood and bones of animals - the bones gave a higher temperature and were glowing longer</td>
<td>cold; warmer in the immediate surroundings of the fire, but farther away from the fire the temperature quickly got colder, inside the basins it was warmer than the average outside temperature; at the entrances of caves the temperature was the same as outside, deeper inside the caves it was warmer, around 0 to +5°C</td>
<td>in the basins and at the entrances of caves the temperature was around the same as the daily average outside temperature, deeper in the caves it was a cooler, 8-12°C</td>
<td></td>
</tr>
<tr>
<td>Building of primitive habitats</td>
<td></td>
<td>motte and bunker houses, Százhalombatta (Bronze Age); Tiszajenő - Százhalombatta (4. millennium BC); Csanatelej (4. millennium BC); Nyíregyháza - Mandabokor scythian house (7-4. century BC); Endrőd and Szolnok bank of the river Zagyva - semi-subterranean houses</td>
<td>motte and bunker house, Százhalombatta (Bronze Age)</td>
<td>rectangle shaped, semi-subterranean house; walls made out of woven wood sticks (wattle) and are plastered with mud; roof structure supported by posts and piles; thatch roof</td>
<td>inside and outside kilns, smouldering pits, grating kilns</td>
<td>inside temperature was an acceptable 8-16°C because of the open fireplaces and kilns, air quality depended on the air density of the building</td>
<td>the temperature was pleasant in summer, due to the building being sunk into the ground; no overheating in summer</td>
<td></td>
</tr>
</tbody>
</table>
I. Previous to history of architecture in Hungary (until then 10th century)

<table>
<thead>
<tr>
<th>Architecture of the Roman Empire in Hungary</th>
<th>between the 1st and the 7th century</th>
</tr>
</thead>
<tbody>
<tr>
<td>architecture of dwelling-house is diverse (dwelling-houses with stores, craftsmen houses, detached villas); generic structures: wall made out of stones and bricks, low angled pitch roofs, roofing with tile covering; flat ceiling: plank, beam, reed structures, floor and wall heating</td>
<td>Architecture of Migration Period between the 7th and the 10th century</td>
</tr>
<tr>
<td>Gorsium(Tác), Palatinus - urban villa (7th century); Nemesvámos, Balácapuszta - central building of Villa rustica (2-3th century); Budapest, Aquincum - dwelling-houses</td>
<td>co-occurrence of mobile and fixed habitats</td>
</tr>
<tr>
<td>development in unbroken rows, walls made out of stones and bricks, stock bricks and hollow bricks; low angled pitch roof; roofing tiles; glazed windows: flat ceiling: plank, beam, reed - layer order</td>
<td>jurs and temporary singular space houses</td>
</tr>
<tr>
<td>portable smolder holders, but the centralized underfloor heating is more significant - the aim is to heat the floor, principle of operation: heat transfer through air flow (it consisted of 3 parts: the fire making chamber, the cellar like heating space under the premises up, a hollow system in the walls to help the ascending airflow - this system reduced the moisture condensation in the faces of the walls) this heating system also helped in a better insulation of the rooms</td>
<td>houses with wattle walls (Fonyód - Bélatelep); log houses (Edelény - borsodi földvár); bunker house (Kardoskút, Doboz-Hajdúíirtás, Tiszalík - Rázom,Oroszháza); reconstructions of bunker houses can be found in the Ages of Arpád open-air ethnographic museum - Tiszalík, Archeological Park - Szarvasgede and</td>
</tr>
<tr>
<td>the quality of doors and windows defined the inside temperature, the floor and wall heating provided a high level of comfort, large faces of the walls and floors were always warm, the air temperature was between 14-16°C</td>
<td>soil house from the Age of Arpád (sample building in the EMESE - Archeological Park)</td>
</tr>
<tr>
<td>in stone buildings with little windows the inside temperature followed the daily mean temperature with a low fluctuation; no overheating in summer</td>
<td>semi-subterranean house, covered by ground; small house (2-3 by 3-4 meters); rounded square or circle shape; the lower part of the walls was the side of the excavation, the upper part was clay poached wicker (patics) and soil, the roof structure</td>
</tr>
<tr>
<td>Hajnóczi Gyuli - Polgárván</td>
<td></td>
</tr>
</tbody>
</table>

II. Romanesque architecture 1000-1241

<p>| living in two places is characteristic: summer - shelter, tents; winter - solid buildings, Material in villages and towns: reed (rarely wood or stone) typical is the semi-subterranean house | open fireplaces in the center of the house, the smoke left the house through the door and splits on the roof |
| houses with wattle walls (Fonyód - Bélatelep); log houses (Edelény - borsodi földvár); bunker house (Kardoskút, Doboz-Hajdúíirtás, Tiszalík - Rázom,Oroszháza); reconstructions of bunker houses can be found in the Ages of Arpád open-air ethnographic museum - Tiszalík, Archeological Park - Szarvasgede and |
| as a result of the open fireplace the temperature in winter was an acceptable 4-12°C; air quality depended on the air density of the building; farther away from the fire the temperature got colder | as a result of the open fireplace the temperature in winter was an acceptable 8-16°C; air quality depended on the air density of the building |
| the jurt was overheated in summer, due to its small thermal inertia | the temperature was pleasant in summer, due to the building being sunk into the ground; no overheating in summer |
| Magyar Régészet |</p>
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Architecture</th>
<th>Important Buildings和Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Gothic architecture</td>
<td>1241-1300</td>
<td>Royal architecture: Castle of Tata, keep, Nagyváraszony; castle with tower, Gyula; Civil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dwelling-houses: the Budapest Castle Hill - Tárnok street 14, Országház street 18-20; Religious</td>
</tr>
<tr>
<td>Mater and Late Gothic architecture</td>
<td>1300-1526</td>
<td>Royal architecture: Castle of Tata, keep, Nagyváraszony; castle with tower, Gyula; Civil</td>
</tr>
<tr>
<td>Early and High Renaissance</td>
<td>1458-1541</td>
<td>The Royal Palace, Visegrád (1477-1485 - rebuilt)</td>
</tr>
<tr>
<td>IV. Renaissance (1458-1686)</td>
<td></td>
<td>The country was divided into three parts, the residential building evolved differently in all</td>
</tr>
<tr>
<td></td>
<td></td>
<td>structures made out of stone, in the back yard of palace is two storey cloister; Hercules</td>
</tr>
</tbody>
</table>
|                           |                                        | Fontain in the middle of the court; living rooms and bedrooms were on the second storey, with a rectangle shaped plan, with a large inner court; stoves were similar to stoves in nowadays, these provided the highest comfort until the 19-20th century (until the appearance of glassed surfaces gets higher, the...
### Mater and Late Renaissance (1541-1711)

