Passive House library in Taiwan

A comparison of the building performance between Passive house buildings and natural ventilation buildings

Chi-Hua Liu
Master's thesis spring 2023

Chalmers School of Architecture
Department of Architecture and Civil Engineering
Architecture and Planning Beyond Sustainability, MSc

Examiner: Paula Femenias
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ABSTRACT

Taiwan's goal is to achieve 'Net Zero Carbon Emissions' in all new buildings by 2050, with over 85% of existing buildings meeting this standard. However, energy efficiency loses significance if the indoor environment fails to meet human comfort and health standards. This discrepancy might prompt occupants to resort to alternative heating or cooling methods, potentially increasing energy consumption beyond conventional buildings.

Sustainable building strategies in Taiwan, especially in its subtropical climate, heavily lean towards natural ventilation. Emphasizing thermal comfort and energy efficiency, these strategies prioritize heat dissipation, dehumidification, and cooling. They often rely on non-mechanical systems like sun shading and natural air convection through openings. In contrast, Passive house principles focus on constructing airtight, thermally insulated buildings without thermal bridges.

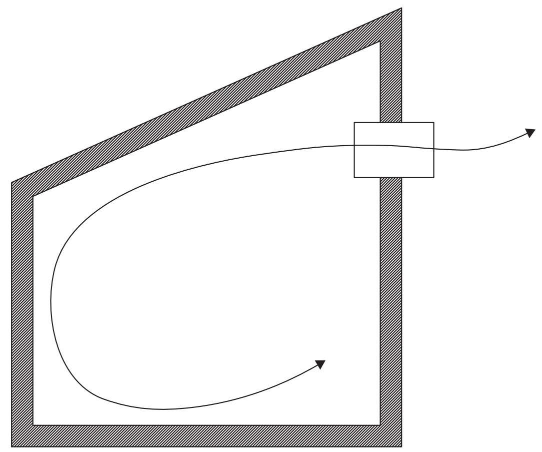
Nevertheless, challenges posed by urban environments, including uncontrolled temperature, humidity, pressure differences, air pollution, insects, and the urban heat island effect, question the suitability of natural ventilation in Taiwan's context.

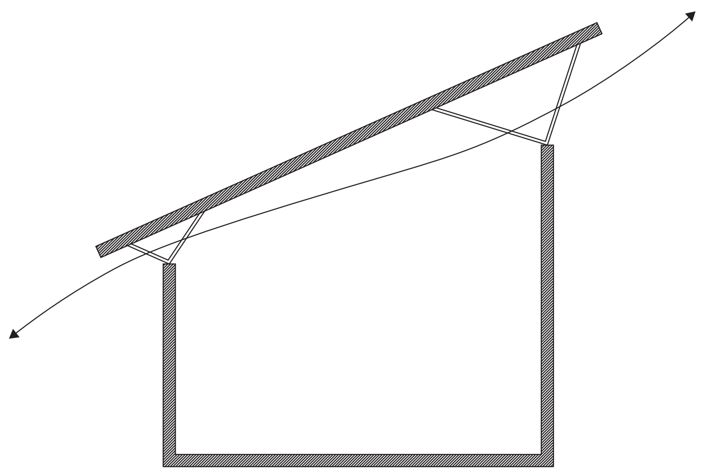
Since 2010, Passive House, offering controllable indoor comfort, has gradually found its way into subtropical regions like Taiwan. It aims to provide comfortable indoor conditions with minimal heating and cooling loads by integrating structural design and building systems.

This master's thesis endeavors to design a library using Passive house strategies and compare its performance with buildings relying on natural ventilation. The research begins by studying the Beitou Library, renowned for its low-energy consumption via natural ventilation and receiving the highest evaluation index for sustainable building design in Taiwan.

The thesis will propose a design for a Passive House library and compare its daylighting and energy performance with the existing Beitou Library. To ensure an unbiased comparison, the thesis site mirrors that of the Beitou Library, and the spatial requirements of the original library are considered. By delving into the redesign of a library, this thesis aims to evaluate the feasibility and applicability of Passive House principles in Taiwan's architectural landscape.

Keywords:
Passive house, Community Library, Human Comfort"





STUDENT BACKBGROUND

Chi-Hua Liu

Academics

Master's degree in Architecture and Planning Beyond Sustainability (2021-2023)
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CONTENTS

A. INTRODUCTION

Background and purpose

Taiwan aims to achieve 'Net Zero Carbon Emissions' for all new buildings by 2050, with over 85% of existing buildings complying with this standard. However, the efficacy of energy-efficient buildings hinges on maintaining human comfort. Otherwise, occupants may resort to additional heating or cooling methods, significantly impacting spatial experience and potentially leading to higher energy consumption than conventional buildings.

This master's thesis centers on prioritizing human comfort and energy efficiency by employing Passive house principles and daylight simulation tools in designing an urban library in Taiwan's subtropical environment. Passive house focuses on providing comfortable indoor conditions with minimal heating and cooling loads through structural coordination and efficient facilities. Currently, sustainable building design in Taiwan predominantly revolves around natural ventilation, emphasizing thermal comfort and reducing HVAC energy consumption.

Strategies prioritize heat dissipation, dehumidification, and cooling, relying largely on non-mechanical systems like sun shading and air convection through openings. Conversely, Passive house aims for airtight, thermally insulated structures to minimize mechanical ventilation and reduce energy consumption. However, natural ventilation's limitations in Taiwan's urban context have been evident.

In winter, when temperatures drop to 16°C with over 80% relative humidity, users close windows to insulate the indoor space and resort to mechanical systems, causing heat loss due to inadequate thermal bridging-free design.

During summer, temperatures exceeding 35°C and over 75% relative humidity, compounded by the urban heat island effect and density, hinder efficient airflow for ideal air convection. Additionally, pollutants (such as PM2.5) and flying insects pose challenges unaddressed by natural ventilation. In spring, the introduction of high-temperature, high-humidity air into the cooler indoor spaces result in indoor condensation due to thermal differences.

Considering these challenges, how does Passive house offer a controllable indoor comfort?

Since 2010, Passive house have gradually emerged in subtropical areas like Taiwan. Aimed at reducing building energy consumption, Passive house, with its thermal bridge-free and insulation designs offer a controlled indoor climate, potentially presenting a viable solution for Taiwan's environment compared to natural ventilation through building openings.

This master's thesis intends to propose a new library design using Passive house strategies and conduct a comparative analysis of building performance with the existing Beitou Library, known for its natural ventilation design and recognition as a sustainable building in Taiwan. Through the result, to propose a Passive house library to test and evaluate whether the Passive house strategy is able to adapt to Taiwan's environment and climate and the challenges.

For the comparison, the site of this thesis is chosen on the same location as the existing Beitou Library in Beitou, Taipei, to objectively evaluate energy and indoor climate performance in identical conditions. The spatial requirements of the Beitou Library also serve as the requirement for this thesis.

Aim

• By using an existing library (natural ventilation building) as a reference, this thesis aims to design a library with both effective daylighting and fulfilling passive house standard for human comfort and low energy consumption. Then, propose a comparison in terms of building performance with the existing library.

Meanwhile, we propose the adaptability of passive housing in the Taiwanese environment.

Research questions

• How passive house strategies and tools could support energy-efficient building design in the hot and humid climate.

• What are the benefits or drawbacks of using passive strategies compared to natural ventilation design.

Delimitations

• For the objective comparison of the passive house library and the existing library under the same conditions, the site, and the space requirements are taken from the existing library.

• In addition to the architectural design, this thesis will focus on the evaluation of daylighting, building envelope and energy consumption of use phase in LCA.

Methods

1. Case study of an existing library designed with natural ventilation

-Basic information
-Statistics of building performance
-A Summary of the data
-Feedback from users' experience

2. Site analysis

-Location
-Climate
-Local context

3. Design development

-Schematic design
-Detail Design

4. PHPP and Daylight simulation Model Testing and adjusting

-Try different variation of opening, shading and the U value of the building envelope for the best balance of daylighting and energy consumption.
-Technical reports.

5. Final design proposal

-Floor plans
-Project emblematic image/drawing
-Detail drawings
-Isometric drawings

6. Conclution and reflection

-Comparison with the existing Beitou library in terms of building performance.
-Discussion of the adaptation of
-Passive house in Taiwan's climate and social context.

B. INVESTIGATION

B-1. Introduction of design assistance tools

Simulation Aided Design

In this master’s thesis, Design proposal is developed by taking Passive house strategy and daylight simulation into account to achieve the high quality of thermal comfort and daylighting whinin a efficent energy consumption.

1. Passive house

Passive houses is a building for energy efficiency, comfort and affordability, and it allow for space heating and cooling related energy savings of up to 90% compared with typical building stock and over 75% compared to average new builds.

Criterias of Passive house Classic

Space Heating Demand	not to exceed 15kWh annually OR 10W (peak demand) per square metre of usable living space
Space Cooling Demand	roughly matches the heat demand with an additional, climate-dependent allowance for dehumidification
Renewable Primary Energy (PER)	the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 60 kWh per square meter of treated floor area per year for Passive house Classic.
Airtightness	maximum of 0.6 air changes per hour at 50 Pascals pressure (as verified with an onsite pressure test in both pressurised and depressurised states).
Thermal Comfort	Thermal comfort must be met for all living areas year-round with not more than 10% of the hours in any given year over 25°C.

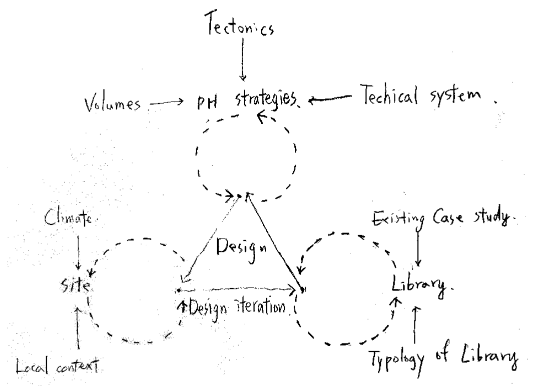


Fig. 01
Mindmap of the design process

Strength of Passive house

Minimizing the interference from outside to achieve:

IAQ High indoor air quality

Good thermal comfort

With

Lower cost for heating and cooling

Lower carbon emissions

How Passive house be applied to different climate

Passive house is more of a methodology or approach than a fixed building style. It's designed to be adaptable, considering the specific country and climate where it is implemented.

While the objectives of Passive House remain consistent across all climates and countries, the methods used can be tailored to suit the specific environmental conditions. The fundamental principles and physical equations remain constant; however, the variables, or boundary conditions, differ based on the climate.

Consequently, the Passive House design approach can be flexibly applied to various circumstances to determine the most suitable solutions for a specific country and its climate.

5 Passive house principles

Thermal insulation
All opaque building components of the exterior envelope of the house must be very well-insulated.

Passive house windows
The window frames must be well insulated and fitted with low-e glazings filled with argon or krypton to prevent heat transfer.

Ventilation heat recovery
Efficient heat recovery ventilation is key, allowing for a good indoor air quality and saving energy. In Passive house, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.

Airtightness of the building
Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurised and depressurised).

Absence of thermal bridges
All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges which cannot be avoided must be minimised as far as possible.

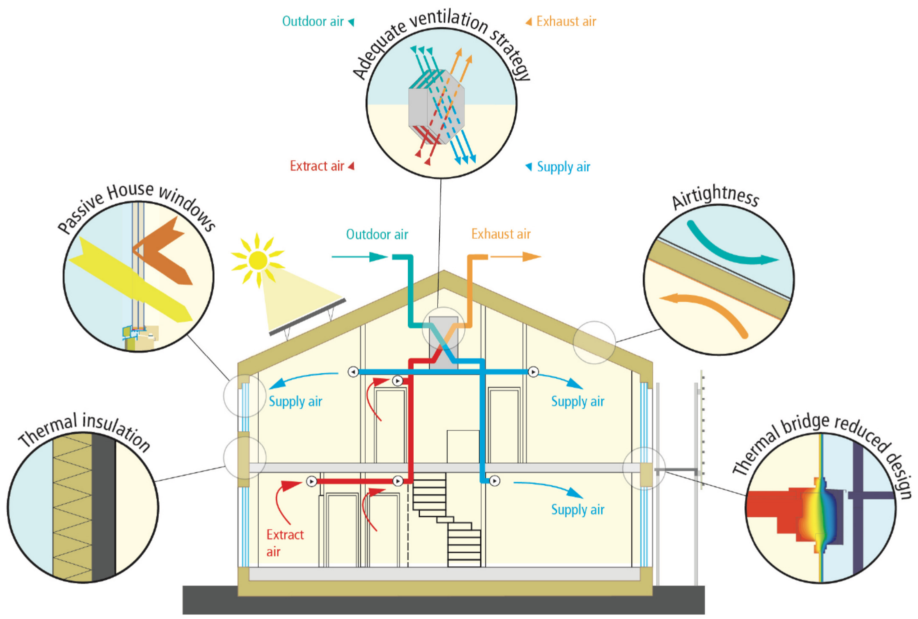


Fig. 02
Image of Passive house principles

Tool: DesignPH & Passive House Planning Package (PHPP)

• DesignPH is the 3D modelling tool for the PHPP, it is a plugin for SketchUp. Firstly it will simplify the process of entering data into PHPP and secondly it will provide preliminary feedback on the performance of the design within SketchUp.

• PHPP contains everything necessary for designing a properly functioning Passive house. The PHPP prepares an energy balance and calculates the annual energy demand of the building based on the user input relating to the building’s characteristics.
It is a Excel based energy calculation tool. Mainly, it provides results for the following:

- Heating demand per year [kWh/(m²a)] and maximum heating load [W/m²]

- Cooling demand per year [kWh/(m²a)] and maximum cooling load [W/m²] (in case of active cooling)

- Summer comfort in case of passive cooling: frequency of overheating [%]

- Demand for renewable primary energy (PER) per year and primary energy demand (PE) of all energy services in the entire building [kWh/(m²a)]

- Assessment of the annual renewable energy gains [kWh/(m² ground area)]

Fig. 03
Icons of Passive house tools

2. Tool: Velux Daylight Visualizer

Fig. 04
Icons of Velux Daylight visualizer

Good daylighting design can improve the health, mood, cognitive abilities and productivity of the occupants at home, school, or work while reducing the energy consumption of the building.

VELUX Daylight Visualizer is a professional lighting simulation tool for analyzing building daylight conditions. It is intended for use in the early design phase of a building to inform architects and engineers about the impact of various design choices on daylight performance.

In this thesis, the daylight factor is the main element to consider. Daylight factor (DF) is a daylight availability metric that expresses as a percentage the amount of daylight available inside a room (on a work plane) compared to the amount of unobstructed daylight available outside under overcast sky conditions (Hopkins,1963). The critical building properties that determine the magnitude and distribution of the daylight factor in space are (Mardaljevic, J. (2012)):

- The size, distribution, location, and transmission properties of the facade and roof windows.
- The size and configuration of the space.
- The reflective properties of the internal and external surfaces.
- The degree to which external structures obscure the view of the sky.

The higher DF the more daylight is available in the room. Daylight Factor <2% – Room looks gloomy, electric lighting needed most of the day. Daylight Factor 2-5% – Room has daylight appearance. Artificial lighting required on occasion. Daylight Factor >5% – Room has strong daylight appearance. Electric lighting rarely needed, but thermal issues may arise.

<u>Criterias of daylight in this thesis</u>

Median target daylight factor for the main areas: 2%-4.5%.
Minimum target daylight factor (D_{TM}) above 0.7% for ≥ 95% of the area.

3. Workflow of the design development

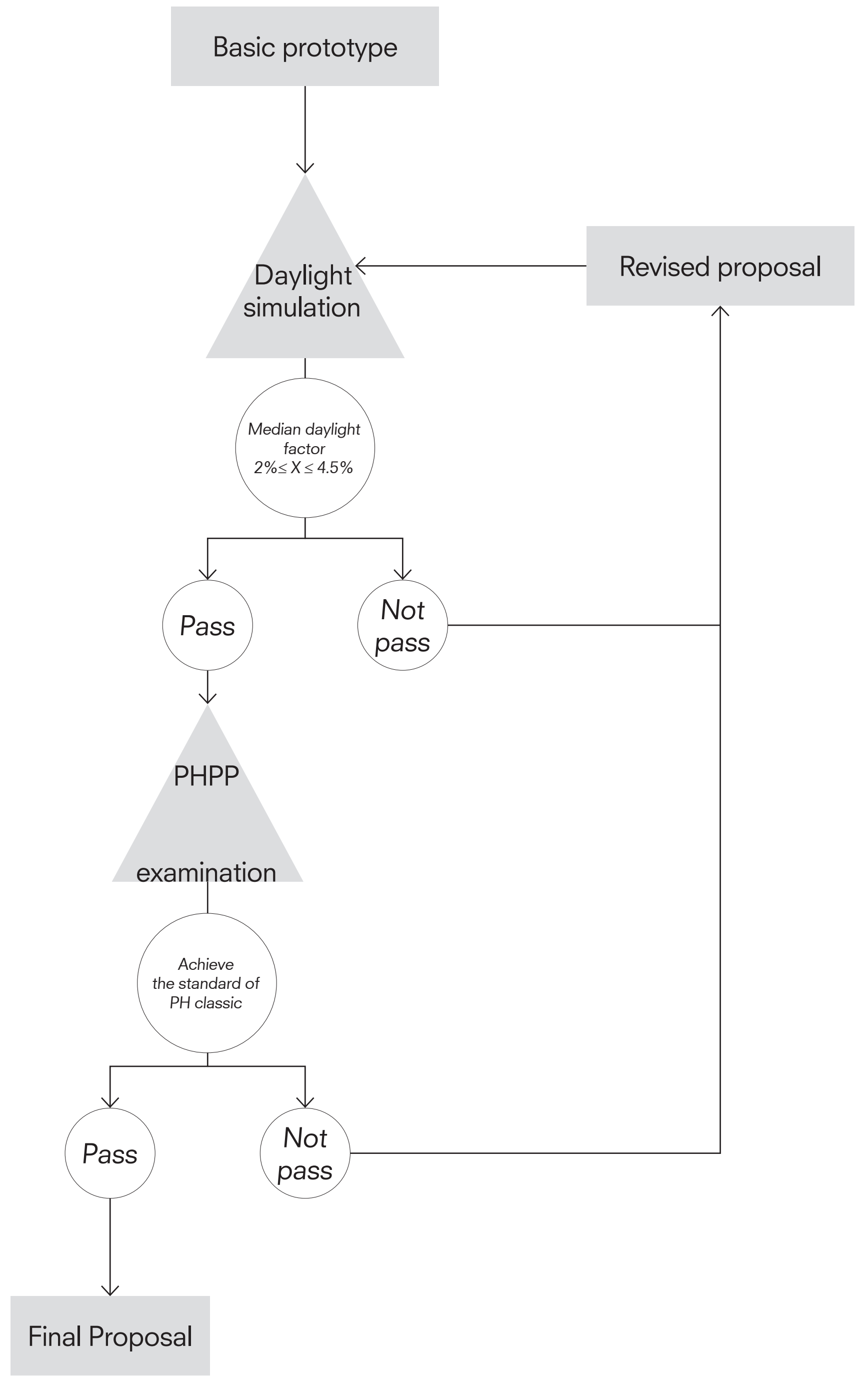


Fig. 05
Diagram of the design method

B-2. Case study of the existing project

Case study-Beitou Library

Fig. 06
Image of Beitou library

To facilitate the comparison between Passive houses and buildings relying on natural ventilation, this chapter centers on analyzing the existing Beitou Library. The examination involves scrutinizing indoor thermal comfort and energy consumption monitoring data alongside user feedback. These data sets will serve as the benchmark and reference for comparing against the Passive house proposal in this master's thesis.

The Beitou Library, designed with a natural ventilation approach, is a noteworthy project in sustainable building design in Taiwan. This project garnered the highest accolade in Taiwan's sustainable building design evaluation index.

Fig. 07
Image of Beitou library

- Project Name: Taipei Public Library Beitou Branch
- Location: Taipei, Taiwan
- Architect Office: Bio architecture Formosana
- Completion Year: 2003
- Site Area: 34797.94 m²
- Building area: 802.87 m²
- Total floor area: 1963 m²
- Structure: SC, RC, Timber structure
- Floors: B1F, GF, 1F

Architectural program	Area	Footprint(m2)	Description(m2)
Entry hall	Entrance	60	
	Reciption	60	
	Information Search	100	
Reading area	Open-shelf area	360	180(Shelves area) 180(Reading area for 70 people)
	Children's Area	300	150(Shelves area) 150(Reading area for 50 people)
	Periodicals	300	150(Shelves area) 150(Reading area for 60 people)
	Café	100	40 people
	Multifunction Room	100	65 people
Administrative Area	Staff Offices	80	
	Storage	50	
Total		1510	
Others	Toilets		30%
	Garbage room		
	Circulation		
Total		1963	Capacity: 300 people

Fig. 08
architectural program of Beitou library

Beitou Library-Energy demand during a year

	percentage of monthly electricity consumption	amount of monthly electricity consumption(kWh)	amount of monthly Cooling Energy Demand (kWh)
Aug 2007	69%	37160	25640.4
Sep 2007	65%	30480	19812
Oct 2007	44%	23360	10278.4
Nov 2007	4%	14200	568
Dec 2007	2%	10000	200
Jan 2008	1%	10520	105.2
Feb 2008	2%	9800	196
Mar 2008	1%	9680	96.8
Apr 2008	22%	9560	2103.2
May 2008	21%	12120	2545.2
Jun 2008	64%	13440	8601.6
Jul 2008	70%	25280	17696
Total		205600	87842.8

Floor area(m2)	2004
Cooling demand per year (kWh/m²a)	43.83
Energy Use Intensity (EUI) (kWh/m²a)	102.59

Fig. 09
Sheet of Energy demand (Monthly)

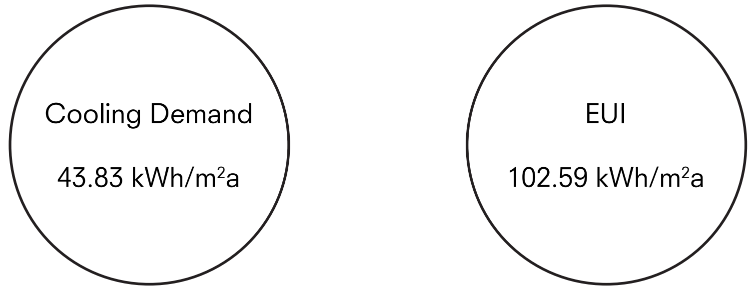


Fig. 10
Energy demand of the year

Based on the monitoring report (Enertek Sustainable Design & Technology, 2008), the air conditioning (AC) system in the Beitou Library is primarily operational from April to October, aimed at maintaining the indoor temperature within the range of 28 ± 2°C. For the remaining months, it operates in "fan" mode, implying reduced or minimal cooling requirements.

However, it's essential to note that despite the target indoor temperature being set at 28°C rather than the Passive house standard of 25°C, the annual Space Cooling Energy Demand is reported as 43.83 kWh/m²a. This energy demand exceeds the Passive house requirement, which specifies that it should not exceed 15 kWh/m²a, without even considering the energy consumed for dehumidification purposes.

Beitou Library-Monitoring report of thermal comfort

Summer
(May-Oct)
with AC

Indoor Temp:
28 ± 2 °C

RH: 60%-75%

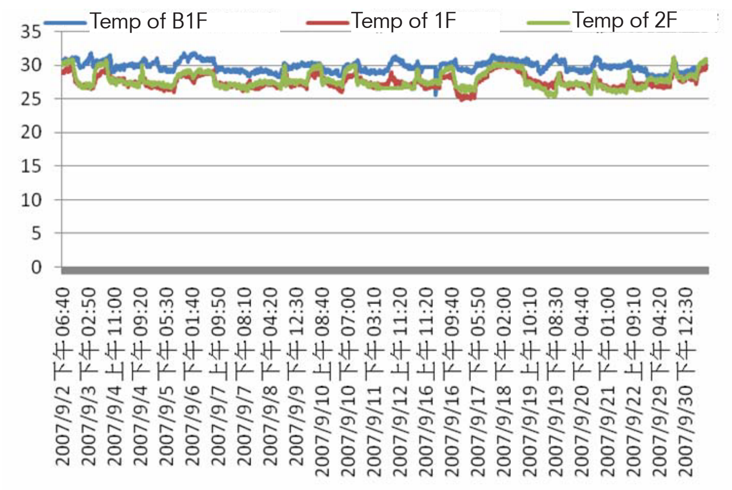


Fig. 11
Indoor Temperature of September 2007

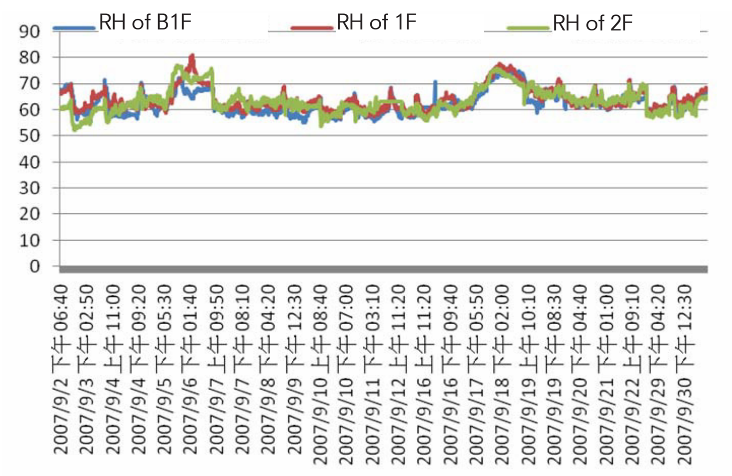


Fig. 12
Indoor Relative Humidity of September 2007

Winter
(Nov-Apr)
without AC

Indoor Temp:
15-25°C

RH: 50%-75%

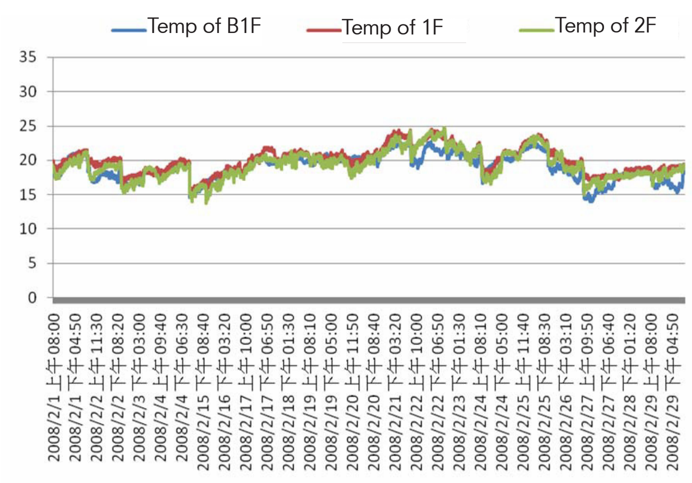


Fig. 13
Indoor Temperature of February 2008

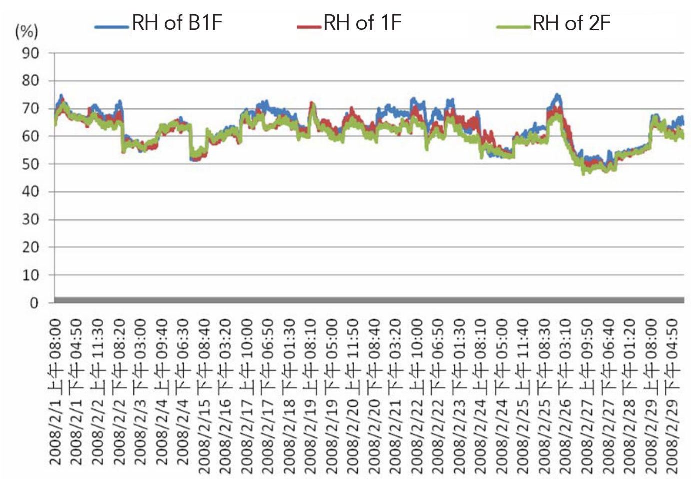


Fig. 14
Indoor Relative Humidity of February 2008

Requirement of Passive house

Temperature:
Not more than 10 % of the hours in a given year over 25 °C.
Summer: < 25°C
Winter: > 20°C

Relative Humidity:
Must not exceed 12g/kg for more than 20% of the year (~60%RH at 25°C).

Based on the monitoring report, the air conditioning (AC) system is actively used from May to October to maintain the indoor temperature within the range of 28 ± 2°C.

In accordance with Passive house standards, indoor temperature requirements dictate that all living areas must maintain temperatures below 25°C for not more than 10% of the hours in a given year. Thus, in terms of achieving a consistently comfortable indoor climate, the natural ventilation strategy implemented in the Beitou library falls short.

The provided table demonstrates significant fluctuations in temperature and humidity during February, likely due to the use of open windows for natural ventilation. This fluctuation underscores the unstable and uncontrollable nature of indoor thermal comfort during periods when active conditioning is not in use.

Beitou Library-A survey after used

The users take the library as a communal space in daily life.

Most of the users are the people live in this area.

Statistics of the days people come

	amount of times	%
Monday	145	30.5%
Tuesday	177	37.1%
Wednesday	191	40.0%
Thursday	162	34.0%
Friday	177	37.1%
Saturday	245	51.6%
Sunday	218	45.8%

Statistics of how long it take to get to the library

time spent	amount of people	%
in 15m ins	289	58.7
15~30m ins	120	24.4
31~60m ins	60	12.2
1~2h rs	18	3.7
2h rs	5	1.0
total	492	100.0

This community library offer the multiple uses for social functions.

Statistics of user's purpose of the visit

purpose	amount of times	%
read newspaper	93	18.8
read magazines	145	29.2
check out & return	297	59.9
read books	273	55.2
study	144	29.1
search	84	16.9
meet friends	21	4.2
surf the Internet	79	15.9
attend events	10	2.0
ask for info	1	0.2
catalog search	11	2.2
sit and chill	79	16.0
just pass by	48	9.7
others	12	2.4

The survey, conducted in 2016 and comprising over 500 questionnaires, delved into the utilization, administration, and upkeep of buildings.

The gathered data illustrates that approximately 50% of respondents visit the library during weekends, with a substantial 30% to 40% visiting on weekdays. This trend highlights the significance of the local library in their daily routines. This observation finds support in the statistics pertaining to the purposes for visiting the library and the proximity of the library to the respondents' residences.

These statistics collectively indicate that the library caters primarily to local residents, underscoring its importance and relevance in their lives.

Beitou Library-Feedback from users

- Staffs

• Poor ventilation.
• Because of the humidity, the eletricity consumption of dehumidifier is a problem.
• the spaces lack of flexibility, it’s hard to adapt different use.

- Readers

• Open shelf area is too close to the children area and main hallway, readers are disturbed easily.
• indoor temperature is not cool enough.
• When windows are opend, the air from outside is often not only too humid, but also not convecting, furthermore, there are too many mosquito outdoor.
• Not enough daylighting in the indoor space.
• The terraces are good places to stay, and it will be better if it was wider.

Conclusion(design goals that extracted from reports)

The findings from the reports on the existing library will be taken into account in the design process for this thesis.

While this thesis aims to present a distinct and original project rather than enhancing the existing library, the reports on the current library serve as valuable references. They provide insights into the social context and the site's specific requirements and usage patterns. These insights will significantly inform the proposed design, ensuring it responds to the needs identified through the existing library's data and observations.

• Low energy consumption with controllable indoor climate.

The goal of low energy consumption should not be achieved by compromising human comfort.

• A balance between daylighting and solar gain.

To achieve the median daylight factor in between 2% and 4.5% in the main areas.

• A communal space for the local residents in daily routine.

The public area and reading area play a main role in the community library. It is not only a simple library but also a communal space for the residents to spend time and enjoy the view from here.

• Flexible zonings for different use.

The flexibility of the zones can be adapted to different needs. To be able to distinguish zones for readers and visitors, zones open for weekday and weekend.

C.
SITE ANALYSIS

Site location and Environvent issue during a year

The selected site for comparison is situated in the Beitou district of Taipei City, Taiwan, the same location as the existing Beitou library. In this urban setting, various uncontrollable environmental factors such as temperature, humidity, wind (pressure differences), air pollution, insects, and the urban heat island effect greatly influence natural ventilation performance. Over a year, observations reveal specific challenges with this ventilation approach:

During winter, indoor temperatures are around 16°C, and relative humidity is over 80%, necessitating the closure of windows to prevent cold outdoor air from entering. Consequently, mechanical systems exchange the air and warm the indoor space. However, the lack of consideration for thermal bridging in building envelopes contributes to significant heat loss, compromising energy efficiency.

