CZECH TECHNICAL UNIVERSITY IN PRAGUE
Faculty of Civil Engineering

Department of Indoor Environmental and Building Services Engineering

Comparison of Systems for Heating, Cooling and Ventilation in Residential Building in Two Climatic Zones

Porovnání systémů vytápění, chlazení a větrání v bytovém domě ve dvou klimatických oblastech

MASTER THESIS

2018/2019 Bc. David Šnajdr

Advisor of Master Thesis: doc. Ing. Michal Kabrhel, Ph.D.

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I. OSOBNÍ A STUDIJNÍ ÚDAJE

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Studijní program: Budovy a prostředí

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Studie na téma Systémy pro úpravu vnitřního prostředí v subtropickém klimatu

Seznam doporučené literatury:
Daniels, Klaus: Technika budov - Příručka pro architekty a projektanty. Jaga 2003. ISBN 80-88905-60-5.
Kabele, Karel : TECHNICKÁ ZAŘÍZENÍ BUDOV. Vytápění. ČVUT. Praha 2014. ISBN 978-80-01-05203-7
ČSN EN 12831-1.
Papež, Karel: Energetické a ekologické systémy budov 2 : Vzduchotechnika, chlazení, elektroinstalace a osvětlení. ČVUT, Praha 2007.
Gebauer, Gunter: Vzduchotechnika. Era 2007. ISBN 8073660918

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Podpis vedoucího práce Podpis vedoucího katedry

III. PŘEVZETÍ ZADÁNÍ

Beru na vědomí, že jsem povinen vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je nutné uvést v diplomové práci a při citování postupovat v souladu s metodickou příručkou ČVUT „Jak psát vysokoškolské závěrečné práce" a metodickým pokynem ČVUT „O dodržování etických principů při přípravě vysokoškolských závěrečných prací".

21.2.2019
Datum převzetí zadání Podpis studenta(ky)

I declare, that the Master thesis was made on my own, based on consultations with my advisor doc. Ing. Michal Kabrhel, Ph.D.

. . . .

Bc. David Šnajdr

I give thanks to my advisor doc. Ing. Michal Kabrhel, Ph.D. for expert guidance, advices and helpfulness in consultations. I would also like to thank all colleagues from Research Center for Energy Technology and Strategy at National Cheng Kung University in Tainan, who were very helpful and gave me advices on designing a variant for Taiwan.

Abstract

The Master thesis deals with the design of selected technical building equipment for an apartment building, which is designed for two different climatic zones. It is the Czech Republic, which climate is mostly mild and continental and Taiwan, which lies in the subtropical climate. The design of individual professions is based on local standards and requirements that differ in both climatic areas.

Simplified project documentation for heating, cooling and ventilation was created. The documentation includes basic calculations, drawings and technical reports.

In the text part, the individual systems for indoor environment modification in a subtropical climate are described as a study using a simulation model. This is compared to the Czech Standards.

Keywords: heating, cooling, ventilation, comparison of two climatic zones

Abstrakt

Diplomová práce se zabývá návrhem vybraných technických zařízení budov pro bytový dům, který je navrhován pro dvě odlišné klimatické oblasti. Jedná se o Českou republiku, která leží v mírném a kontinentálním klimatu a Taiwan, který leží v subtropickém klimatu. Návrh jednotlivých profesí vychází z místních standardů a požadavků, které se v obou klimatických oblastech liší.

Byla vypracována zjednodušená projektová dokumentace pro vytápění, chlazení a větrání. Dokumentace obsahuje základní výpočty, výkresy a technické zprávy.

V textové části jsou jako studie popsány jednotlivé systémy pro úpravu vnitřního prostředí v subtropickém klimatu s využitím simulačního modelu. Toto je srovnáno s českými standardy.

Klíčová slova: vytápění, chlazení, větrání, porovnání dvou klimatických oblastí

Table of content

1. Introduction and workflow

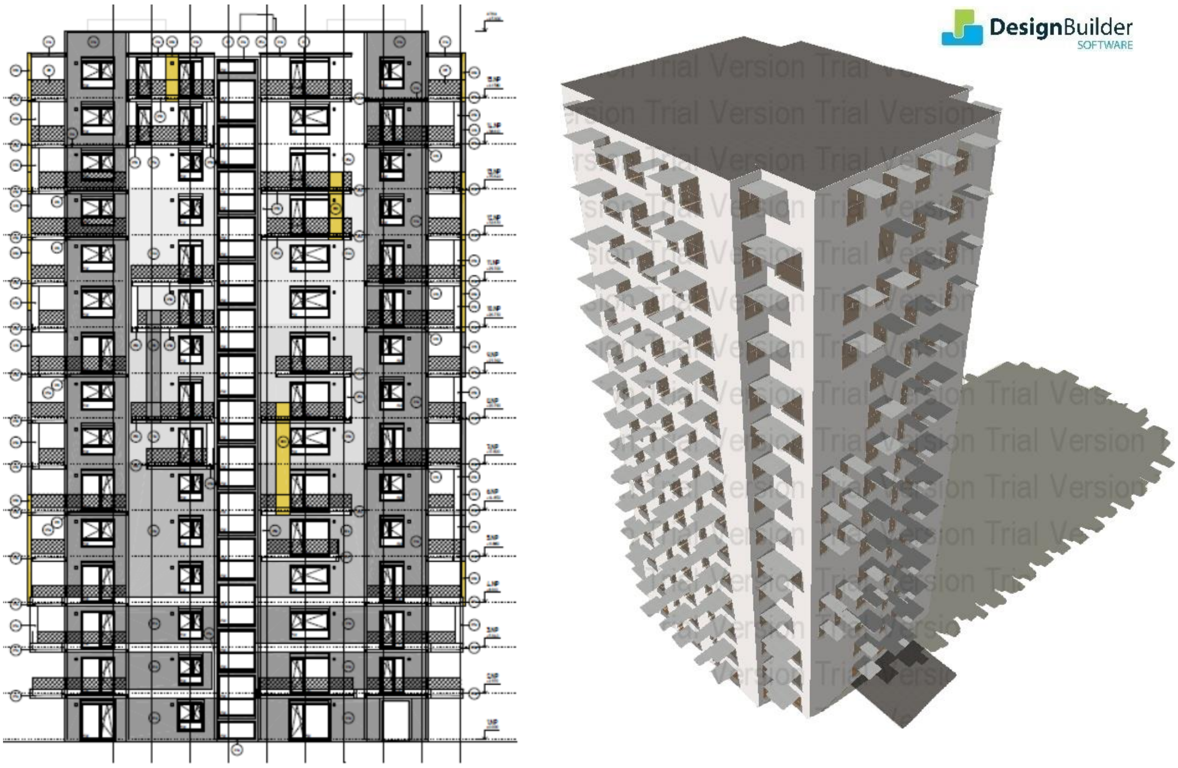
In the Czech Republic we are accustomed to certain system standards in the households which regulate the indoor environment. The whole republic is located in a mild and continental climate, resulting in the need to heat, cool, ventilate, etc. However, it is interesting to see how these needs differ in other climate areas. I had an opportunity to compare this during an exchange study program in Taiwan, where I worked on my thesis.

This text part deals with a different approach to the design of technical systems for the treatment of the indoor environment in the subtropical climate, where Taiwan is. For this purpose, the work is solved as a comparison with the solution in the Czech Republic (mild and continental climate). The basic differences between the used systems and their input data are described. Based on this, the basic project documentation for the selected apartment building in both climatic areas is proposed. A simulation model was created as a comparison tool. Its outputs are used for energy and other calculations. Below are some examples from Taiwan environment, including photos.

The following data in this text part are partially described as general or directly related to the chosen residential building NeoRiviera and its simulation model.

2. Simulation model as a comparison tool

For demonstration purposes, comparison, energy and other purposes, I created a model of the solved NeoRiviera residential building in DesignBuilder software. This model corresponds to the proposed design documentation for two solved climatic areas. It is the same building that is located in Prague, Czech Republic and Tainan, Taiwan. Depending on the parameters in this work and on the properties of the structures, technical equipment, etc., the building was adapted to local standards. Therefore, the data will be different and can be further processed.



Pic. 1: NeoRiviera eastern view (on the left) + visualization (on the right)

The subject of the project is a new residential complex called NeoRiviera. The building has 15 above-ground floors and 1 underground floor. In the underground floors there is a cellar, garbage depot and technical facilities. There are 70 housing units on the above-ground floors.

3. Climate and geographic conditions

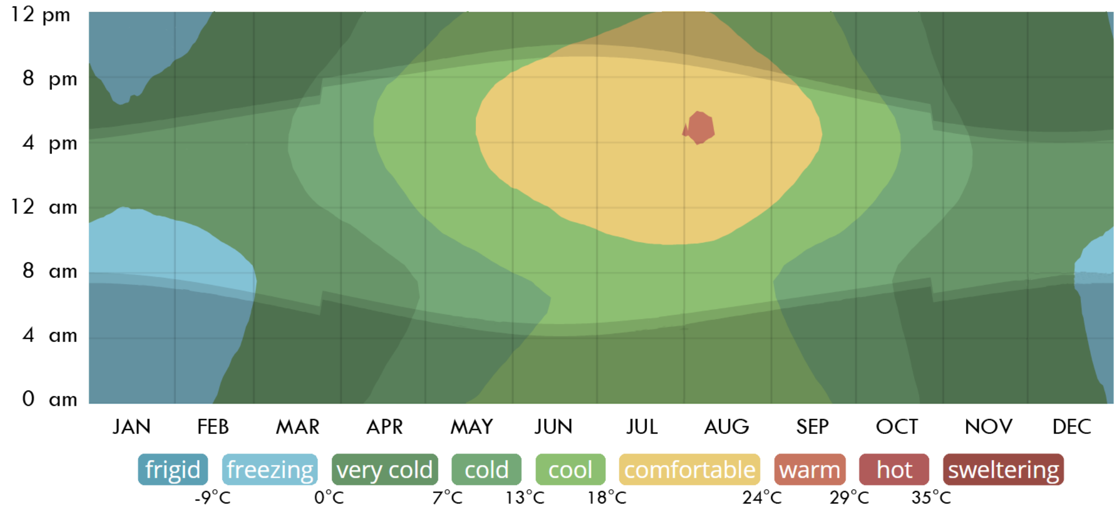
Climatic and geographical conditions directly affect the overall effective design of technical systems and their energy consumption. Therefore, both climatic areas - the Czech Republic and Taiwan - are described below.