<table>
<thead>
<tr>
<th>1541-1686</th>
<th>of them. Some parts had the typical castle architecture, other parts were famous for the manor houses, fortifield castles were typical for the time.</th>
</tr>
</thead>
</table>

### V. Islamic architecture (1541-1686)

<table>
<thead>
<tr>
<th>1541-1686</th>
<th>During this period no significant residential building was built. New buildings were only built when no appropriate building was found, or when a new type of function e.g.: minarett.</th>
</tr>
</thead>
</table>

### VI. Baroque architecture (1618-1795)

<table>
<thead>
<tr>
<th>1618-1711</th>
<th>Between 1630 and 1700 there was a Turkish presence in Hungary. This uncertain situation obstructed the widespread architecture. Typical were late Renaissance style buildings, residential buildings in cities, manor houses and cottages in villages. At the same time in villages the development of the Hungarian vernacular architecture began.</th>
</tr>
</thead>
</table>

#### Early Baroque (1618-1711)

| 1618-1711 | | 
| --- | --- | --- |
| Between 1630 and 1700 there was a Turkish presence in Hungary. This uncertain situation obstructed the widespread architecture. Typical were late Renaissance style buildings, residential buildings in cities, manor houses and cottages in villages. At the same time in villages the development of the Hungarian vernacular architecture began. | Cottage (the oldest cottage in the Carpathian Basin), Torocó (Romania); Esterházy Manor House, Kismarton (Austria); Fabricius House, Sopron (17th century) | ghotical style elements; development in unbroken rows; building with 3 stories, atrium; walls made out of stock bricks |
| **Manor houses**: Manor House of Edelény, Edelény; Szavolya Manor House, Ráckeve; Ráday Manor House, Pécel; Széchenyi Manor House, Nagycenk; Grassalkovich Manor House, Hatvan; Esterházy Manor House, Fetrőd-Esterháza; Royal Manor House of Gödöllő; Gödöllő; Civil dwelling-houses: Bécsi kapu square 5; Országház street 44, the Budapest Castle Hill | | tile ovens in the corner of the bedrooms |
| **Manor houses**: Manor House of Edelény, Edelény; Szavolya Manor House, Ráckeve; Ráday Manor House, Pécel; Széchenyi Manor House, Nagycenk; Grassalkovich Manor House, Hatvan; Esterházy Manor House, Fetrőd-Esterháza; Royal Manor House of Gödöllő; Gödöllő; Civil dwelling-houses: Bécsi kapu square 5; Országház street 44, the Budapest Castle Hill | | the development in unbroken rows prevented the quick cooling down of the house; the heating of the building was easier; the stoves provided an appropriate comfort in winter |
| **Manor houses**: Manor House of Edelény, Edelény; Szavolya Manor House, Ráckeve; Ráday Manor House, Pécel; Széchenyi Manor House, Nagycenk; Grassalkovich Manor House, Hatvan; Esterházy Manor House, Fetrőd-Esterháza; Royal Manor House of Gödöllő; Gödöllő; Civil dwelling-houses: Bécsi kapu square 5; Országház street 44, the Budapest Castle Hill | | the amount of glazed surfaces gets higher, the heat load grew in summer because of this, but no overheating in summer |

### Mater and Late Baroque (1711-1795)

<table>
<thead>
<tr>
<th>1711-1795</th>
<th>residential buildings get bigger, tenement houses were typical in this period, at first with 3 stories, later with elevators 4-6 stories. Typical structures: iron weight-bearing structures, framework structures and floor beams, walls made out of stock brick, 3 types of buildings: tenement houses in Budapest, examples: Báthory street 20, Bedő</th>
<th>hearths and stoves in the living rooms and the bedrooms</th>
<th>the amount of glazed surfaces gets higher, the heat load grew in summer because of this, but no overheating in summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential buildings get bigger, tenement houses were typical in this period, at first with 3 stories, later with elevators 4-6 stories. Typical structures: iron weight-bearing structures, framework structures and floor beams, walls made out of stock brick, 3 types of buildings: tenement houses in Budapest, examples: Báthory street 20, Bedő</td>
<td>Houses in ( \text{Houses in} )</td>
<td>ceramic stoves provided the highest comfort (according to the demands of this period)</td>
<td>usage of shading</td>
</tr>
</tbody>
</table>