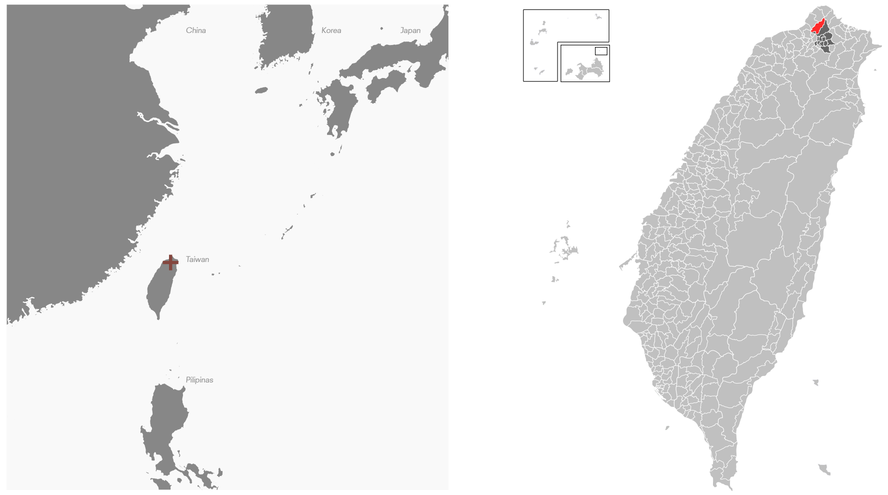
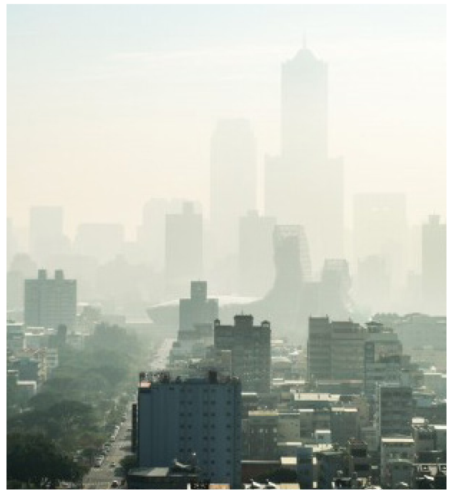


Fig. 15
Location of the site

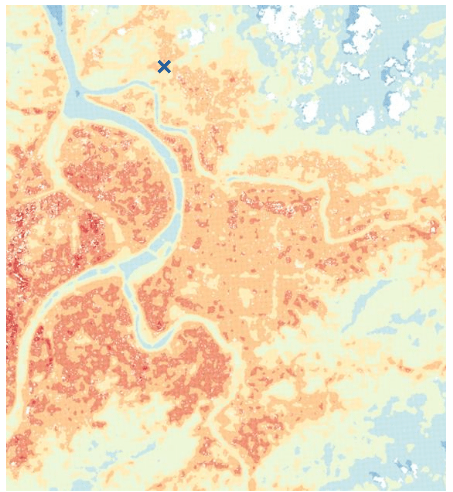
In summer, temperatures soaring above 35°C and relative humidity exceeding 75% pose challenges due to the urban heat island effect and dense urbanization, hindering effective airflow for ideal air convection. Additionally, issues arise with pollutants, notably PM2.5, and flying insects, which cannot be adequately managed through natural ventilation.

In spring, the introduction of high-temperature and humidity air into indoor spaces with lower temperatures often lead to condensation issues within the indoor environment.



Left *- Fig. 16*
Image of smog with PM2.5

Right *- Fig. 17*
Image of flying insects



Left *- Fig. 18*
Image of urban heat island effect in Taipei (2019)

Right *- Fig. 19*
Image of condensation on inside of walls

Climate zones distribution of Passive house

Taiwan falls under the climatic classification of "very hot, often humid" according to the zoning system established by the Passive House Institute. Winter seasons are typically brief and mild, with daily average temperatures consistently above 16°C. However, in summer, temperatures frequently exceed 30°C. Notably, relative humidity remains consistently high at around 70% to 80% throughout the year, underscoring the critical need for effective cooling and dehumidification systems in buildings.

Precisely meeting the Passive house criteria in this climatic zone necessitates a keen focus on several factors. These include optimizing the U-values of building components, ensuring airtightness, managing solar radiation, and strategically implementing Mechanical Ventilation with Heat Recovery (MVHR) systems. These considerations should be adjusted and fine-tuned through simulations to achieve Passive house standards tailored to Taiwan's specific climate conditions.

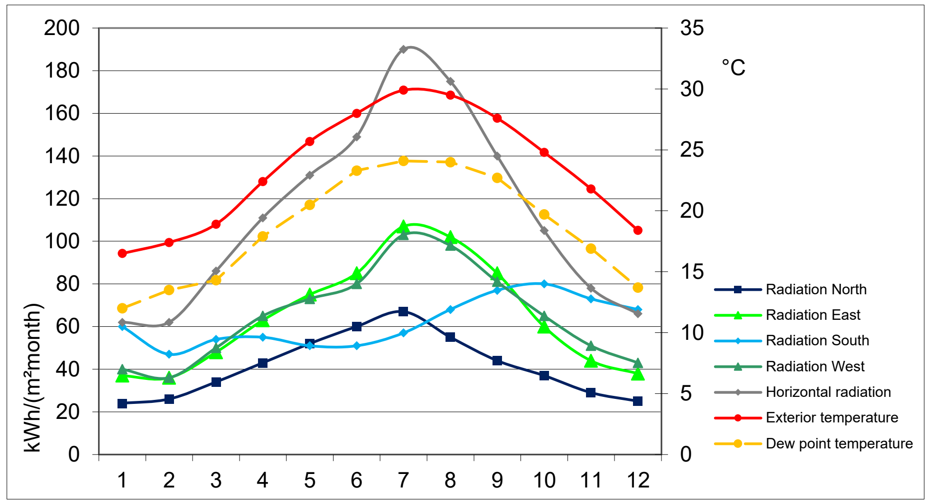


Fig. 21
Chart of the radiation on the site (Monthly)

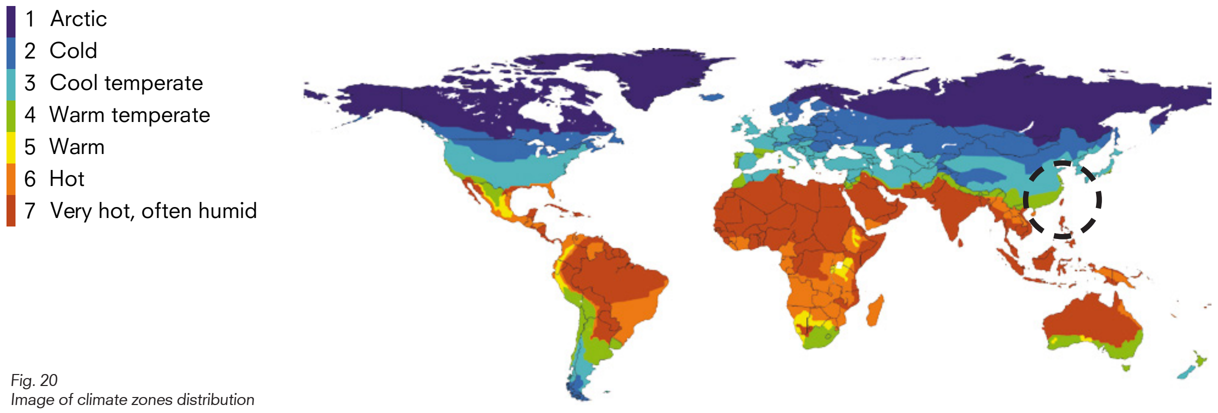


Fig. 20
Image of climate zones distribution

	Month	1	2	3	4	5	6	7	8	9	10	11	12	Heating load		Cooling load		PER	
	Days	31	28	31	30	31	30	31	31	30	31	30	31	Weather 1	Weather 2	Weather 1	Weather 2	factors	
	TW0001a-Taipeh	Latitude °	25.03	Longitude °	121.53	Altitude [m]	9			ΔT Summer [K]	5.0	T Comfort criterion [°C]	7.0	Radiation: [W/m²]		Radiation: [W/m²]			
° C	Exterior temperature	16.5	17.4	18.9	22.4	25.7	28.0	29.9	29.5	27.6	24.8	21.8	18.4	11.5	13.9	32.3	31.2	1.25	Occupant electricity (
kWh/(m²month)	Radiation North	24	26	34	43	52	60	67	55	44	37	29	25	45	15	105	80	1.25	Domestic hot water
kWh/(m²month)	Radiation East	37	36	48	63	75	85	107	102	85	60	44	38	50	15	190	180	1.35	Heating
kWh/(m²month)	Radiation South	60	47	54	55	51	51	57	68	77	80	73	68	60	20	115	225	1.55	Cooling
kWh/(m²month)	Radiation West	40	36	50	65	73	80	103	98	81	65	51	43	50	20	185	190	1.60	Dehumidification
kWh/(m²month)	Horizontal radiation	62	62	86	111	131	149	190	175	140	105	78	66	80	25	335	305		
° C	Dew point temperature	12.2	13.5	14.3	17.9	20.5	23.3	24.1	24.0	22.7	19.7	16.9	13.7			27.6	28.0		
° C	Sky temperature	8.0	10.3	11.0	14.1	17.7	20.1	20.7	20.7	18.2	16.2	13.3	9.7			27.7	28.2		
	Comment	Meteonorm. Compared with various sources.																	
° C	Ground temperature (project-specific)	21.4	20.9	20.2	24.6	24.3	24.3	24.6	25.1	25.8	26.3	26.7	21.7	21.4	21.4	24.6	24.6		
	Relative humidity	76%	78%	75%	76%	73%	76%	71%	72%	75%	73%	74%	74%						

Fig. 22
Meteorological data of Taipei

Site

Situated in the northernmost district of Taipei City, Taiwan, the Beitou library site is nestled within the Beitou Hot Spring Park, adjacent to a hot spring creek originating from the Beitou Thermal Valley. The area's unique geographical the layout is flanked by concave valleys, with towering slopes rising to at least 20 meters on both the northern and southern sides.

The historical significance of this location dates back to the Japanese occupation period (1895-1945) when it was developed as a hot spring area. This heritage has continued to shape the area, establishing it as a prominent destination for hot spring enthusiasts in northern Taiwan. Notably, the site's eastern side houses a preserved former public bathhouse, currently serving as the Beitou Hot Springs Museum, a testament to its historical significance.

Accessibility is a key feature of the site, with the metro station just a 5-minute walk to the west, offering convenient transportation. Moreover, it takes approximately an hour by metro from the center of Taipei City. The primary flow of traffic and visitors is predominantly from the west side of the site, contributing to its accessibility and connectivity to the broader Taipei area.

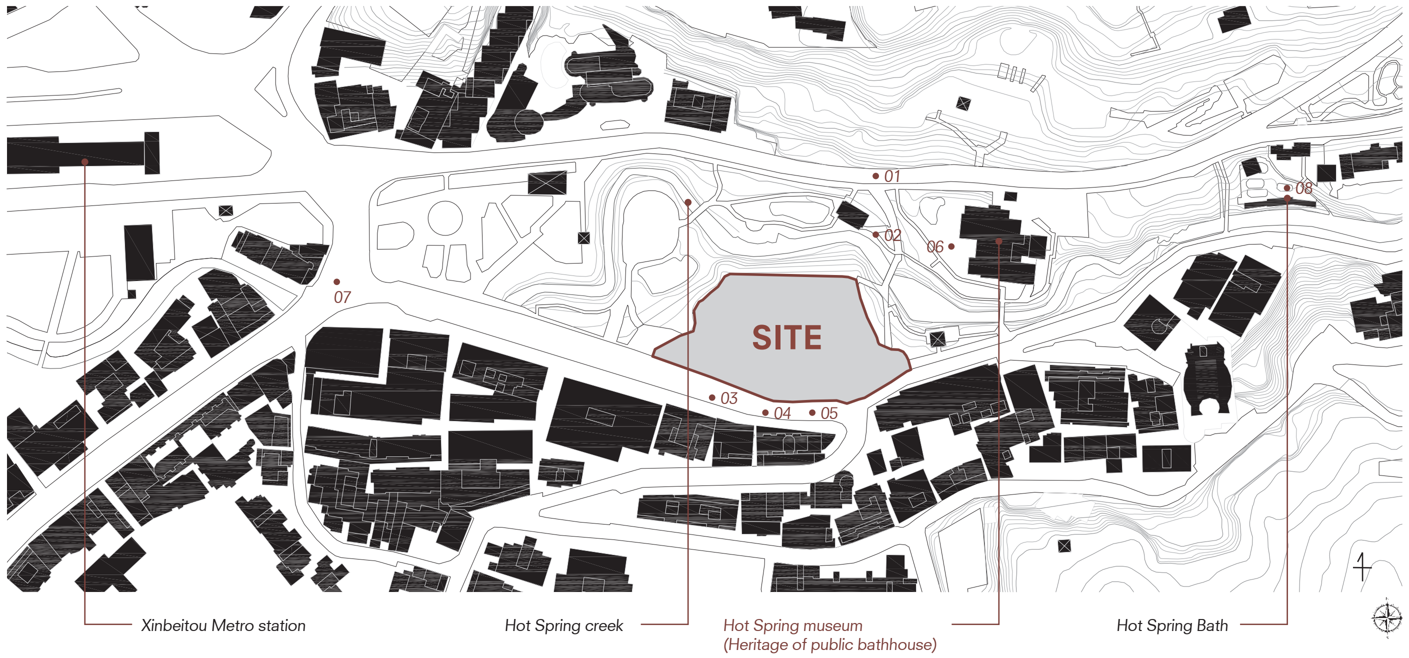


Fig. 23
Site analysis

Fig. 24
Images of the site

The area is flanked by concave valleys, with slopes rising to at least 20 meters on both the northern and southern sides.

Fig. 25
Section of the site

The site is mainly east-west oriented, with the Hot Springs creek on the north, and green areas to the east and west, surrounded by dense planting.

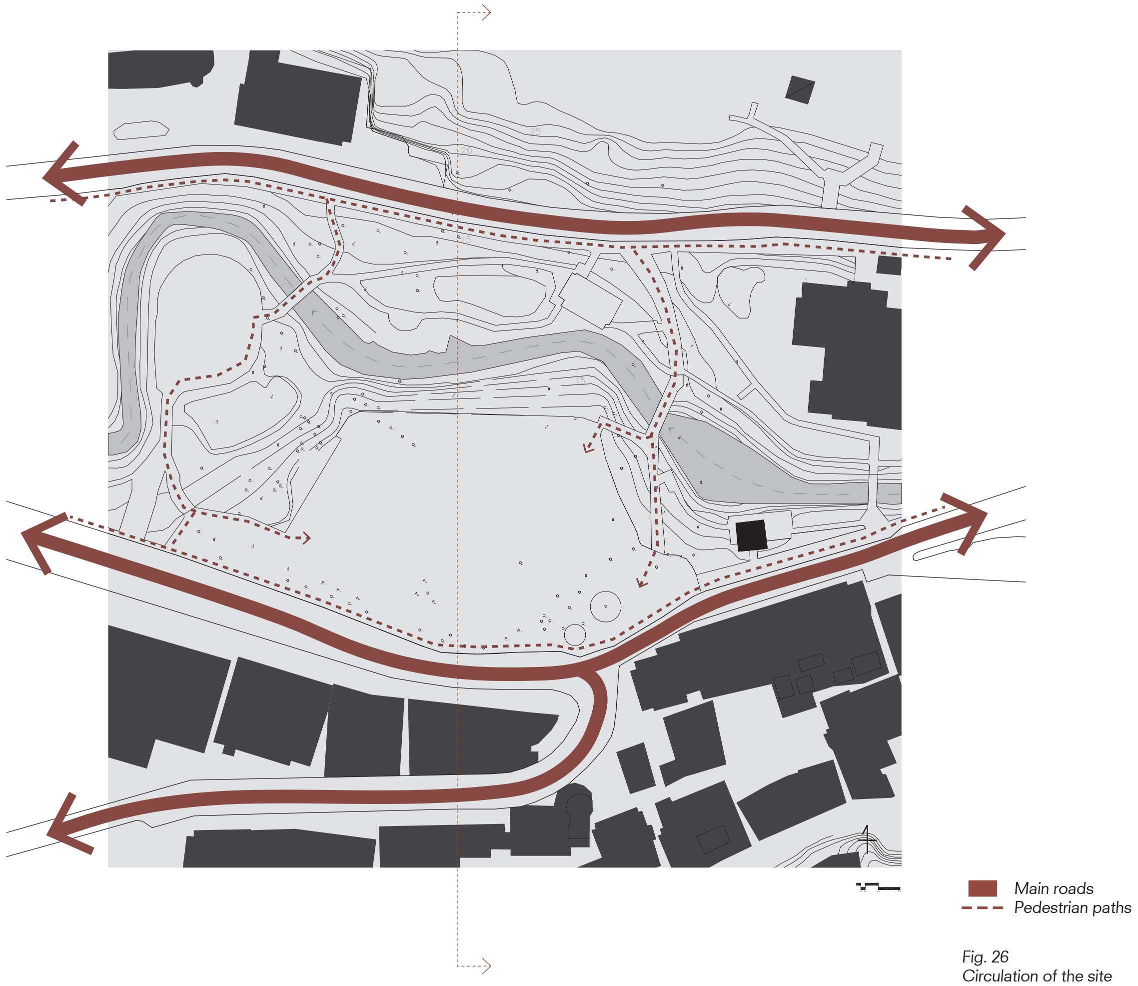


Fig. 26
Circulation of the site

The site surrounded by sulfur air

The primary source of Beitou hot springs releases hydrogen sulfide gas, which Upon contact with oxygen, it transforms into sulfur dioxide.

According to research conducted by Wang in 2001, prolonged exposure to sulfur dioxide in the environment can lead to eye and respiratory ailments. Environmental monitoring data comparing sulfur dioxide (SO2) concentrations between schools in hot spring areas and non-hot spring regions showed statistically significant differences. The findings also revealed a higher prevalence of upper respiratory issues in Beitou's hot spring area than in non-hot spring regions.

As a result, prioritizing the building's airtightness and ensuring superior indoor air quality (IAQ) in Beitou becomes imperative to prevent the intrusion of sulfur dioxide from the external environment.

Fig. 27
Image of the thermal valley

Fig. 28
Hot spring creek from the thermal valley

Local context-culture of being slow

According to a survey of existing library users' feedback, it is evident that local residents consider the community library not only as a place to borrow books and acquire knowledge but also as a space for relaxation, slowing down, and getting away from daily routine. This idea will be continued in this project and will serve as a motivation for space organization principles.

The development of these daily habits and customs can be traced back to the cultural context.

The foundation of this area's development is rooted in the Japanese onsen (hot spring) culture from the Japanese colonial period, which continues to influence the region, not only in economic industry but also in various aspects of daily life and culture.

To understand these inherited lifestyle patterns, the spatial layout of the nearby Beitou Public Bathhouse, built during the Japanese colonial period in 1911 (now the Beitou Hot Spring Museum), provides some clues.

On the first floor of the Beitou Public Bathhouse, right above the bath area, there is a public space with tatami flooring called "Ohiroma". In Japanese culture, there is a banquet space for hosting guests on formal occasions. Daily, the area is open to casual use. After bathing in the hot spring, people would sit or lie in this public space, chat with friends, drink, and relax. People have a habit of enjoying this blank time and relaxing in this space after their hot spring experience without rushing to leave.

When comparing photographs from the present day and the past, even though the building is not a bathhouse anymore, it's still used similarly. This lifestyle continues to have an impact on people.

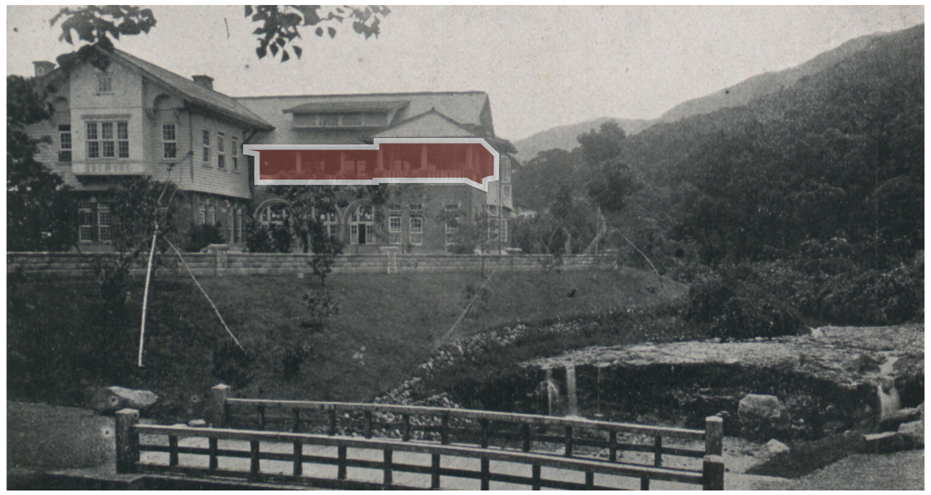


Fig. 29
Image of Beitou public bathhouse

Fig. 30
Image of Ohiroma in Beitou public bathhouse (hot spring museum) nowadays

Fig. 31
Image of Ohiroma in Beitou public bathhouse during the Japanese occupation period

Here, it's necessary to introduce the Japanese architectural element "Hiroen(広縁)".

It often surrounds the buildings and connects to spaces. It can be defined as "a fuzzy boundary between inside and outside." It acts as an extension of indoor space to the outside and outdoor space to the inside, serving as a buffer between indoor and outdoor environments. It can also be understood as a form of Japanese-style veranda and a corridor connecting space to space or simply a place for people to linger and rest to enjoy the view of the garden.

On the other hand, in Japanese architecture, spaces are not constructed by explicitly function and walls. Instead, the space is defined by the few wooden columns and paper slide doors between the ceiling and the floor, creating a flexible plane. The space is defined only after specific objects and boundaries are added to this domain based on factors like the events' scale, nature, and publicness.

In the case of the Beitou Public Bathhouse, the element of "Ohiroma" and "Hiroen" helps maintain the flexible and redefinable state of the space, leaving the functionality of the space to be passively defined by users, time, weather, objects, and other factors.

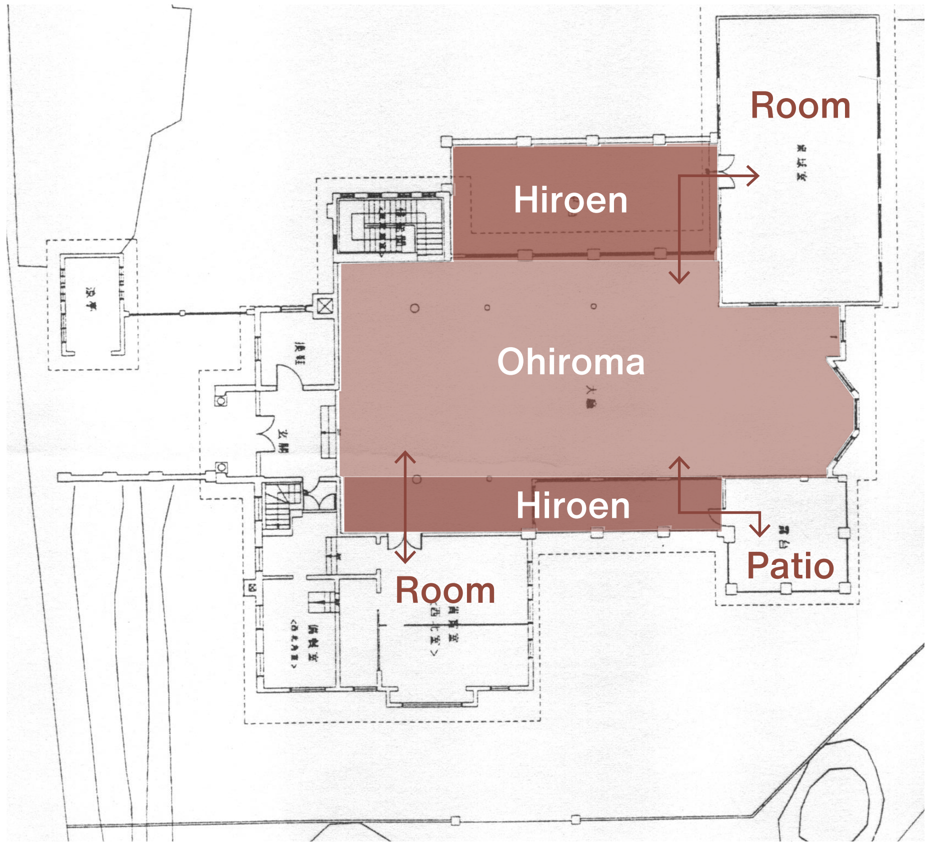


Fig. 32
Plan of the first floor

D.
DESIGN DEVELOPMENT

Concept

• Enlarge common spaces, to offer people a space to pause in their daily life.

Spread the spaces horizontally. Take the concept of Hiroen and Ohiroma from Beitou public bathhouse to disassemble the spaces and re-stitch them.

1. Create a dynamic moving experience.

2. To zone the spaces for distinguishing the area of readers and visitors/tourists.

3. Interact with the natural surroundings during the transition between indoor and outdoor space.

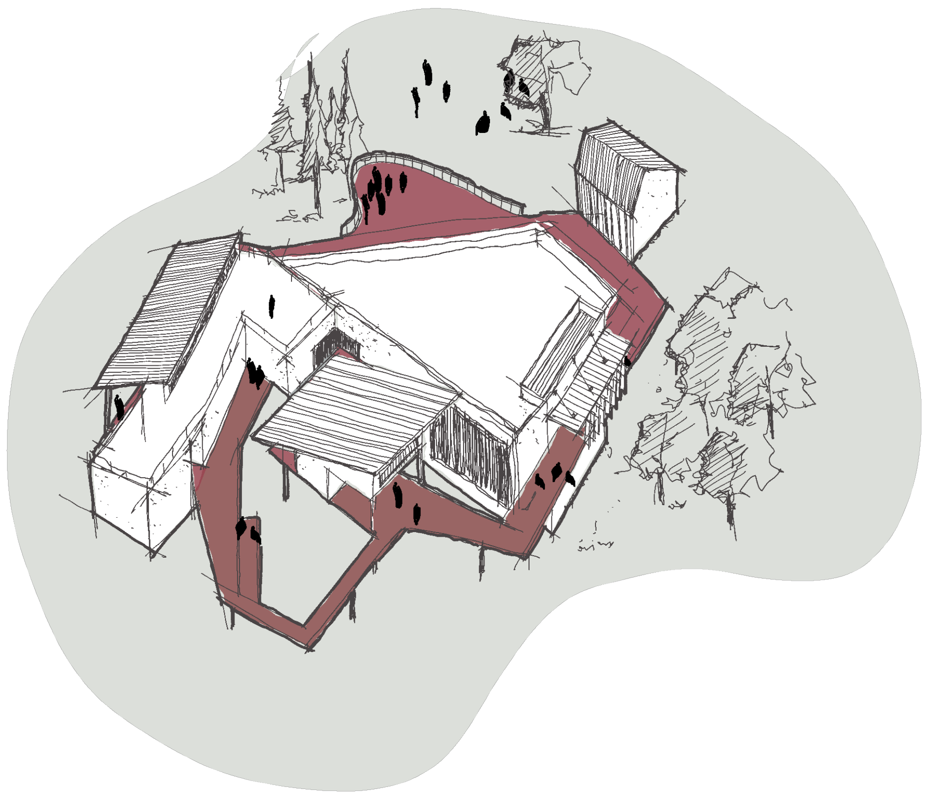


Fig. 33
Concept drawing

Key parameters

In design phases, the key parameters below reflected by the local meteorological data need to be considered. By the testing process, to find out a balanced result with both sufficient daylight performance and fulfilling the requirement of Passive house.

Schematic Design Phase:

- Orientation (the main factor determining solar access)
- The compactness of the building (for a better energy efficiency)
- Form with Simple geometric

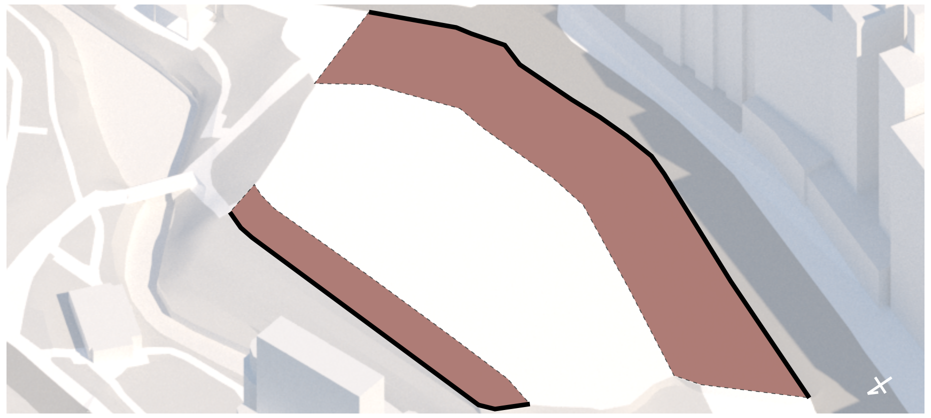
Detail Design Phase:

- Opaque building envelope (Construction and insulation systems)
- Transparent building envelope (Glazing | Windows | Doors)
- Median daylight factor of every main areas should be between 2%-4.5%.
- Mechanical systems (Ventilation units | Heating(Cooling) system)

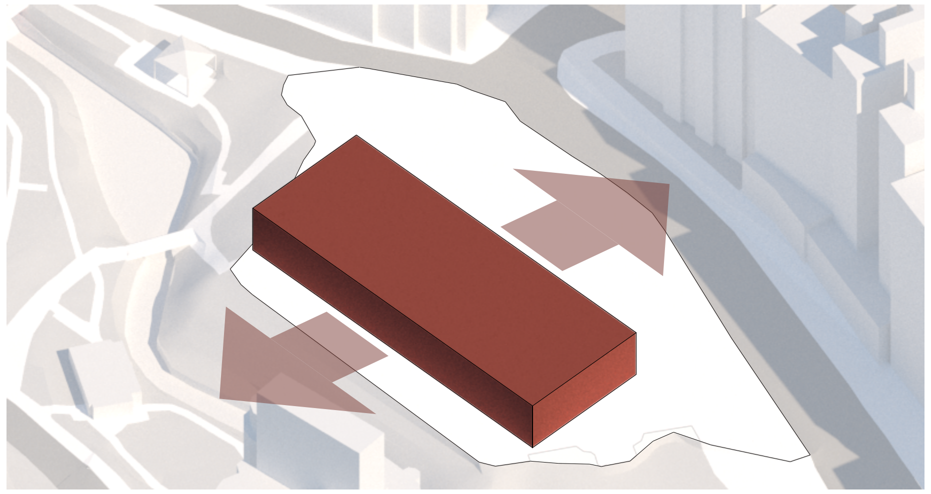
Schematic Design

The development of the basic prototype

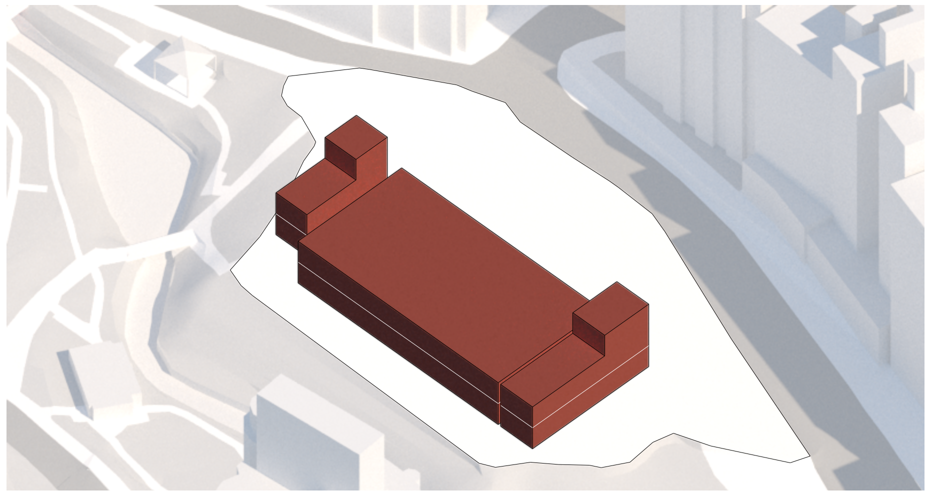
1. Open space
The creek-side space and the front plaza space are preserved to respond to the hot spring creek on the north side and the main road on the south side.