3.1 General information – Czechia

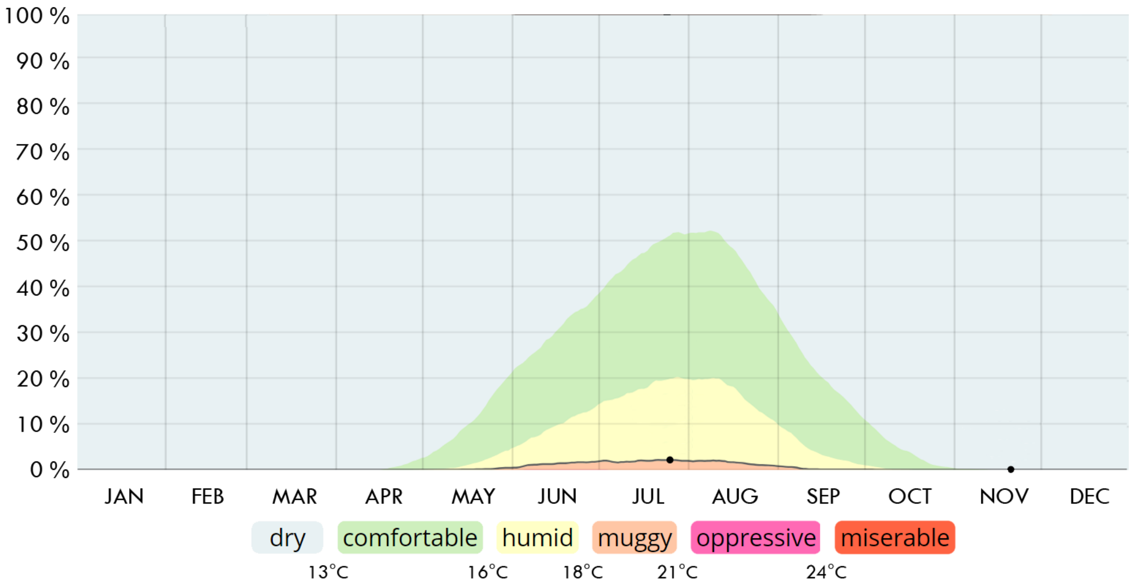
Czech Republic is located in the central Europe at 50° north latitude and 16° east longitude. It borders with Germany, Poland, Slovakia and Austria. The area of Czech is 78,866 km^2 and the population is 10,58 mil. people. The climate in Czech Republic is mostly mild and continental. The precipitation is mostly steady with heavier rains in the summer season. Most of the territory in Czech is classified as humid continental climate.

Pic. 2: Location of Czech Republic on the Globe (1)

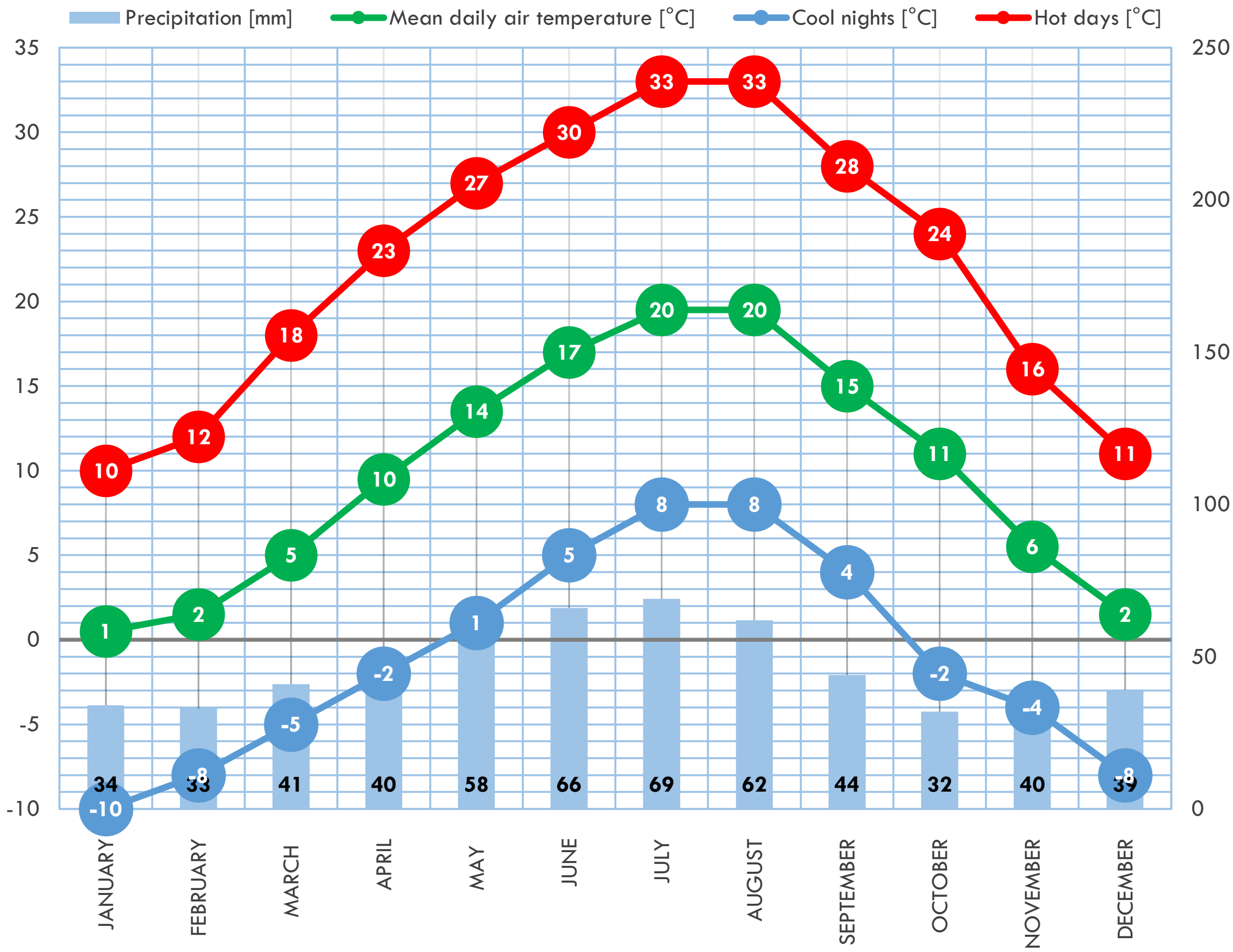
The placement of Czech Republic in the centre of Europe has a significant influence to the local climate conditions. It is characteristic with the temperature fluctuation. There are considerable air temperature fluctuations in winter and summer. But there are also great differences between the day and night air temperature. The hottest month is June and July. The coolest months are December, January and February.



Pic. 3: Average hourly temperature in Prague (2)



Pic. 4: Humidity comfort levels in Prague (2)



Pic. 5: Climate data Prague, Czech Republic (3)

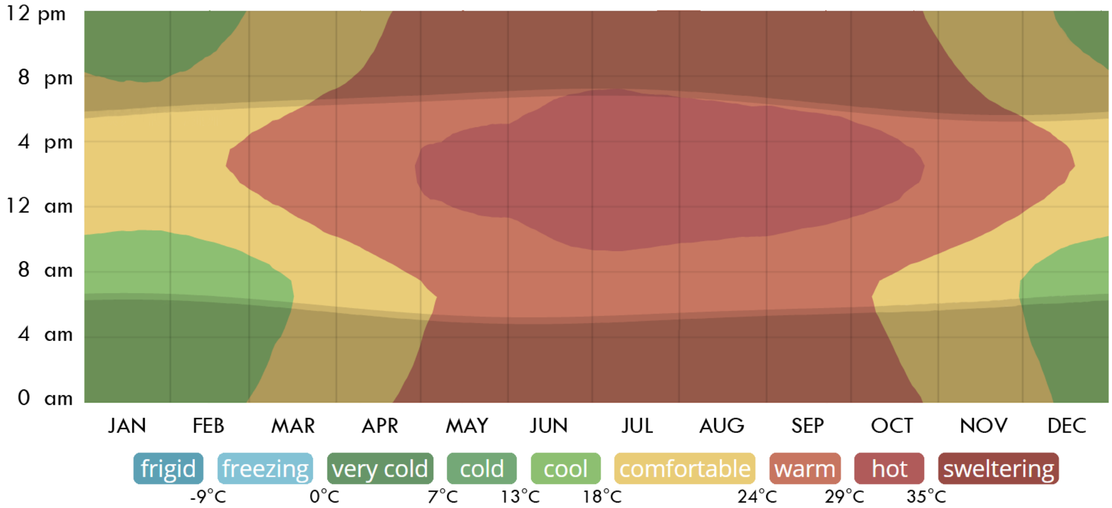
Central Europe has four seasons. Spring, summer, autumn and winter. Spring starts on the 1st march and it is characterized by temperatures around 10 °C. Summer is the hottest season, temperature could reach 35°C according to the locality. The autumn is known for lower temperatures, it also brings rain. Winter temperature can get under -20 °C, the lowest temperature in Czech was measured -40 °C.

3.2 General information – Taiwan (ROC)

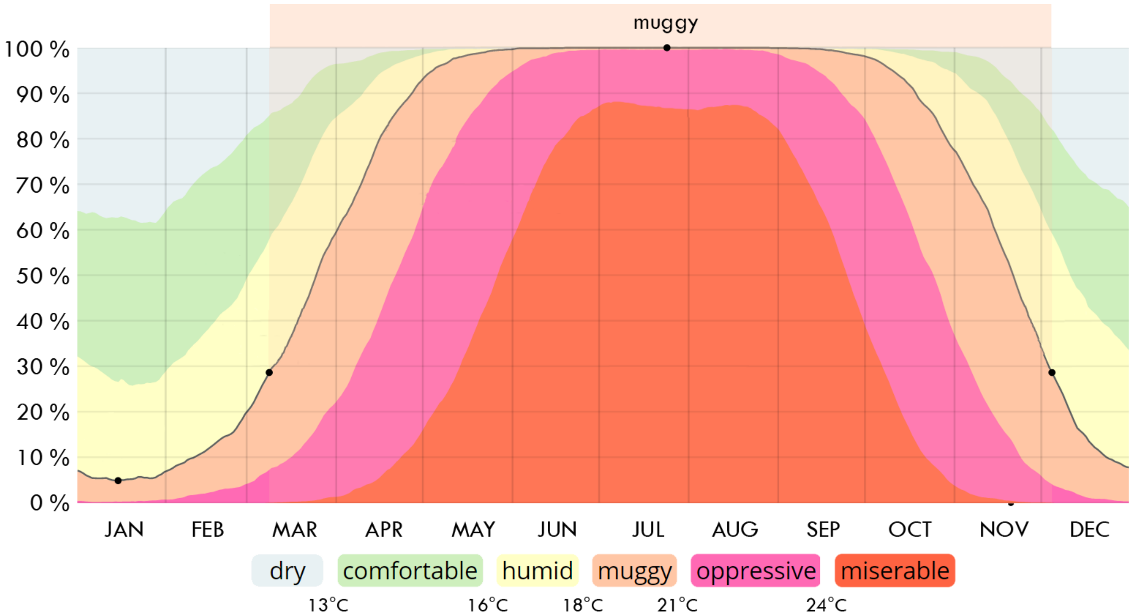
Republic of China (ROC), known as Taiwan, is located in the east Asia at 24° north latitude and 121° east longitude. The highest point is 3 952 m a. s. l. Taiwan is being surrounded by the South China Sea, Philippine Sea and the East China Sea. The island was created by the tectonic shifts and volcanic activity. The capital city is Taipei. The area of Taiwan is 36,197 km^2 and the population is 23,57 mil. people. The Taiwanese climate is classified mainly as humid subtropical. The sky is cloudy during most of the time in the year. There is a rainy/typhoon season from June to October.