### Mater and Late Renaissance (1541-1686)

<table>
<thead>
<tr>
<th>1541-1686</th>
<th>House, Sopronkereszttü (Austria); Bethlen Fortified Castle, Keresd (Romania); Manor House of Márkusfalva, Márkusfalva (Slovakia); Manor House of Pácint, Pácint; Rákóczi Castle, Sárosptak</th>
<th>one storey, with four corner towers, little windows in great distances from each other</th>
<th>heat load grew in summer; but no overheating in summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>House, Sopronkereszttü (Austria, 1625)</td>
<td>hearths and stoves of centralized heating systems); at first the performance of the stoves was low, possibly because the comfort level was compared to the low comfort levels of the past</td>
<td></td>
</tr>
<tr>
<td>VII. Architecture of Historism and Turn of the century</td>
<td>1867-1914</td>
<td>reinforced concrete structures. The thickness of the load bearing walls are reduced. The facades of the building do not show the structural systems behind them. The flats of the tenement houses had several rooms, sun light, views and orientation were not aspects.</td>
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<tr>
<td>House, Honvéd street 3; Houses in Wekerle Housing Settlement, Budapest; villas in Budapest (example: Babochay Villa)</td>
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<tr>
<td>Wekerle Housing Settlement, Budapest (1908 - architect: Kós Károly)</td>
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<tr>
<td>house, tenement house with bachelor flats and family houses / terraced houses and semi-detached houses</td>
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<td>tile stoves; gas convector heating of this period), the specific of these stoves was the 8-10°C temperature gradient, and temperature fluctuation was normal</td>
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<tr>
<td>structures on the facade provided protection from overheating</td>
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<tr>
<td>VIII. Architecture Between the Two World Wars</td>
<td>1914-1944</td>
<td>Private constructions turned toward the modern design. Typical buildings were the tenement houses, with indoor staircases. Other types of houses were villas and family houses.</td>
<td></td>
</tr>
<tr>
<td>OTI Tenement Houses, Budapest - Georgia House (architect: Baráth Béla, Novák Endre), Budapest; Villa in Széchenyi street (architect: Kősa Zoltán), Budapest; Villa in Berkenye street (architect: Kozma Lajos)</td>
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<tr>
<td>OTI Tenement Houses with 203 flats, Budapest (architects: Arkay, Faragó, Fischer, Heysa, Ligeti, Molnár, Pogány, Preisch, Vadász - 1934)</td>
<td></td>
<td>group of tenement houses; 8 stories high towards the square, 6 stories high on the other side, the complete structures is supported by a slab foundation made out of reinforced concrete (80 centimeters thick); furnace room and coal bunker were in the basement</td>
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<td></td>
<td></td>
<td>spread of the centralized heating system was typical in this period; solid fuel; gravitational or steam heated systems; controlling these systems was hard, but it provided an appropriate temperature; the temperature fluctuation was 2-3 °C</td>
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<tr>
<td></td>
<td></td>
<td>usage of shading structures on the facade provided protection from overheating</td>
<td></td>
</tr>
<tr>
<td>IX. Architecture of the Socialism</td>
<td>1945-1989</td>
<td>Shortage of flats is the most important problem in this period. To solve this problem precast building were built - large panel structures and standard designs. The housing estates show the conceptual thinking of urban planning</td>
<td></td>
</tr>
<tr>
<td>Settlements: József Attila Settlement, Budapest - districtIX; Havanna Settlement, Budapest - district XVIII; Tenement Houses in Budapest: Úri street 32. (architect: Farkasdy Zoltán); Úri street 26-28. (architect: Horváth Lajos KÖZTI); Lévay street 8. (architect: Varga Levente)</td>
<td></td>
<td>loose layout of buildings, large green surfaces; 10 and 4 storey buildings; precast large panel structure</td>
<td></td>
</tr>
<tr>
<td>József Attila Settlement, Budapest (1957-1967 and 1979-1981)</td>
<td></td>
<td>district heating system, boiler house and a coal bunker are in the basement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>centralized heating system, usually with an inappropriate setup, the temperatures of the dwellings was different, the system could not be controled from the units, usually the lower sories were colder, the higher sories were warmer than required</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the protection form overheating was not provided, people did not use outside shading structures</td>
<td></td>
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<td></td>
<td></td>
<td><a href="http://www.arb.br">http://www.arb.br</a></td>
<td></td>
</tr>
<tr>
<td>Conventional Houses 1989-</td>
<td>X. Contemporary architecture</td>
<td></td>
<td></td>
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<td>---</td>
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</tr>
<tr>
<td>Family House, Plíscešaba - Pest Region (architect: Kolossa József, Kolossáné Bartha Katalin); Guesthouse, Pécs - Baranya Region (architects: Ásztai Bálint and Kovács Csaba); Family House, Nagykovácsi, Pest Region (architects: Földes László and Balogh Csaba); Family House, Budakeszi, Pest Region (architects: Bártfai Szabó Gábor, Bártfai-Szabó Orsolya); Apartment house, Budapest, district II. (architect: Tomay Tamás)</td>
<td>In the contemporary architecture of residential houses the architectural intention and the functional design, are achieved simultaneously and in regard to the inhabitants needs.</td>
<td></td>
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<tr>
<td>Passive Houses 2009-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualified passive house, Budaörs - Pest Region (2011)</td>
<td>Specific heating (and cooling) power demand: 14 kWh/m² year, Heat required for heating: 12 W/m², Power demand of cooling: 5 W/m². Engineering systems: heat pump, floor tempering, low temperature ceiling heating and cooling; solar panel for creating domestic hot water (DHW) supply with buffer storage, filled up by heat pump in sun-free conditions.</td>
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</tr>
<tr>
<td>Detached passive family house (concrete structure, with insulation), Szada - Pest Region; detached passive family house Orosházá, Békés Region; semi-detached passive house (concrete structure, with insulation), Fót - Pest Region; passive family house (concrete structure, with insulation), Páty - Pest Region; in the structural system is a reinforced concrete slab forming of the building shell, 50 centimeters of heat insulation on the upper closing slab, 27 centimeters of heat insulation under the floor; the forming of the building is compact, its orientation is southern, it has a rectangle shaped plan; the higher amount of glazed surfaces and the higher comfort demands cause a demand for cooling; outside shading structures are not always applied</td>
<td></td>
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</tr>
<tr>
<td>Low energy demand houses; the pleasant inside air-condition can be provided without an active heating and cooling system; the term passive can be used; when a building is qualified by the German Passivhaus Institute and by the Passivhaus Dienstleistung GmbH; the qualified passive houses have to comply with German standard;</td>
<td></td>
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</tr>
<tr>
<td>Foundation and pad footing, ascending structures: POROTHERM 30, 38 - supporting wall, reinforced concrete circular pillars, slab: precast beams, with weight secondary blocks, and reinforced concrete, insulation material: in the roof structure - 17-20 centimeters rock wool, in the wall - 6 centimeters rock wool insulation, facade is made out of Wienerberger VALERIAN facing brickwork, roof structure: conventional wood framework, Antracit coloured ceramic tile covering, windows and doors: 4-6-4 thick insulative glazing</td>
<td></td>
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<tr>
<td>Individual, or central radiator heating, the annual heating energy demand is 150 kW/m²</td>
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<tr>
<td>Low amount of the heat loss, a greater need of attention on outside shading structures; the demand of cooling</td>
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</tbody>
</table>
Studying the sample buildings from the different time periods, significant differences can be discovered through time regarding the condition of air in the interior. The research shows, that the interior spaces of the houses could be tempered more and more precisely throughout the history. For example 70 years ago 2-3 °C fluctuation in air temperature was considered normal in heating season, however, the temperature fluctuation nowadays is only 0,3 °C.