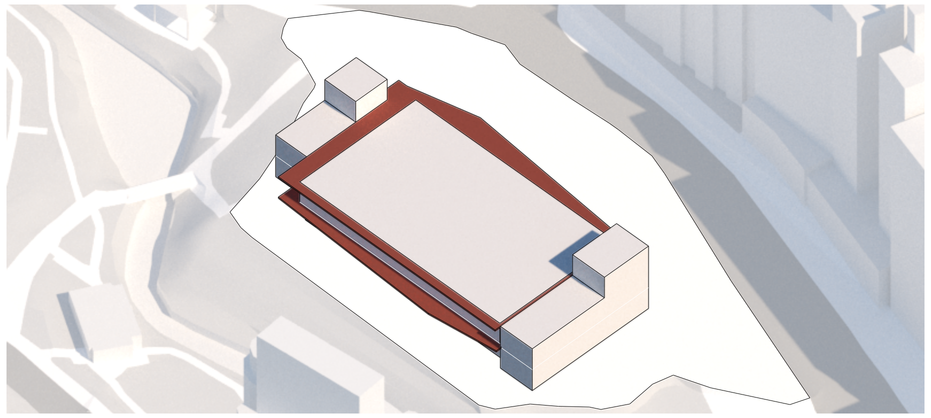


2. Configuration
The configuration of the building volume is designed to maximize energy efficiency while ensuring indoor thermal comfort and air quality with minimal energy consumption. This is achieved by adopting a compact rectangular volume and orienting the longer side of the rectangle in a north-south direction, thereby reducing heat absorption from the east and west sides, which are the primary sources of heat radiation.

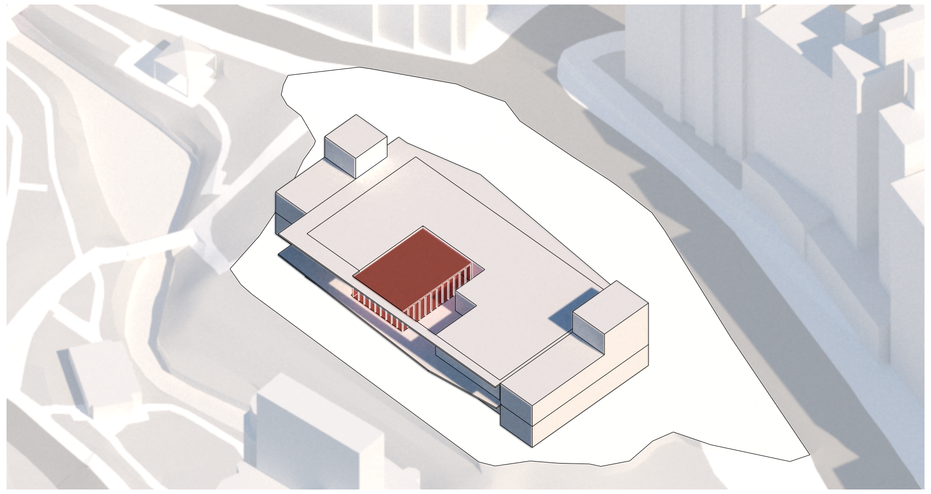


3. Divide
The building volume is divided into the central main volume and two subsidiary volumes on the sides. The main functions of the library are consolidated within the main volume to enhance the efficiency of energy usage. Service spaces such as stairwells, restrooms, and utility rooms are located in the subsidiary volumes on the east and west sides. Additionally, these subsidiary volumes serve as physical barriers to block heat radiation from the east and west sides toward the main volume.

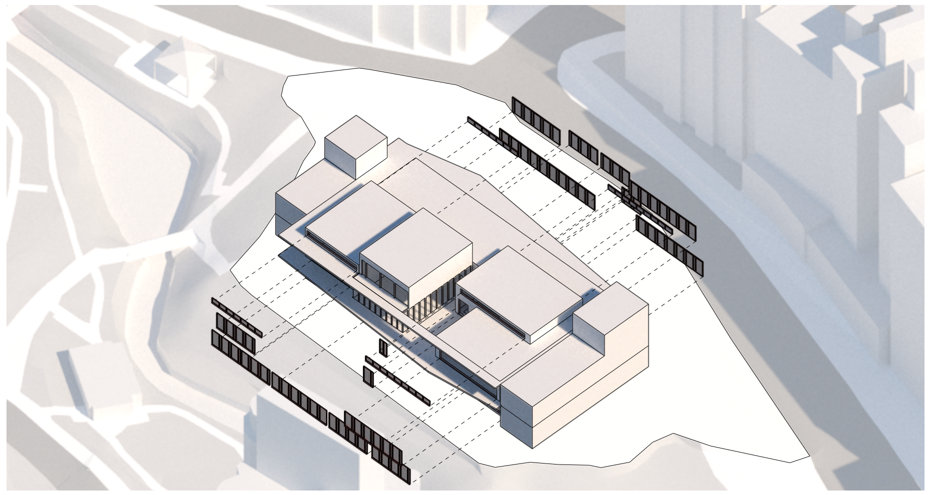




4. Connections
Surround the building volume with a corridor, which not only serves as an external sunshade but also connects volumes with volumes and spaces with spaces.



5. "Ohiroma" and "Hiroen"
Incorporate the spatial concept of "Ohiroma", and transform the corridor into a "Hiroen" thus creating an ambiguous zone between indoor and outdoor spaces. the boundaries of the space become fluid, allowing users to define it for themselves and encouraging interactions with the natural outdoor environment, whether it's walking, stopping, sitting, or lying down.



6. Daylight capture
Maximize the window area on the north and south sides of the building to capture the maximum daylighting area on these two sides with less heat radiation, thus reducing the need for artificial lighting. Additionally, add side skylights in the main space on the first floor to supplement the interior's central daylighting requirements and provide a more comfortable ceiling height.

Detail Design

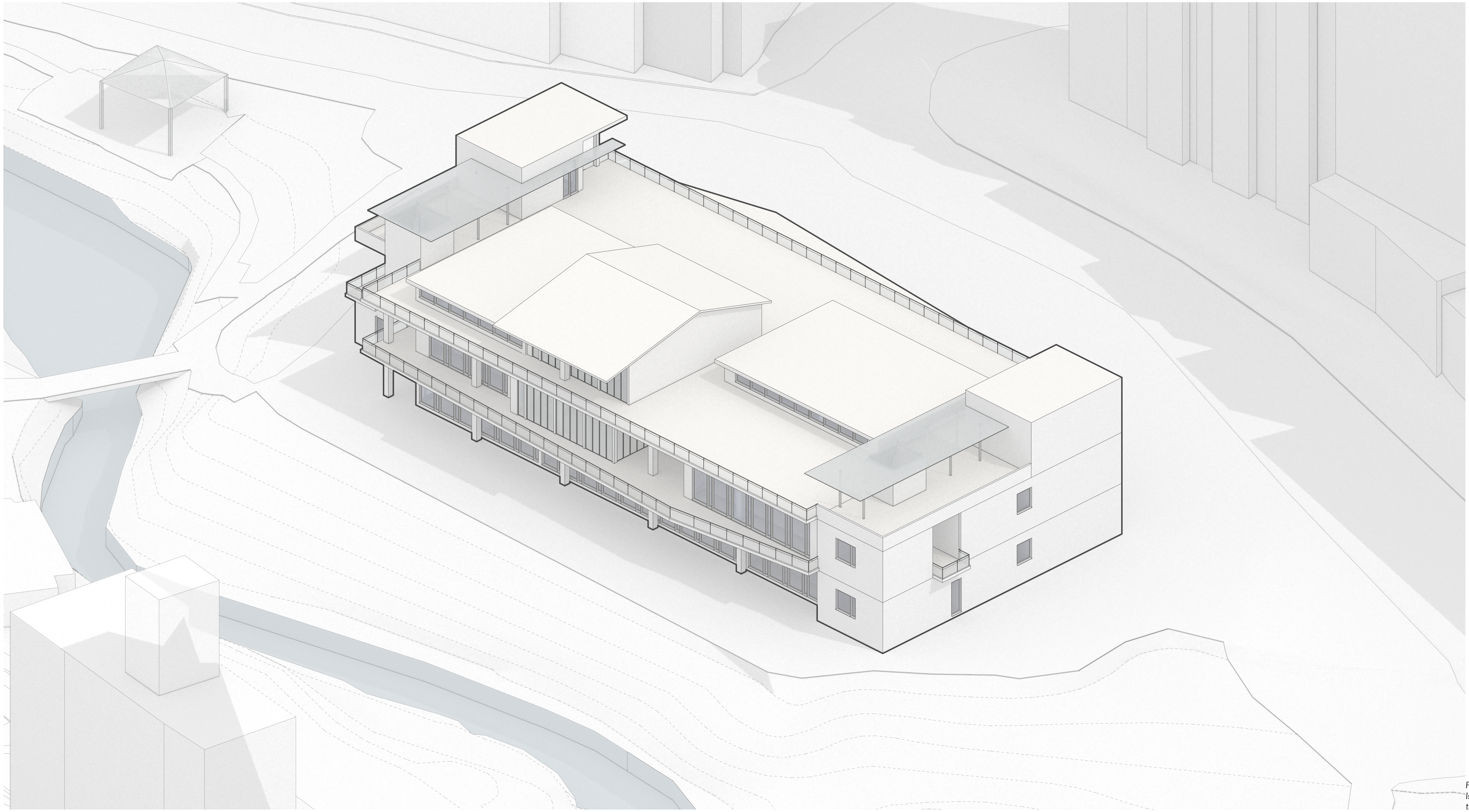


Fig. 34
Isometric veiw of the original type

Daylight visualization
-Basic prototype

Analyze the daylight performance of the original type (maximizing window area) using the VELUX Daylight Visualizer, assess the Median daylight factor for each major space within the main volume. This helps identify which spaces have a median daylight factor exceeding 4.5%, indicating potential issues with over-brightness and overheating. The results serve as the target for optimizing the design in the following steps..

The simulation results indicate that the median daylight factor for the two multifunction rooms on the ground floor, the two discussion rooms, and the open shelf area on the first floor exceeds 4.5%. This means there is a risk of excessive brightness and overheating in these spaces. Therefore, the following steps focus on adjusting and optimizing these areas for the best solution.

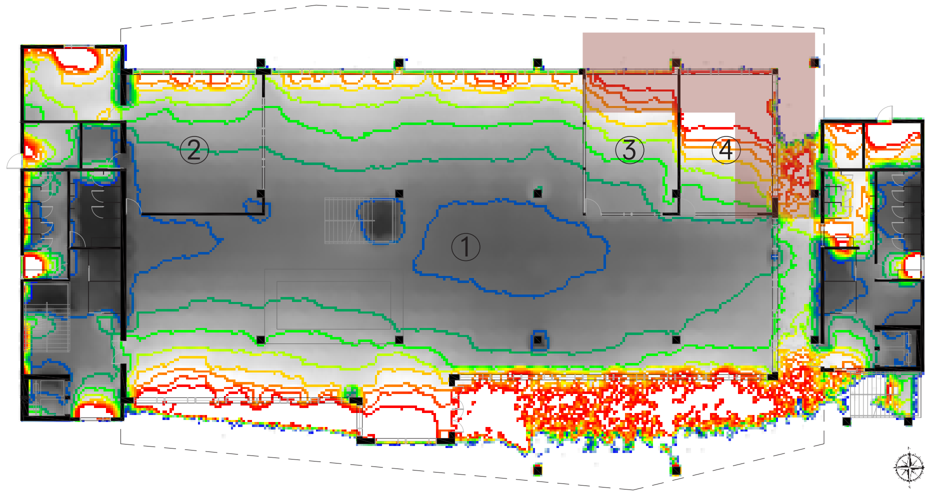


Fig. 35
Velux daylight simulation of the ground floor

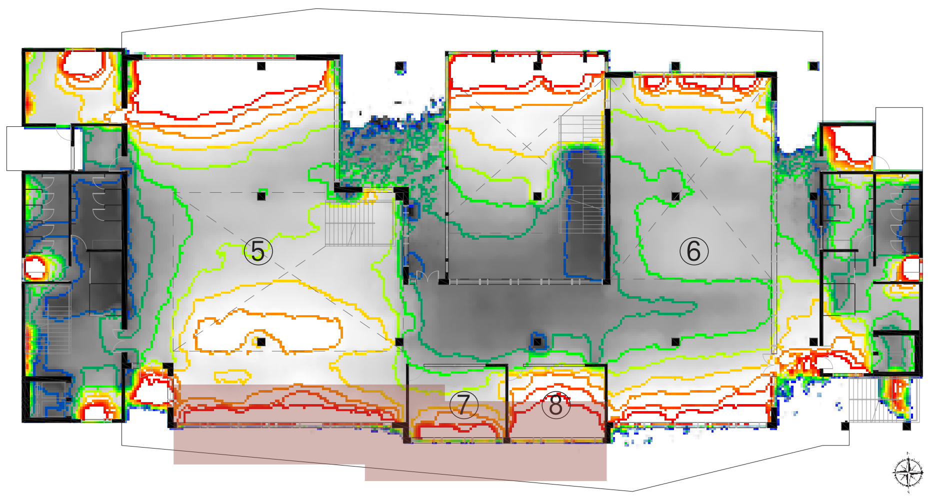
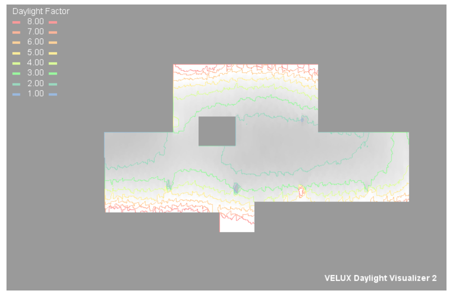
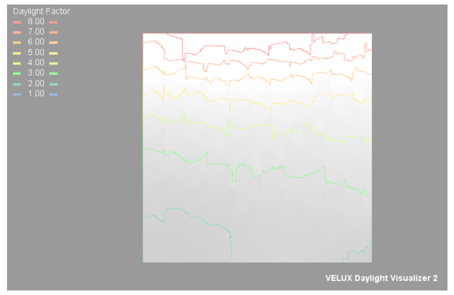


Fig. 36
Velux daylight simulation of the first floor



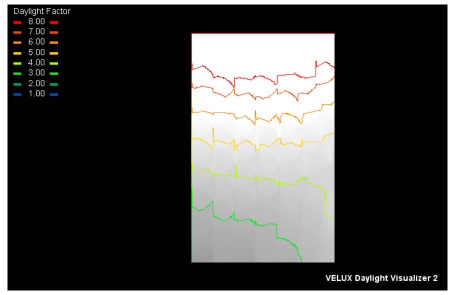
1. Entrance hall & Children's area

D_m : 2.90%
D_{av} : 3.48%
D_{TM} (Above 0.7%) : 99%



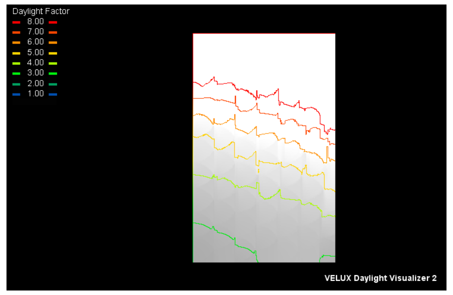
2. Staffs office

D_m : 3.47%
D_{av} : 4.04%
D_{TM} (Above 0.7%) : 100%



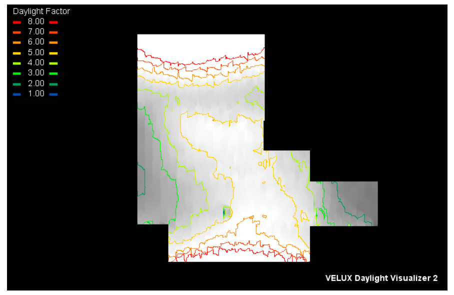
3. Activity room A

D_m : 4.81%
D_{av} : 5.41%
D_{TM} (Above 0.7%) : 100%



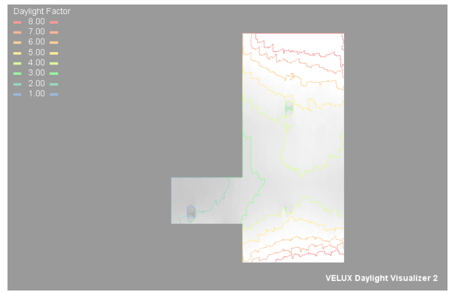
4. Activity room B

D_m : 5.44%
D_{av} : 6.20%
D_{TM} (Above 0.7%) : 100%



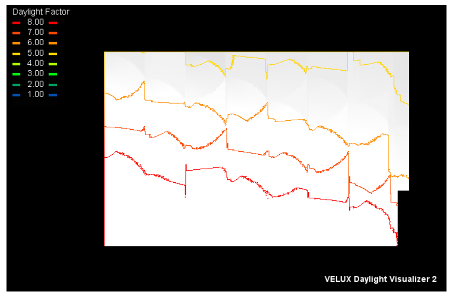
5. Open shelf area

D_m : 4.64%
D_{av} : 4.97%
D_{TM} (Above 0.7%) : 99%



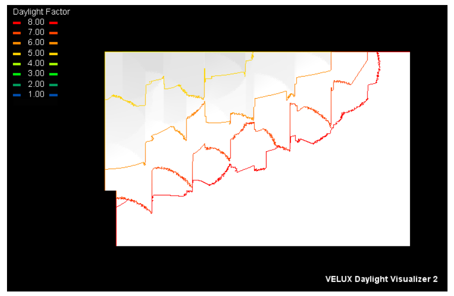
6. Periodicals area

D_m : 4.38%
D_{av} : 4.76%
D_{TM} (Above 0.7%) : 99%



7. Discussing room A

D_m : 6.75%
D_{av} : 7.10%
D_{TM} (Above 0.7%) : 100%



8. Discussing room B

D_m : 7.87%
D_{av} : 7.98%
D_{TM} (Above 0.7%) : 100%

D_m : Median daylight factor
D_{av} : Average daylight factor

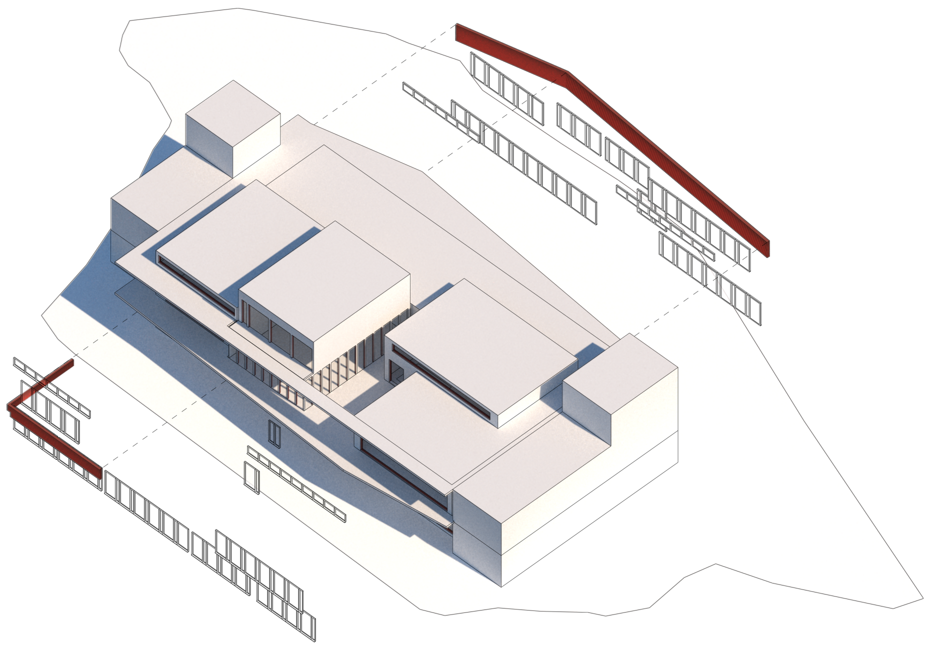
Fig. 37
Velux daylight simulation specific to each main area

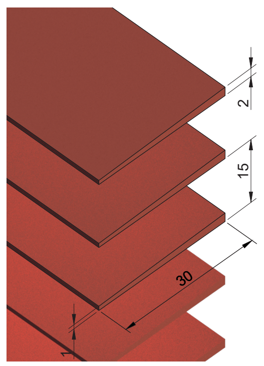
Optimization

While striving for a median daylight factor between 2% and 4.5% in each main area, it's crucial to note that the solar heat loads are impacted by changes in the building's appearance. Achieving high energy efficiency in Passive house buildings require a delicate balance between daylight performance and solar heat loads in this case.

To accomplish both the median daylight factor goal and the reduction of solar heat loads, it is suggested to utilize exterior shading devices for windows and enhance building envelope insulation (the higher U value).

Alt 1. Incorporating external shadings





This alternative preserves the same window area and adds a horizontal external shading structure resembling a louver system, starting from the ceiling height and extending downward to approximately 2.3m along the window area. The shading structure consists of panels that are 30cm wide, 2cm thick, spaced 15cm apart.

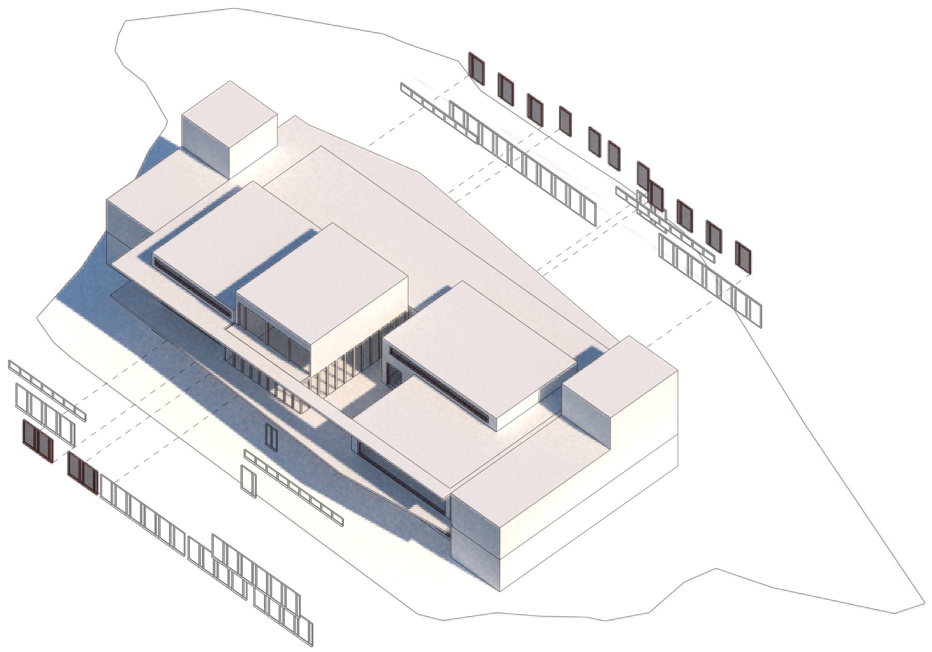
Fig. 38
Alt 1. Incorporating external shadings

Two potential solutions are under consideration to adjust spaces with excessively high median daylight factors:

1. Incorporating external shadings.
2. Reducing the window area.

Both options aim to ensure that the Median daylight factor for each main space falls within the range of 2% to 4.5%. Additionally, they target a minimum daylight factor (DTM) above 0.7% for at least 95% of the area.

Alt 2. Reducing the window area



This alternative aims to reduce the window area for spaces with a Median daylight factor exceeding 4.5%, resulting in a decrease in the overall building's window-wall ratio from the original 37.4% to 31%.

Fig. 39
Alt 2. Reducing the window area

Alt 1. Adding external shadings

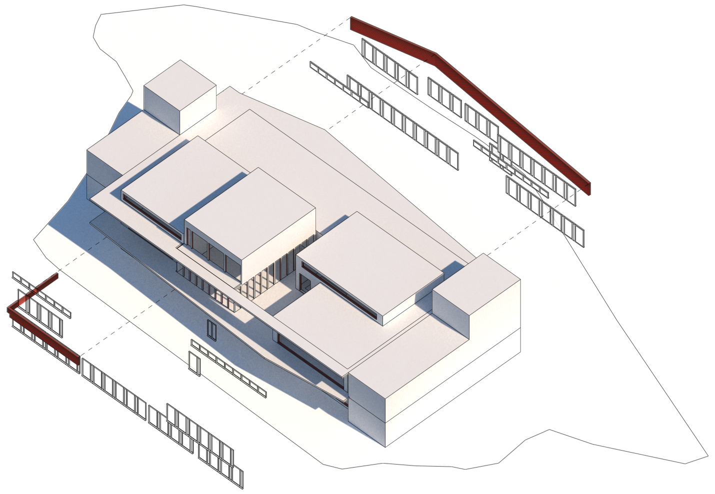


Fig. 40
Alt 1. Incorporating external shadings

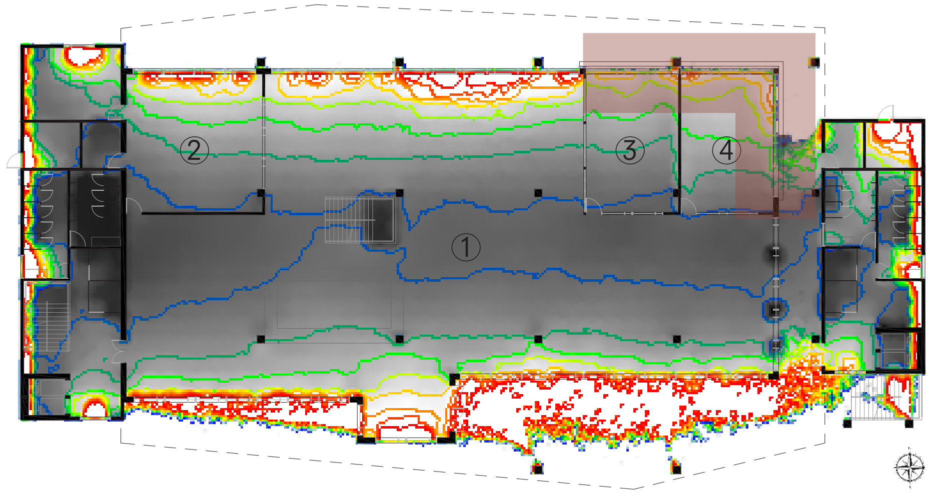


Fig. 41
Velux daylight simulation of the ground floor

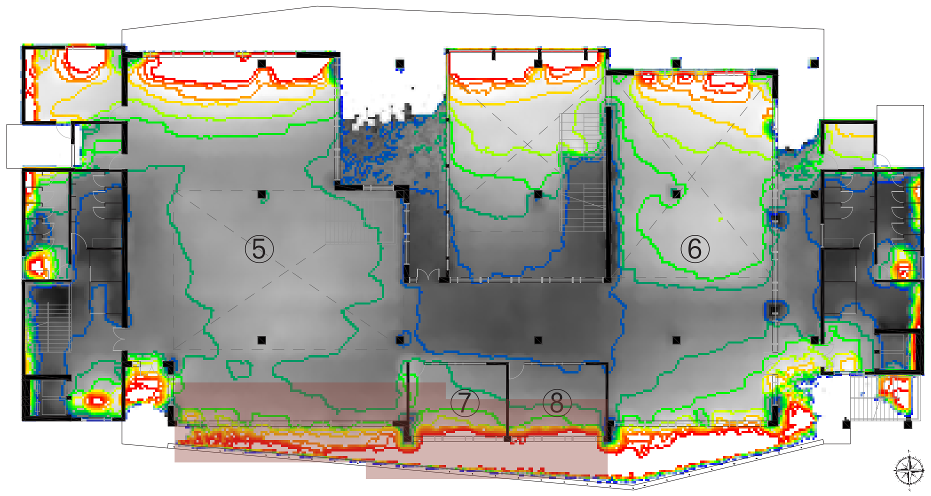
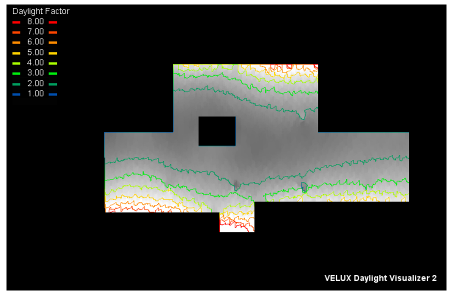
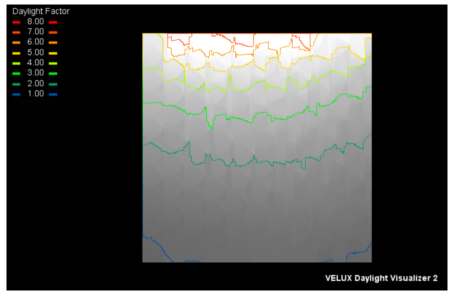