Pic. 6: Location of Taiwan on the Globe (1)

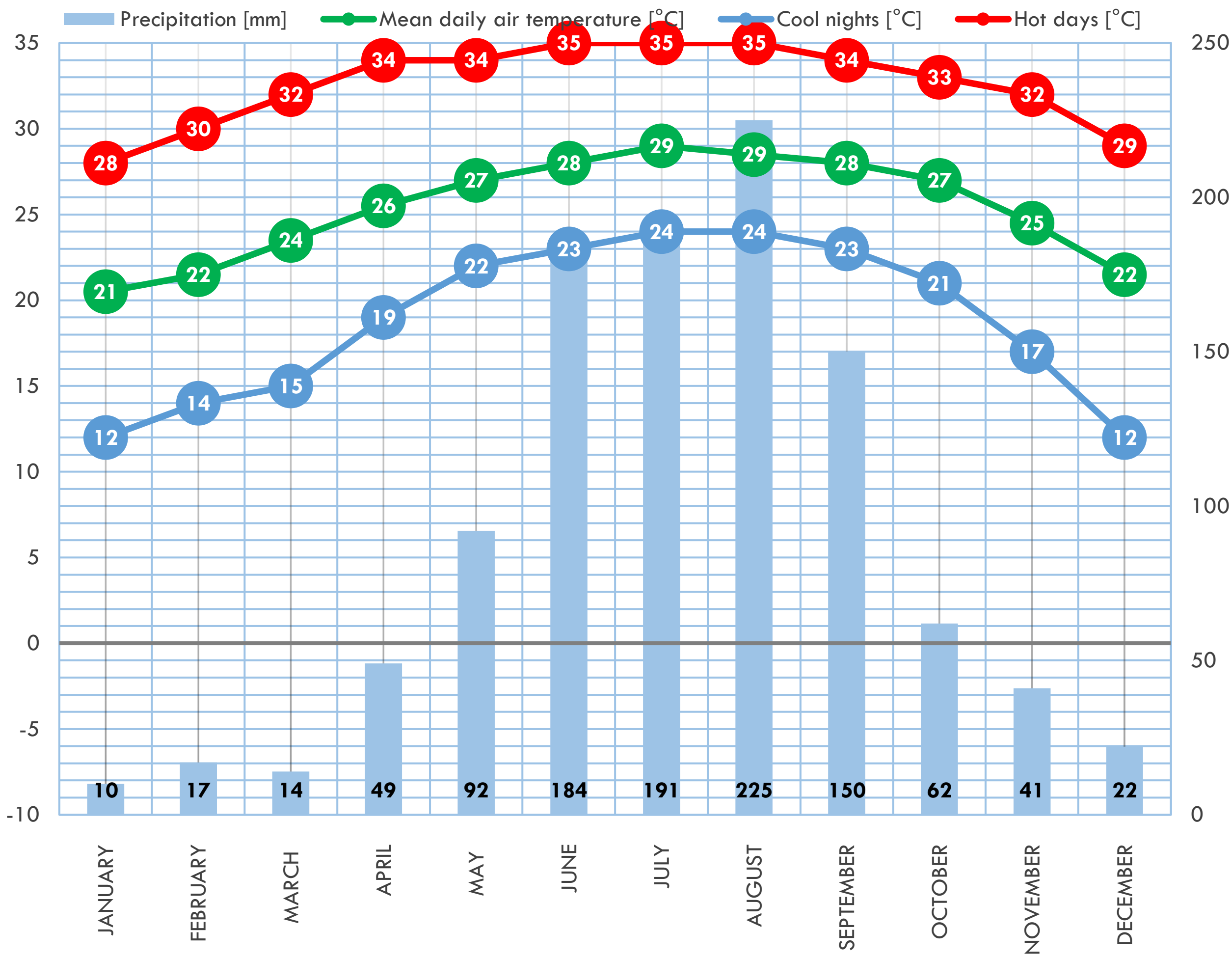
Location of Taiwan and its placement in the ocean determines local climate. The winters days and nights are colder than summer ones. The mean air temperature fluctuation between summer and winter is around 7 °C. In Czech Republic the difference is 25 °C, which is more than 3 times more. It is raining significantly less in the winter. The humid summer time is coming in April. The average month precipitation is way higher due to upcoming summer monsoon in June. In this time, intensive raining can cause flooding. Summer storms above the sea can also initiate creation of a typhoon.



Pic. 7: Average hourly temperature in Tainan (2)



Pic. 8: Humidity comfort levels in Tainan (2)

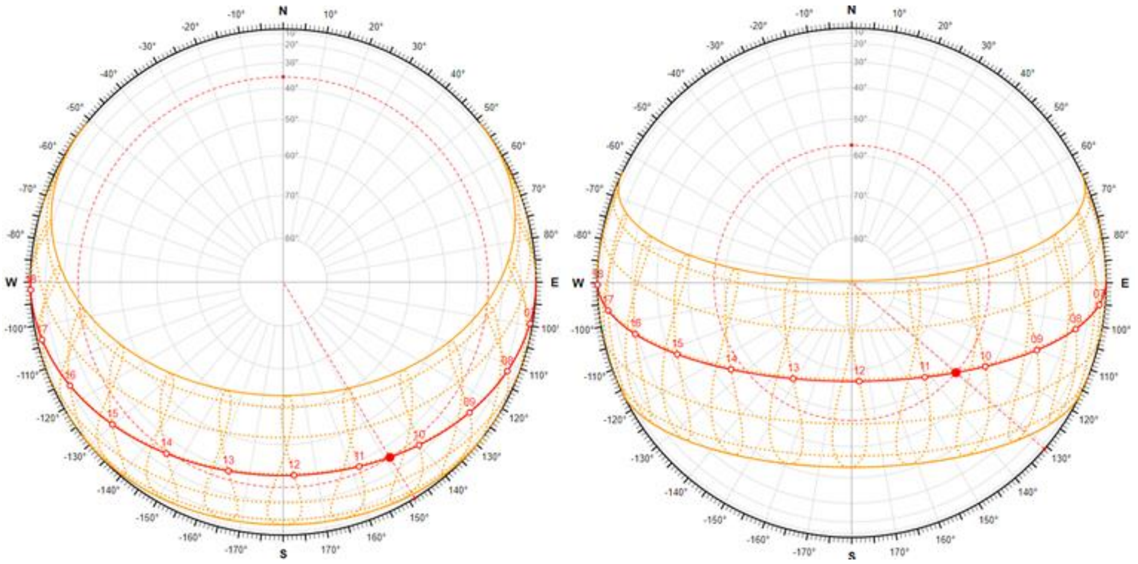


Pic. 9: Climate data Tainan, Taiwan (3)

In comparison with Czech, the total amount of precipitation during the year is two times higher. Also, most of the precipitation rains during the summer season. In Czech it is raining more stable. On the other hand, the air temperature fluctuation is more stable in Taiwan. The most noticeable difference is the absolute humidity of the air. The warmer air can hold larger amount of water vapor.

3.3 Sun path specification – Prague, Czechia and Tainan, Taiwan

Prague is located at the 50° north latitude. Taiwan lies at the 24°north latitude. So, the sunshine in Prague comes more from the horizon, while the sunshine at Tainan comes more from above. This position also influences the summer and winter day time. During the summer solstice, the Sun shines on Tainan for 13,5 hours. In Prague the Sun shines for 16,4 hours. During the winter solstice, the Sun shines on Tainan for 10,8 hours. In Prague, the Sun shines only for 8 hours. The amount of incident light greatly affects the local climate.



Pic. 10: Sun diagram – Prague, Czech Republic (left side) and Tainan, Taiwan (right side) (4)

4. Construction parameters

4.1 Thermal-technical properties of the main external constructions

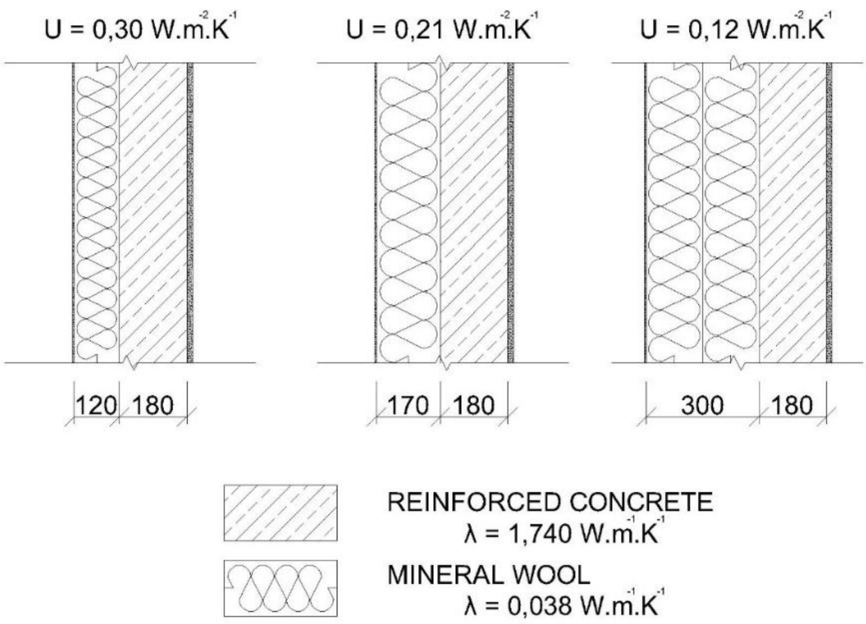
Thermal resistance of external constructions is an important parameter in energy efficient building design. Therefore, the Czech Republic has set standards to be followed.

Used U-values according to Czech standards:

Heat transfer coefficient			
Construction	Required values $U_{N,20}$	Required values for nZEB 0,7	Recommended values for passive building 0,4
	[W/(m²·K)]		
Thermal bonds	0,02	0,014	0,008
External wall	0,30	0,21	0,12
Flat roof	0,24	0,17	0,10
Ceiling	0,30	0,21	0,12
Floor	0,45	0,32	0,18
Windows	1,50	1,05	0,60
Roof windows	1,40	0,98	0,60
Door	1,70	1,19	0,85

Table 1: Heat transfer coefficients of exterior constructions in the Czech Republic (5)

An example of the required thermal insulation thickness to meet the requirements:



Pic. 11: Thermal insulation thickness for different U-values

In Taiwan there are simplified requirements of U-values for external constructions. Thermal insulation is basically being used only for roof to prevent building of undesirable overheating from solar radiation. There is no such a thing as a classification of buildings based on energy consumption and its context as you can see in Czechia.

The following table summarizes the heat transfer coefficient values of the main structures that are calculated in the simulation model. The values for Taiwan are representative values that are required for buildings there.

Heat transfer coefficient U [W/(m²·K)]		
Construction	Prague, Czech Republic	Tainan, Taiwan
External wall	0,23	2,80
Flat roof	0,16	0,80
External window	1,10	2,50

Table 2: Table of main used U-values in model, Prague (CZE) vs. Tainan (TW)

As far as windows are concerned, for buildings in the Czech Republic are parameters of openings important data for effective design. High-performance windows (double or triple-paned) and doors are being used. Therefore solar gain is managed to exploit the sun's energy for heating purposes in the heating season and to minimize overheating during the cooling season.