The breakdown of eras in the book „Magyar építészettörténet” by Jenő Rados (History of Hungarian Architecture) was used as a basis for determining the chronological units to be studied. In order to be clear and complete this book handles the periods of the Hungarian history complete with the periods of the history of architecture, and demonstrates the most conspicuous characteristics of these periods with sample buildings.

In contrast to the materials in the literatures used, this chapter only concentrates on the built residential buildings. The original subdivisions from the Rados-book have been changed due to the concentration on the residential function: the architecture of classicism, romanticism and eclecticism units can be found merged under the name 'Architecture of Historicism and Turn of the century' in Table 2., because the sample buildings from these periods do not shows any differences regarding the condition of interior air. The other 9 periods stayed unchanged. The table does not contain any data from Islamic architecture, during this period there was no significant residential building built. The original chronological breakdown ending with the era Architecture of the Socialism, was complemented with the Period of Contemporary Architecture, which is relevant to the curriculum.

All of the sub-periods from the table, and their general architectural characteristics, are presented with sample buildings. At each of the sub-periods, one typical sample building is detailed with information for an analysis. The structure, the heating system and the condition of air in summer and in winter time are detailed about this building in the table.

We can follow the technological development in this table, and as a result the improvement of the condition of interior comfort. It is surprising, that when compared, the centralized heating system used between the Two World Wars was a much more comfortable solution then the heating system of the pre-fabricated panel buildings in the period of the Socialism. The configuration of the district heating system coming as a component with the large pre-fabricated panel system, was often constructed incorrectly. This caused a non-equable interior condition of air in parts of the building, and as a result of the lack of facade shadings the buildings were overheated in summer.

An other curiosity is coming from the medieval ages when the members of higher social classes were living in keeps, where the temperatures were between 0 and 10 °C, at the same time in villages in the farmer’s bunker houses the condition of interior air was a more comfortable 20 to 22 °C. The table shows clearly: the comfort demands of the living spaces have changed throughout the history!

In the past people often compensated the unpleasant temperatures in the living spaces with additional methods, for example with the use of wall carpets, thicker bed linens or layered clothing. Nowadays humans’ willingness to adapt to extreme values of air conditions is decreasing. In contrast to solutions from the past, people of today want to reach the comfortable temperature sensation for themselves by adjusting the exact extent of the heating or cooling, as opposed to for example wearing appropriately layered clothing in lower tempered situations. The change of habits is worth considering. In an average Hungarian dwelling-house during wintertime keeping the interior temperatures 1 °C lower than usual can result in a 10% reduction of energy usage for this time period.

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### Chapter 3. Energetics and Climatic Conditions

#### Table of Contents

3.1. The definition of the climate
3.2. The classification of the climatic conditions
Interior areas are protected from the external environmental effects by the building’s outer shell. The external environmental effects are determined by the climatic conditions of the given areas. These climatic conditions have an impact on the energies entering a building.

This chapter shows the relations between climatic conditions and their effects on the building’s energy use. The aim of this chapter is to draw attention to the influence of the climatic conditions on the possible energy gain of buildings and on the proper construction of the building structures and shells.

Definitions of the meteorological terms are explained based on the book titled 'Éghajlattan' written by György Péczely.

3.1. The definition of the climate

Climate is defined as an interactive system of physical properties and events of the atmosphere interacting with the environment and each other in a given area over a period of time (usually a few decades). Climatology is a discipline of climatic conditions.

The factors that effect climate are: altitude, the distance from the Equator and the distance from seas. The incident angle of solar radiation depends on the distance from the equator, the amount of precipitation and the mitigation effect of large water surfaces depend on the distance from the seas. The altitude expresses the intensity of the effects of highland climates.

3.2. The classification of the climatic conditions

Even though climate is a complex phenomenon a demand for the systematization of different climates based on their similarities and the territorial distribution of the climatic types was revealed during the first period of the organized climatic data collection at the end of the 19th century. It’s obvious that climate classifications are only stereotyped versions of the reality. These classifications are limited to underline some of the most determinative factors and create a spatial distinction. The practical usability of the climatic classifications usually depends on the selected factors used to define the climatic types.

The basis of every climatic classification is the thermal zonality and the climatic events based on this zonality. Different classifications list the same main climatic zones: 1. tropical, 2. subtropical, 3. temperate, 4. subarctic, 5. polar. Moreover it is reasonable to separate a highland climate zone in the area higher mountains, although highland climate is not an individual climatic zone, it is a special local version within the main climatic zones.

The listed five main climatic zones can be divided into further climatic types according to the annual course of temperature, the typical extremes of the annual course of temperature, the annual precipitation amount and its seasonal distribution. György Péczely modified and improved the Trewartha climatic classification for it to be more like the real climatic conditions. This modified classification can be seen in the following:

Figure 3.1.

3.2.1. Climatic classification:

A) tropical climates
A1.) tropical rainforest
A2.) savanna
A3) tropical dry savanna
A4.) low latitudes
A4a.) zonal deserts
A4b.) cool coastal deserts near cold ocean currents
B) subtropical climates
B5.) subtropical steppe
B6.) Mediterranean
B6a.) hot-summer Mediterranean
B6b.) cool-summer Mediterranean
B7.) humid subtropical
C) temperate climates
C8.) maritime temperate
C9.) humid continental climate with longer warm season
C10.) humid continental climate with shorter warm season and cold winter
C11.) temperate steppe
C12.) temperate desert
D) subarctic climates
C13.) maritime subarctic
C14.) continental subarctic
E) polar climates
E15.) tundra
E16.) ice cap
F) highland climates
Table 3. - Climatic Conditions and their Effects presents – based on the modified Trewartha climatic classification by György Péczely – the characteristics of the different climatic types and their effects on the construction of building shells. In this table every climate type is described with representative factors e.g.: average yearly precipitation sum, precipitation amount in summer and winter, wind (circulation) in summer and winter, temperature, mean temperature of the warmest and the coldest month. Moreover this table also reveals the effects of different climate types on the building energetics.