Fig. 42
Velux daylight simulation of the first floor



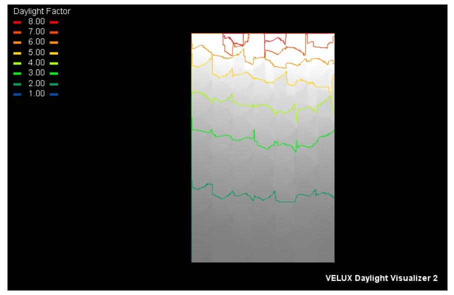
1. Entrance hall & Children's area

D_m : 2.13%
D_{av} : 2.66%
D_{TM} (Above 0.7%) : 99%



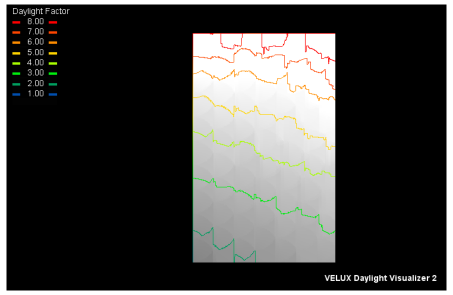
2. Staffs office

D_m : 2.14%
D_{av} : 2.65%
D_{TM} (Above 0.7%) : 100%



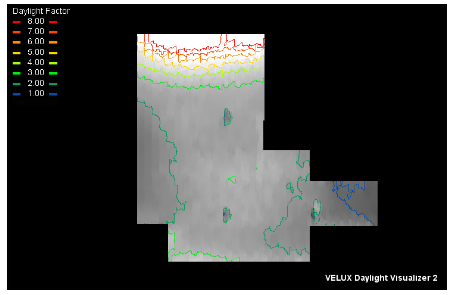
3. Activity room A

D_m : 2.80%
D_{av} : 3.34%
D_{TM} (Above 0.7%) : 100%



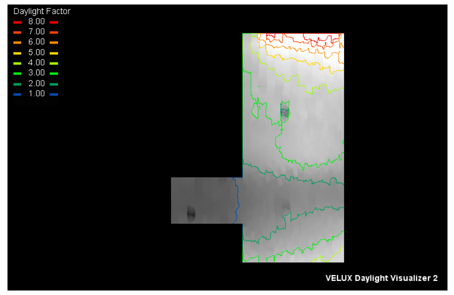
4. Activity room B

D_m : 4.16%
D_{av} : 4.46%
D_{TM} (Above 0.7%) : 100%



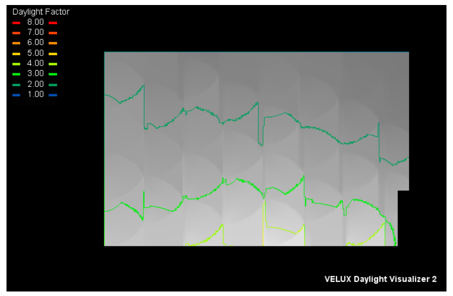
5. Open shelf area

D_m : 2.38%
D_{av} : 2.93%
D_{TM} (Above 0.7%) : 99%



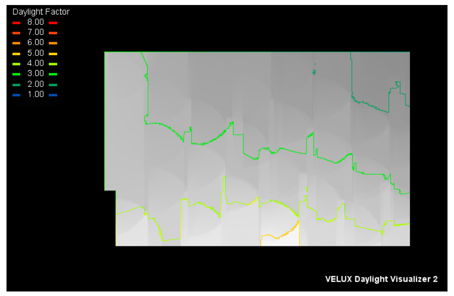
6. Periodicals area

D_m : 2.85%
D_{av} : 2.90%
D_{TM} (Above 0.7%) : 96%



7. Discussing room A

D_m : 2.23%
D_{av} : 2.39%
D_{TM} (Above 0.7%) : 100%



8. Discussing room B

D_m : 3.10%
D_{av} : 3.15%
D_{TM} (Above 0.7%) : 100%

D_m : Median daylight factor
D_{av} : Average daylight factor

Fig. 42
Velux daylight simulation specific to each main area

Alt 2. Reducing the window area

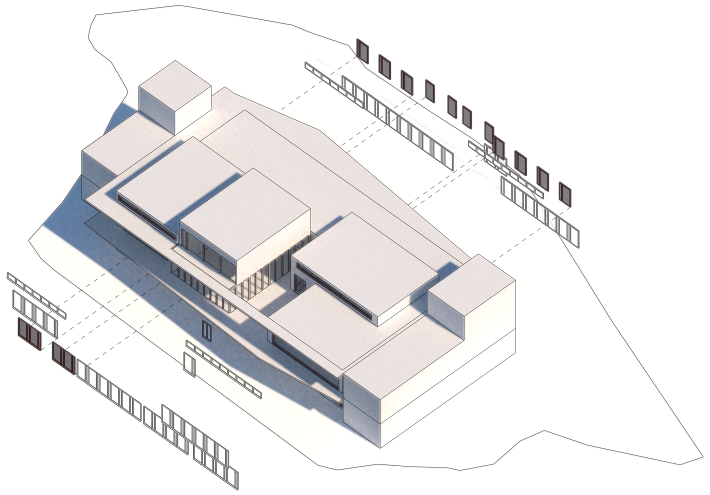


Fig. 43
Alt 2. Reducing the window area

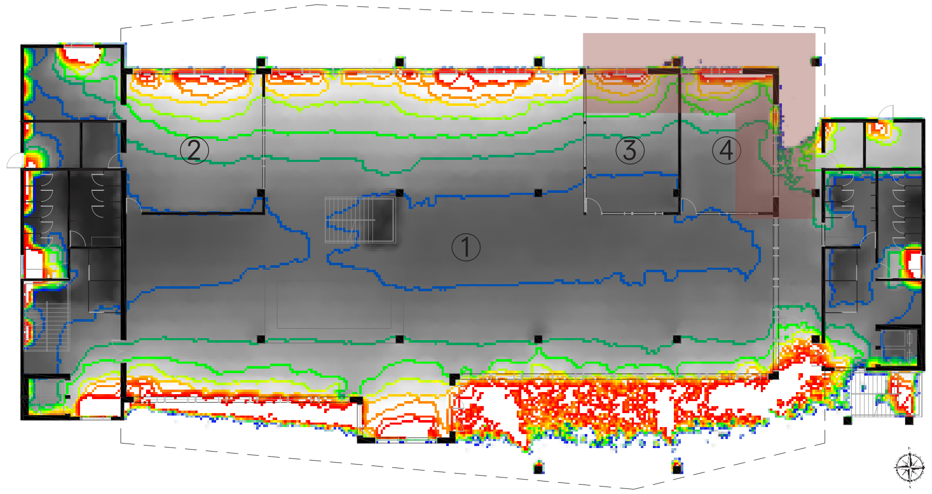


Fig. 44
Velux daylight simulation of the ground floor

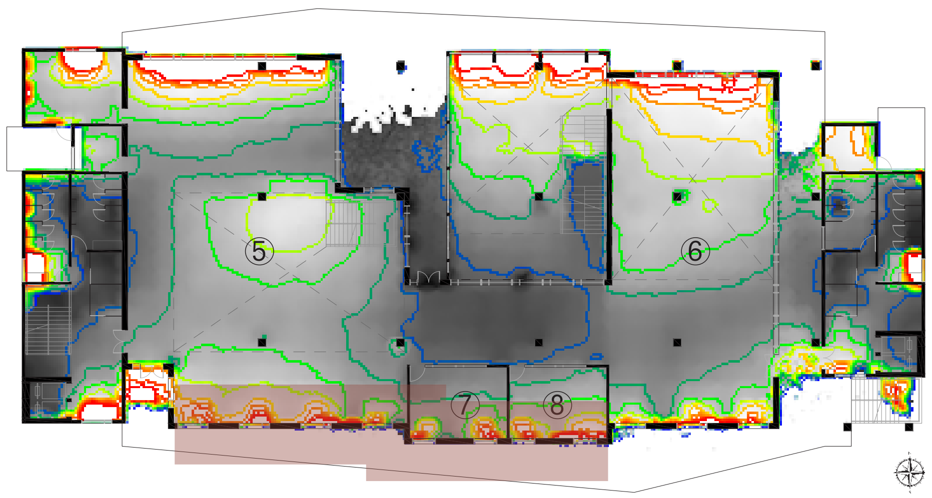
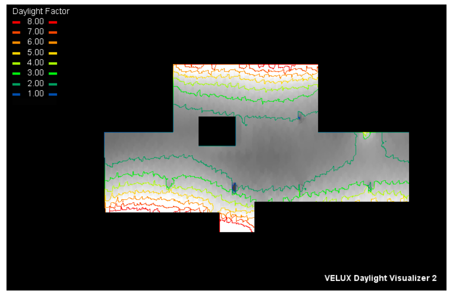
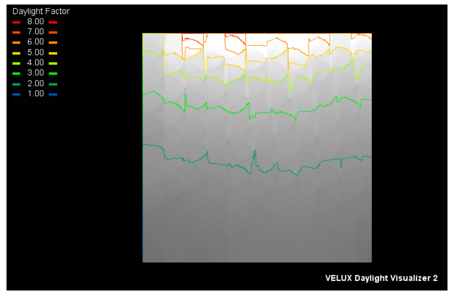


Fig. 45
Velux daylight simulation of the first floor



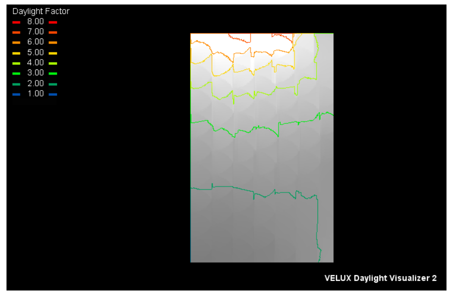
1. Entrance hall & Children's area

D_m : 2.38%
D_{av} : 3.03%
D_{TM} (Above 0.7%) : 99%



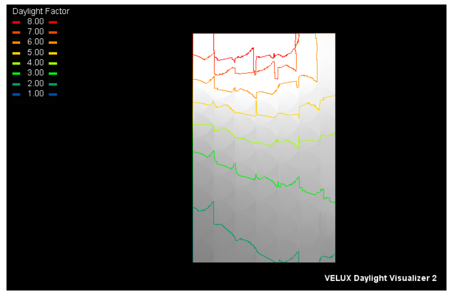
2. Staffs office

D_m : 2.18%
D_{av} : 2.66%
D_{TM} (Above 0.7%) : 100%



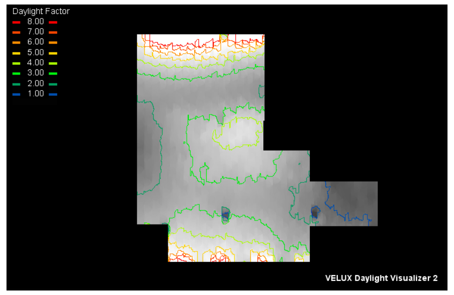
3. Activity room A

D_m : 2.52%
D_{av} : 3.02%
D_{TM} (Above 0.7%) : 100%



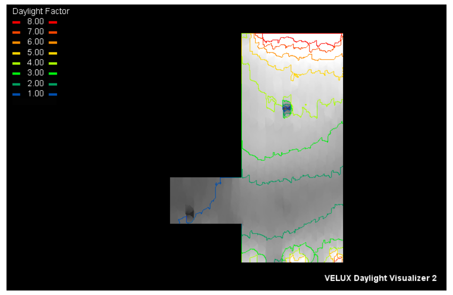
4. Activity room B

D_m : 3.67%
D_{av} : 4.20%
D_{TM} (Above 0.7%) : 100%



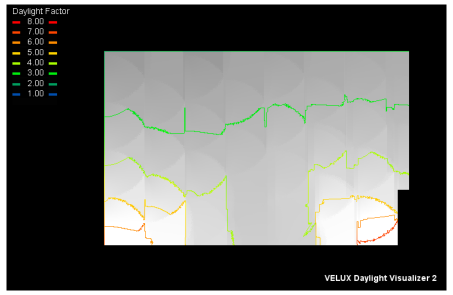
5. Open shelf area

D_m : 2.63%
D_{av} : 3.00%
D_{TM} (Above 0.7%) : 97W%



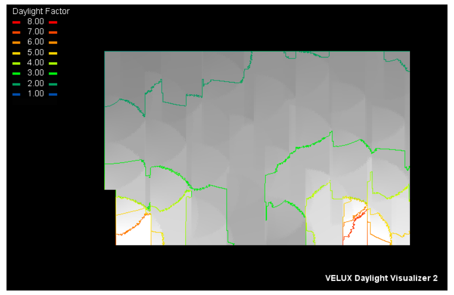
6. Periodicals area

D_m : 2.90%
D_{av} : 3.16%
D_{TM} (Above 0.7%) : 98%



7. Discussing room A

D_m : 3.46%
D_{av} : 3.64%
D_{TM} (Above 0.7%) : 100%



8. Discussing room B

D_m : 2.67%
D_{av} : 2.95%
D_{TM} (Above 0.7%) : 100%

D_m : Median daylight factor
D_{av} : Average daylight factor

Fig. 46
Velux daylight simulation specific to each main area

Passive house Examination -Parameters of Components

The primary challenge in this project is insulating outdoor sulfur gas while addressing the essential cooling and dehumidification requirements in Taiwan, particularly in the subtropical region. Consequently, concerning the equipment system, in addition to ensuring high airtightness of the building envelope and the filtration performance of the outdoor unit, a key component is the energy recovery ventilation system (ERV System) with high humidity recovery. Mainly during winter, when temperatures drop, it's crucial to maintain lower moisture levels indoors to sustain low relative humidity. In this project, a 70% recovery rate, the ERV system is implemented.

In terms of the building envelope, the building components are insulated with thermal materials to prevent heat transfer from outside.

The parameters for PHPP employed in this thesis are based and revised on research and recommendations from the Passive House Institute (PHI) for hot-summer, warm-winter climate zones. These parameters are further tested and adjusted through PHPP to achieve that at least one of the alternatives meets the minimum Passive house standards.

Given that this project emphasizes natural lighting, the window area is larger than typical to maintain a Median Daylight Factor between 2% and 4.5%. Consequently, to reduce cooling demands while accommodating large windows, the U-value of the roof and floor is set lower than the recommendations for the Hot Summer, Warm Winter climate zone from PHI.

Treated floor area (TFA)

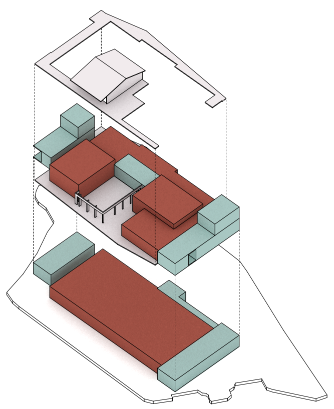


Fig. 47
For calculating the treated floor area, each area within the thermal envelope are weighted(100% or 60%) by the different usefulness of the building.

TFA considered 100%
TFA considered 60%

In the PHPP, the calculation of TFA distinguishes the spaces in building envelope into main spaces (100% taken into accounts), and auxiliary rooms, circulation areas (60% taken into accounts) depending on the use of the rooms.
This done is in order to encourage efficient use of high quality spaces inside the thermal envelope and to take into account the various internal heat gains.
Therefore, except the TFA of the main spaces within the central volume is considered as 100%, the spaces in the side volumes and circulation areas is considered as 60%.

SUBJECTS	PARAMETERS	
	Design project	Recommendation of Hot Summer Warm Winter by PHI (Wolfgang Feist, 2016)
External Wall: U-value [W/(m²k)]	0.335	0.34
Roof: U-value [W/(m²k)]	0.216	0.36
Floor : U-value [W/(m²k)]	0.596	2.27
Absorption coefficient roofs	0.60 (untreated wood)	0.25 (white, smooth surfaces)
Absorption coefficient walls	0.60 (untreated wood)	0.25 (white, smooth surfaces)
Window frame: U-value [W/(m²k)]	1.6	1.6
Glazing of windows: U-value [W/(m²k)] / g-value	1.19 / 0.31	1.19 / 0.31
Air change rate at 50 pa [h⁻¹]	0.6	0.6
Efficiency of heat recovery	0.74	0.7
Efficiency of humidity recovery	0.70	0.7
Night ventilatiion via windows	no	no
Active cooling	yes	yes
Heating	air HP(Combined ventilation units)	air HP(Combined ventilation units)
Cooling	air HP(Combined ventilation units)	air HP(Combined ventilation units)
Dehumidification	additional dehumidificator	additional dehumidificator

Filter for removing sulfur gas (SO_2)

Product number:
CITYCARB E by Camfil
For gas as SO_2, NO_3, Ozone

A compact V-Bank air filter with particulate and molecular media to remove solid and gaseous contaminants in one filter stage. It can be used in existing installations to remove medium concentrations of most external and internal pollutants with ePM10 80% efficiency according to ISO16890.

Fig. 48
Air filter for sulfur gas

Result of PHPP examination

Through the process of testing different parameters and simultaneously evaluating two alternatives, the results indicate that the Alt 2. can, using the same parameter settings, achieve the Passive house standards first.

Upon reviewing the data, it is evident that the Alt 2. outperforms the Alt 1. by a slight margin in terms of energy demand in both space heating and space cooling. This result suggests that, in terms of energy performance for thermal comfort, reducing the window area is more effective than adding an external shading facilities.

In conclusion, the final proposal is the Alt 2, which involves reducing the window area.

Alt 1. Adding external shadings

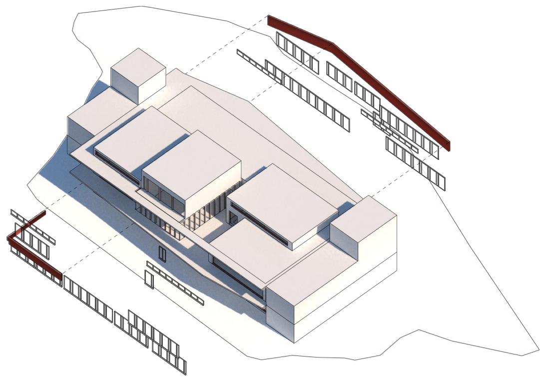


Fig. 49
Alt 1. Incorporating external shadings

• Treated floor area	m^2	1838.2			
• Space heating					
Heating demand	kWh/(m^2a)	1.4	≤	15	●
Heating load	W/m^2	9	≤	10	●
• Space cooling					
Cooling + Dehum. demand	kWh/(m^2a)	29.2 +22.7	≤	51	○
Frequency of excessively high humidity(> 12 g/kg)	%	0	≤	10	●
• Airtightness					
Pressurisation test result n_{50}	1/h	0.6	≤	0.6	●
• Primary Energy Renewable (PER)					
PER demand	kWh/(m^2a)	57.7	≤	60	●
PER gerneration	kWh/(m^2a)	65	≥	60	●
Passive house Plus					Not Achieved

Alt 2. Reducing the window area

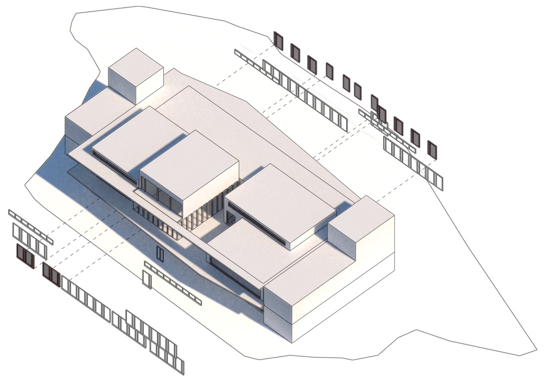
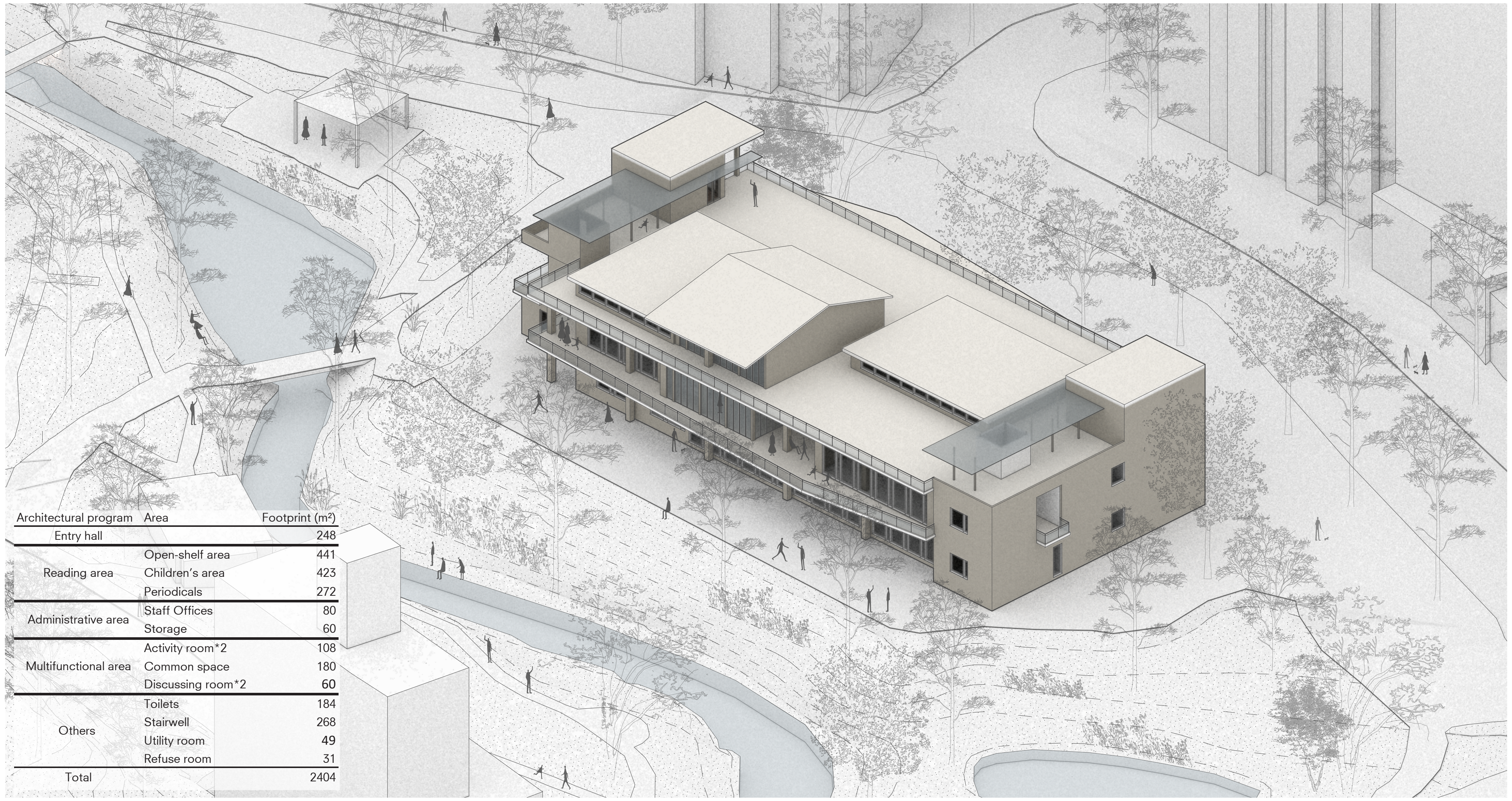


Fig. 50
Alt 2. Reducing the window area

• Treated floor area	m^2	1838.2			
• Space heating					
Heating demand	kWh/(m^2a)	1.2	≤	15	●
Heating load	W/m^2	8	≤	10	●
• Space cooling					
Cooling + Dehum. demand	kWh/(m^2a)	28.3 +22.7	≤	51	●
Frequency of excessively high humidity(> 12 g/kg)	%	0	≤	10	●
• Airtightness					
Pressurisation test result n_{50}	1/h	0.6	≤	0.6	●
• Primary Energy Renewable (PER)					
PER demand	kWh/(m^2a)	56.8	≤	60	●
PER gerneration	kWh/(m^2a)	65	≥	60	●
Passive house Plus					Achieved

E. PROPOSAL



Architectural program	Area	Footprint (m²)
Entry hall		248
Reading area	Open-shelf area	441
	Children's area	423
	Periodicals	272
Administrative area	Staff Offices	80
	Storage	60
Multifunctional area	Activity room*2	108
	Common space	180
	Discussing room*2	60
Others	Toilets	184
	Stairwell	268
	Utility room	49
	Refuse room	31
Total		2404

Fig. 51
Isometric view of the final proposal

Overall, to enhance energy efficiency, the configuration is based on a compact geometric rectangle. The building consists of a central main volume and two subsidiary volumes on the sides. This composition is reflected in the spatial distribution, with the central volume housing main spaces (reading areas, activity spaces, entrance hall, etc.), and the subsidiary volumes accommodating functions for short-term occupation (restrooms, stairwells, utility rooms, refuse rooms, etc.).

To address strong sunlight and the hot and humid environment, three main strategies are employed in the building form and window design to achieve passive house goals and excellent natural lighting:

1. Since heat radiation mainly comes from the east and west sides, the short side of the rectangular volume is placed on the east-west side to reduce the heated surface area.

2. The main volume is placed between the subsidiary volumes on the east and west sides, reducing the absorption of heat radiation in the main-use spaces through physical barriers.

3. Windows are mainly concentrated on the north and south sides, where heat radiation is lower. This strategy provides natural lighting and reduces energy consumption for artificial lighting and indoor heat gain.

The form factor is the ratio between a building's total surface area (including walls, roof, and ground floor) and its treated floor area. A smaller form factor indicates a more efficient building shape with reduced surface area from which heat can be collected. For a passive house, a form factor below 3.0 is deemed ideal. In the context of this proposal, the form factor is measured at 2.46, signifying an efficient building design with a favorable ratio of surface area to treated floor area.

On the ground floor, the entrance hall is accessed from the south. Staff offices are strategically located adjacent to the entrance hall, facilitating efficient management and emergency response. Additionally, they are positioned next to the children's reading area for convenience.

Additionally, two multifunctional activity rooms are provided to meet the community's needs for children's activities. One of these rooms is separated from the children's area by sliding partitions, allowing for flexible use of space. These partitions can be opened to connect with the children's area when necessary.

On the first floor, inspired by the Beitou Public Bathhouse, the spatial concepts of "Ohiroma" and "Hiroen" are transplanted here, aiming to extend the local cultural lifestyle. The spatial form of "Ohiroma" is presented as a common space located outside the thermal envelope and as a core, connecting indoor and outdoor.

Regarding indoor spaces, the open shelf and periodical areas are placed on the east and west sides of the common space. Additionally, two discussion rooms are placed on the south side of the connected central corridor, strategically avoiding user interference in the reading area. For outdoor spaces, this area is adjacent to the wide veranda conceptualized as "Hiroen," initiating the characteristics of the common space.

It provides interactivity between the interior and exterior through sliding partitions and windows facing the open shelf area. Additionally, the spatial configuration can be adjusted as needed to accommodate event requirements and weather.