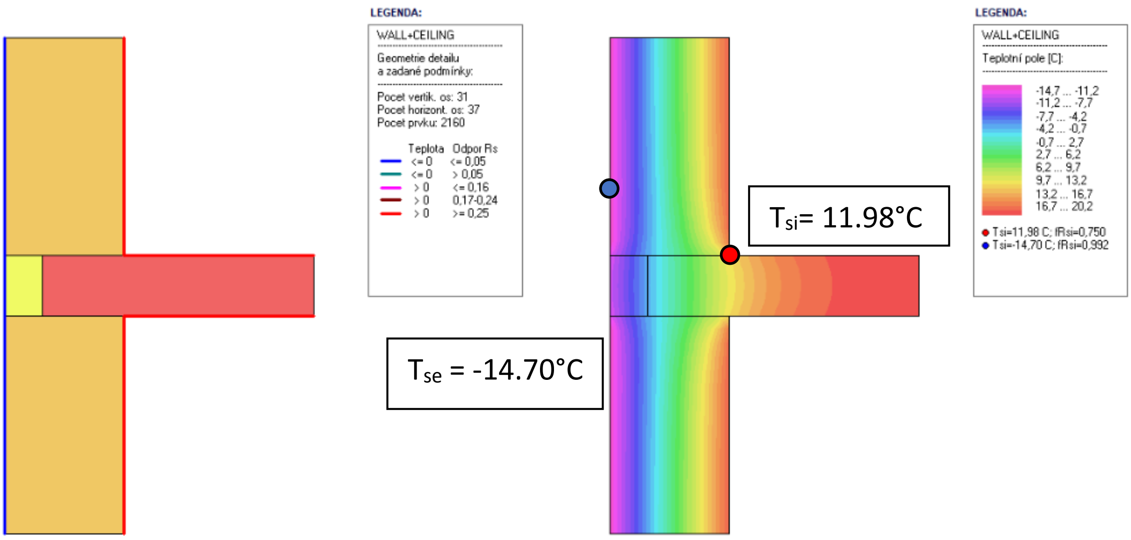
In contrast, windows and doors with lower thermal and air tightness requirements are used in Taiwan. Windows are typically single-glazed.

4.2 Thermal bridges as an undesirable phenomenon

Escaping heat follows the path of least resistance. Thermal bridging generally occurs when there is a break in, or penetration of the building envelope (e.g. insulation).

Example: Situation 1)

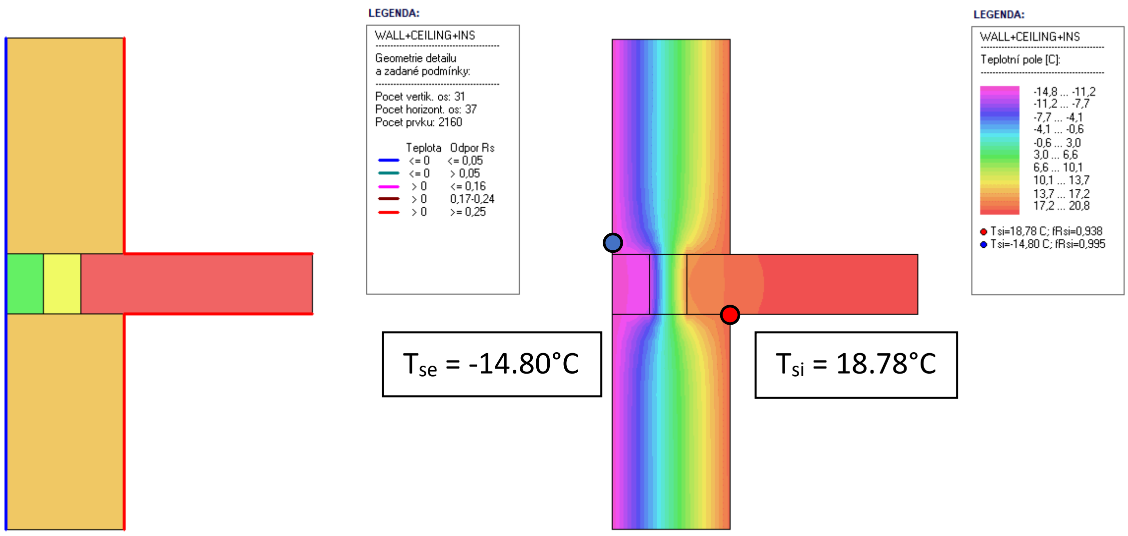
- External wall: Bricks Porotherm 44 Profi
- Horizontal construction: Reinforced concrete



Pic. 12: Thermal bridges, example 1 (6)

Example: Situation 2)

- External wall: Bricks Porotherm 44 Profi
- Horizontal construction: Reinforced concrete + **insulation of extruded polystyrene**



Pic. 13: Thermal bridges, example 2 (6)

The example shows the impact of the thermal bridge on the internal surface temperature. In situation 2, when the structure is continuously filled with thermal insulation, the internal surface temperature (T_{si}) is almost 5°C higher than in situation 1.

In Taiwan, thermal bridges are not studied. It is evident that this issue is a more serious topic for heating for extreme temperature differences between indoor and outdoor environments.

4.3 Airtightness

The envelope of representative Czech building must be extremely airtight, preventing infiltration of outside air and loss of conditioned air.

- the total air permeability of buildings is evaluated by the air exchange at a pressure difference of 50 Pa, it is given as a value n_{50}
- $n_{50} \leq 1{,}5\ h^{-1}$ for a low-energy house
- $n_{50} \leq 0{,}6\ h^{-1}$ for a passive house
- method of determination - blower door test

In Taiwan there is no requirement for airtightness by law. It depends on the type of indoor ventilation but infiltration of structures is often used as a natural ventilation combined with unequal-pressure ventilation. Natural ventilation is almost always used in residential buildings. However, forced ventilation can be found, for example, in office buildings. I had the opportunity to look at some of the project documentation, and the air from the exterior is typically fed into the rooms and mixed with the indoor air. Exhaust air is solved by leaking windows and doors because they are not really airtight. If there are no windows in the space it is common to use air handling unit with cold recovery, typically with efficiency slightly over 60%.

In Tainan's simulation model, due to infiltration is expected eight times higher air exchange than in the building in Prague.

Pic. 14: An example of none airtightness construction, NCKU campus, Tainan, Taiwan

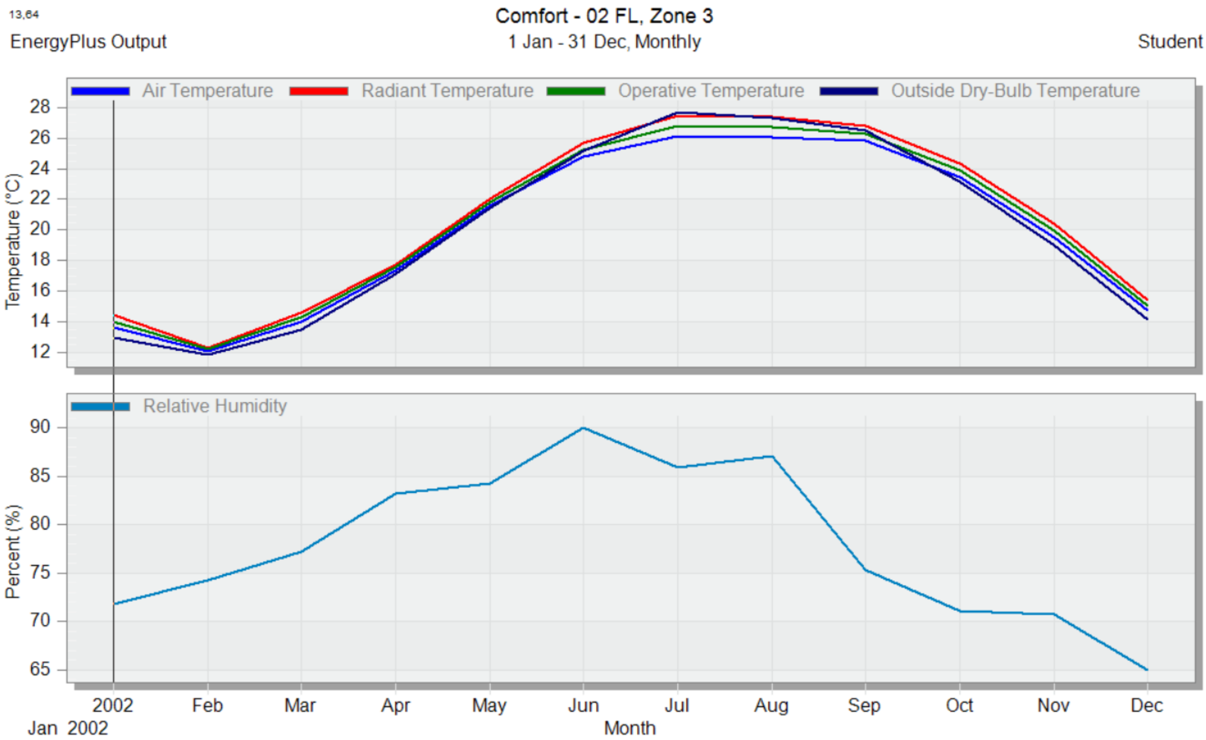
This photo is from NCKU campus. The seminar room is fully air-conditioned, although we can see that exterior door are not airtight.

5. Main technical equipment of buildings which are consuming energy

5.1 Heating system

Buildings in Prague is necessary to provide with heating system. Design temperature for Prague is - 12°C.

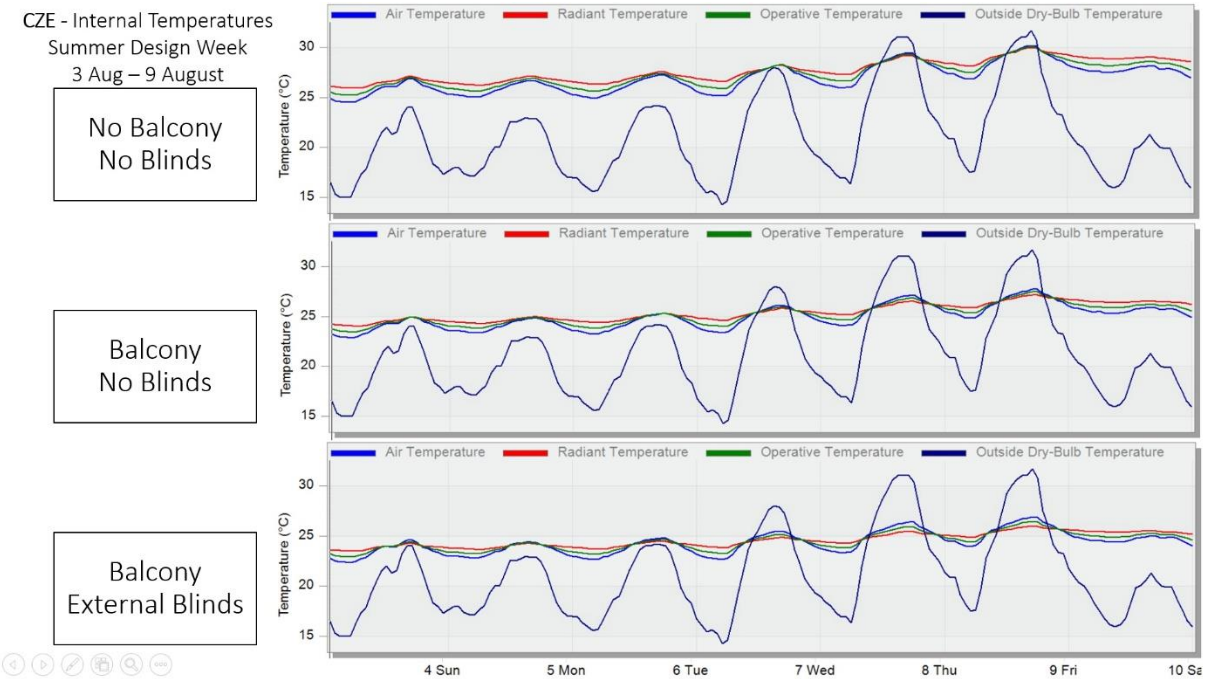
In Tainan we would calculate with design temperature around 10°C. The temperature character is shown in the graph above *(Pic.9)*. Although the indoor air temperature in dwelling units in winter reaches up to 12°C according to simulation, the heat sources are not installed in the apartments. From my experience of staying in this period at the dormitory in Taiwan, it was occasionally slightly colder, but I didn't mind it and I didn't miss a heating system there. People basically no need to heat the buildings up. In the following graph we can see the model situation in dwelling units.