Table 3.1. Table No 3.

<table>
<thead>
<tr>
<th>climatic zone</th>
<th>climate type</th>
<th>average yearly precipitation sum (mm)</th>
<th>precipitation amount - summer</th>
<th>precipitation amount - winter</th>
<th>wind (circulation) - summer</th>
<th>wind (circulation) - winter</th>
<th>temperature value</th>
<th>mean temperature of the warmest month (°C) / mean temperature of the coldest month (°C)</th>
<th>effects climate on building energy in summer</th>
<th>mean temperature of the coldest month (°C)</th>
<th>effects climate on building energy in sumne</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.) tropical rainforest climate</td>
<td>every season is wet, average annual amount above 1500 mm</td>
<td>precipitation maximum occur during the time of the highest sun position</td>
<td>every season is wet</td>
<td>mostly Inter Tropical Convergence Zone (ITCZ) and equatorial west wind zone</td>
<td>annual mean temperature at least 22 °C, average annual fluctuation under 5 °C</td>
<td>n.a.</td>
<td>above 18°C</td>
<td>heavy decay, expectur structu heat-ins due to a weather cco</td>
<td>increases cooling demand summer, summate with go thern storage capacit only a f opening: no openin am openin near ir ground in in indoor temperate wateri struct due to bi; amount precipita</td>
<td></td>
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</tr>
<tr>
<td>2.) savanna climate</td>
<td>average annual amount between 500 - 1500 mm</td>
<td>summer is the rainy season, the average precipitation maximum is above 60 mm at least in 3 months</td>
<td>winter is the dry season, the average precipitation maximum is under 20 mm at least in 3 months</td>
<td>Inter Tropical Convergence Zone (ITCZ) in the rainy season, equatorial west wind is typical (less than 8 months)</td>
<td>east winds of the trade wind zone are typical in the dry season</td>
<td>average annual fluctuation between 5 - 15 °C</td>
<td>above 28°C</td>
<td>above 18°C, never goes below 12°C</td>
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</tr>
<tr>
<td>A) tropical climates</td>
<td>3.) tropical dry savanna climate</td>
<td>average annual amount between 200 - 500 mm, erratic fluctuations</td>
<td>a short, 1 or 2 months long wet period, short, 1 or 2 months long wet period</td>
<td>several months without rain</td>
<td>mostly part of the trade wind zone, under the influence of Inter Tropical Convergence Zone (ITCZ) in summer</td>
<td>average annual fluctuation between 5 - 15°C</td>
<td>above 28°C</td>
<td>above 18°C, never goes below 12°C</td>
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<tr>
<td>4a.) climate of zonal deserts</td>
<td></td>
<td>average annual amount under 200 mm, most of this precipitation amount is</td>
<td>no typical seasonal distribution of rain</td>
<td>under the influence of trade wind zone or subtropical anticyclone (high pressure area), western winds all year long</td>
<td></td>
<td>average annual fluctuation between 5-15°C</td>
<td>above 28°C</td>
<td>above 12°C</td>
<td>shading and cool prots sandstorms strong wind</td>
<td>water-tight to infrequent but intensive</td>
<td></td>
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<tr>
<td>4.) climates of the low latitudes</td>
<td>caused by infrequent showers</td>
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<tr>
<td>4b.) climates of cool coastal deserts near cold ocean currents</td>
<td>average annual amount under 50 mm, predominantly from fog condensation</td>
<td>no typical seasonal distribution of rain</td>
<td>easterly wind of the trade wind zone</td>
<td>average annual fluctuation between 5 - 10 °C</td>
<td>between 17 - 23°C</td>
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<tr>
<td>5.) subtropical steppe</td>
<td>between 200 - 500 mm</td>
<td>summer months without rain</td>
<td>short, 1 or 2 months long wet period</td>
<td>dry trade wind zone or subtropical high pressure zone most of the year, west wind zone in winter</td>
<td>n.a.</td>
<td>average above 28°C, hot summer</td>
<td>between 6 - 12°C</td>
<td>no cooling or shading due to a comfortable temperature in summer</td>
<td>perimeter structure with good thermal storage capacity and small windows</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### B) Subtropical Climates

<table>
<thead>
<tr>
<th>6a.) Hot-Summer Mediterranean Climate</th>
<th>Average Annual Amount is Between 500 - 1000 mm</th>
<th>Summer is the Dry Season, at Least in 3 Months the Average Precipitation Maximum is Under 20 mm</th>
<th>Winter is the Rainy Season, at Least in 3 Months the Average Precipitation Maximum is Above 60 mm</th>
<th>Under the Influence of Subtropical High Pressure Zone</th>
<th>Under the Influence of Extratropical West Wind Zone</th>
<th>Annual Mean Temperature Above 14°C</th>
<th>Above 22°C</th>
<th>Above 4°C</th>
<th>Outer Perimeter Structure with Good Thermal Storage Capacity Due to a Warm Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>6b.) Cool-Summer Mediterranean Climate</td>
<td>Average Annual Amount is Between 500 - 1000 mm</td>
<td>Frequent Fog Formation</td>
<td>Winter is the Rainy Season, at Least in 3 Months the Average Precipitation Maximum is Above 60 mm</td>
<td>Under the Influence of Subtropical High Pressure Zone, Cold Sea Flows</td>
<td>Under the Influence of Extratropical West Wind Zone</td>
<td>n.a.</td>
<td>Under 22°C, Relatively Cold</td>
<td>Above 4°C</td>
<td>Thicker Outer Perimeter Structure Due to a Colder Summer</td>
</tr>
<tr>
<td>7.) Humid Subtropical Climate</td>
<td>Between 1000 - 1500 mm</td>
<td>Maximum Precipitation in Summer</td>
<td>Minimum Precipitation in Winter</td>
<td>West Wind Zone, Monsoon Effect</td>
<td>Annual Mean Temperature Above 14°C</td>
<td>Above 22°C</td>
<td>Above 6°C</td>
<td>Shading Structures or Narrow Windows Due to the Strong Sunshine, Large Amount of Precipitation Will Influence Perimeter Structure</td>
<td></td>
</tr>
<tr>
<td>8.) maritime temperate climate</td>
<td>homogeneous annual distribution, precipitation minimum in spring, precipitation maximum in fall all time of the year under the influence of west wind and mid-latitude cyclone</td>
<td>annual mean temperature above 8 °C, average annual fluctuation under 15 °C between 14 - 18°C</td>
<td>between 1 - 6°C</td>
<td>impermeable structures and few openings due to uniformly high precipitation, heating demand in summer, no heating demand in winter</td>
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</tbody>
</table>
### C) temperate climates