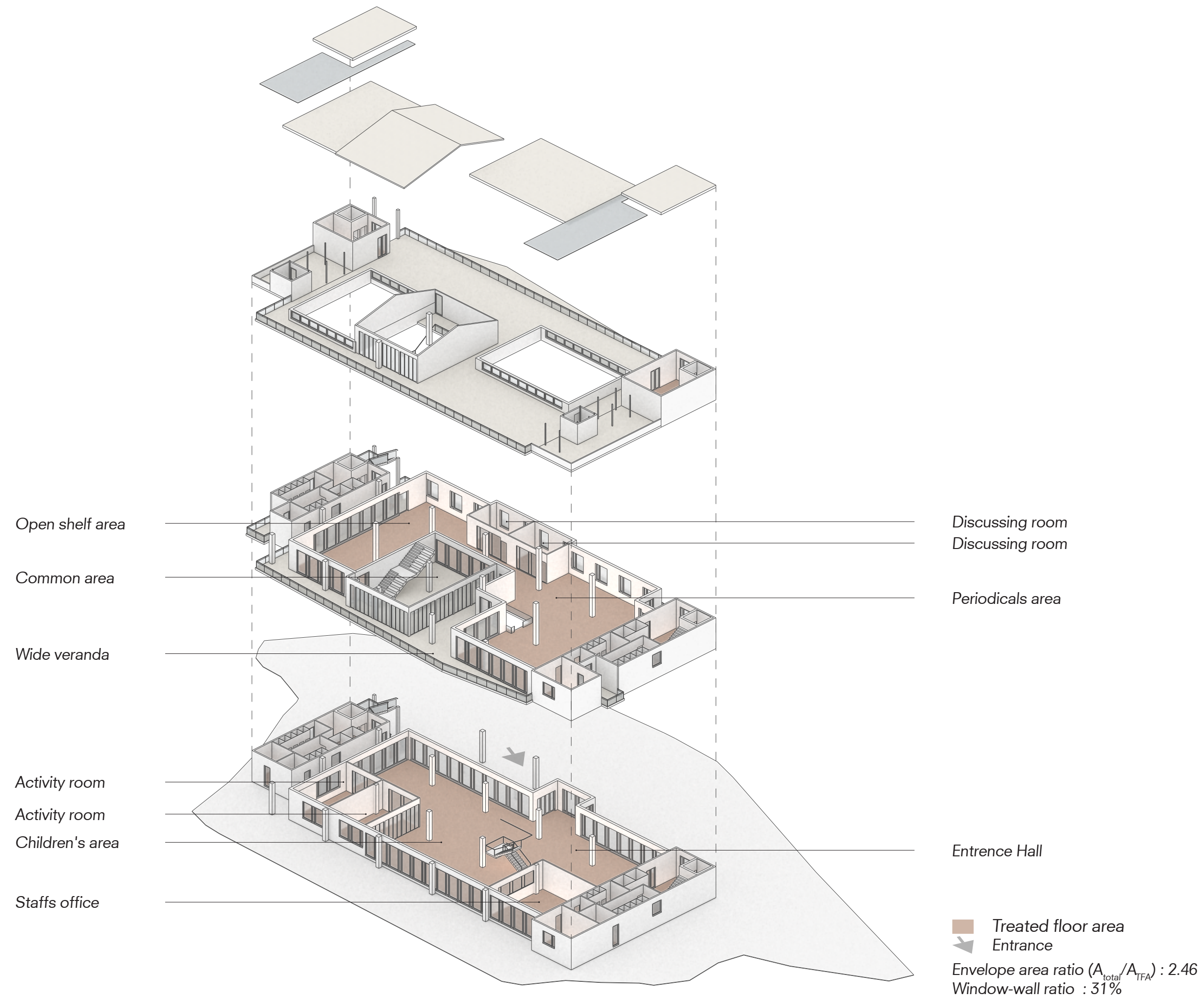


Fig. 52
architectural programmes

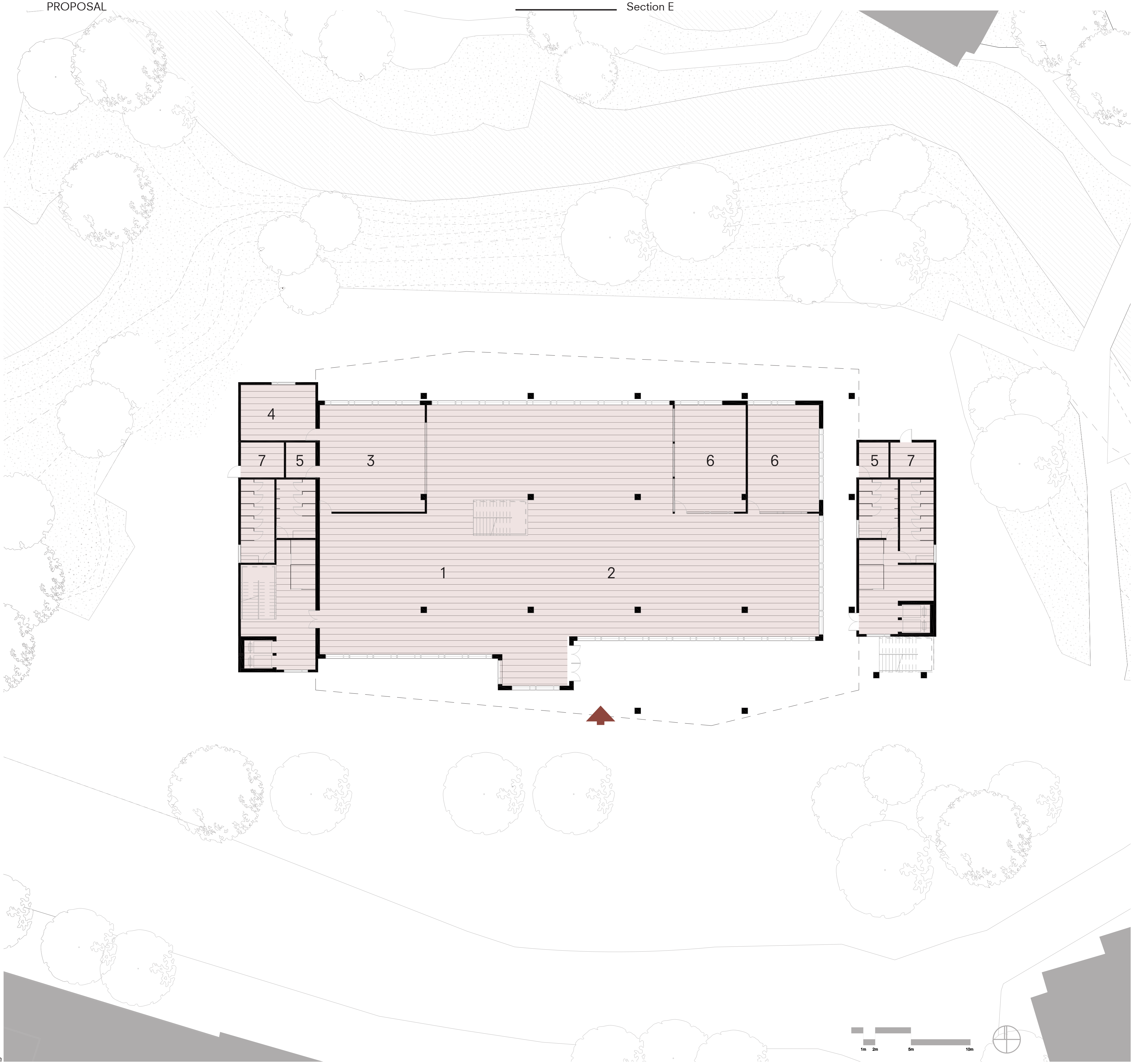


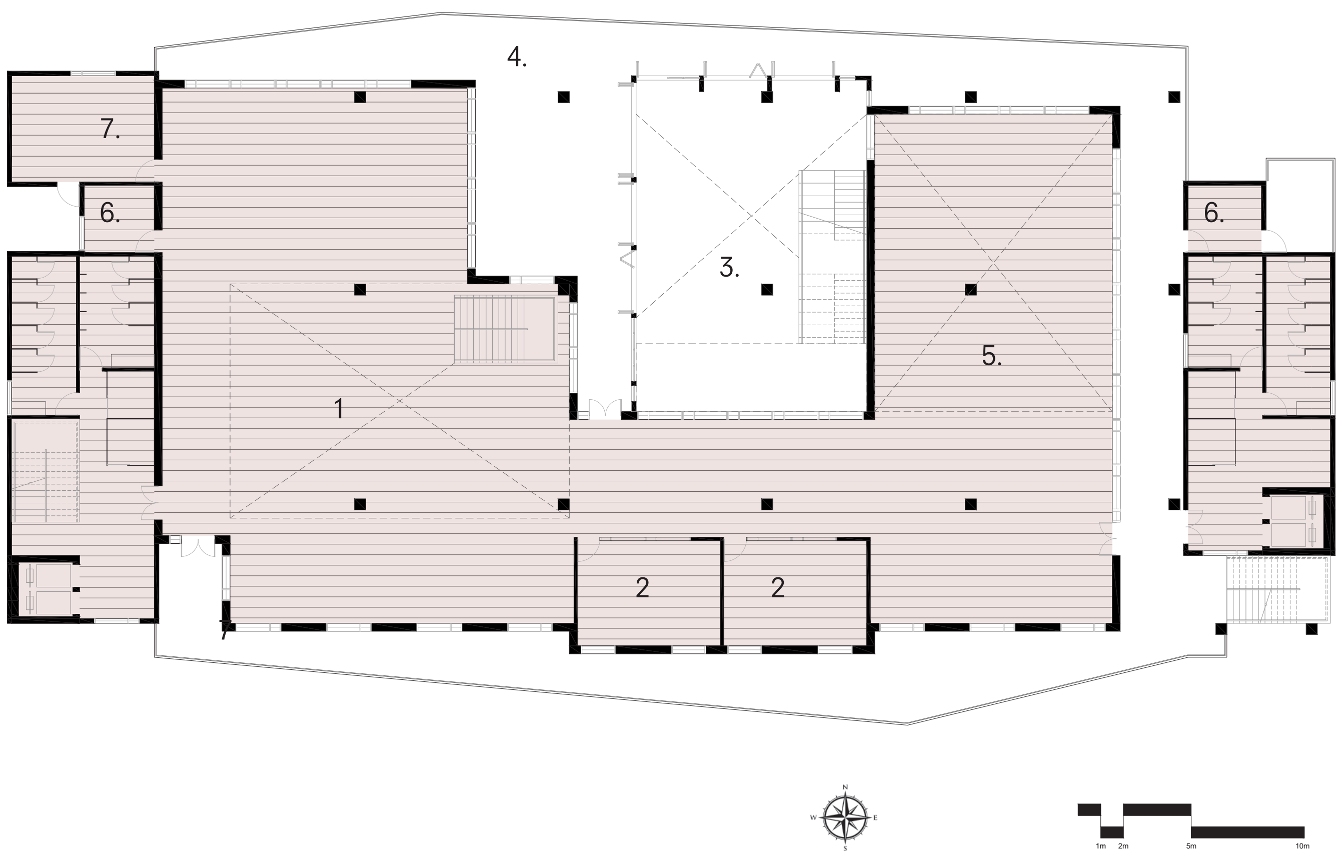
Fig. 54
Ground floor plan

Ground Floor plan

Legend

1. Entrance hall
2. Children's area
3. Staff Office
4. Storage
5. Utility Room
6. Activity room
7. Refuse room

Treated floor area



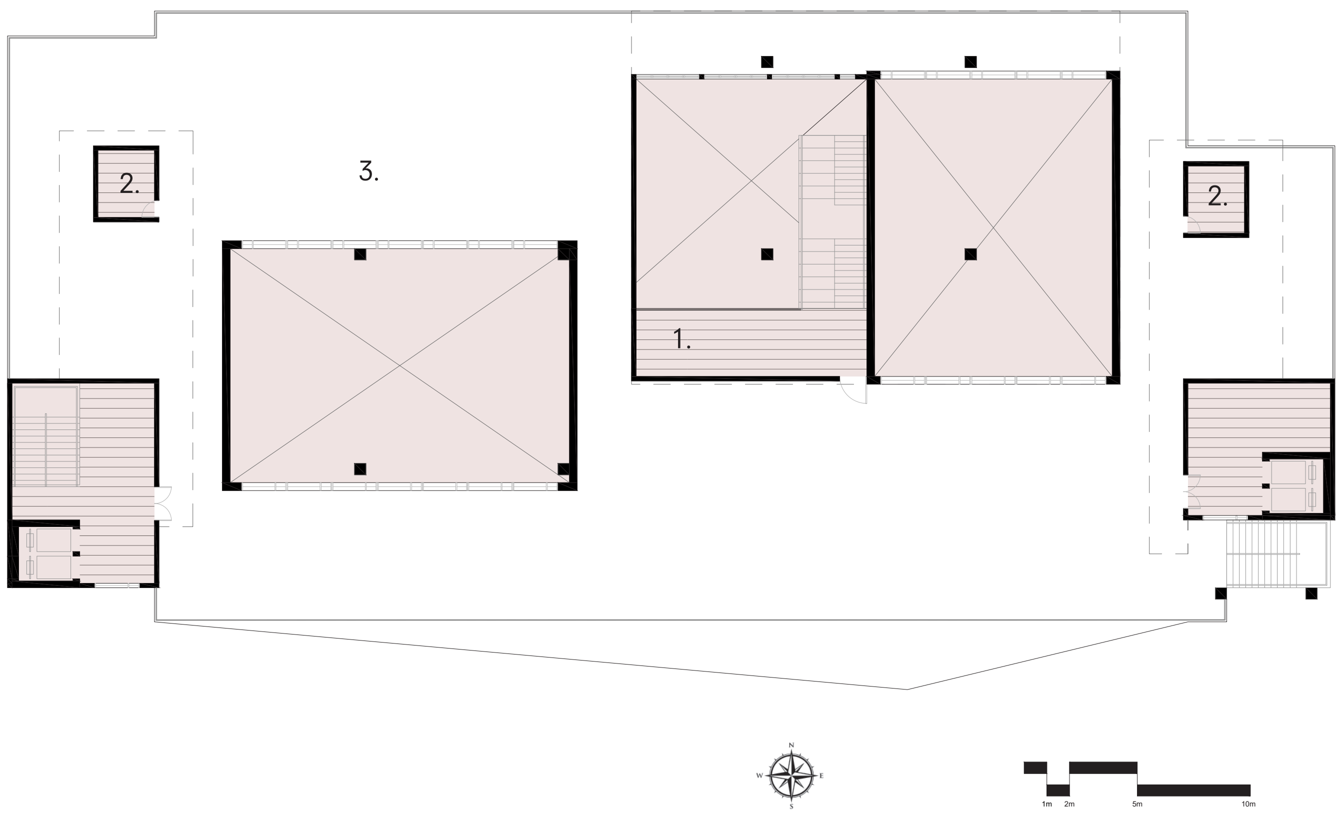
First Floor plan

Legend

1. Open shelf area
2. Discussing room
3. Common space
4. Varanda
5. Periodicals area
6. Utility Room
7. Storage

Treated floor area

Fig. 55
First floor plan



Roof top plan

Legend

1. Common space
2. Utility room
3. Roof terrace

Treated floor area

Fig. 56
Roof top plan

Common space and varanda

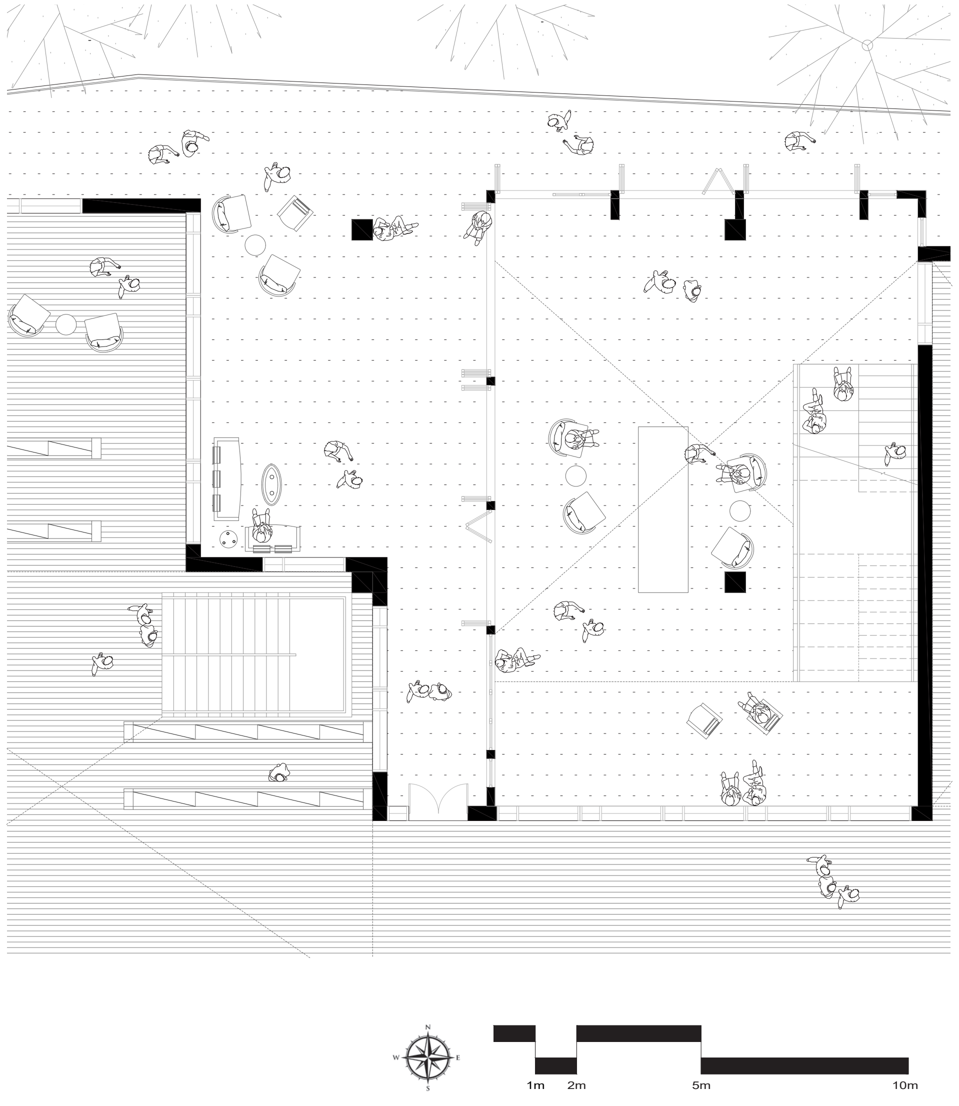


Fig. 56
Detail plan

Fig. 57
Common space and varanda

The common space serves as an intermediary between the outdoors and indoors, also functioning as a buffer zone between the thermal envelope and the outdoor environment.

In terms of spatial experience, apart from the synergy with adjacent spaces, talking to this shared space itself, the characteristic of spatial indeterminacy also acts as an intermediary space between inside and outside. In this space, users can freely sit or lie down, enjoying purposeless moments in daily life or used as a venue for community activities. Reminiscent of the "Ohiroma" and "Hiroen" in the Beitou Public Bathhouse.

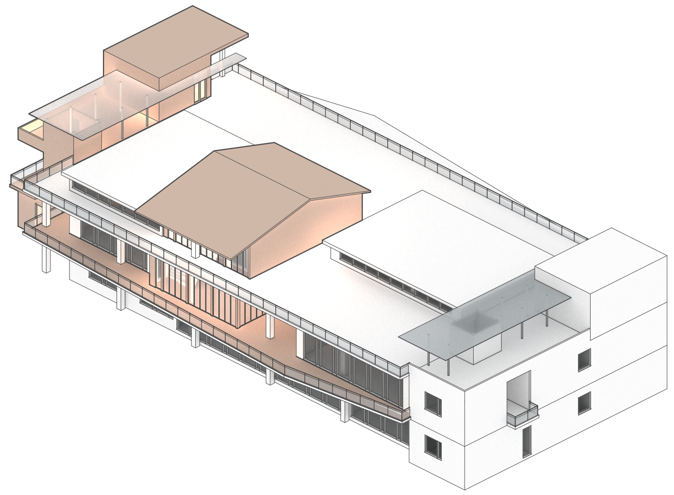
Common space and wide varanda

Being located within the hot spring park, the wide veranda surrounding the reading area and common space connect various spaces, providing an intersection between the reading space and the natural environment. In the form of an elevated pavilion within the park, it allows people to wander and experience the outdoor environment freely.

In terms of the Passive house strategy, this buffer space creates a barrier to prevent excessive heat from the sun, thereby reducing the cooling demand for the indoor reading area.

Fig. 58
Common space

Zoning management:
During the closed days, the common space on the first and top floors, including the wide veranda can be accessed independently from the east-side subsidiary volume's entrance and made available for community activities. It can also serve as a patio for residents visiting the Beitou Hot Spring Park, offering a shaded area to rest and enjoy tea under the scorching sun.



Area that can be opend during the closed days

Fig. 53
Zoning management

Detail drawings of building envelope

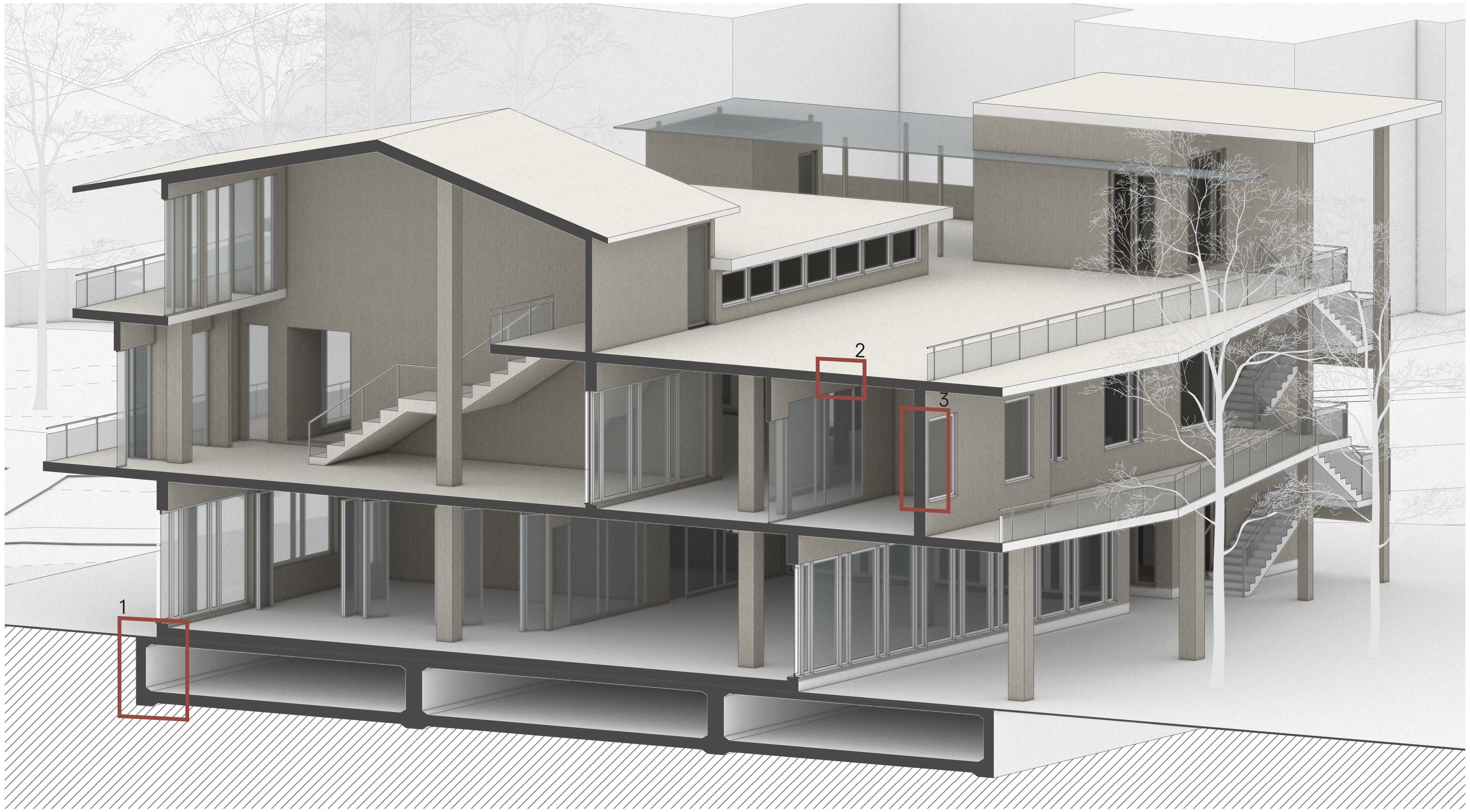
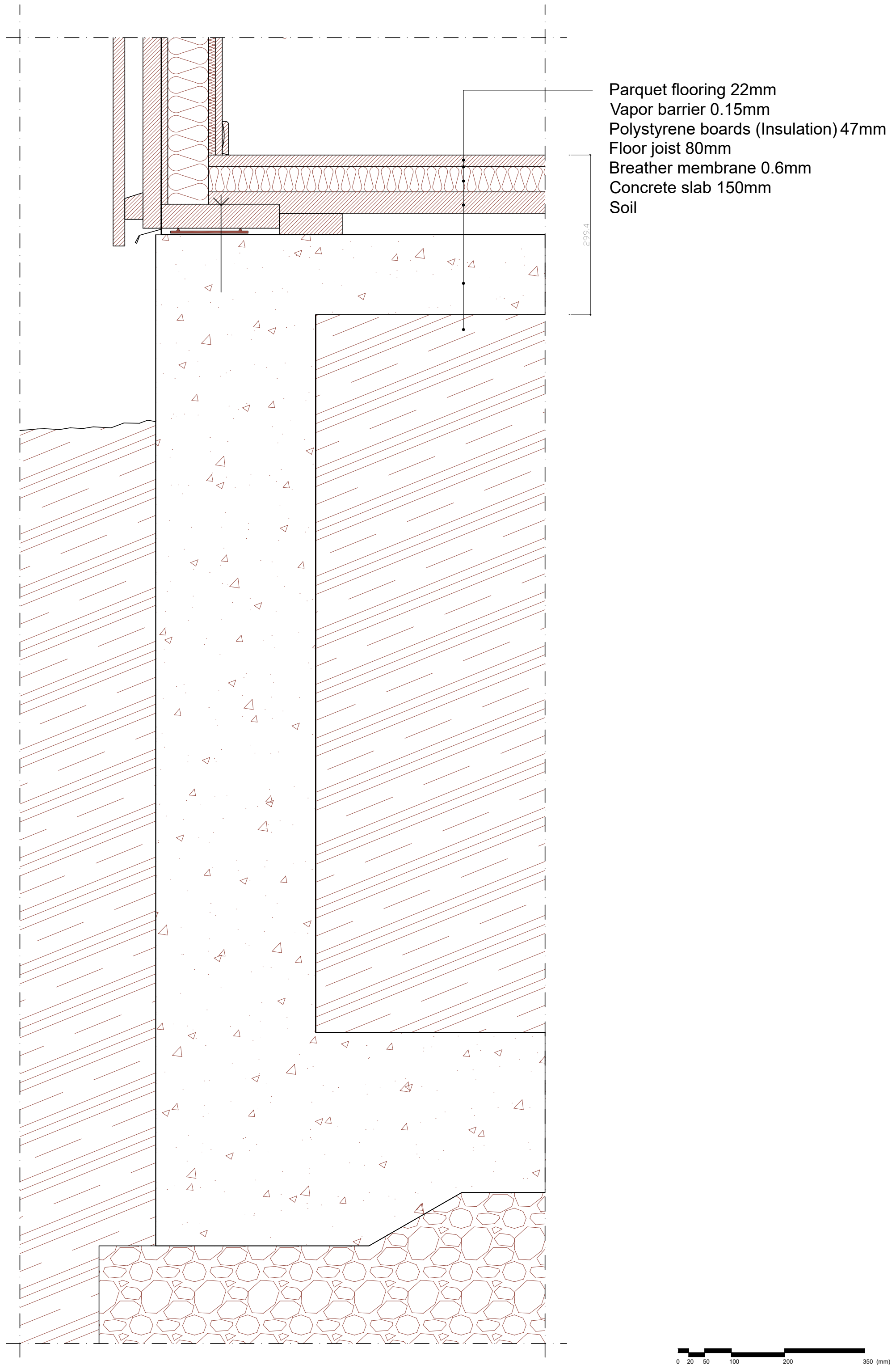


Fig. 59
Section

1. Slab and foundation

Thickness [cm]: 29.9
U value [W/(m²K)]: 0.596



Description of building assembly	Assembly no.
Floor	03ud

Orientation of building assembly (or R_{si})	0.1	Interior insulation?	
Adjacent to (or R_{se})	0	U-value supplement [W/(m²K)]	

Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
Parquet flooring	0.180					22
Vapor barrier	0.143					0
Polystyrene boards (Insulation)	0.035					47
Floor joist	2.170					80
Breather membrane	0.143					1
Concrete slab	2.100					150
Percentage of sec. 1:	100%	Percentage of sec. 2:		Percentage of sec. 3:		

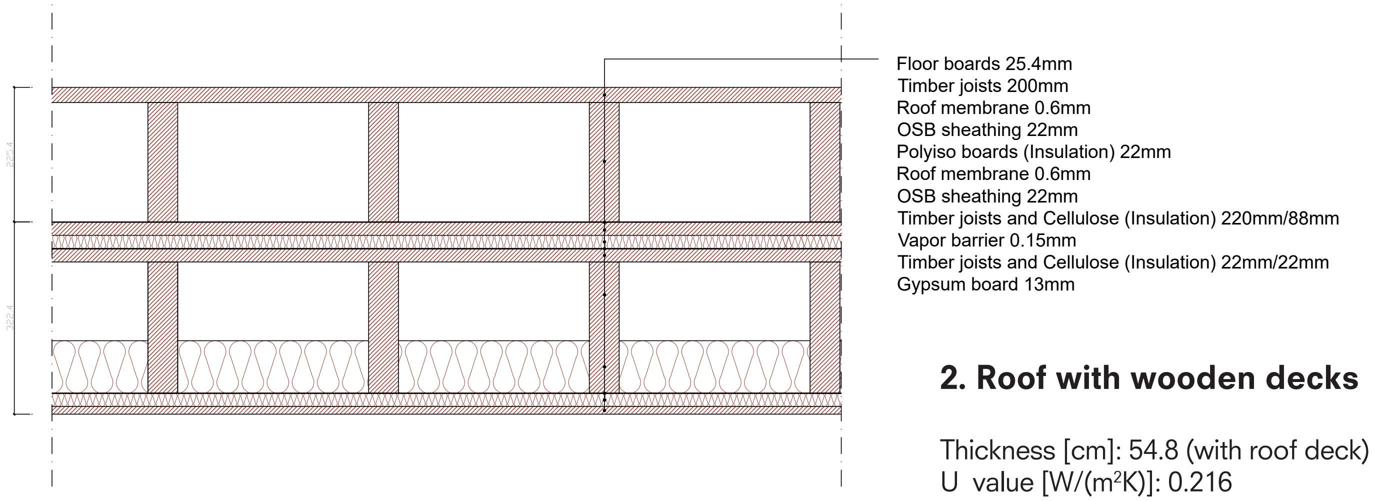
Heat transmission resistance coefficients

Interior R_{si}: 0.10 m²K/W

Exterior R_{se}: 0.00 m²K/W

Total thickness [cm]: 30.0

U-value [W/(m²K)]: 0.596

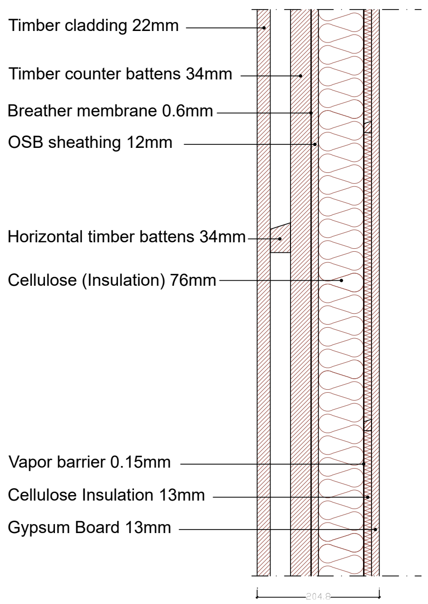


2. Roof with wooden decks

Thickness [cm]: 54.8 (with roof deck)
U value [W/(m²K)]: 0.216

Description of building assembly						Assembly no.
Roof (Timber clad)						04ud
Orientation of building assembly (or R_{si})	0.17				Interior insulation?	
Adjacent to (or R_{se})	0.04				U-value supplement [W/(m²K)]	
Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
Roof Membrane	0.143					1
OSB sheathing	0.130					22
Polyiso boards (Insulation)	0.022					22
Roof Membrane	0.143					1
OSB sheathing	0.130					22
Timber joists	0.000					132
Cellulose (Insulation)	0.038					88
Vapor barrier	0.143					0
Cellulose (Insulation)	0.038					22
Gypsum board	0.076					13
Percentage of sec. 1:	100%	Percentage of sec. 2:		Percentage of sec. 3:		

Heat transmission resistance coefficients				
Interior R_{si}:	0.17	m²K/W	Total thickness [cm]:	**32.2**
Exterior R_{se}:	0.04	m²K/W	U-value [W/(m²K)]:	**0.216**



3. Exterior wall

Thickness [cm]: 20.5
U value [W/(m²K)]: 0.335

Description of building assembly						Assembly no.
Wall(Exterior)						01ud
Orientation of building assembly (or R_{si})	0.13				Interior insulation?	
Adjacent to (or R_{se})	0.04				U-value supplement [W/(m²K)]	
Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
Timber cladding	0.130					22
Horizontal timber battens	2.170					68
Breather membrane	0.143					1
OSB sheathing	0.130					12
Cellulose (Insulation)	0.038					76
Vapor barrier	0.143					0
Cellulose (Insulation)	0.038					13
Gypsum board	0.076					13
Percentage of sec. 1:	100%	Percentage of sec. 2:		Percentage of sec. 3:		

Heat transmission resistance coefficients				
Interior R_{si}:	0.13	m²K/W	Total thickness [cm]:	**20.5**
Exterior R_{se}:	0.04	m²K/W	U-value [W/(m²K)]:	**0.335**

To harmonize with the surroundings, the choice of materials for the building's appearance plays a crucial role. In addition to using reinforced concrete for the foundation and ground-level floor slabs to mitigate moisture from the soil, the façade and roof mainly feature wooden boards similar to those used in the Beitou Hot Spring Museum (the former Beitou Public Bathhouse).

Overview of the Passive house examination -Cooling demand

As previously mentioned, in Taiwan (a subtropical region), achieving optimal indoor thermal comfort primarily revolves around cooling and dehumidification. The main factors contributing to this objective lie in building envelope design and systems.

The graphic of energy balance cooling(fig.60) identifies areas needing improvement. In this project, the heat loads of the building envelope alone account for over 50% of the overall heat load. The window solar heat and transmission comprise nearly 30% of the overall heat load. Therefore, balancing daylighting performance with the heat load brought in through the windows is critical.

The energy consumption of this project could yield better results since the windows in this project use double-glazing instead of the more advanced triple-glazing with superior U-values and g-values.

However, the primary goal of this master's thesis is to achieve Passive house standards with the most efficient design combination rather than achieving the lowest energy consumption through the highest building performance. Therefore, to address the feasibility of Passive house standards in Taiwan's climate and environment, the choice was made to use the more common and less technically advanced double-glazed windows.

On another note, the chart below(fig.61) illustrates the useful cooling demand represents the heat quantity that must be removed from the building throughout the year to establish a comfortable indoor climate. The chart indicates that, in achieving Passive house standards, the cooling system needs to be operational only between May and October.

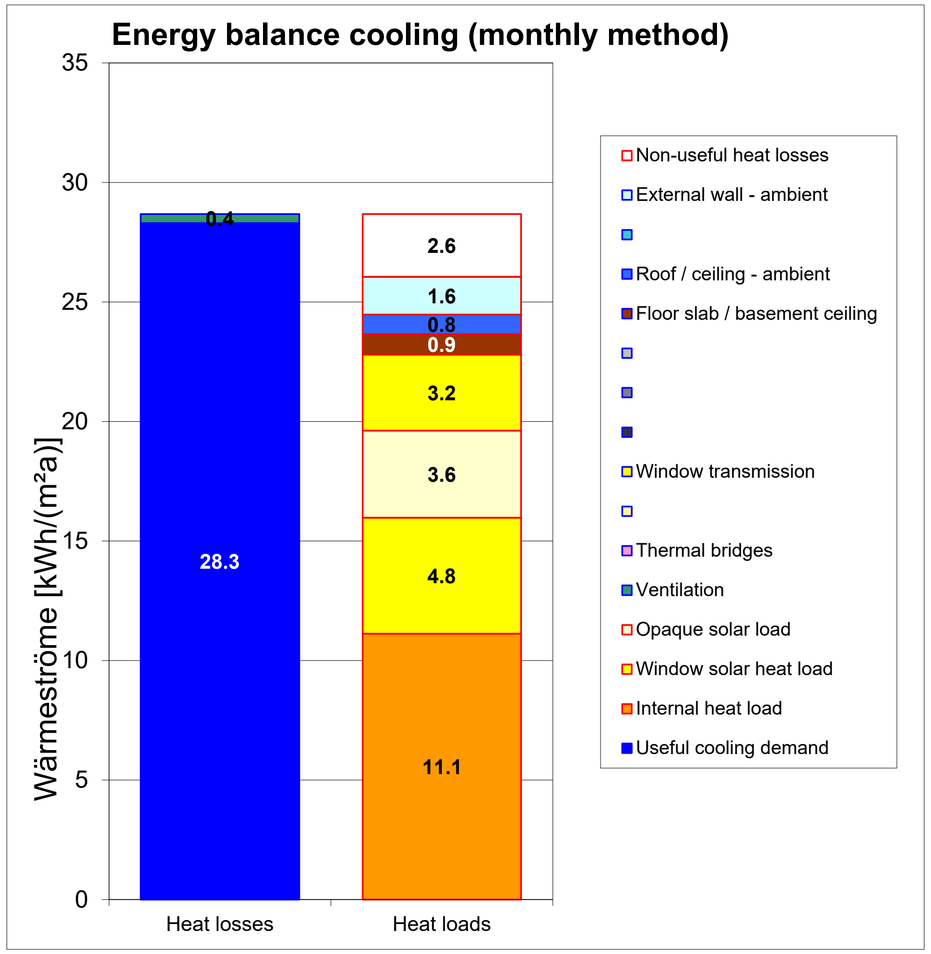


Fig. 60
Chart of Energy balance Cooling (monthly method)

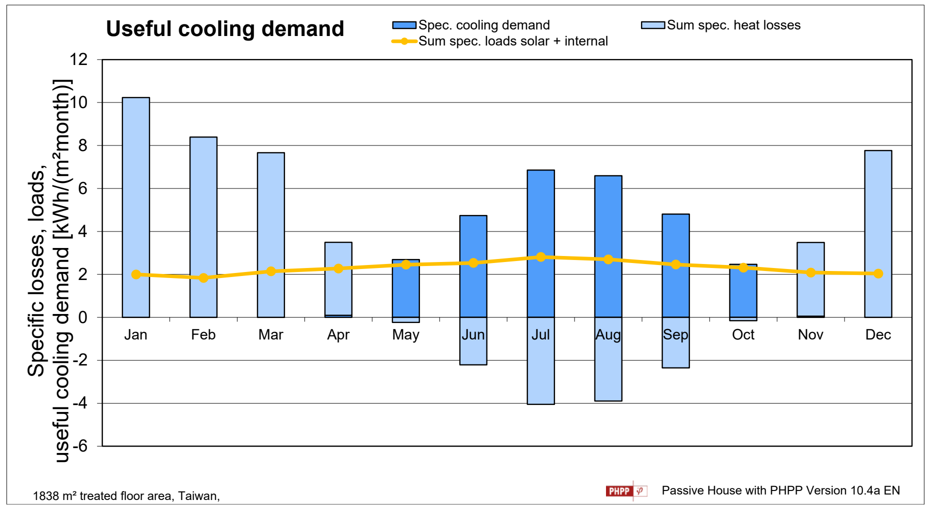


Fig. 61
Chart of useful cooling demand

Overview of the Passive house examination -Humidity demand

A detailed humidity balance monthly can be found in Fig. 62.

The corresponding diagram shows two bars for each month. The humidity loads are shown on the left, with dehumidification contributions on the right.

Depending on the climate and month, the outdoor air can increase or reduce indoor air humidity. The outdoor air volume flows can therefore turn up in the left or right bar. They are shown broken down into the different types of ventilation (ventilation system with supply air, infiltration/windows/extract air system, and summer ventilation). The contributions from active dehumidification are included in the bar on the right and shown with hatching.

According to the chart, the airtightness established by the building envelope and thermal-bridge free, in conjunction with an actively dehumidifying ERV system, the humidity load is primarily concentrated between April and November, with the highest load observed in July. The additional humidity load primarily stems from the supply air ventilation system.

It's noteworthy that during the hottest and most humid months of July and August, no need to turn on the additional dehumidification to meet the demand since the ERV system has already offered extra indoor dehumidification energy then the total humidity load.

Overall, it has effectively maintained consistently good indoor humidity control during the whole year (specifically, at 60% relative humidity at 25 °C).