Pic. 15: Indoor temperatures and relative humidity in NeoRiviera, Tainan, Taiwan (7)

5.2 Cooling systems

For residential buildings placed in Prague is not necessarily common to install a cooling system. Cooling load could be reduced by effective shading, site orientation and so on. Let's have a look at simulation showing the influence of those thing according to internal temperature in flat. Indoor temperatures around 26°C with effective shading seems to be very acceptable. While indoor temperature without shielding through balconies and blinds reaches 30°C.



Pic. 16: Simulation of internal temperature according to shading, Prague (CZE) (7)

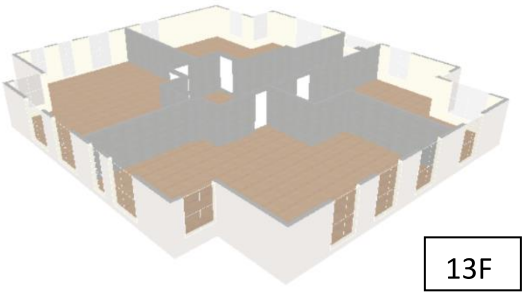
Almost every residential building in Tainan is equipped with cooling system. Thermal load is here way higher and AC unit are also reducing air humidity. Typical installation is multi-split but very frequently is possible to see just single split and furthermore just single air conditioning unit.

Pic. 17: Single air conditioning unit from interior (on the left), exterior (on the right). NCKU dormitory – student room, Tainan, Taiwan

Pic. 18: AC outdoor units. FX Hotel in Tainan, Taiwan

5.2.1 Comparison of the cooling load of the residential building

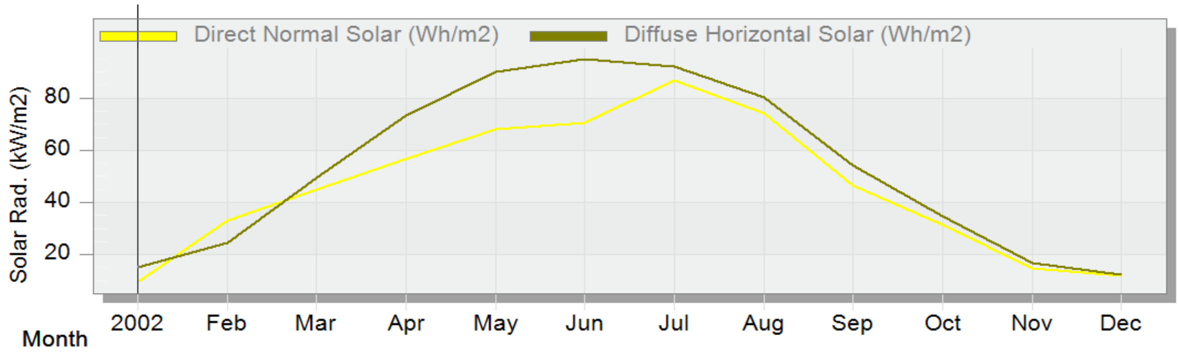
In both simulation models (Prague and Tainan) was selected the same dwelling unit (n. 14131) and the same floor (13F) to compare cooling load.



13F

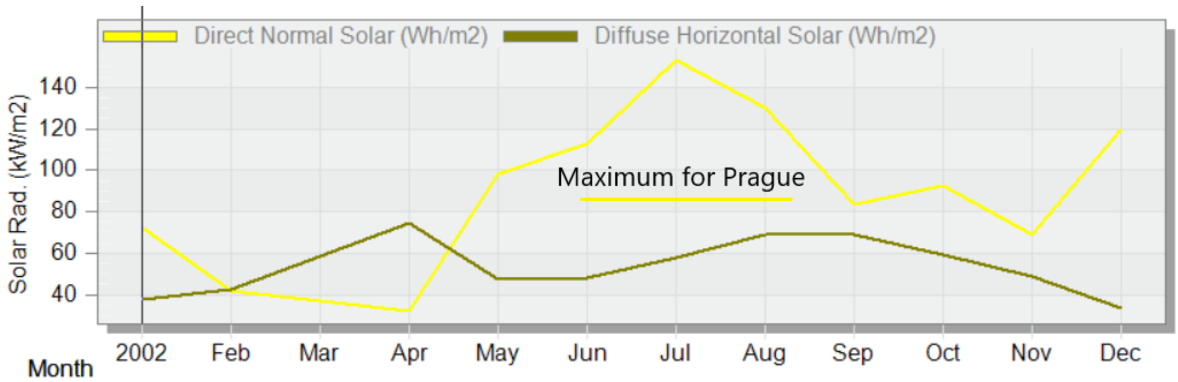
Firstly, it is possible to notice how the annual solar radiation differs for both selected location:

Prague



Pic. 19: Annual solar radiation, Prague, Czechia (7)

Tainan



Pic. 20: Annual solar radiation, Tainan, Taiwan (7)

There is a big difference in solar radiation between these two sites. The amount of solar energy hitting the surface for the summer design week in Tainan is almost twice as high as in Prague. On the other hand, from sun path diagram *(Pic.10)* is visible, that the sunshine in Prague comes more from the horizon, while the sunshine at Tainan comes more from above. It means that window surface in Tainan is less exposed to sun, especially while taking balconies into consideration.

Further, the table provides characteristics related to the design of the cooling device. The cooling load for an apartment in Tainan is more than 5 times higher than for an apartment in Prague. The main different input data are the above-described parameters of exterior structures and climatic data including solar radiation.

SELECTED FLAT						
Flat Number	Floor Area [m²]	Volume of Area [m³]	Parameter	Parameter Unit	Location	
					Prague, Czechia	**Tainan, Taiwan**
14131	65,9	194,6	Design Capacity	[kW]	**2,26**	**11,86**
			Total Cooling Load	[kW]	**1,96**	**10,31**
			Prevailing Air Temperature	[°C]	**26**	**25**
			Max. Operative Temperature in Day	[°C]	**29,2**	**26,6**
			Design Cooling Load Per Floor Area	[W/m²]	**35,6**	**180,0**

Table 3: Cooling design data for selected dwelling unit (7)

SELECTED FLOOR						
Floor Number	Floor Area [m²]	Volume of Area [m³]	Parameter	Parameter Unit	Location	
					Prague, Czechia	**Tainan, Taiwan**
13F	371,9	1098,9	Design Capacity	[kW]	**12,01**	**63,83**
			Total Cooling Load	[kW]	**10,44**	**55,5**
			Prevailing Air Temperature	[°C]	**26**	**25**
			Max. Operative Temperature in Day	[°C]	**28,4**	**26,7**
			Design Cooling Load Per Floor Area	[W/m²]	**29,7**	**140,9**

Table 4: Cooling design data for selected floor (7)

5.3 Ventilation systems

In Czech climatic conditions it is very convenient and sometimes even necessary to use so-called forced ventilation with effective recuperation. Even in residential buildings. It is a mechanically supplied and exhausted air into a space that transfer heat/cold to each other through an exchanger. Typically with an efficiency of around 80%.

We can't find above-mentioned type on mechanical ventilation with recuperation in residential buildings in Taiwan. One of the main reasons are the local climatic conditions. The recovery is most prosperous with higher temperature differences between the transfer air. While in the Czech Republic the temperature difference between indoor air and exterior may be around 35°C in winter, the biggest difference for Taiwan is in summer and it is commonly around 12°C. Cold recovery would not be as effective in this case. But that does not mean that it will be meaningless in the future.

The overall airtightness of the structures would also need to be solved. As mentioned above, Taiwan has no requirements according to airtightness. Around the windows and doors there is sometimes parallel gap with size of several millimeters. This is not a failure to follow the assembly procedure.

Criteira of indoor air quality for occupied spaces in Taiwan:

室內空氣品質標準 Criteria of indoor air quality

中華民國 101 年 11 月 23 日行政院環境保護署環署空字第 1010106229 號令訂定發布全文共五條

第 一 條　本標準依室內空氣品質管理法（以下簡稱本法）第七條第二項規定訂定之。

第 二 條　各項室內空氣污染物之室內空氣品質標準規定如下：

項目	標準值		單位
二氧化碳（CO_2）	8 hrs 八小時值	1000 一０００	ppm（體積濃度百萬分之一）
一氧化碳（CO）	8 hrs 八小時值	9 九	ppm（體積濃度百萬分之一）
甲醛（HCHO）	1 hr 一小時值	0.08 ０・０八	ppm（體積濃度百萬分之一）
總揮發性有機化合物(TVOC，包含：十二種揮發性有機物之總和)	1 hr 一小時值	0.56 ０・五六	ppm（體積濃度百萬分之一）
細菌(Bacteria)	最高值	1500 一五００	CFU/m^3（菌落數/立方公尺）
真菌(Fungi)	最高值	一０００。1000 但真菌濃度室內外比值小於等於一・三者，不在此限。	CFU/m^3（菌落數/立方公尺）
粒徑小於等於十微米（μm）之懸浮微粒（PM_{10}）	24 hrs 二十四小時值	75 七五	$\mu g/m^3$（微克/立方公尺）
粒徑小於等於二・五微米（μm）之懸浮微粒（$PM_{2.5}$）	24 hrs 二十四小時值	35 三五	$\mu g/m^3$（微克/立方公尺）
臭氧（O_3）	8 hrs 八小時值	0.06 ０・０六	ppm（體積濃度百萬分之一）

第 三 條　本標準所稱各標準值、成分之意義如下：

一、一小時值：指一小時內各測值之算術平均值或一小時累計採樣之測值。

Pic. 21: Criteria of indoor air quality for occupies spaces in Taiwan (8)

Although the air in Taiwan is for most of the time of year really humid, there is no direct requirement relating to the humidity. Air humidity reduction is achieved by the use of air conditioning units where humidity is being removed as a condensate.