<table>
<thead>
<tr>
<th></th>
<th>Humid continental climate with longer warm season</th>
<th>Humid continental climate with shorter warm season and cold winter</th>
<th>Temperate steppe climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>9)</td>
<td>Precipitation: 500 - 1000 mm; Maximum in summer; Minimum in winter, spring</td>
<td>Precipitation: 400 - 800 mm; Maximum in summer; Minimum in winter</td>
<td>Precipitation: 200 - 400 mm; Maximum in summer; Minimum in winter</td>
</tr>
<tr>
<td></td>
<td>All year under the influence of west wind and mid-latitude cyclone</td>
<td>Extratropical west wind zone influence all of the year, periodical easterly wind zone effects in summer</td>
<td>Extratropical west wind zone influence all of the year, periodical easterly wind zone effects in summer</td>
</tr>
<tr>
<td></td>
<td>Average annual fluctuation: 15 - 30 °C</td>
<td>Average annual fluctuation: above 30 °C</td>
<td>Average annual fluctuation: above 22 °C</td>
</tr>
<tr>
<td></td>
<td>Perimeter structure with good thermal storage capacity due to a small-scaled cooling demand</td>
<td>No cooling demand</td>
<td>No cooling demand</td>
</tr>
<tr>
<td></td>
<td>Above 18 °C, Under -3 °C</td>
<td>Above 18 °C, Under 0 °C</td>
<td>Above 22 °C, Between -5 °C and 0 °C</td>
</tr>
</tbody>
</table>
### 12.) temperate desert climate

- **Average Annual Precipitation:** Under 200 mm
- **Summer vs. Winter:** Predominantly dry
- **Temperature Range:** Fluctuation above 30 °C
- **Demand:** -25°C

### 13.) maritime subarctic climate

- **Average Annual Precipitation:** Between 600 - 1200 mm
- **Distribution:** Homogeneous annual distribution, precipitation maximum in spring and fall
- **Temperature Range:** Average annual fluctuation above 40 °C
- **Demand:** Air conveying materials to cool inside

### 14.) continental subarctic climate

- **Average Annual Precipitation:** Between 200 - 500 mm
- **Temperature Range:** Average annual fluctuation above 40 °C
- **Demand:** Occasional heating demand due to a colder summer

---

**D) subarctic climates**
<table>
<thead>
<tr>
<th>Climate Type</th>
<th>Precipitation</th>
<th>Monthly Mean Temperature</th>
<th>Heating Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.) Tundra Climate</td>
<td>Under 250 mm</td>
<td>Between 0 - 10°C</td>
<td>Occasional heating to a colder summer</td>
</tr>
<tr>
<td></td>
<td>Summer precipitation is typical</td>
<td>Maximum in a 3-months long period</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polar West Wind Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extratropical West Wind Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.) Ice Cap Climate</td>
<td>Under 100 mm</td>
<td>Under 0°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accumulation of snow progressively becomes ice</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All the year under the influence of polar west wind zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polar West Wind Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.) Tropical Highland Climate</td>
<td>N.A.</td>
<td>Under 10°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snow line above 4000 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Daily fluctuation grows with altitude</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The aim of the research was to find and study representative buildings from the different climatic areas. The contents of this chapter can be illustrated best by the examples of vernacular architecture of different climatic areas, due to the fact that vernacular architecture responds the most conspicuously to the external effects of the environment. It is interesting to observe how sensitively the vernacular architecture reacts - opposite to the contemporary mostly non site-specific, fashionist architecture - to the environment of their buildings. Hopefully this site-specific knowledge of the vernacular architecture, which could intuitively form a local cultural environment, can be revitalized by the methods of the site-specific planning.

Based on the listed buildings, it can be defined how the different climatic conditions influence the energy use of the buildings in summer and winter. Moreover the different cultural backgrounds and local building materials also have an influence on the architectural characteristics of the presented buildings. During the research it has become clear that in the various climatic areas fundamental differences can be observed in the constructions of the buildings and the building’s outer shells.

The listed climatic types were correlated to the Hungarian conditions. The climate of Hungary is temperate, humid continental climate with a longer warm season, compared to the other climatic types medium temperature values are characteristic without extreme wind or precipitation conditions. There is at least one example from the local vernacular architecture to every climatic type. When there were more examples found, buildings built from different building materials can be studied and compared within a climatic type.

Besides the location a general description of the main structures and building materials can be found in the table on the example buildings. It can be seen from the table that for example buildings built out of soil in the areas of the tropic, temperate or tundra climate differ from the adobe and soil structures used in the Hungarian vernacular architecture.

From the interior temperature values of the presented buildings listed in the last two columns it can be seen that climatic conditions have a great effect on the users’ demands on the comfort requirements with the interior spaces. It is astonishing how many people in the other parts of the world live in extreme conditions compared to the listed characteristic of interior temperature values in Hungary.

The various outer perimeter structures of the listed buildings demonstrate that climatic conditions not only influence the energies entering the building, they also have a huge impact on the outer shells and other structures of the buildings. Moreover, climatic conditions have an effect on the inhabitants’ demands on the requirements about their living environment.

**Chapter 4. Energetics and location**

The previous chapter showed, to what measure the climatic conditions of specific climates can effect the energies entering the building and the configuration of the
buildings’ outer shells and other structures. This chapter deals with climate of smaller places within a climate zone. It gives insight into the different environmental effects on a building within a climate zone, and into what influence these different effects can have on a building configuration from the viewpoint of building engineering.