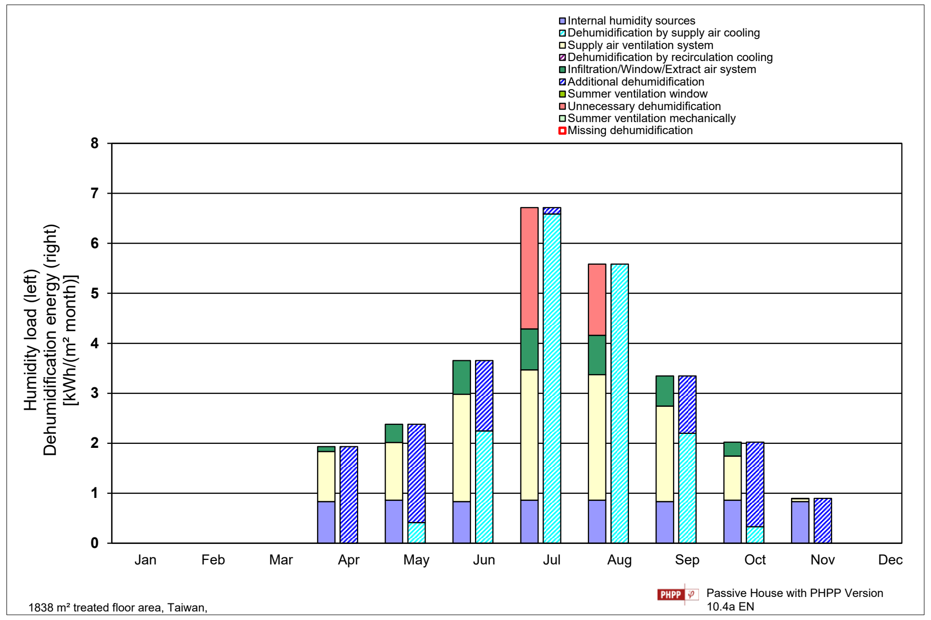
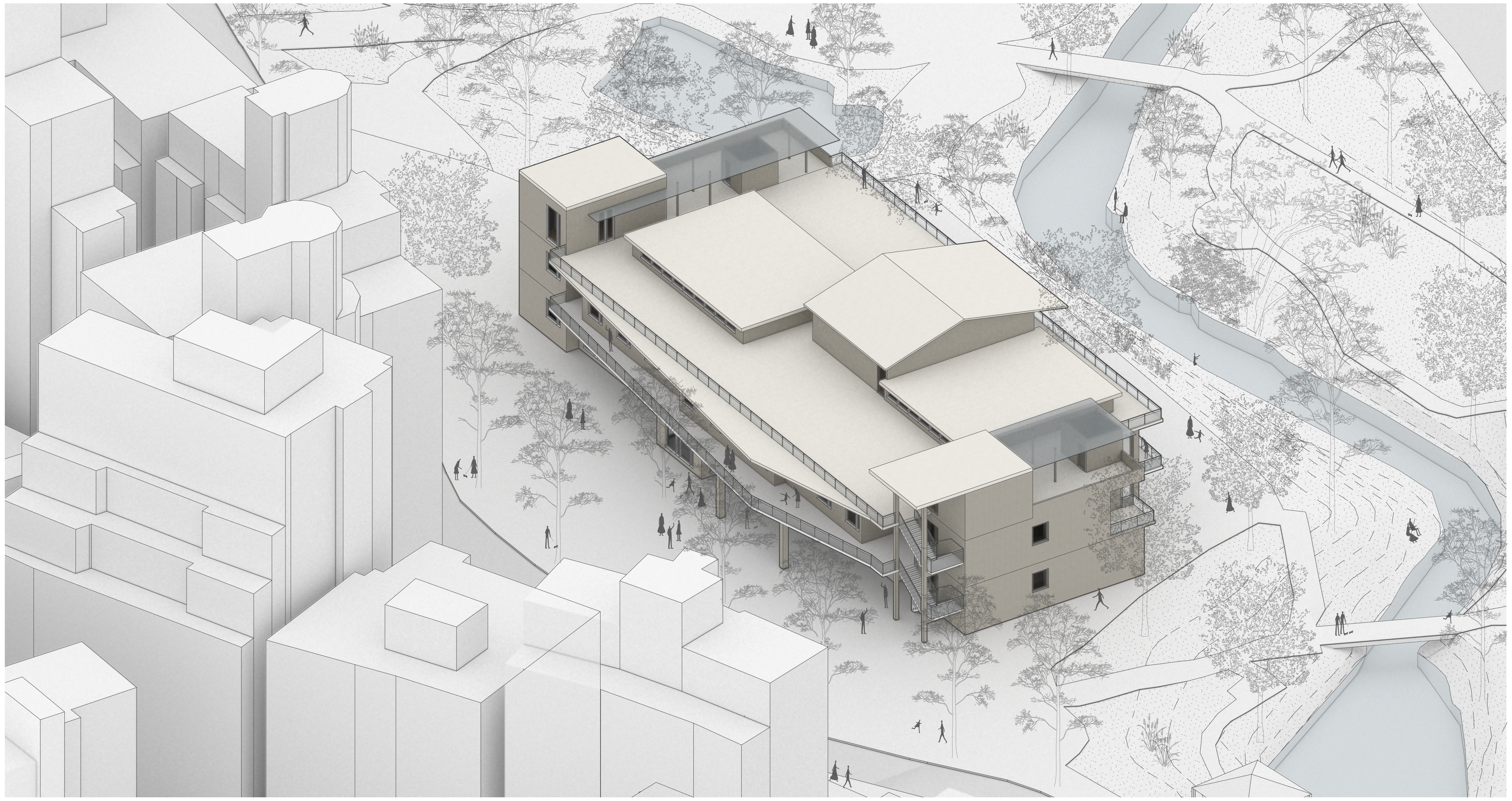


Fig. 62
Chart of Humidity load



Comparison
-Thermal comfort and IAQ

The control of temperature and humidity can be illustrated in two ways: first, the preservation of books and collections, and second, maintaining stable and good thermal comfort.

Firstly, according to "Libraries: A Design Manual"(2018), for Indoor Climate Conditions of Library Space, the best humidity control is recommended to be between 40%- 55%. If it exceeds 65%, it will cause damage to the books in the long run. According to the monitoring report of the existing Beitou library, the humidity of it is over 60% most of the time.

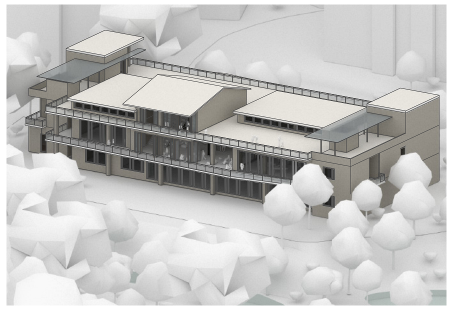
Secondly, regarding the standard of human comfort, referring to the CBE's tool, the chart on the left of Fig. 63 shows that the indoor environment of the final proposal, in which the indoor temperature is 25°C and the humidity is 60% in summer, is in the comfort zone; however, by the data from the monitoring report, the result of existing Beitou Library on the right of Fig. 63 shows that it is not in the comfort zone.

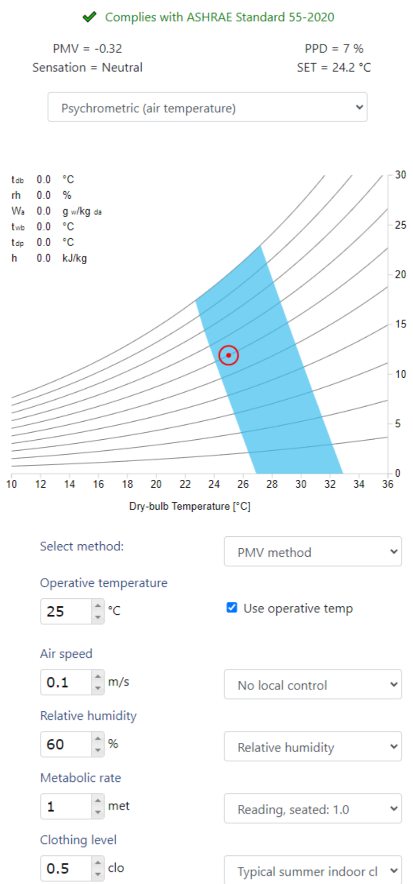
It's worth noting that in a passive house, users still have the option to open windows as needed. A passive house offers the choice to close all the windows and doors while ensuring comfort and indoor air quality.

Indoor air quality (IAQ)
Besides controlling temperature and humidity, the passive house library significantly improves indoor air quality by effectively managing outdoor factors like air pollution, insects, and sulfur dioxide. Achieved through building airtightness and controlled outdoor air exchange systems, it enhances thermal comfort and human well-being and prevents damage to library collections and equipment.

Proposal

Existing Beitou library





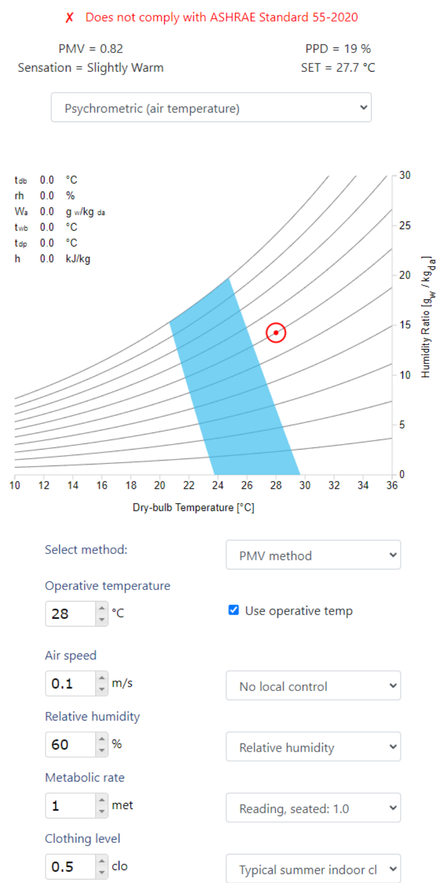


Fig. 63
Psychrometric chart generated by CBE comfort tools shows the comfort zone in the summer time

Comparison
-Energy performance of Cooling and dehumidification

Fig. 65 shows that the electricity demand for cooling in the existing Beitou Library is measured at 43.83 kWh/m2a (without additional dehumidification). In contrast, the passive house proposal with an ERV system (SEER: 2.5) and additional dehumidification significantly reduces to 22.7 kWh/m2a (see the detail in Fig. 64). This highlights the effectiveness of an airtight building envelope coupled with an active ventilation system in maintaining thermal comfort and energy efficiency.

The existing Beitou Library reduces the demand for cooling by compromising human comfort. The indoor temperatures in summer are controlled at 28±2 °C. Although the energy demand is lower than that of conventional buildings, this is a stuffy and uncomfortable indoor environment regarding user feedback and comfort standards. Apart from the thermal comfort, since the existing Beitou Library does not have active dehumidification, the energy consumption is only operated from cooling. The simulation shows that even if the passive house library is equipped with active dehumidification, the overall energy consumption is still lower than that of the existing Beitou Library.

Therefore, compared to the existing Beitou Library, the passive house proposal improves energy efficiency through airtightness, thermal bridge-free, and effective thermal insulation of the building envelope while maintaining good thermal comfort, reducing energy consumption.

Results			Sensible kWh/(m²a)		Latent kWh/(m²a)		SEER		Electricity demand kWh/(m²a)
Cooling contribution by:	Supply air cooling	(	28.3	+	19.6	) /	2.6	=	18.6
	Recirculation cooling	(		+		) /		=	
	Dehumidification				8.3	/	2.0	=	4.1
	Panel cooling					/		=	
	Post heating		0.0			/	-	=	0.0
	Cooling distribution					/	2.6	=	
Total cooling contribution		(	28.3	+	27.9	) /	2.5	=	22.7
Useful cooling demand			28.3		22.7				

Fig. 64
Result of electricity demand of Passive house proposal

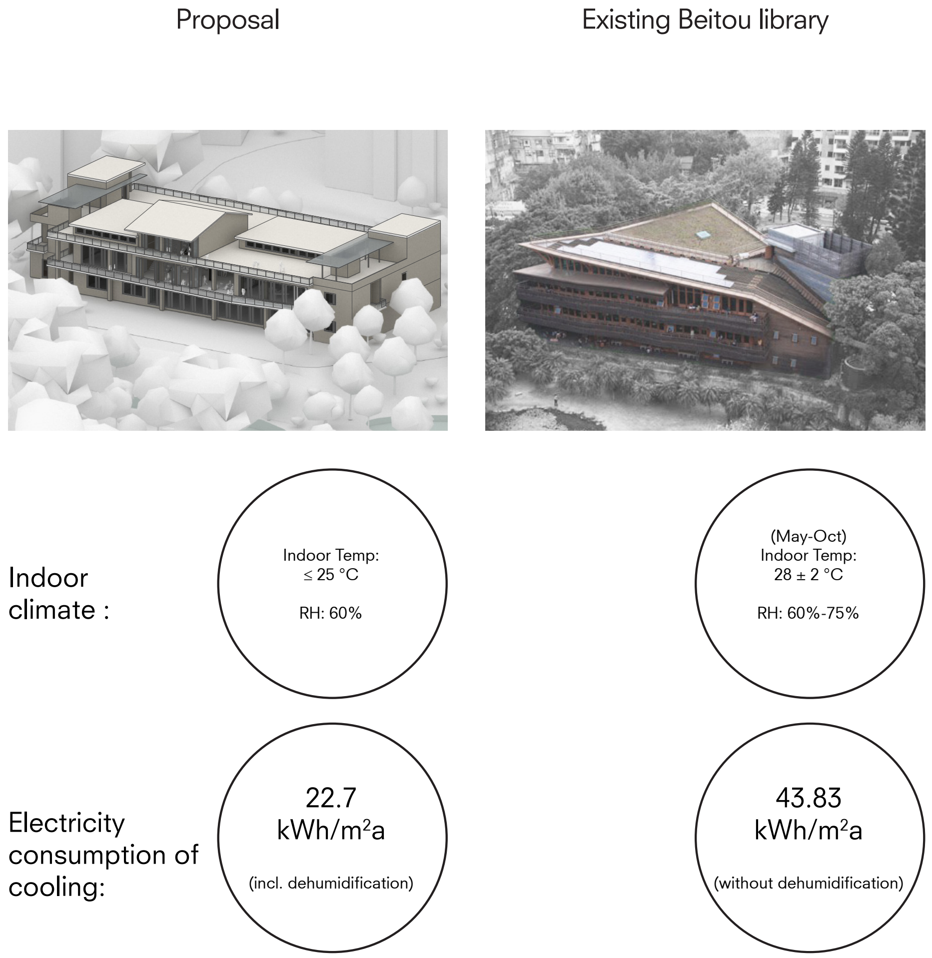


Fig. 65
Energy performance of Cooling and dehumidification

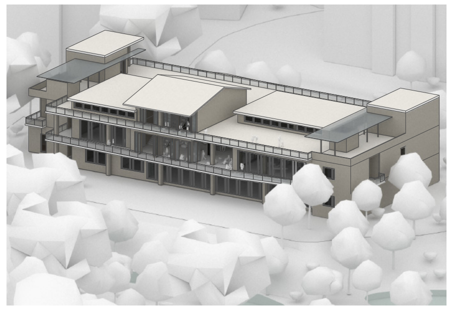
Comparison
- Final energy demand and Daylighting performance

The PE demand can not be calculated since there is no regulation and official data from the government or organizations. However, since the proposal site is on the same site as the existing Beitou library, which means the proposal relies on the same energy supply system as the existing Beitou library. Thus, in this thesis, the final energy demand is used to evaluate the energy efficiency between the two projects under the same energy supply system. The calculation result in Fig. 66 shows that the total energy demand of the proposal is 46.17 kWh/m2a, while that of the existing Beitou Library is 102.59 kWh/m2a. The result shows that the PH building can reduce more than 50% of the energy consumption than the naturally ventilated building with a better thermal comfort environment.

Further discussing its primary energy, countries are gradually changing the use of primary energy to renewable primary energy. During the transition phase, PE will finally approach zero as we reach a society powered by 100% renewable energy. Examining the two projects by the PER factor made by PHPP for Taipei shows that from the PER demand, the PER demand of the proposal is 56.8kWh/m2a. In contrast, the existing Beitou library's is 149.48kWh/ m2a (fig. 67).

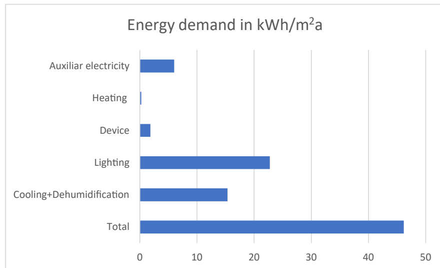
• Daylighting performance
The survey at Beitou Library revealed a strategy of reducing overall indoor lighting intensity to save energy, utilizing localized focal lighting like individual lamps on bookshelves and reading tables to meet specific needs. In contrast, the proposed passive house library achieves a Median Daylight Factor between 2% and 4.5% in main areas to minimize the artificial lighting, ensuring a well-lit reading environment throughout the space while meeting passive house standards.

Proposal	Existing Beitou library



Final energy demand:

Proposal	Existing Beitou library
46.17 kWh/m^{2}a	102.59 kWh/m^{2}a



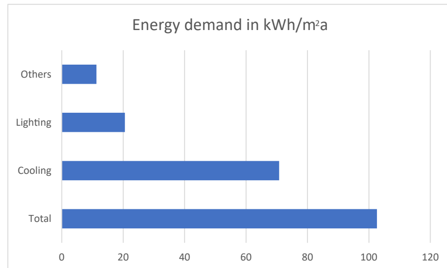


Fig. 66
Energy demand

Primary energy renewable(PER) demand:

Proposal	Existing Beitou library
56.80 kWh/m^{2}a	149.48 kWh/m^{2}a

**PER factors*
Cooling: 1.55
Dehumidification: 1.60
Occupant electricity: 1.25
Heating: 1.35

Fig. 67
Primary energy renewable(PER) demand

F. CONCLUSIONS

• What are the benefits or drawbacks of using passive strategies compared to natural ventilation design?

• Advantages:

1. Stable Ventilation Rate and Filtration System:
The system maintains a stable ventilation rate and includes a filtration system, ensuring good indoor air quality throughout the year without being affected by external factors like mosquitoes, sulfur dioxide, or climatic factors such as wind flow.

2. Energy consumption:
Through the simulation by PHPP, the final proposal's final energy demand is more than 50% lower than the existing Beitou Library, which has natural ventilation.

3. Not Against Natural Ventilation:
Passive houses do not oppose window ventilation. Instead, they enable maintaining high air quality and thermal comfort even during window-closed conditions, such as winter or severe air pollution.

4. Well integration with Local Architectural Elements:
Passive house design strategies can integrate existing elements in humid and hot climates, such as external veranda, grilles, and awnings. This reduces the need for cooling and blends passive houses into the local cultural context, enhancing harmony and interaction with the site environment.

• Disadvantages:

1. Spatial Form Limitations:
To maintain the high energy efficiency of cooling, heating, and ventilation systems, the spatial organization tends to be compact, limiting the flexibility, possibility and aesthetic appeal of indoor spaces.

2. Higher Technical Threshold for Construction and Maintenance:
The construction and maintenance of passive houses require higher technical expertise, leading to increased costs and complexities during both the construction and usage phases.

3. Increased User Learning Costs:
Users may need help understanding the operation of equipment systems, potentially leading to unnecessary energy wastage when not used correctly.

4. High Embodied Energy:
Although passive houses significantly reduce operational energy, the passive house assessment process often overlooks the higher embodied energy. Neglecting the calculation of embodied energy creates a significant blind spot in the assessment of compliance with low carbon buildings, as the low energy performance of passive houses in the use phase is based on the more complex structural and building service systems invested in the construction phase.

5. Limitations in Practical Airtightness Consideration:
The PHPP evaluation tool used by the Passive House Institute (PHI) does not consider the actual usage scenarios, such as the frequency of people entering and exiting spaces and its impact on indoor temperature, humidity, and air quality. This oversight can affect the accuracy of energy usage assessments.

• How passive house strategies and tools could support energy-efficient building in the hot and humid climate.

• By this project, a set of rules listed below guided the Passive house strategies to accommodate for humid and hot climates:
1. Building Orientation
In humid and hot climates, the primary concern is indoor overheating. Therefore, it is recommended to orient the building north-south to minimize heat gain which is mainly collected from the east and west. Additionally, reducing windows facing south or incorporating external shading systems is advised.

2. Building Volumes
Passive houses typically reduce energy losses by having compact volumes with minimal surface areas. However, considering spatial functionality and aesthetics, the combination of the building elements from the local context in humid and hot climates is possible. The flexible use of semi-outdoor spaces on the second floor and expanded external veranda enhances shading performance and integrates with local architectural elements and user habits.

3. Space Layout
3-1. In addition to functional considerations, ventilation design should be incorporated into spatial organization to achieve the most efficient ventilation duct system. Therefore, it is recommended to place ventilation devices centrally and close to the exterior walls. Spaces for intake, such as reading areas and offices, and exhaust, such as toilets, and storage rooms, should be strategically arrangezd to facilitate smooth air circulation and shorten duct lengths.
3-2. To reduce indoor heat gain, service spaces like toilets, storages and stairwells can be positioned on the east and west sides as a physical block to avoid the impact of heat radiation from the east and west to the primary space.

4. Building Envelope
Due to the smaller indoor-outdoor temperature difference in humid and hot climates, for achieving passive house standards, the recommended U-value the building envelope is at least 0.335 for walls and 0.216 for roof. The wall thickness, maintained at 20.5 cm through high-performance insulation, is comparable to conventional RC constructions without compromising the size of the indoor space.

5. Window Systems
In humid and hot climates, triple-glazed windows are unnecessary. Double-pane Low-E glass with a U-value of 1.19 and a G-value of 0.31 is suggested. Window sizes and side skylights are adjusted using daylight simulation tools to ensure deep indoor spaces receive adequate natural light.

6. Energy and Humidity Exchange System
Exchange System Due to the year-round high humidity, it is recommended that an Energy Recovery Ventilation (ERV) system with at least 70% heat and humidity recovery be adopted. This will reduce the need for cooling and dehumidification.

7. Cooling and Dehumidification System
System an independent dehumidification device is recommended in addition to the cooling system.

• Performance simulation tools assistance:
1. PHdesign+PHPP
This thesis utilizes PHdesign+PHPP as an evaluation tool. Through PHdesign modeling, data is exported and imported into PHPP for a more in-depth analysis of building details, structural, service system, and usage patterns. The planning results are assessed to determine whether the design complies with passive house standards, and the design is adjusted based on the evaluation results. In the decision-making process for building envelope design, the tool assists in considering factors such as form factor, U value of the building envelope structure, and design strategies responding to heat radiation from different directions. This ensures real-time adjustments in the design process for optimal thermal comfort and energy efficiency.

However, challenges arose during the implementation despite the gradual updates and iterations of PHPP by the Passive House Institute to make it applicable to different climate zones. Some aspects of analysis need to be improved because PHPP's development was initially focused on requirements for a temperate climate. For instance, different regions and countries' energy supply conditions and national policies influence factors like PER and PE. In the case of the project in Taipei's Beitou district, there needs to be more relevant data, leading to reliance on final energy demand for assessing energy performance rather than Primary Energy demand. Moreover, the lack of consideration of embodied energy creates a blind spot in the assessment of carbon emissions. In practice, it is important to note that in order to design a sustainable low carbon building, other tools should be used to obtain a more complete carbon emission analysis.

In addition, as the assessment of PHPP involves the overall planning of building service systems and building design, including air-conditioning system, ventilation system, energy system, etc., it requires more comprehensive and cross-disciplinary knowledge in design application. Architects work together with the technical team will achieve a better integration.

2. Velux Daylight Visualizer
Due to PH building envelopes' high insulation and thermal bridge-free requirements, the building shell design should use structures with the optimal U value for energy efficiency. However, because walls can achieve a better U value than windows, PHPP favors low window-to-wall ratios, potentially compromising natural lighting and increasing the demand for artificial lighting. Therefore, the project incorporates Velux daylight simulation to adjust the design to balance natural lighting and indoor overheating concerns. This ensures reasonable window openings and sufficient natural light in the indoor environment, avoiding issues like glare and increased cooling demand associated with oversized windows.

Reflection

This master's thesis has attempted to approach design from the perspective of the passive house strategy, aiming to achieve an energy-efficient building with good thermal comfort. This has led to a deeper understanding of the design methods, current trends, and challenges in passive house design.

• Neglect of the evaluation of embodied energy in Passive house assessment
Some challenges for Passive house need to be addressed. Presently, Passive house standards mainly concentrate on the energy use within the "use stage", emphasizing operational energy and neglecting embodied energy. But as equipment efficiency improves and renewable energy usage increases, the share of operational energy will drop, and embodied energy will become more significant.

In this project, since Taiwan's evaluation of low environmental impact buildings primarily concentrates on embodied carbon rather than embodied energy. Due to my limited resources, I lack of the database to provide an analysis and evaluation of the embodied energy in the project. Moreover, due to the unavailability of material calculation documents for the existing Beitou Library, thus, limitations in assessing embodied energy and comparing it were encountered.

In addition, in this thesis, Besides the comparison of final energy demand, the energy comparison also focuses on Primary Energy Renewable Demand (PER demand),an index for assessing the new standard of Passive house classic, rather than Primary Energy Demand (PE demand). PER demand assumes that buildings use 100% renewable energy for their systems. Since PHI has cooperated with Taiwan's organization to establish the PER factor for Taiwan, PER demand is taken in this thesis to compare the result. Whereas PE requires consideration of various factors, such as a country's energy policies, energy supply system, and has not been precisely calculated for Taiwan due to the lack of coefficients for various primary energy types, which is a limitation in the design process of this thesis. However, However, since the proposal and the existing library on the site use the same energy sources, they share the same energy supply system. Thus, the comparison can be made based on Final Energy Demand as an alternate measure to compare energy consumption levels.

Whether Passive house continues to develop, the building components may become increasingly crucial for the efficiency. Circular economy in architectural industry should be take more serious. For instance, a circular economy model, Philips' Light-as-a-Service initiative, might present an opportunity by purchasing the lighting hours rather than light bulbs, resulting in energy cost and carbon emission savings. Hence, integrating and transforming the building materials, products, and systems industries for architecture might be a crucial focus.

• Approach of Passive house design and Natural ventilation building design
In terms of architectural form and spatial organization, in the case of the library building, for example, because of the considerations of administration, access control, books handling and the need for a large space to provide for the collection of books and reading, there is a tendency towards a single volume in terms of design principles, or to link different volumes to each other through indoor corridors. I decided to start from a single volume, because I wanted to adopt the design principle of Passive house as much as possible in this thesis, that is, to keep a lower form factor, instead of trying the atypical approach, so as to achieve a principled comparison with the existing Beitou Library, a building that emphasizes on natural ventilation (which also adopts the single volume design).

From the statistics of the user survey of the existing Beitou Library, it is learnt that it does not have very positive feedback on thermal comfort and indoor air quality, as described in the Investigation chapter of this thesis, it exists with poor air convection in the depths of the indoor space and toilets, too humid and stuffy in summer, mosquito and insect problems due to being in a park, insufficient warmth in winter when the windows are closed, and so on. Relatively speaking, since thermal comfort and indoor air quality are the greatest emphasized advantage of Passive house, the final proposal is indeed better than the existing Beitou Library in these aspects. However, it necessitates alignment with the overall technological advancements in the construction industry and user proficiency in operating equipment systems to realize passive houses' energy efficiency advantages fully.

In addition, in terms of construction and maintenance costs and the consumption of embodied energy, it may not be as good as a naturally ventilated building due to its heavy reliance on complex structures and building service systems, it need a further evaluation to answer.

If this thesis can be developed further, I will try to combine the two approaches to find the possibility of balancing the aesthetics of the space with the good thermal comfort and well being of the users. I will probably still adopt the principles of Passive house in certain spaces but not insist on the whole project. I will only insist the Passive house strategies in the main spaces for good indoor thermal comfort and controlled air quality, and separate the secondary and walkway spaces from the main spaces and adopt a natural ventilation strategies. One possibility is to firstly address the need for access control at the ground floor, and above the ground floor to adopt a covered clustered volumes planning, so that the spatial organization can be more relaxed, under the condition of relaxing the form factor, to increase the chance of air convection indoor spaces and outdoor paths, so as to reduce the amount of service systems and structures required for Passive house, and to have a freer form design, and to achieve the goal of low carbon emissions in general.

• Limitation of spatial experiences and architectural form
Natural ventilation has more possibilities in terms of architectural form and spatial experience than passive houses, which is due to a different focus on

architectural design. Passive architecture places great emphasis on volume and spatial organization, focusing on the surface area of the volume and spatial compactness, and discourages clustered spatial organization, which limits the freedom of planning. In contrast, natural ventilation buildings place more emphasis on air convection between spaces, air pressure differences, and shading systems, thus allowing for more variation in architectural form and spatial experience.

In the process of research and design, I have also gained a lot of knowledge about the cases of natural ventilation buildings and passive houses, and there are cases of combining the two design methods. Through the experience of this master's thesis, I acknowledged the importance of finding the balance between this two approaches, in terms of architectural form, spatial experience, stability of indoor thermal comfort, and carbon emissions, and this is the direction I will continue to study and practice.

In this thesis, I understand that the energy performance-based design approach has difficulties in designing the spatial experience. While trying to create spatial possibilities under limited conditions during the design process, although I had hoped to create spatial experience through the connection of volumes and corridors in the design concept draft, I still chose to compromise on the premise of optimizing energy efficiency. Although this put me in a difficult situation, I gained valuable experience from trying to learn new systems, different entry points, and making design decisions based on data, as opposed to the conceptual and spatial experience-based design approach that I had adopted in my previous architectural studies and work. I will continue to explore the balance between spatial quality and energy efficiency in my future career in the trend of sustainable architecture.

In conclusion, user needs remain the primary goal in architecture design. With the development of technology, if a pure natural ventilation building cannot effectively create suitable indoor environments under adverse and unstable environment conditions, approaches like Passive House, integrating technology and products into architectural design to achieve better indoor environments, along with integrated strategies like transitioning to a circular economy, combining with natural ventilation design to minimize the mechanical ventilation spaces could be a viable alternative.