5.4 Preparation of hot water

In the residential sector, hot water preparation is most often central. In the technical room there is a hot water tank from which hot water is transported to individual housing units. In the simulation model for Prague, the central supply system of heat is the heat source for the tank.

In Taiwan, water is typically heated by instantaneous water heaters, where the source of heat is natural gas or electricity. The fundamental difference is that the water is before heating stored in tanks that are freely placed on the roof. In these climatic conditions, the water itself has a higher temperature, even though the water tanks and piping are usually insulated. Water in the pipeline network is not drinkable, so it can be stored like this. This system is often supplemented with solar water heating panels.

The following photo shows rooftop steel water tanks. Some of them are complemented by solar panels, depending on the individual resident's solution.

Pic. 22: Rooftop water storage – steel tanks, Tainan, Taiwan

5.5 Sanitary installations

5.5.1 Drinking water distribution

There is drinking water in all piping networks in the Czech Republic. It is heated for the use of hot water or used for all other purposes including drinking. Water must therefore meet the given hygienic criteria.

In Taiwan, tap water is being cleaned but it is not drinkable. Water for other purposes is stored on the roof *(Pic.22)* for the local needs of each building and also directly lead to utilities. Water for drinking purposes is dealt with individually according to the requirements of individual apartments. Many new houses are actually equipped with a water filtration system, where water filters that can be hooked up to each kitchen faucet are used. The other option is to use water form refill station which in necessary to transport to each dwelling unit, typically in blue plastic barrels.

It is interesting to see how the water distribution fittings can be seen. An example is the following photo. The reason why these fittings and pipes are just freely uncovered outside is that the outside temperature is never negative, so there is no freezing in the pipeline.

Pic. 23: Water meters (on the left) and water meter station (on the right), Kuala Lumpur, Malaysia

5.5.2 Sewerage

Especially interesting is the different tracing of sewerage systems that we can meet in the subtropical climate. There is no danger of freezing, just as in a mild climate, so pipes and fittings can be led freely outside without insulation, as can be seen in this photo.

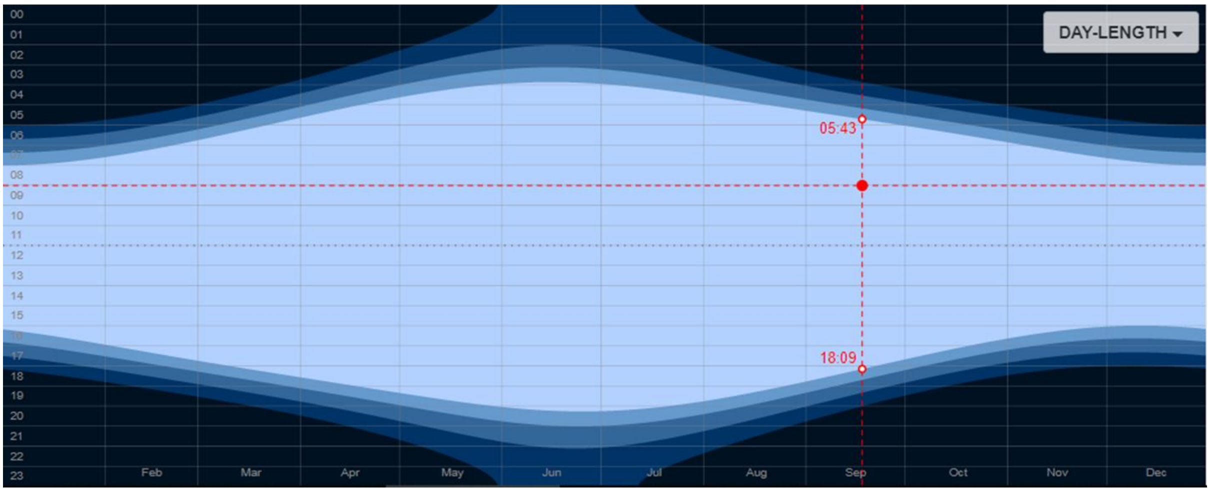
Pic. 24: Sewerage along the facade, residential building, Singapore

5.6 Lighting

Consumption of energy of lightning systems depends on the source of the light. Classical old bulb consumes much more energy than LED bulb, which has higher efficiency. In principle, there is no significant difference in the light sources used. Energy consumption for lighting will vary slightly, especially in terms of season. During the summer solstice, the Sun shines on Tainan for 13,5 hours. In Prague the Sun shines for 16,4 hours. During the winter solstice, the Sun shines on Tainan for 10,8 hours. In Prague, the Sun shines only for 8 hours.

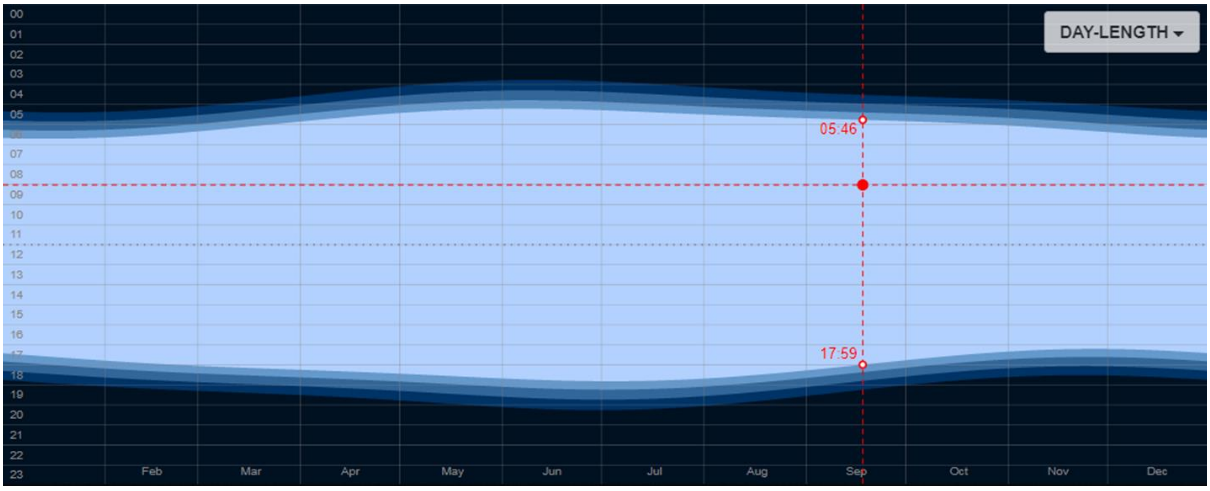
The following diagrams show how the amount of daylight varies during the year:

Prague



Pic. 25: Diagram of day length – Prague, Czech Republic (3)

Tainan



Pic. 26: Diagram of day length – Tainan, Taiwan (3)

While staying in Taiwan I could easily notice the difference. During the year, the length of the day does not change as much as in the Czech Republic during the winter and summer. The sun sets here quite early all year. However, this is not the only reason affecting the use of artificial lighting. A different way of life, length of working hours and so on also play a role. These differences can be noticed in Taiwan, but they are not the subject of this work.

5.7 Summary of technical equipment used in the simulation model

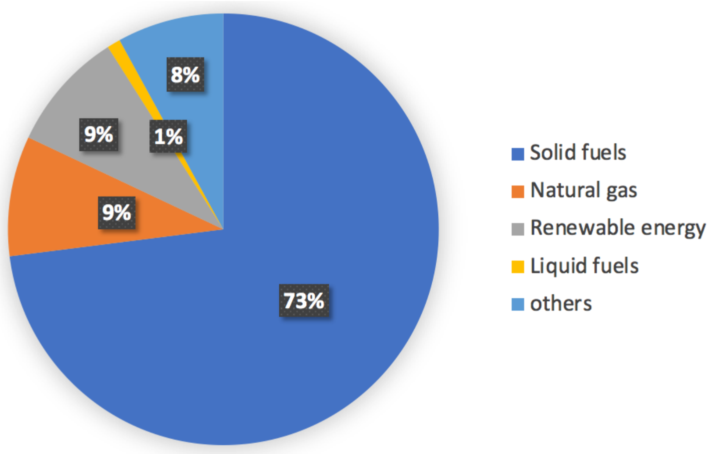
Technical equipment	Prague (CZE)	Tainan (TW)
Heating	✓	
Cooling	✓	✓
Mechanical air ventilation	✓	
DHW	✓	✓
Lightning	✓	✓

Table 5: Table of technical equipment summary for simulation model

6. Energy analysis for NeoRiviera building

For most households in the Czech Republic, heating energy consumption is dominant, followed by hot water heating. According to the Czech Statistical Office, this energy is almost from 70% imported for apartment buildings. The source of such energy is usually not a single fuel type. It differs according to the location where the central heat supply is being used.

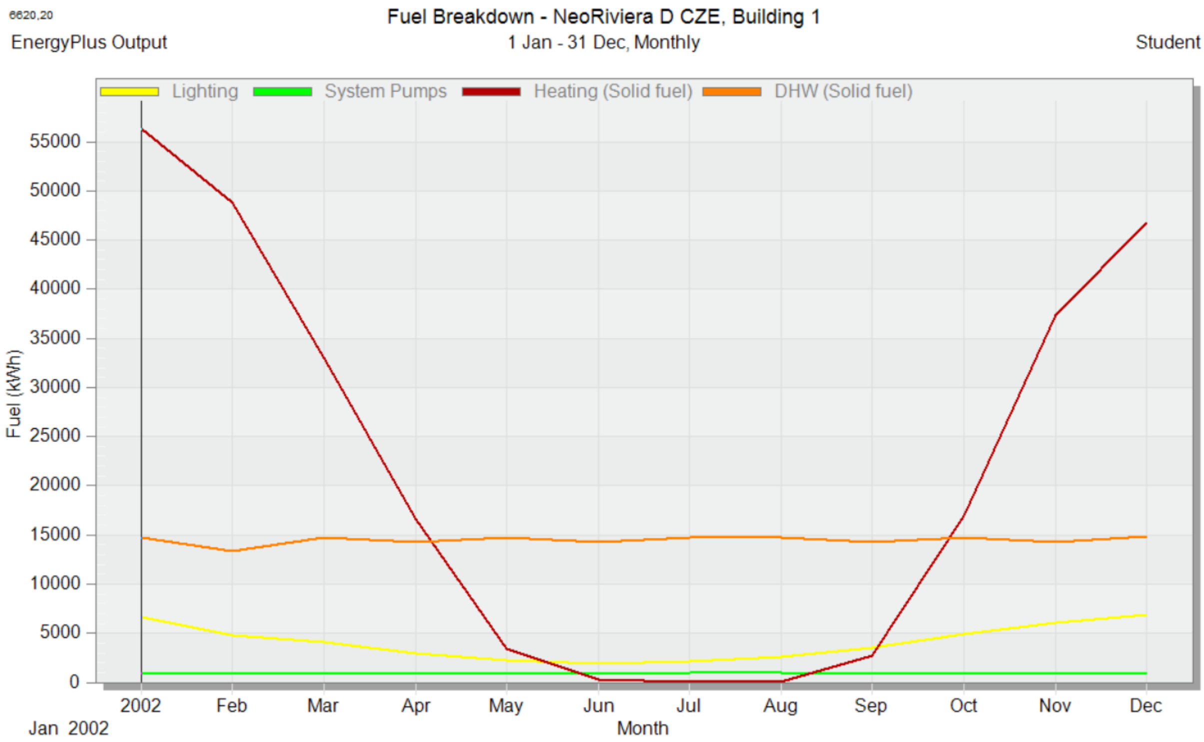
In DesingBuilder is such a fuel breakdown not easy. Therefore, this energy is represented by solid fuels, which, after all, make it more than 70% as we can see in the following diagram for Prague.