Specifically scaled climatic phenomena can be matched to the extents of regions on Earth’s surface. The measure of extent counts both in the horizontal and in the vertical direction. There is no understanding amongst specialists in the determination of the spatial limits of climatic phenomena.

The fundament of the study is the classification of Japanese researcher Masatoshi Yoshino, which shows the different climatic phenomena’s vertical and horizontal dimensions.

This classification can be observed on Illustration 6. - Spatial dimensions of climatic events.

**Figure 4.1.**

Matching the climatic categories determined by Yoshino with spatial scales was accomplished by Hungarian professor György Koppány, on Illustration 7. - Spatial scales of clime categories. Within the global climate of Earth, three main categories exists related to the climatic phenomena’s spatial dimensions: macro-, meso- and microclimate. This curricula – because of its small extent – does not address the phenomena of microclimate.

**Figure 4.2.**

The zonal climate discussed in the previous chapter belongs to the group of macro climates, which is the zonal order of climatic components. The characteristic of regional climate, which belongs into the class of macro climate is, that in addition to climate determining factors, it also takes the major separate surface units and the effects created by them into consideration.

Showed in the 3. chapter, Péczely’s modified Trewartha climate classification regarding the zonal climate of Hungary determines two climate areas: most of the area of the country is in ‘humid continental climate with longer warm season’ climate area, and only the north-eastern part of the country and the higher mountain areas with colder winters belong to ‘humid continental climate with shorter warm season and cold winter’. György Péczely has already shown, if we applied the climate classification created for global systematization to the area of Hungary, it would be unable to reveal those relatively small, and yet well sensible climatic differences, that exist in the country.

György Péczely set up a new system of viewpoints for the more precise determination of Hungarian areas’ climatic regions. He studied the different areas water- and heat balance, than made up 16 combinations from their degrees. In Hungary he observed 12 of them, and based on these, he determined Hungary’s climate areas. Illustration 8. - György Péczely’s clime classification in Hungary. This climatic classification is already more particular, takes the regional qualities into account, but then it still remains on the level of macroclimate.

**Figure 4.3.**

Towards even more site specific and precise data, the chapter discusses local- and topoclimate within mesoclimate. The local climate is a climate that periodically changes compared to its surroundings due to the effect of cities, lakes and topography. Topoclimate is a climate with even finer structural differences within the previous climate.

We can define the notion of topoclimate, on the same spatial dimension as meso- and microclimate. Topoclimatology is a fast developing discipline of climatology. It denotes climate of small areas where climatic differences can constantly be revealed between these areas and their environment, therefore they have an individual climate.

**Table 4.1.** Table No 4.

<table>
<thead>
<tr>
<th>local climate</th>
<th>environmental effects</th>
<th>building energy effects of local climates</th>
<th>examples of vernacular architecture on savannah climate</th>
<th>code of the pictures</th>
<th>source of the pictures</th>
<th>picture/drawing by</th>
<th>map link</th>
</tr>
</thead>
<tbody>
<tr>
<td>mountain</td>
<td>affected by the greatest amount of solar radiation; typically a warm area, depending on durable structures due to high wind speeds;</td>
<td>source: <a href="http://www.flickr.com">www.flickr.com</a></td>
<td><a href="http://copepodo">copepodo</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern slope</td>
<td>Northern slope</td>
<td>Built environment</td>
<td>Forest</td>
<td></td>
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<td></td>
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<tr>
<td>----------------</td>
<td>----------------</td>
<td>-------------------</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effected by the greatest amount of solar radiation; typically a warm area - same as the mountain peak, plateau, hilltop area; radiation reception of southern slopes is greater than that of the plains</td>
<td>Effected by a smaller amount of solar radiation, than the mountain peak, plateau, hilltop area; souther slope area; lower mean temperatures; lower radiation reception than on the southern slopes or plains</td>
<td>Thermal surplus compared to open spaces, warmest areas are the densely built city environments, a phase delay can be observed in the daily warm up, compared to open spaces: usually it is colder in them morning and warmer in the evening, the phenomena occurs due to the thermal inertia and the own wind systems of the built environments</td>
<td>A lower mean temperature in forest areas, then in open spaces, due to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible need of outside shading due to the high amount of solar radiation</td>
<td>Possible need for thicker structures with good heat-insulating properties</td>
<td>Dense layout of buildings; temperature surplus due to the change in the Earth's surface, no need for thick outer perimeter structures due to the higher temperatures, need for structures with good thermal storage capacity, and outer shadings, due to warm and solar radiation intense summers</td>
<td>Possible need for thicker</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zafimaniry wooden houses</td>
<td>Ema house</td>
<td>Gurunsi earth houses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daniel Coulaud - Cambridge University Press, 1998</td>
<td></td>
<td></td>
<td>Plant Design Online</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In vernacular architecture the different cultures reacted to the typical environmental effects that surrounded their houses according to their own limits of technical development. It’s important to note that compared to the vernacular architecture’s tools, today’s technologies do not limit the site-specific design. The example buildings in the table draw attention to the architecture references in different mesoclimates within ‘savannah’ climate, which covers great areas on almost every continent on Earth.

In addition to the basic differences showed in the table before, it’s important to mention the situations within the city. These situations are related to as topoclimates by climatology. A lot of researchers deal with the climate evolving within cities, where the temperature shows the most visible change compared to its environment, primarily temperature is growing, which manifests in city heat islands. The Illustration 9 - Schematic distribution of excessive temperature in town, its cross-sectional view and its
In addition to the temperature factors studied in this chapter, from the viewpoint of building service engineering wind also can be determinative whose drying and cooling effect can cause temperature decrease. The wind can not only appear in greatly dimensioned areas, but on quite small areas as well. These are the so called local winds. The shore wind appears on sea shores and lake shores, alternating direction within a single day. During daytime the land warms up quickly and intensively, thus it gets hotter than the surface of the lake or the sea. Therefore the air close to the surface streams from the high pressured water surface to the hotter, low pressured continent (lake wind, sea wind). Naturally, aloft the the circle closes, thus the air flows from the land towards the water. At night the situation is inverted, the sea, ocean cools down slower, therefore at night the water surface stays warmer and the air flows from the cooler continent to the warmer sea and aloft the circle closes (shore wind, continental wind). This phenomenon can be observed among others at lake Balaton.