G.
APPENDIX

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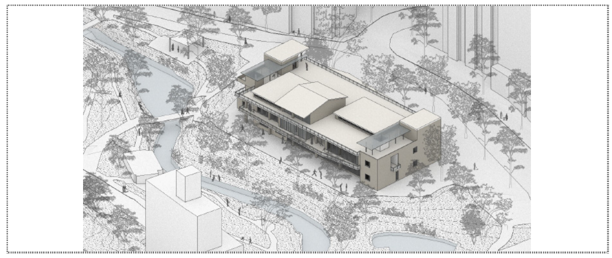
PHPP REPORT

Passive House-Verification

10.4a EN



Building:			
Street:			
Postcode/City:			
Province/Country:	TW-Taiwan		
Building type:			
Climate data set:	TW0001a-Taipeh		
Climate zone:	5: Warm	Altitude of location:	9 m
Home owner / Client:			
Street:			
Postcode/City:			
Province/Country:			

Architecture:	Passive house library in Taiwan	**Mechanical engineer:**	
Street:		Street:	
Postcode/City:		Postcode/City:	
Province/Country:		Province/Country:	
Energy consultancy:		**Certification:**	
Street:		Street:	
Postcode/City:		Postcode/City:	
Province/Country:		Province/Country:	

Year of construction:		Interior temperature winter [°C]:	20.0	Interior temp. summer [°C]:	25.0
No. of dwelling units:		Internal heat gains (IHG) winter [W/m²]:	1.9	IHG summer [W/m²]:	1.9
No. of occupants:	300.0	Specific heat capacity [Wh/K per m² TFA]:	132	Mechanical cooling:	x

Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	1838.2				
Space heating	Heating demand	kWh/(m²a)	1	≤	15	-	Yes
	Heating load	W/m²	8	≤	-	10	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	51	≤	51		Yes
	Frequency of overheating (> 25 °C)	%	-	≤	-		-
	Frequency of excessively high humidity (> 12 g/kg)	%	0	≤	10		Yes
Airtightness	Pressurisation test result n_{50}	1/h	0.6	≤	0.6		Yes
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	120	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	57	≤	60	60	Yes
	Renew. energy generation (in rel. to projected building footprint area)	kWh/(m²a)	65	≥	-	-	

I confirm that the values given here have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

Passive house Classic? Yes

Task:	First name:	Surname:	Signature:

Certificate-ID	Issued on:	City:

Project data imported from designPH 2.1.15a 2023-10-24 17:00:59 +0200

Project overview

Passive House with PHPP Version 10.4a EN

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

Basic data

	Language free texts			
	EN-English			
Building, name of the object				
Street:				
Postcode/City:				
Province/Country:			TW-Taiwan, Province of China	
Building type:				
Building use:	23-Non-res.: Other			
Climate: Zone / Data set	5: Warm		TW0001a	
Climate: Height above sea level	9	m		
New building / Retrofit:	1-New building			
Building energy standard / Building class	10-Passive house		10-Classic | PER (renewable)	
Year of construction / Year of construction of existing building				
Number of dwelling units		Dwelling units		
Number of occupants / Method	300	P	User-defined	
Occupancy rate	6	m²/P		
Home owner name / E-mail				
Architect name / E-mail	Passive house library in Taiwan			
Mechanical engineer name / E-mail				
Energy consultant name / E-mail				
Interior temperatures winter / Summer	20	°C	25	°C
Internal heat gains (IHG) winter / Summer	1.9	W/m²	1.9	W/m²
IHG values	1-User-defined			
Spec. heat capacity / mechanical cooling	132	Wh/(K*m²$_{TFA}$)	1-Yes	
Project certificate ID / Date				
Certification body Name / E-mail				
Certifier first name / Last name				

Specific values according to Passive House-Verification

Treated floor area A_{TFA}	1838	m²			
	Specific value		Requirement	alternatively	
Annual space heating demand	**1**	kWh/(m²a)	15	-	
Heating load	**8**	W/m²	-	10	
Cooling + dehumidification demand	**51**	kWh/(m²a)	51		
Frequency of overheating	**-**	%		> 25 °C	
Frequency of excessively high humidity	**0**	%	10%	> 12 g/kg	
Airtightness pressure air change rate test n_{50}	**0.6**	1/h	0.6		
Primary energy renewable (PER demand)	**57**	kWh/(m²a)	60	60	
Generation of renewable energy	**65**	kWh/(m²a)	-	-	
(Reference to projected building footprint)					
Non-renewable primary energy (PE demand)	**120**	kWh/(m²a)	-		
Heating, cooling, DHW, auxiliary electricity, occupant electricity					
Specific PE demand - mechanical system / CO_2-equivalent	75	kWh/(m²a)	19343	kg/(m²a)	
Heating, DHW, auxiliary electricity (no occupant electricity)					
Chosen primary energy factors for the PE demand determination	1-PE factors (non-renewable) PHI Certification				

Energy performance value (monthly method)

	Heating period		Cooling period	
Transmission heat losses of opaque components Q_T	2	kWh/(m²a)	-3	kWh/(m²a)
Transmission heat losses of transparent components Q_T	4	kWh/(m²a)	-3	kWh/(m²a)
Heating degree hours exterior	7	kKh/a	-6	kKh/a
Heating degree hours ground	-3	kKh/a	-2	kKh/a
Ventilation heat losses Q_V	2	kWh/(m²a)	0	kWh/(m²a)
Available solar heat gains Q_S	2	kWh/(m²a)	8	kWh/(m²a)
Internal heat gains Q_I	6	kWh/(m²a)	11	kWh/(m²a)
Utilisation ratio heat gains h_G / Heat losses h_L	72	%	143	%
Heat gains Q_G / Useful heat losses $Q_{L,u}$	6	kWh/(m²a)	-9	kWh/(m²a)

Mean quality for building components

	Specific demand		Requirement EnerPHit component method (if chosen)	
Mean U-value th. envelope to ext. air (without windows & int. insulation)	**0.28**	W/(m²K)	-	W/(m²K)
Mean U-value th. envelope to ground (without interior insulation)	**0.60**	W/(m²K)	-	W/(m²K)
Mean U-value interior insulation to outside air	**-**	W/(m²K)	-	W/(m²K)
Mean U-value interior insulation to ground	**-**	W/(m²K)	-	W/(m²K)
Heat loss/ load of building envelope to ground	**-4.7**	kWh/(m²a)	-	kWh/(m²a)
Mean U-value windows/entrance doors	**1.48**	W/(m²K)	-	W/(m²K)
Ventilation system eff. heat recovery efficiency	**74**	%	-	%

Building envelope and site

Building envelope area A_{total} / Treated floor area A_{TFA}	4527	m²	1838	m²
A/V-ratio / Envelope area ratio (A_{total}/A_{TFA})		1/m	2.46	
Window area / Window percentage of total envelope	670	m²	45	%
Specific solar aperture / Passive solar heating contribution	0	%	2720	kWh/a
Projected building footprint (as per PHPP) / Site area	1518	m²		m²

Opaque building components

External wall

U-value (mean value) / Areas	0.33	W/(m²K)	1489.04	m²
Most common assembly: Designation / Certificate-ID	Wall(Secondary space)			
U-value / Thickness	0.34	W/(m²K)	205	mm
Total area / Area percentage	765.68	m²	51	%

Assembly	Material	λ [W/(mK)]	Thickness [m
1.	Timber cladding	0.130	22
2.	Horizontal timber battens	2.170	68
3.	Breather membrane	0.143	1
4.	OSB sheathing	0.130	12
5.	Cellulose (Insulation)	0.038	76
6.	Vapor barrier	0.143	0
7.	Cellulose (Insulation)	0.038	13
8.	Gypsum board	0.076	13

Roof/Top floor ceiling

U-value (mean value) / Areas	0.22	W/(m²K)	1185.75	m²
Most common assembly: Designation / Certificate-ID	Roof (Timber clad)			
U-value / Thickness	0.22	W/(m²K)	287	mm
Total area / Area percentage	1185.75	m²	100	%

Assembly	Material	λ [W/(mK)]	Thickness [m
1.	Roof Membrane	0.14	1
2.	OSB sheathing	0.13	22
3.	Polyiso boards (Insulation)	0.02	22
4.	Roof Membrane	0.14	1
5.	OSB sheathing	0.13	22
6.	Timber joists		132
7.	Cellulose (Insulation)	0.04	88
8.	Vapor barrier	0.14	0

Floor slab / Basement ceiling

U-value (mean value) / Areas	0.60	W/(m²K)	1181.94	m²
Most common assembly: Designation / Certificate-ID	Floor			
U-value / Thickness	0.60	W/(m²K)	299.8	mm
Total area / Area percentage	1181.94	m²	100	%

Assembly	Material	λ [W/(mK)]	Thickness [m
1.	Parquet flooring	0.18	22
2.	Vapor barrier	0.14	0
3.	Polystyrene boards (Insulation)	0.04	47
4.	Floor joist	2.17	80
5.	Breather membrane	0.14	1
6.	Concrete slab	2.10	150
7.			
8.			

Windows / Doors / Shading systems

Window: U_W-value (mean value) / Area	1.48	W/(m²K)	670.25	m²
Frame: U_f-value (mean value) / Area	1.60	W/(m²K)	190.81	m²
Glazing: U_g-value (mean value) / Area	1.19	W/(m²K)	479.44	m²
$\Psi_{Glazing\ edge}$ (mean value) / $\Psi_{Installation}$ (mean value)	0.04	W/(mK)	0.040	W/(mK)

Window frames

Most common assembly: Designation / Certificate-ID	PH-FRAMES: average thermal quality			
Window area / Area percentage	670.25	m²	100	%
Mean $\Psi_{Glazing\ edge}$	0.040	W/(mK)		
Operable window: mean U_f-value / mean frame width	1.60	W/(m²K)	110	mm
Operable window: $\Psi_{installation}$	0.042	W/(mK)		
Fixed glazing: mean U_f-value / mean frame width		W/(m²K)		mm
Fixed glazing: $\Psi_{installation}$		W/(mK)		
Curtain wall façade: mean U_f-value / Mean frame width		W/(m²K)		mm

Glazing

Most common assembly: Designation / Certificate-ID	PH Glazing			
U_g-value / g-value	1.190	W/(m²K)	0.31	
Area / Area percentage	479.44	m²	72	%

Entrance doors

Most common assembly: Designation / Certificate-ID		

Temporary Sun protection

Shading reduction factors: Orientation	Reduction factor Winter		Reduction factor Summer	
North	30	%	27	%
East	8	%	9	%
South	8	%	7	%
West	14	%	17	%
Horizontal	100	%	100	%

Ventilation

Ventilation system

Type of ventilation / Number of units	1-Balanced PH ventilation with HR		8	
Mean airflow rate / Mean air change rate	3600	m³/h	0	1/h
Effective HR efficiency / Electrical efficiency	74	%	0.35	Wh/m³
Humidity recovery efficiency	70	%		

Ventilation unit (most common execution)

Description / Certificate ID	unit 1			
Heat recovery efficiency / Electrical efficiency	75	%	0.35	Wh/m³
Energy recovery efficiency	70	%		
Frost protection / Limit temperature	0		0	°C
Installation site	0.00			
Effective heat recovery efficiency	75	%		

Subsoil heat exchanger

Mean efficiency / Mean effective HR efficiency	0	%	0	%
Most common component: Efficiency / Effective heat recovery efficiency	0	%	0	%

Airtightness

Airtightness test pressure at n_{50} / Air permeability q_{50}	0.60	1/h	1.07	m³/(hm²)
Net air volume for pressurisation test / Infiltration flow $n_{V,Rest}$	8088	m³	0.05	1/h

Summer ventilation

Basic ventilation

Air change via vent. system with supply air:	0.49	1/h		
HR/ER	Automatic bypass, controlled by enthalpy difference			
		1/h		
Window ventilation air change rate:	0.00	1/h		

Additional night ventilation

Window ventilation: air change rate	0.00	1/h		
		1/h		Wh/m³

Cooling

Internal humidity sources	10.0	g/(P*h)		
Useful cooling demand sensible / latent	28.3	kWh/(m²a)	28	kWh/(m²a)
Cooling load	13	W/m²		

System

Mean COP / electricity demand	2.5		22.73	kWh/(m²a)
Performance ratio cold water distribution pipes		%		

Cooling units

Supply air cooling (w/ recirculating air if necessary), Unit: denomination / Certificate-ID	unit 1			
Number of units / Seasonal energy efficiency ratio	19		2.6	
Max. cooling capacity / Cyclic operation limit	6.7	kW	6.7	kW
		kW		kW
		m³/h		
Additional dehumidification: Seasonal energy efficiency ratio / Waste heat into room	2.0			
		kWh/(m²a)		kWh/(m²a)

Heat generator (Heating and DHW)

Space heating demand (specific/absolute)	**1.22**	kWh/(m²a)	**2248**	kWh/a
Performance ratio heating distribution	100	%		
Total heat request of DHW system incl. storage tank (specific/absolute)	**0.00**	kWh/(m²a)	**-5**	kWh/a
DHW demand for showers / Other per person and day (at 60 °C)		litre/person/d		litre/person/d
Performance ratio of DHW distribution		%		
Performance ratio DHW distribution incl. storage		%		
Compact unit				
Designation / Certificate ID				
Covered fraction heating / DHW		%		%
Efficiency heating / DHW				
Final energy demand / Number of units		kWh/(m²a)		
Heat pump (HP)				
Water-based heating with HP: Designation / Certificate ID				
Heat source				
Air to air HP: Designation / Certificate ID				
Quantity				
HP or split unit: Designation / Certificate-ID	Standard inverter split unit(s)			
Heat source / Quantity	1-Outdoor air		1	
Separate HP for DHW: Designation / Certificate-ID	Standard air/water heat pump			
Heat source	1-Outdoor air			
Total contribution space heating / DHW	100	%	100	%
Mean efficiency space heating / DHW	4.8			
Total electricity demand	#VALUE!	kWh/(m²a)		
Direct electric				
Covered fraction Heating / DHW		%		%
Final energy demand Heating / DHW		kWh/(m²a)		kWh/(m²a)
Boiler				
Type / Fuel				%
Covered fraction Heating / DHW		%		%
Efficiency Heating / DHW				
Final energy demand		kWh/(m²a)		
District heating				
Standard heat generator				
PE factor energy carrier / CO_2 emission factor		kWh/kWh		g/kWh
Covered fraction heating / DHW		%		%
Performance ratio heat transfer station / Final energy demand		%		kWh/(m²a)
Other				
Designation heating / DHW				
Energy carrier for space heating / DHW				
Covered fraction heating / DHW		%		%
Efficiency heating / DHW				
Final energy demand		kWh/(m²a)		
Drain water heat recovery (shower)				
Designation / Certificate ID				
System efficiency stationary / dynamic	0	%	0	%

Solar thermal

Collector				
Collector area / Specific collector area		m²	0.00	m²/P
Deviation from north / Angle of inclination from the horizontal		°		°
Contribution DHW	**0**	kWh/a	**0**	%
Contribution space heating	**0**	kWh/a	**0**	%
Contribution total	**0**	kWh/a	**0**	%
Solar storage	50 litre, 0.1 W/K Heat loss rate			

Photovoltaics

Largest array: System denomination / PV module technology	System 5		4-Mono-Si	
Nominal current / Nominal voltage	10.00	A	34.00	V
Nominal power / Number of PV modules	340.00	Wp	38	pcs
Deviation from north / Angle of inclination from the horizontal	180	°	16	°
Total annual yield PV	**98014**	kWh/a		

Occupant electricity and auxiliary electricity

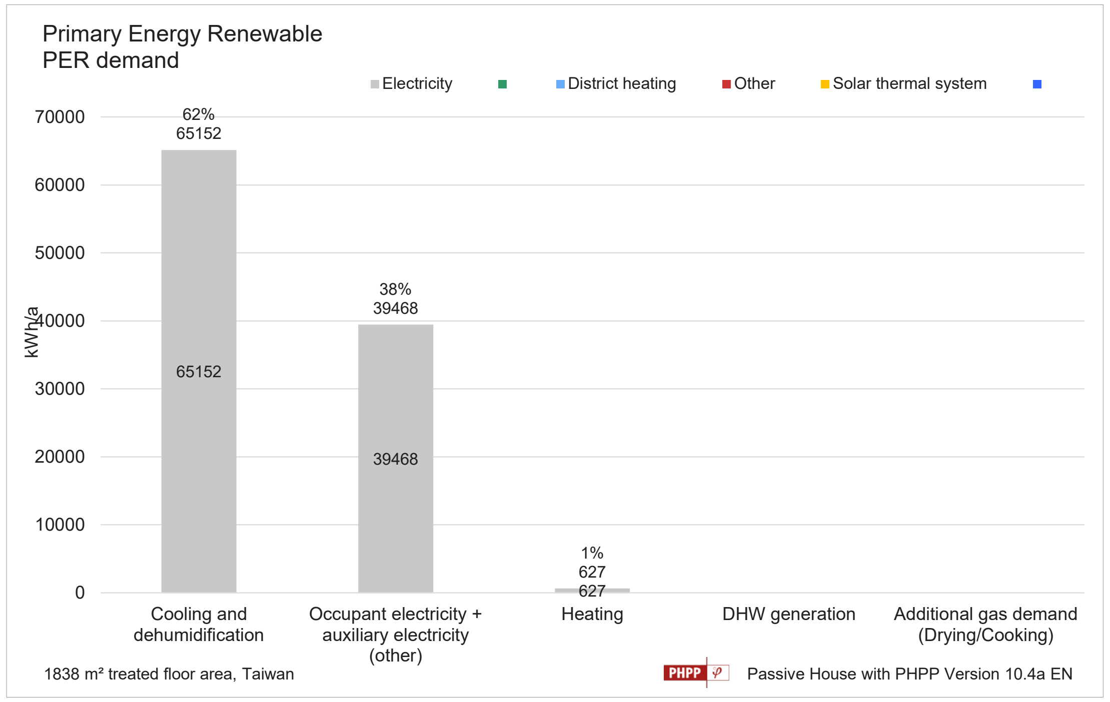
Auxiliary electricity		
Ventilation	11036	kWh/a
Heating system		kWh/a
DHW system		kWh/a
Solar thermal		kWh/a
Cooling and dehumidification	0	kWh/a
Other	0	kWh/a
Total	**11036**	kWh/a
Occupant electricity demand residential	**#DIV/0!**	kWh/a
Occupant electricity demand non-residential	**31574**	kWh/a

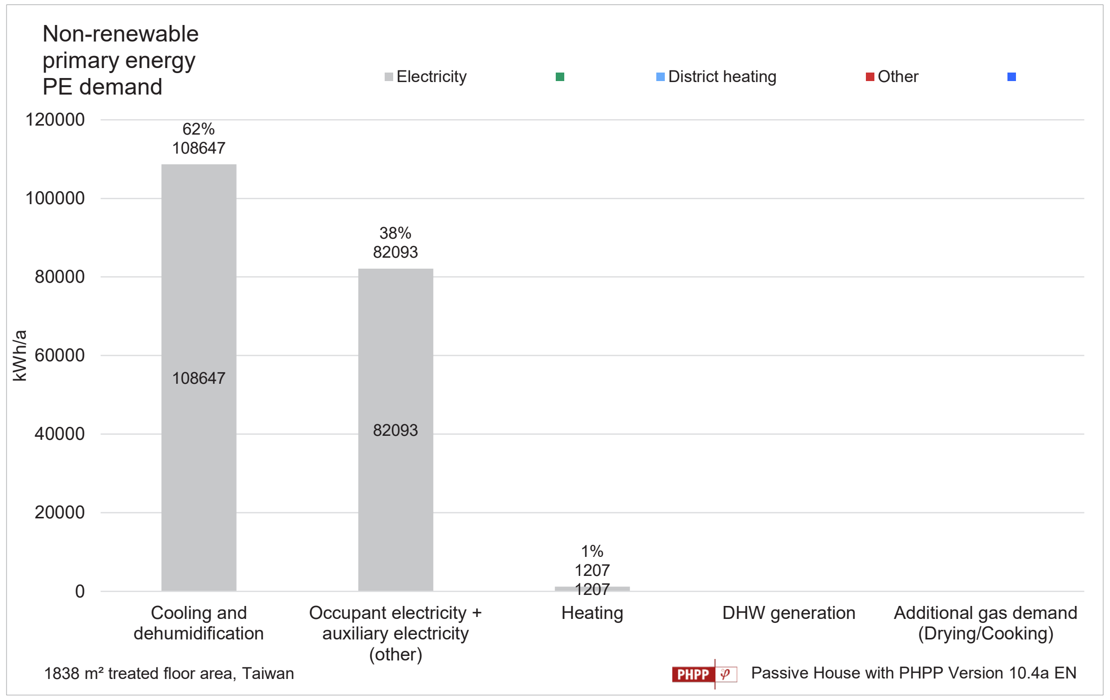
Project overview

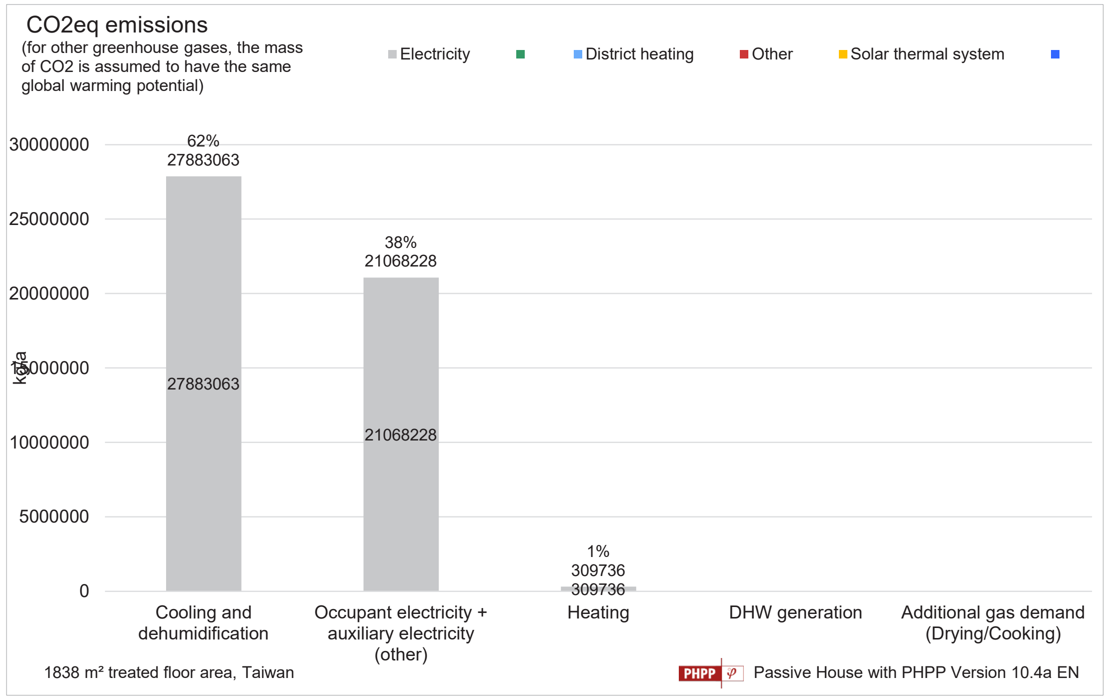
/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

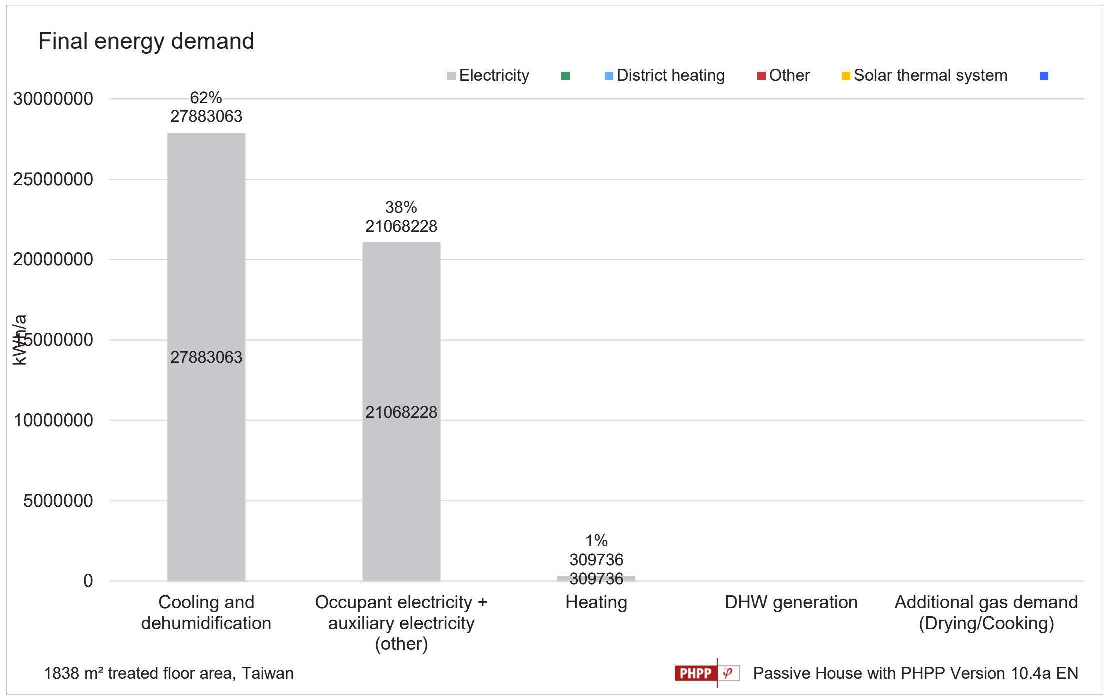
Diagrams

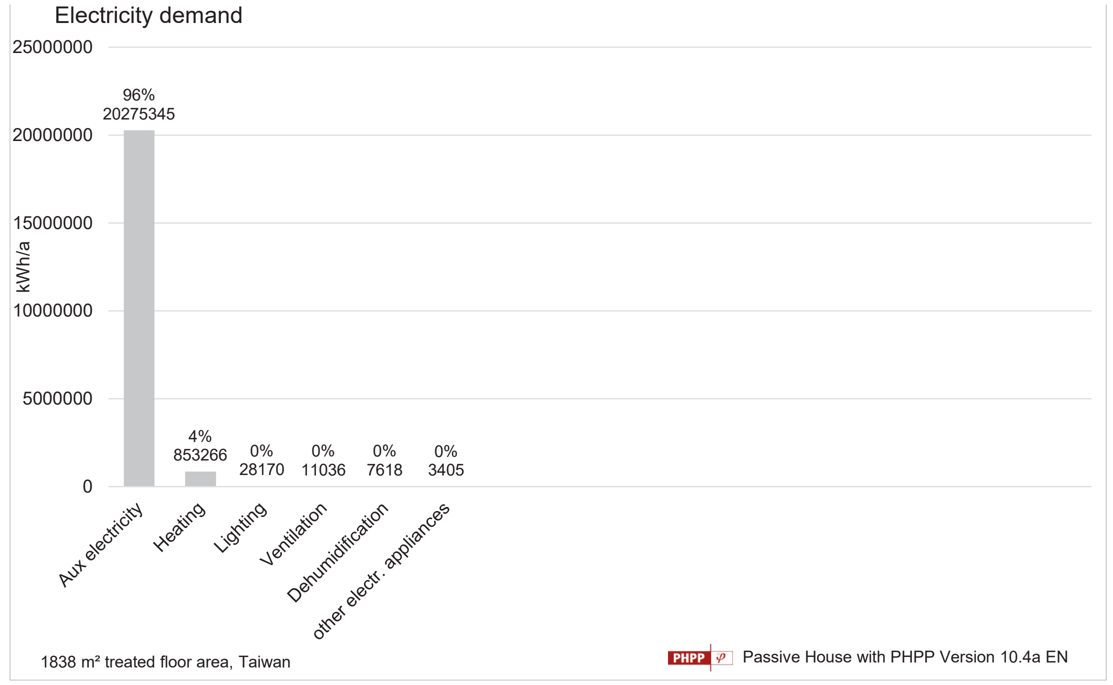
Area reference energy demand:
1-absolute values

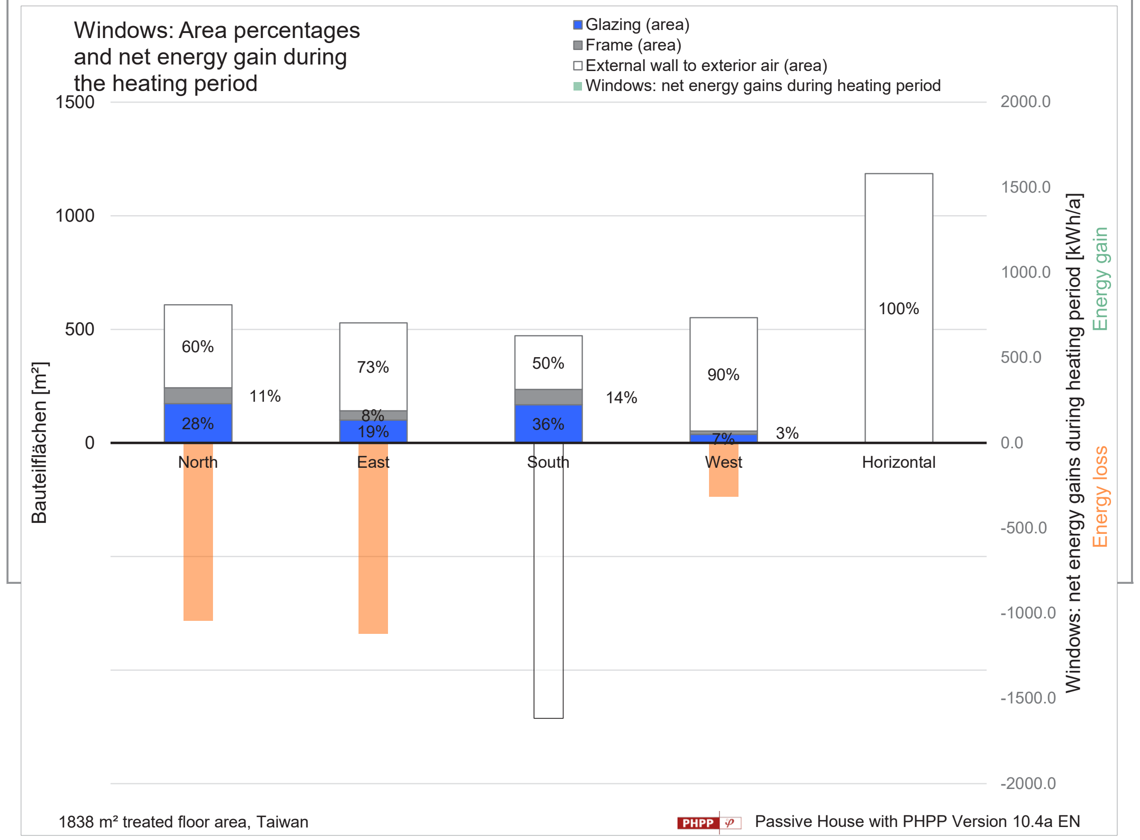












Specific energy demand for heating (monthly method)

Passive House with PHPP Version 10.4a EN

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

Interior temperature:	20	°C
Building type:		
Treated floor area A_{TFA}:	1838.2	m²
Spec. Capacity:	132	Wh/(m²K)

The sum of the heating periods calculated through the monthly method is presented on this worksheet.

Transmission heat losses Q_T

Building assembly	Temperature zone	Area m²		U-value W/(m²K)		Temperature reduction factor		G_t kKh/a		kWh/a	Per m² of TFA
External wall - ambient	A	1489.0	*	0.331	*	1.00	*	7	=	3383	1.84
External wall ground/basement	B		*		*	1.00	*		=		
Roof / ceiling - ambient	A	1185.7	*	0.216	*	1.00	*	7	=	1760	0.96
Floor slab / basement ceiling	B	1181.9	*	0.596	*	1.00	*	-3	=	-2015	-1.10
	A		*		*	1.00	*		=		
	A		*		*	1.00	*		=		
	A		*		*	1.00	*		=		
Windows	A	670.3	*	1.484	*	1.00	*	7	=	6817	3.71
Exterior door	A		*		*	1.00	*		=		
Thermal bridges ambient (length/m)	A		*		*	1.00	*		=		0.00
Perimeter thermal bridges (length/m)	P		*		*	1.00	*		=		0.00
Thermal bridges ground (length/m)	B		*		*	1.00	*		=		0.00
Sum of all areas of the building envelope		4527.0				Total transmission heat losses Q_T			=	9944	kWh/(m²a) 5.4

Ventilation heat losses Q_V

	m²		m		m³
Reference volume for the ventilation system, V_V (A_{TFA}*h)	1838	*	4.00	=	7353

	$n_{V,system}$ 1/h		η^*_{SHX}		η_{HR}		$n_{V,Res}$ 1/h		$n_{V,equi,fraction}$ 1/h
Effective air change rate Ambient $n_{V,e}$	0.490	*(1-	0%	)*(1-	0.74	)+	0.046	=	0.171
Effective air change rate Ground $n_{V,g}$	0.490	*	0%	*(1-	0.74	)		=	0.000

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation losses ambient Q_V	7353	*	0.171	*	0.33	*	7	=	2850	1.6
Ventilation losses ground $Q_{V,e}$	7353	*	0.000	*	0.33	*	-13	=	0	0.0
							Total ventilation heat losses Q_V	=	2850	1.6

Total heat losses Q_L

	Q_T kWh/a		Q_V kWh/a		Reduction factor night/weekend lowering		kWh/a	kWh/(m²a)
(	9944	+	2850	) *	1.0	=	12795	7.0

Available solar heat gains Q_S

Orientation of the area	Reduction factor see 'Windows' worksheet		g-value (perp. radiation)		Area m²		Global radiation kWh/(m²a)		kWh/a
North	0.17	*	0.31	*	242.2	*	109	=	1414
East	0.04	*	0.31	*	140.9	*	159	=	306
South	0.05	*	0.31	*	234.8	*	229	=	775
West	0.08	*	0.31	*	52.4	*	169	=	225
Horizontal	0.00	*	0.00	*	0.0	*	276	=	0
Sum opaque areas									1849

Total available solar heat gains Q_S = 4569 kWh/a; 2.5 kWh/(m²a)

Internal heat gains Q_I

kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
0.024	*	121	*	1.9	*	1838.2	=	10142	5.5

Utilisation factor heat gains η_G

			kWh/a	kWh/(m²a)
Free heat Q_F	$Q_S + Q_I$	=	14711	8.0
Ratio free heat to losses	Q_F / Q_L	=	1.15	
Utilisation factor heat gains h_G		=	72%	

Total heat gains Q_G

$\eta_G * Q_F$ = 10547 kWh/a; 5.7 kWh/(m²a)

Annual heating demand Q_H

$Q_L - Q_G$ = 2248 kWh/a; 1.2 kWh/(m²a)

Limit value

15 kWh/(m²*a)

Requirement met? Yes

Climate data

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

Passive House with PHPP Version 10.4a EN

PHPP

Selection of climate data

Country:	TW
Region:	All
	1-Sort alphabetically
Climate data set:	TW0001a
Climate zone:	5: Warm

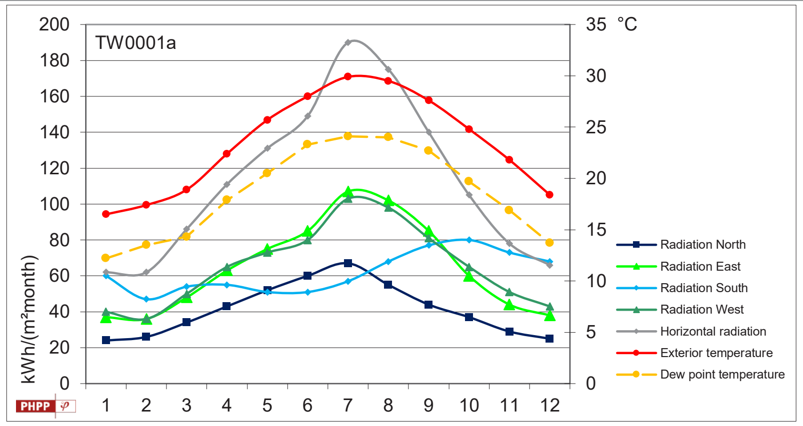
Altitude

Weather station:	9	m
Building location:	9	m
Temperature increase Summer:		°C

Result overview

Annual heating demand	1.2	kWh/(m²a)
Heating load	8.3	W/m²
Frequency of overheating	-	%
Sensible cooling	28.3	kWh/(m²a)
Latent cooling	22.7	kWh/(m²a)
Cooling load	12.7	W/m²
PER demand	56.8	kWh/(m²a)