Pic. 27: Types of fuels for production of imported energy (9)

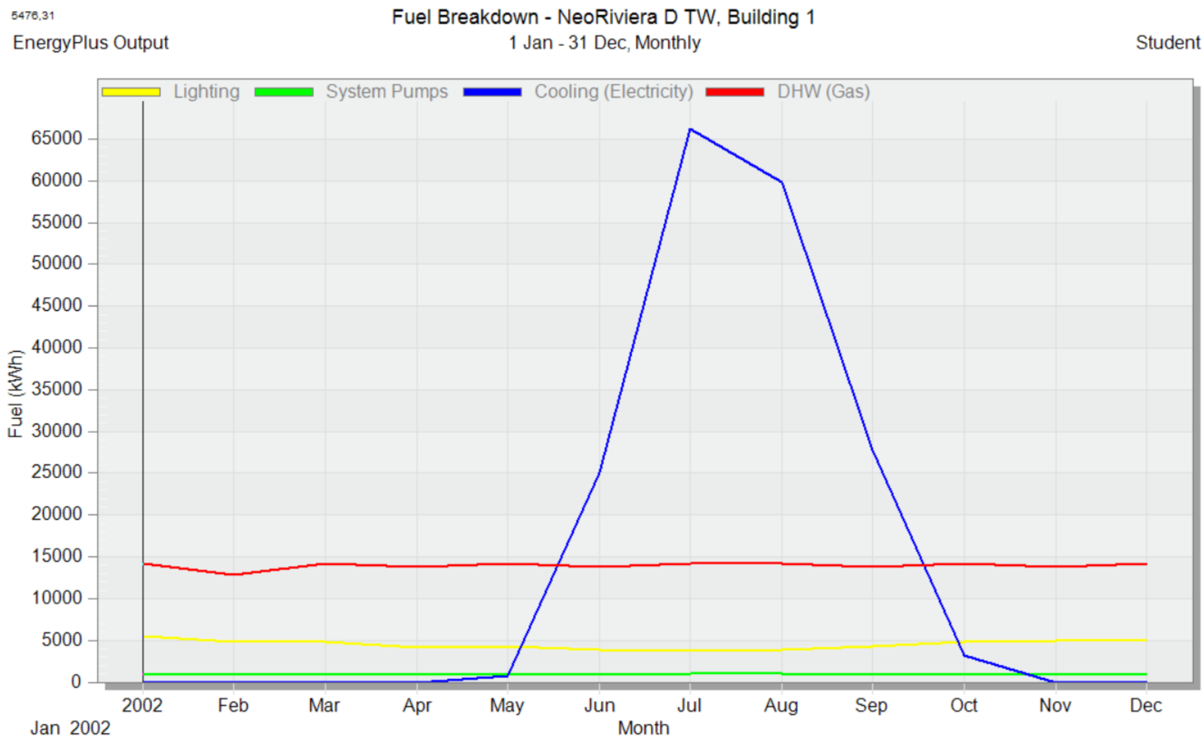
6.1 Fuel breakdown - monthly

Prague



Pic. 28: Fuel breakdown – monthly, Prague, Czechia (7)

Tainan

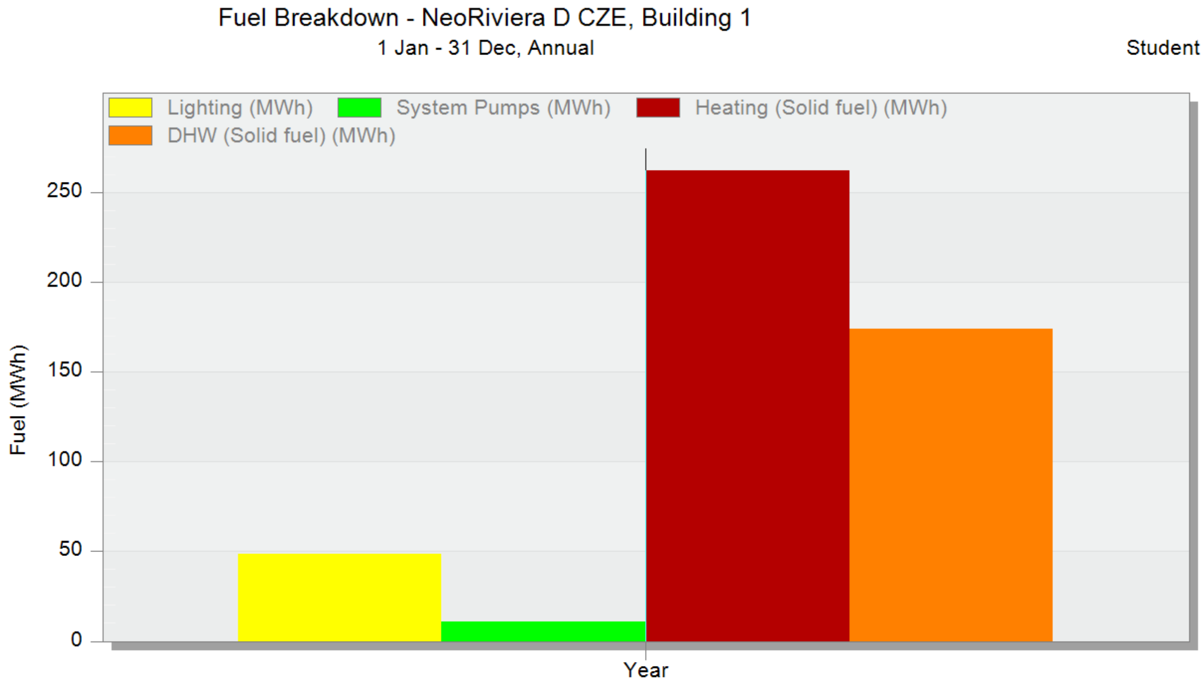


Pic. 29: Fuel breakdown – monthly, Tainan, Taiwan (7)

The data from simulation prove our expectations due to climatic condition. In the Czech Republic heating season starts at the end of the September and ends in the May. On the other side, in Taiwan cooling season is exactly opposite, it starts from the May and ends in the November. Consumptions of energy for lightings systems reflecting the different length of the daylight. In the Czech Republic during the summer has day about 16 hours but in the winter only 9-10. In Taiwan sunshine stays almost the same during whole year.

6.2 Fuel breakdown – annual

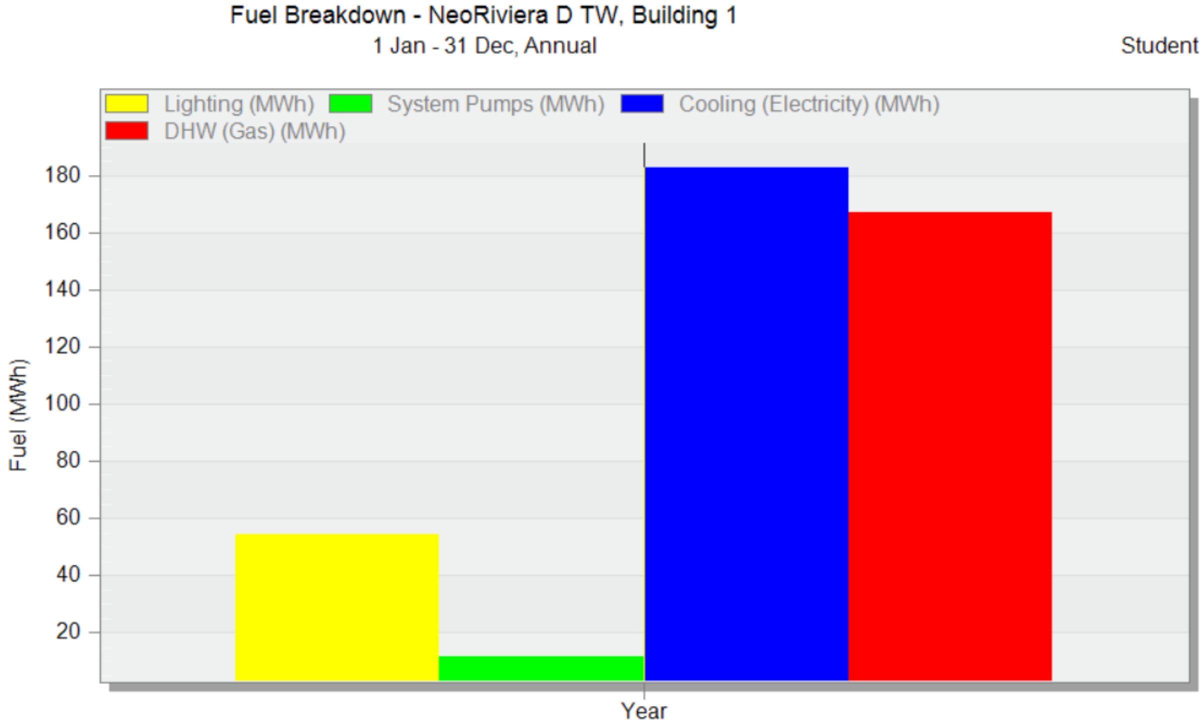
Prague



Lighting (MWh)	48,54
System Pumps (MWh)	10,96
Heating (Solid fuel) (MWh)	262,26
DHW (Solid fuel) (MWh)	173,90

Pic. 30: Fuel breakdown – annual, Prague, Czechia (7)

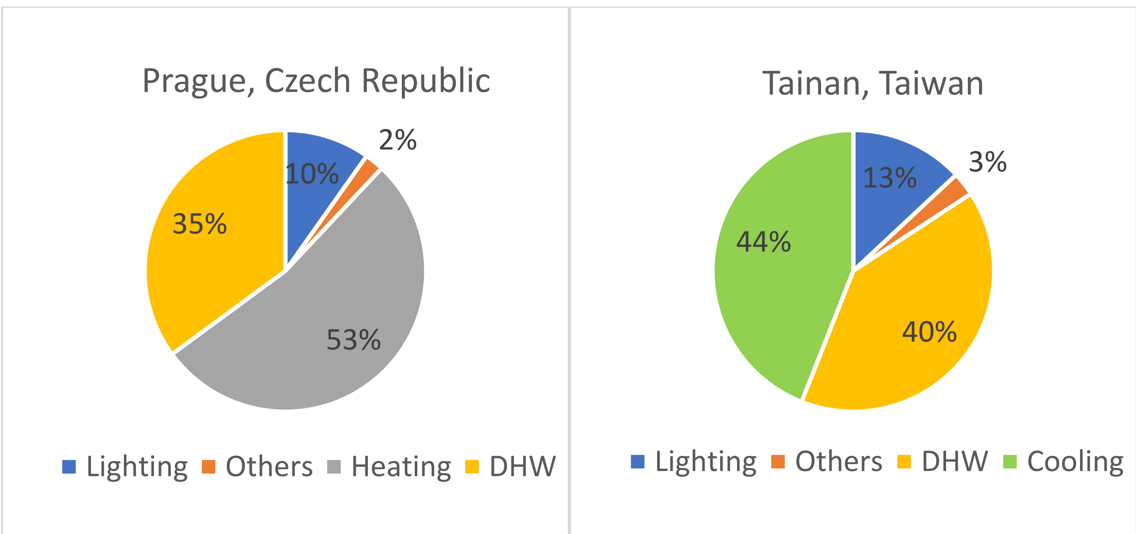
Tainan



Lighting (MWh)	54,20
System Pumps (MWh)	11,32
Cooling (Electricity) (MWh)	182,86
DHW (Gas) (MWh)	167,17