On sloping surfaces, an individual wind system, the so called mountain-valley wind comes about. At daytime on the better warming upper part of the slope the air pressure is low, thus convection evolves, which makes air motion upwards from the valley (valley wind). At night on the upper convex part of the slope, due to the high surface radiation, the air cools quicker. The cold air starts to flow down aside the slope towards the valley (mountain wind). In the valley a „cold air lake“ can appear at this time.

Along with the natural makings that determine topoclimate, the intervention of humans can also considerably effect the climatic conditions of a location. Heat islands typically appear in manmade cities. The lowering of this extra temperature coming with this phenomenon could be the task of urban designers. In case of Barcelona, during the design of the street network, the dominance of the cooling effect of the sea wind was an important feature to keep. In Barcelona urban designers wanted to moderate the expected extreme environmental effects by the use of the observed natural phenomena. Energy consumption of the cities can be made more efficient by measuring and using – on the contrary of today’s habit of ignoring or generalizing – site-specific data.

Chapter 5. The DROID and its history

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5.1. The invented measuring system and its three components:
   5.1.1. The measuring device;
   5.1.2. The evaluating algorithm;
   5.1.3. The visualization software;

Recognizing the significance of the presented and studied facts in the various chapters of the curriculum, the geometrical shape of a building and the building-energetical effects of the local environment, a patented interdisciplinary invention, a newly designed measuring equipment and software system came to life at the Budapest University of Technology and Economics.

The system called DROID creates site and building geometry-specific data measured individually on the construction site and organizes them into a database. Information gathered from the database the individual building energetic conditions can be used already in the early phases of design. The result: significant energy- and cost-savings, plus the local architectural character reappears!
5.1.1. The measuring device:

designed and built by the research team for measuring and processing building energetically significant environmental conditions on surfaces angled typical of our buildings. For designing the shape of the measuring device the Department of Residential Building Design announced an ideas competition for students of architecture. The winning group of students became part of the designing team.

5.1.2. The evaluating algorithm:

The research team cooperating with building energy and meteorology-measuring technology experts created and is still refining the connection of the data provided by the measuring system with the building energetic calculations to prepare a possible modification of the standards for future building energetic calculations. More precise data results in more precise dimensioning, which could lead to an approximate 20% energy-saving - according to the prior calculations.

5.1.3. The visualization software:

developed by the research team, it performs simulations with data received from the measuring system and the model of the building’s concept made by the architect. This 3D software presents the future energetic behavior of the new building. So the architect can design energetically sensitive buildings even in the early concept making phases: economically optimal buildings come to life while adapting energetically and culturally to the local specificities.

Chapter 6. About the project

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Test Exercise

The first four chapters demonstrated that the inhabitants’ demands and the environmental effects impacting the building are significantly differing in time and space. In the following, a system of criteria will be presented for a building’s study, to be used in the future. We hope that based on this system of criteria, the present dimensioning - based on generalized data - and the result of a complex site-specific dimensioning methodology will be easy to compare. Besides general data the dimensioning also takes the specific characteristics of the site into consideration, thus approaching from the a bigger total to a smaller detail.

Safari Power Saver
Click to Start Plug-in

Test Exercise

Make an analysis of an existing building in respect of site-specific planning!

Method of analysis / solution of the exercise:

The first step of the analysis is the evaluation of the data on the building in respect of the community of inhabitants and their demands regarding comfort levels. After this the energy dimensioning of the building is done according to the existing regulation, using the general data of the building and projected average meteorological data from over the country. Energy dimensioning used in this first step is not site-specific, as it is based only on average rough geometrical resolution weather data. As a result of the previous thoughts, this dimensioning can be applied only after the building is architecturally designed, it does not give any prior suggestion about the geometry and lay out of the building.

The second phase of the dimensioning methodology applicable in the future – which shows the study of the building site – contains data about the local climate, orography and all kinds of data which could effect the more optimal lay-out, geometry and structural design of the building, the energetic map of the site is created.

Students have to create a data sheet from a selected dwelling-house, considering the presented complex dimensioning methodology as scheme.

Task sheet 1. – Scheme of the task

The whole curriculum –including the data sheet – wants to draw attention to the lacks and mistakes of the existing dimensioning system, or rather to the importance and possibilities of the site-specific building design. The forming of the the site-specific approach and the reform of the building energy dimensioning methodology is a long process, the current status of this process is summarized in this curriculum. The DROID measuring system, the evaluation algorithm and the visualization software – keeping up with technology and changing needs – are under constant development and refinement. As a result, this curriculum is an always changing and expanding collection of information following the constant developments.

Chapter 7. Bibliography and Recommended Literature:

- Debreceni Egyetem, Meteorológiai Tanszék, kiadott előadásianyag: meteor.geo.klte.hu/old/oktatas/kornyklim/tereklima01mm.rtf
- Debreceni Egyetem, Meteorológiai Tanszék, kiadott előadásianyag: http://meteor.geo.klte.hu/meteorologia/index/hu/doc/tereklima01.pdf
- Péczely György (1979): Éghajlattan, Budapest: Nemzeti Tankönyvkiadó
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- Table 3. - Climatic Conditions and their Effects
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- Audio No. 5. - Energetics and location
- Audio No. 6. - The DROID and its history

Chapter 9. Test Questions on the curricula

9.1. Chapter 1.:
- Define comfort!
- Write down the current temperature in your room at home!
- What is the main medical complaint referring on the Sick Building Syndrome?

9.2. Chapter 2.:
- Select an architectural subperiod, and write down the typical heating methods of the example building!
- Select 2 architectural subperiods, and compare the comfort demands of the periods!
- How did people adapt to the unfavorable indoor temperature values in the past?

9.3. Chapter 3.:
- What are the factors effecting climate?
- Name the main climatic zones!
- What effects do climatic conditions have on buildings and their inhabitants?
9.4. Chapter 4.:

Write down the three spatial dimensions of the climatic events!

What is the definition of topoclimatology?

How does wind effect the incoming building energies?

9.5. Chapter 5.:

What is the DROID?

What is the aim of the DROID measuring system?

What are the parts of the DROID?