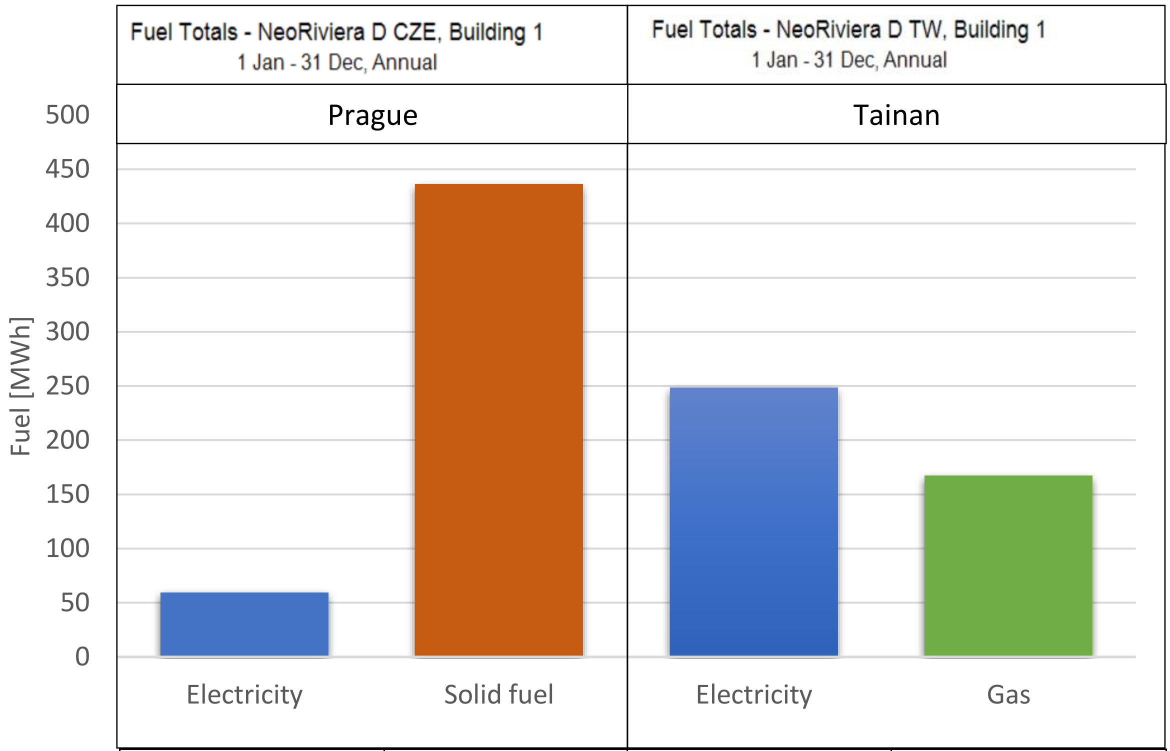
Pic. 31: Fuel breakdown – annual, Tainan, Taiwan (7)

Fuel breakdown diagram of NeoRiviera building for both locations:



Pic. 32: Fuel breakdown diagram – Prague (on the left), Tainan (on the right) (7)

6.3 Fuel totals – summary



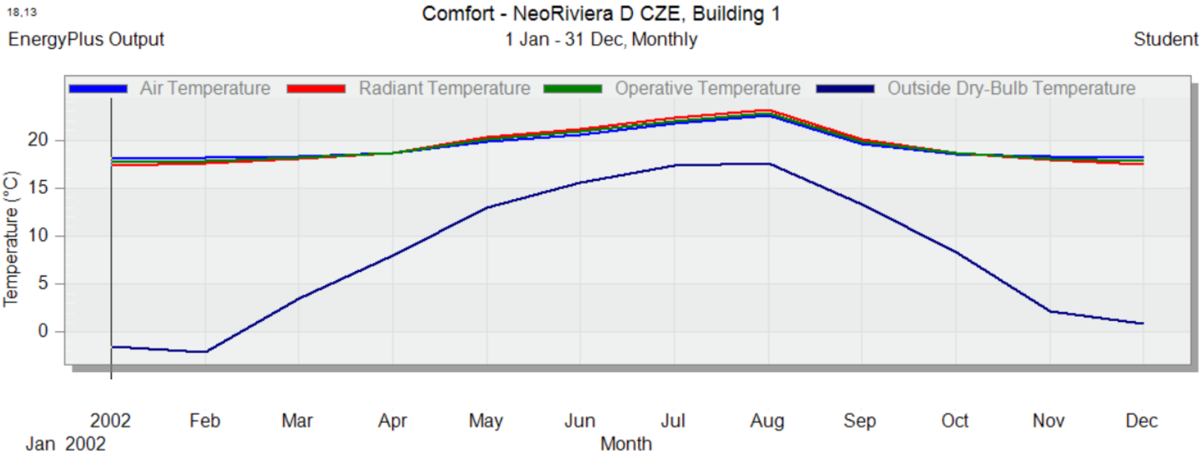
Electricity [MWh]	59,50	Electricity [MWh]	248,37
Solid fuels [MWh]	436,16	Gas [MWh]	167,17

Pic. 33: Total fuels consumption – Prague and Tainan (7)

Total consumption of the energy that we have to provide to the residential building in the Czech Republic is 496 MWh. On the other side, the same residential building in Taiwan we have to supply with 416 MWh. These values are giving us an approximate idea how consumption could look like. It doesn't really make any sense to compare them between each other. However, we can now have an image of building behaviour in such a different climate conditions.

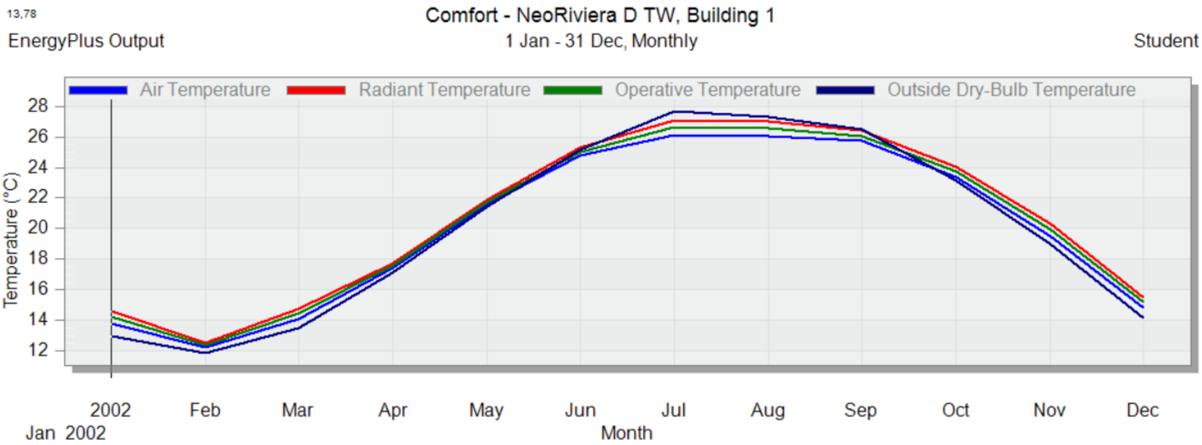
Let's have a look at following graphs. Naturally without any energy supplied, the internal temperature would more likely tend to reflect outside dry-bulb temperature. Of course, depending at least on solar radiation and internal gains. However, the internal temperature curve from the graphs represents the temperature treated by the building's technical facilities.

Prague



Pic. 34: Internal temperatures, Prague, Czechia (7)

Tainan



Pic. 35: Internal temperatures, Tainan, Taiwan

Dark blue curve represents mean daily outside dry-bulb temperature. The more deviating the required internal temperature from this curve, the more this change occurred on the basis of the energy delivered. So, in Tainan, these curves do not differ as much as in Prague. That's one of reasons why above-mentioned total fuel consumption is in Taiwanese case lower.

7. Conclusion

According to the assignment, the basic project documentation of heating, ventilation and cooling for a selected building in two different locations was designed. Considering the fact that these are two completely different climates for the given localities, the proposals of the individual professions are very divergent. This fact made my thesis interesting for me. In local conditions in Taiwan, I tried to find out all the necessary information for the corresponding proposal. I noticed the differences in the environment in which I lived and could complement this work with photo documentation of these observations.

For the needs of the apartment building in Prague, a warm-water heating system with radiators and convectors was designed. The source of heat is central heat supply. Furthermore, local forced equal-pressure ventilation with recovery is designed for each apartment. Cooling is also proposed in the last four floors, where the refrigerant from the roof outdoor cooling units is supplied to the air handling units.

For a residential building in Taiwan, a multi-split cooling system is designed for each apartment independently. Outdoor units are located on the respective balconies. Except exhaustion from sanitary facilities, the housing units are naturally ventilated. The heating system is not used.

The text part of my work does not determine which country is better, uses energy more efficiently or something similar. That would not make sense. The aim is to get an overview of what the designer can meet in this other corner of the world.

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Attachment list

Prague, Czech Republic

A. Heating System

Drawing Part:

- A1.1 01B Floor Plan
- A1.2 4F Floor Plan
- A1.3 13F Floor Plan
- A1.4 Pattern of The Main Manifold
- A1.5 Vertical Scheme – Floor Manifolds

Text Part:

- A1.6 Technical Report
- A1.7 Appliance Design
- A1.8 Pressure Losses Calculation
- A1.9 Heat Losses Calculation Summary
- A1.10 Heat Losses Detailed Calculation – DVD Attachment

B. Air Ventilation and Cooling System

Drawing Part:

- B1.1 01B Floor Plan
- B1.2 4F Floor Plan
- B1.3 13F Floor Plan
- B1.4 Roof Floor Plan
- B1.5 4F+13F Ducts Flow Speed

Text Part:

- B1.6 Technical Report
- B1.7 Ventilation Air Calculation
- B1.8 Table of Cooling Loads –> 13F
- B1.9 Table od Distribution Elements
- B1.10 Air Handling Units Design

Tainan, Taiwan

C. Air Ventilation and Cooling System

Drawing Part:

- C1.1 4F Floor Plan
- C1.2 13F Floor Plan

Text Part:

- C1.3 Technical Report
- C1.4 Table of Cooling Loads –> 4F + 13F

Picture list

Table list