	Data for heating Annual method	Data from monthly balance Heating	Cooling	
Heating / cooling period	0	121	244	d/a
Heating / cooling degree hours	0	7	6	kKh/a
Radiation North	0	109	387	kWh/(m²a)
Radiation East	0	159	621	kWh/(m²a)
Radiation South	0	229	512	kWh/(m²a)
Radiation West	0	169	616	kWh/(m²a)
Horizontal radiation	0	276	1079	kWh/(m²a)



	Month	1	2	3	4	5	6	7	8	9	10	11	12	Heating load		Cooling load		PER	
	Days	31	28	31	30	31	30	31	31	30	31	30	31	Weather 1	Weather 2	Weather 1	Weather 2	factors	
	TW0001a-Taipeh	Latitude °	25.03	Longitude °	121.53	Altitude [m]	9			ΔT Summer [K]	5.0	T Comfort criterion [°C]	7.0	Radiation: [W/m²]		Radiation: [W/m²]			
° C	Exterior temperature	16.5	17.4	18.9	22.4	25.7	28.0	29.9	29.5	27.6	24.8	21.8	18.4	11.5	13.9	32.3	31.2	1.25	Occupant electricity (
kWh/(m²month)	Radiation North	24	26	34	43	52	60	67	55	44	37	29	25	45	15	105	80	1.25	Domestic hot water
kWh/(m²month)	Radiation East	37	36	48	63	75	85	107	102	85	60	44	38	50	15	190	180	1.35	Heating
kWh/(m²month)	Radiation South	60	47	54	55	51	51	57	68	77	80	73	68	60	20	115	225	1.55	Cooling
kWh/(m²month)	Radiation West	40	36	50	65	73	80	103	98	81	65	51	43	50	20	185	190	1.60	Dehumidification
kWh/(m²month)	Horizontal radiation	62	62	86	111	131	149	190	175	140	105	78	66	80	25	335	305		
° C	Dew point temperature	12.2	13.5	14.3	17.9	20.5	23.3	24.1	24.0	22.7	19.7	16.9	13.7			27.6	28.0		
° C	Sky temperature	8.0	10.3	11.0	14.1	17.7	20.1	20.7	20.7	18.2	16.2	13.3	9.7			27.7	28.2		
	Comment	Meteonorm. Compared with various sources.																	
° C	Ground temperature (project-specific)	21.4	20.7	21.1	24.5	24.2	24.3	24.8	25.5	26.2	26.7	27.0	22.8	21.4	21.4	24.8	24.8		
	Relative humidity	76%	78%	75%	76%	73%	76%	71%	72%	75%	73%	74%	74%						

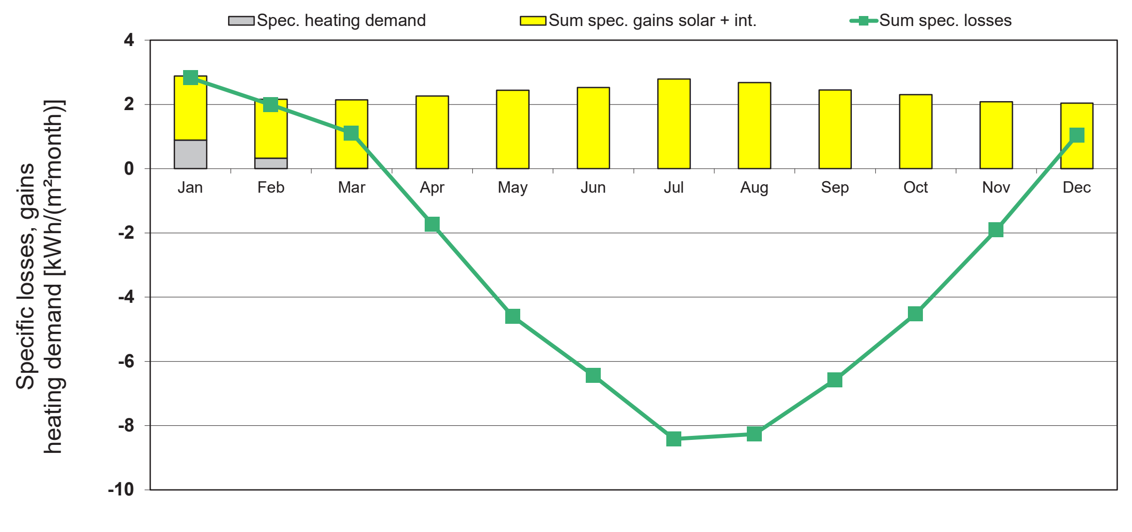
Specific energy for heating (monthly method)

Passive House with PHPP Version 10.4a EN

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

Interior temperature: 20 °C
Building type:
Treated floor area A_{TFA}: 1838 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating degree hours - exterior	2.7	1.8	0.9	-1.6	-4.1	-5.6	-7.2	-6.9	-5.3	-3.4	-1.2	1.3	-29	kKh
Heating degree hours - ground	-1.0	-0.5	0.0	0.4	0.6	0.5	0.2	-0.3	-0.8	-1.3	-1.4	-1.4	-5	kKh
Losses - exterior	5912	3991	2038	-3452	-8876	-12167	-15578	-14950	-11495	-7411	-2514	2868	-61633	kWh
Losses - ground	-721	-333	0	277	415	339	110	-242	-591	-898	-993	-961	-3597	kWh
Sum spec. losses	2.8	2.0	1.1	-1.7	-4.6	-6.4	-8.4	-8.3	-6.6	-4.5	-1.9	1.0	-35.5	kWh/m²
Solar gains - North	311	337	441	558	675	779	869	714	571	480	376	324	6436	kWh
Solar gains - East	71	69	92	121	144	163	206	196	163	115	85	73	1499	kWh
Solar gains - South	203	159	183	186	173	173	193	230	261	271	247	230	2508	kWh
Solar gains - West	53	48	66	86	97	106	137	130	108	86	68	57	1043	kWh
Solar gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar gains - Opaque	429	410	551	698	805	903	1129	1058	880	691	533	459	8545	kWh
Internal heat gains	2598	2347	2598	2515	2598	2515	2598	2598	2515	2598	2515	2598	30595	kWh
Sum spec. gains solar + int.	2.0	1.8	2.1	2.3	2.4	2.5	2.8	2.7	2.4	2.3	2.1	2.0	27.5	kWh/m²
Utilisation factor	97%	91%	52%	100%	100%	100%	100%	100%	100%	100%	100%	51%	-133%	
Annual heating demand	1627	601	10	0	0	0	0	0	0	0	0	9	2248	kWh
Spec. heating demand	**0.9**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.2**	kWh/m²



1838 m² treated floor area, Taiwan,

Passive House with PHPP Version 10.4a EN

Annual heating demand: Comparison

Monthly method	('Heating')	**2248**	**kWh/a**	**1.2**	**kWh/(m²a)** reference to treated floor area according to PHPP
Annual method	('Annual heating')	**276**	**kWh/a**	**0.2**	**kWh/(m²a)** reference to treated floor area according to PHPP

Cooling: specific energy demand for useful cooling

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

The sum of the cooling periods calculated through the monthly method is presented on this worksheet.

Building type:			Treated floor area A_{TFA}:	1838.2	m²
Interior temperature summer:	25	°C	Building volume:	7353	m³
Max. indoor absolute humidity:	12	g/kg	Internal humidity sources:	1.6	g/(m²h)
Spec. capacity:	132	Wh/(m²K)			

Transmission losses Q_T (negative: heat loads)

Building assembly	Temperature zone	Area m²		U-value W/(m²K)		Temperature reduction factor		G_t kKh/a		kWh/a	Per m² of TFA
External wall - ambient	A	1489.0	*	0.331	*	1.00	*	-6	=	-2901	-1.58
External wall ground/basement	B		*		*	1.00	*		=		
Roof / ceiling - ambient	A	1185.7	*	0.216	*	1.00	*	-6	=	-1509	-0.82
Floor slab / basement ceiling	B	1181.9	*	0.596	*	1.00	*	-2	=	-1582	-0.86
	A		*		*	1.00	*		=		
	A		*		*	1.00	*		=		
	A		*		*	1.00	*		=		
Windows	A	670.3	*	1.484	*	1.00	*	-6	=	-5844	-3.18
Exterior door	A		*		*	1.00	*		=		
Thermal bridges ambient (length/m)	A		*		*	1.00	*		=		0.00
Perimeter thermal bridges (length/m)	P		*		*	1.00	*		=		0.00
Thermal bridges ground (length/m)	B		*		*	1.00	*		=		0.00
											kWh/(m²a)
Sum of all areas of the building envelope		4527.0				**Total transmission heat losses Q_T**			=	**-11836**	**-6.4**

Ventilation heat losses Q_V

Information from the 'SummVent' worksheet

Ventilation conductance, vent. unit			**Ventilation parameter s**			**Summer ventilation control**	
exterior $H_{V,e}$	303.7	W/K	Daily temperature fluctuation in summer	5.0	K		HRV/ERV in summer
without HR	1187.8	W/K	Minimum acceptable indoor temperature	22.0	°C	None	
ground $H_{V,g}$	0.0	W/K	Heat capacity air	0.33	Wh/(m³K)	Temperature controlled	
without HR	0.0	W/K	Supply air change rate	0.49	1/h	Enthalpy controlled	x
Ventilation conductance, others			Outdoor air change rate	0.05	1/h	Always	
exterior	112.1	W/K	Window night vent. air change rate, manual @ 1K	0.00	1/h		Additional ventilation
Ventilation system			Air change rate due to mech., autom. controlled vent.	0.00	1/h	Temperature controlled	x
η_{HR}	74%		Specific electricity consumption for this	0.00	Wh/m³	Humidity controlled	
η_{ERV}	70%		Temperature increase	0.0	K		
η^*_{SHX}	0%						

Hygienic change rate:	$n_{V,system}$ 1/h		η^*_{SHX}		η_{HR} (considers bypass)		$n_{V,Rest}$ 1/h		$n_{V,equi,fraction}$ 1/h
Effective air change rate ambient $n_{V,e}$	0.490	*(1-	0%	)*(1-	0.56	)+	0.046	=	0.261
Effective air change rate ground $n_{V,g}$	0.490	*	0%	*(1-	0.56	)		=	0.000

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation losses ambient Q_V	7353	*	0.261	*	0.33	*	1	=	689	0.4
Ventilation losses ground $Q_{V,e}$	7353	*	0.000	*	0.33	*	0	=	0	0.0
Heat losses summer ventilation	7353	*	0.000	*	0.33	*	0	=	0	0.0
					Total ventilation heat losses Q_V			=	**689**	**0.4**

	Q_T kWh/a		Q_V kWh/a		kWh/a	kWh/(m²a)
Total heat losses Q_L	-11836	+	689	=	**-11146**	**-6.1**

Available solar heat gains Q_S

Orientation of the area	Reduction factor		g-value (perp. radiation)		Area m²		Global radiation kWh/(m²a)		kWh/a	kWh/(m²a)
North	0.16	*	0.31	*	242.2	*	387	=	4791	2.6
East	0.05	*	0.31	*	140.9	*	621	=	1447	0.8
South	0.04	*	0.31	*	234.8	*	512	=	1658	0.9
West	0.10	*	0.31	*	52.4	*	616	=	1014	0.6
Horizontal	0.40	*	0.00	*	0.0	*	1079	=	0	0.0
Sum opaque areas									6695	3.6
										kWh/(m²a)
								Total	15607	8.5

Internal heat gains Q_I

	Length cooling period		Spec. power q_I		A_{TFA}			
kh/d	d/a		W/m²		m²		kWh/a	kWh/(m²a)
0.024	244	*	1.9	*	1838.2	=	20452	11.1

Sum heat loads Q_F	Q_S + Q_I =	36059	19.6
		kWh/a	kWh/(m²a)

Utilisation factor heat losses η_L

Ratio of losses to free heat gains	Q_L / Q_F =	-0.31	
Utilisation factor heat losses η_L	=	143%	
		kWh/a	kWh/(m²a)
Useful heat losses $Q_{L,n}$	η_L * Q_L =	-15968	-8.7
		kWh/a	kWh/(m²a)
Useful cooling demand Q_K	Q_F - $Q_{L,n}$ =	52027	28.3
Recommendation	kWh/(m²a) 30	Target value reached?	Yes

Dehumidification demand Q_{Dr}

	Q_{Tr} =	41686	22.7
Recommendation	kWh/(m²a) 21	Target value reached?	No

Cooling: specific energy demand for useful cooling

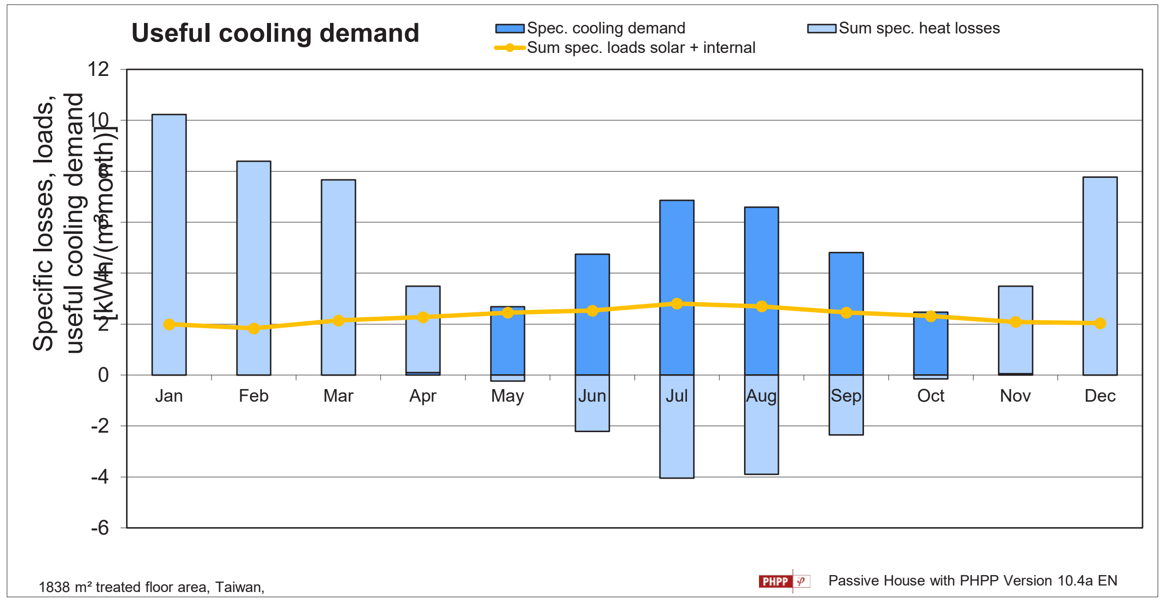
Passive House with PHPP Version 10.4a EN

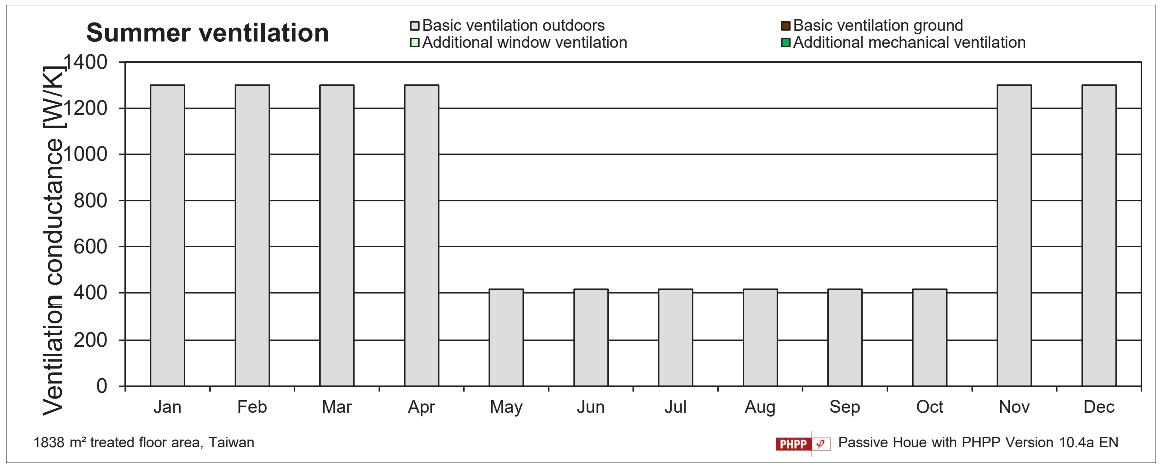
/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

Interior Temperature: 25 °C

Treated floor area A_{TFA}: 1838 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating degree hours - Exterior	6.5	5.2	4.7	2.0	-0.4	-2.0	-3.5	-3.2	-1.7	0.3	2.5	5.1	16	kKh
Heating degree hours - Ground	-1.0	-0.5	0.0	0.4	0.6	0.5	0.2	-0.3	-0.8	-1.3	-1.4	-1.4	-5	kKh
Losses - Exterior	19531	15758	14078	5971	-848	-4398	-7550	-6922	-3727	617	7292	15238	55041	kWh
Losses - Ground	-721	-333	0	277	415	339	110	-242	-591	-898	-993	-961	-3597	kWh
Losses summer ventilation	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Sum spec. heat losses	10.2	8.4	7.7	3.4	-0.2	-2.2	-4.0	-3.9	-2.3	-0.2	3.4	7.8	28.0	kWh/m²
Solar load North	297	322	421	532	644	743	830	681	545	458	359	310	6141	kWh
Solar load East	86	84	112	147	175	198	249	238	198	140	103	89	1818	kWh
Solar load South	194	152	175	178	165	165	185	220	249	259	236	220	2400	kWh
Solar load West	66	59	82	107	120	132	170	161	133	107	84	71	1293	kWh
Solar load Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar load Opaque	429	410	551	698	805	903	1129	1058	880	691	533	459	8545	kWh
Internal heat gains	2598	2347	2598	2515	2598	2515	2598	2598	2515	2598	2515	2598	30595	kWh
Sum spec. loads solar + internal	2.0	1.8	2.1	2.3	2.5	2.5	2.8	2.7	2.5	2.3	2.1	2.0	27.6	kWh/m²
Utilisation factor losses	20%	22%	28%	64%	100%	100%	100%	100%	100%	100%	59%	26%	-2%	
Useful cooling energy demand	0	1	3	169	4941	8714	12601	12120	8837	4533	106	2	52027	kWh
Spec. cooling demand	**0.0**	**0.0**	**0.0**	**0.1**	**2.7**	**4.7**	**6.9**	**6.6**	**4.8**	**2.5**	**0.1**	**0.0**	**28.3**	kWh/m²
Specif. dehumidification demand	**0.0**	**0.0**	**0.0**	**1.9**	**2.4**	**3.7**	**4.3**	**4.2**	**3.3**	**2.0**	**0.9**	**0.0**	**22.7**	kWh/m²
Sensible fraction	100%	100%	100%	5%	53%	56%	62%	61%	59%	55%	6%	100%	56%	





Electricity demand for non-residential buildings

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

Passive House with PHPP Version 10.4a EN

Building type:
Treated floor area A_{TFA}: 1838.2 m²

For dishwasher + washing machine with DHW connection:

Solar fraction of DHW: 0%
Marginal performance ratio DHW: 0%

	PER factors	PE factors	
Electricity:	1.25	2.6	kWh/kWh
RE gas / Natural gas:	1.75	1.1	kWh/kWh
Energy carrier for DHW:			kWh/kWh

Lighting

Room / Zone	Net floor area	Utilisation profile	Façade with windows: Window existing?	Deviation from North	Orientation	Factor	Light transmission glazing	Geometry: input of a typical room: Room depth	Room width	Room height	Lintel height (top of window)	Window width	Daylight utilisation
	m²		[x]	Degrees			-	m	m	m	m	m	
MainHall&Children area_GF	671	1-MainHall&Children area_GF	x	180	South	0.05	78%	21.0	42.0	4.0	3.2	41.2	None
Office_GF	80	2-Office_GF	x	0	North	0.17	78%	9.0	8.9	4.0	3.2	8.0	None
Classroom_GF	54	3-Classroom_GF	x	0	North	0.17	78%	9.0	6.0	4.0	3.2	6.0	None
Classroom_GF	54	3-Classroom_GF	x	0	North	0.17	78%	9.0	6.0	4.0	3.2	6.0	None
Storage_GF_W	30	4-Storage_GF_W	x	0	North	0.17	78%	4.7	6.3	4.0	3.2	2.0	None
MechanicalRoom_GF_W	7	5-MechanicalRoom_GF_W					78%						None
Garbage Room_GF_W	11	6-Garbage Room_GF_W	x	270	West	0.08	78%	3.7	3.0	4.0	3.2	1.0	None
Toilets_GF_W	46	7-Toilets_GF_W	x	270	West	0.08	78%	6.3	7.0	4.0	3.2	1.5	None
Stairwell_GF_W	54	8-Stairwell_GF_W	x	180	South	0.05	78%	8.9	6.3	4.0	3.2	2.0	None
MechanicalRoom_GF_E	7	9-MechanicalRoom_GF_E					78%						None
Garbage Room_GF_E	11	10-Garbage Room_GF_E	x	0	North	0.17	78%	3.0	3.7	4.0	3.2	1.0	None
Toilets_GF_E	46	7-Toilets_GF_W	x	90	East	0.04	78%	6.3	7.0	4.0	3.2	1.5	None
Stairwell_GF_E	33	8-Stairwell_GF_W	x	180	South	0.05	78%	8.9	6.3	4.0	3.2	2.0	None
Reading area_1F	683	13-Reading area_1F	x	0	North	0.17	78%	23.7	42.0	5.0	3.2	24.0	None
Meeting Room_1F	29	14-Meeting Room_1F	x	180	South	0.05	78%	4.7	6.3	4.0	3.2	6.0	None
Meeting Room_1F	29	14-Meeting Room_1F	x	180	South	0.05	78%	4.7	6.3	4.0	3.2	6.0	None
Storage_1F_W	30	15-Storage_1F_W	x	0	North	0.17	78%	4.7	6.3	4.0	3.2	2.0	None
MechanicalRoom_1F_W	9	16-MechanicalRoom_1F_W	x	270	West	0.08	78%	3.1	3.0	4.0	3.2	1.5	None
Toilets_1F_W	46	17-Toilets_1F_W	x	270	West	0.08	78%	6.3	7.0	4.0	3.2	1.5	None
Stairwell_1F_W	54	18-Stairwell_1F_W	x	180	South	0.05	78%	8.9	6.3	4.0	3.2	2.0	None
MechanicalRoom_1F_E	10	19-MechanicalRoom_1F_E	x	90	East	0.04	78%	3.3	3.0	4.0	3.2	1.0	None
Toilets_1F_E	46	20-Toilets_1F_E	x	90	East	0.04	78%	6.3	7.0	4.0	3.2	1.5	None
Stairwell_1F_E	34	21-Stairwell_1F_E	x	180	South	0.05	78%	8.9	6.3	4.0	3.2	2.0	None
Stairwell_2F_W	56	22-Stairwell_2F_W	x	180	South	0.05	78%	8.9	6.3	4.0	3.2	2.0	None
Stairwell_2F_E	32	23-Stairwell_2F_E	x	180	South	0.05	78%	5.2	6.3	4.0	3.2	2.0	None

Total net floor area 2162 m²

Room / Zone	Nominal illuminance	Installed lighting power			Lighting control	Motion detector used?	Utilisation hours per year	User-defined: full load hours of lighting	Full load hours of lighting		Electricity demand	Specific electricity demand (per m² room area)	PER demand	PE demand
	Lux	W/m²	W/m²	W/(m²*100lux)		[x]	h/a	h/a	h/a	h/d	kWh/a	kWh/(m²a)	kWh/a	kWh/a
MainHall&Children area_GF	300		9.8	3.3	1-Manual		2988		1447	5.8	**9510**	14.2	**11888**	24727
Office_GF	300		9.8	3.3	1-Manual		2988		1356.67	5.4	**1059**	13.3	**1324**	2753
Classroom_GF	300		9.8	3.3	1-Manual		2988		1343.33	5.4	**711**	13.2	**889**	1848
Classroom_GF	300		9.8	3.3	1-Manual		2988		1343.33	5.4	**711**	13.2	**889**	1848
Storage_GF_W	200		7.2	3.6	1-Manual		2988		1360	5.5	**290**	9.8	**362**	754
MechanicalRoom_GF_W	200		7.2	3.6	1-Manual		2988		1490	6.0	**80**	10.7	**100**	207
Garbage Room_GF_W	200		7.2	3.6	1-Manual		2988		1360	5.5	**106**	9.8	**133**	276
Toilets_GF_W	200		7.2	3.6	1-Manual		2988		1410	5.7	**467**	10.2	**584**	1215
Stairwell_GF_W	200		7.2	3.6	1-Manual		2988		1415.42	5.7	**549**	10.2	**686**	1428
MechanicalRoom_GF_E	200		7.2	3.6	1-Manual		2988		1490	6.0	**80**	10.7	**100**	208
Garbage Room_GF_E	200		7.2	3.6	1-Manual		2988		1310	5.3	**102**	9.4	**128**	266
Toilets_GF_E	200		7.2	3.6	1-Manual		2988		1420	5.7	**471**	10.2	**589**	1224
Stairwell_GF_E	200		7.2	3.6	1-Manual		2988		1415.42	5.7	**341**	10.2	**426**	886
Reading area_1F	300		9.8	3.3	1-Manual		2988		1454.48	5.8	**9737**	14.3	**12171**	25316
Meeting Room_1F	300		9.8	3.3	1-Manual		2988		1320	5.3	**380**	12.9	**475**	988
Meeting Room_1F	300		9.8	3.3	1-Manual		2988		1320	5.3	**380**	12.9	**475**	988
Storage_1F_W	200		7.2	3.6	1-Manual		2988		1360	5.5	**290**	9.8	**362**	754
MechanicalRoom_1F_W	200		7.2	3.6	1-Manual		2988		1320	5.3	**88**	9.5	**109**	228
Toilets_1F_W	200		7.2	3.6	1-Manual		2988		1410	5.7	**467**	10.2	**584**	1215
Stairwell_1F_W	200		7.2	3.6	1-Manual		2988		1415.42	5.7	**546**	10.2	**683**	1420
MechanicalRoom_1F_E	200		7.2	3.6	1-Manual		2988		1390	5.6	**97**	10.0	**121**	251
Toilets_1F_E	200		7.2	3.6	1-Manual		2988		1420	5.7	**471**	10.2	**589**	1224
Stairwell_1F_E	200		7.2	3.6	1-Manual		2988		1415.42	5.7	**348**	10.2	**435**	905
Stairwell_2F_W	200		7.2	3.6	1-Manual		2988		1415.42	5.7	**568**	10.2	**710**	1477
Stairwell_2F_E	200		7.2	3.6	1-Manual		2988		1370	5.5	**320**	9.9	**400**	832

Average lighting efficiency **3.35** W/(m²*100lux)]

Total lighting **28170** kWh/a **35212** 73241 kWh/a

Electrical devices

Selection from device list:	Quantity	Utilisation profile	Consider for IHG?	Informative: room utilisation: Hours per day	Presence of occupants	informative: Nominal power (full load)	Days per year	Average power in operation: Hours per day	Power per device	Electricity demand	When not in operation: Power per device	Electricity demand	Electricity demand	PER demand	PE demand
				h/d	h/d	W	d/a	h/d	W	kWh/a	W	kWh/a	kWh/a	kWh/a	kWh/a
5- PC (standard)	10	91-Open access library	1	12	12		300	12.0	66.0	2376	1.0	52	**2428**	**3035**	6312
9- Pr nter/Copier/Scanner	1	91-Open access library	1	12	12		300	12.0	270.0	972	1.0	5	**977**	**1221**	2541

Total in operation **3348** kWh/a Total 'not in op.' **57** kWh/a

Total electrical devices **3405** kWh/a **4256** 8852 kWh/a

Kitchen	Used ?	Utilisation profile (predominant use of the building)	Consider for IHG?	Days of utilisation per year	Number of meals per day of use	Norm consumption	Useful energy				Additional heat demand	Electricity demand	PER demand	PE demand
Application	[1/0]	Application		d/a	Meal/d		kWh/a				kWh/a	kWh/a	kWh/a	kWh/a
Cooking:	0	62-Group office	0	250		0.25	0	*	100%	Electric fraction		0.0	0	0
1-Electricity						kWh / Meal		*	0%	Gas fraction	0		0	0
Dishwashing	0	62-Group office	0	250	0	0.10	0	*	100%	Electric fraction		0.0	0	0
2-Cold water connection						kWh / Place setting		*	0%	DHW fraction * (1+ 0.30 [Addl. demand]) * 0.00 [Marginal performance ratio] *(1- 0.00 [Solar fraction]) =	0		#VALUE!	#VALUE!
						kWh/d								
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0
							0					0.0	0	0

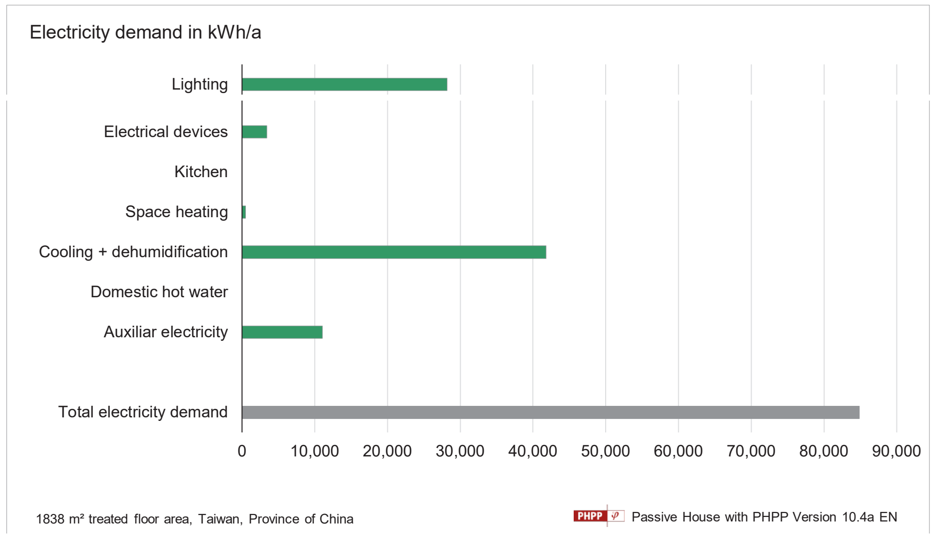
Total useful energy kitchen 0 kWh/a

DHW for dishwashing; additional heat demand 0 kWh/a

Total additional heat demand kitchen: #VALUE! (PER) #VALUE! (PE) kWh/a

Total electricity demand kitchen 0 kWh/a | 0 (PER) | 0 (PE) kWh/a

		Electricity		PER	PE	
Total user electricity		**31574**	kWh/a	**39468**	**82093**	kWh/a
		17	kWh/(m²a)	**21**	**45**	kWh/(m²a)
Electricity demand for:						
Space heating	from 'PER' worksheet, without aux. electricity	464	kWh/a	627	1207	kWh/a
Cooling + dehumidification	from 'PER' worksheet, without aux. electricity	41787	kWh/a	65152	108647	kWh/a
Domestic hot water	from 'PER' worksheet, without aux. electricity	0	kWh/a	0	0	kWh/a
Auxiliar electricity	from 'Aux. Electricity' worksheet	11036	kWh/a	17105	28694	kWh/a
Total electricity demand		**84862**	kWh/a	**122351**	**220641**	kWh/a
		46	kWh/(m²a)	**67**	**120**	kWh/(m²a)



Primary Energy Renewable PER

Passive House with PHPP Version 10.4a EN

/ Climate: TW0001a / TFA: 1838 m² / Heating: 1.2 kWh/(m²a) / Cooling: 51 kWh/(m²a) / PER: 56.8 kWh/(m²a)

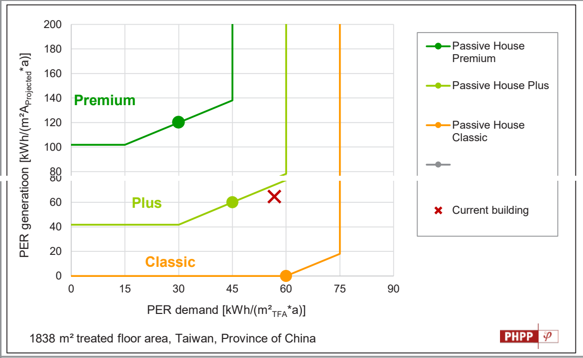
Selection of the heat generation system	Contribution (useful energy) Heating	DHW
2-Heat pump(s)	100%	100%
-		
-		
-		
Additionally: Solar thermal	0.0	0.0 kWh/(m²a)

Building type:		
Treated floor area A_{TFA}:	1838	m²
Projected building footprint $A_{Projected}$:	1518	m²
Heating demand incl. distribution & hydr. frost protection	1.2	kWh/(m²a)
Cooling energy demand incl. dehumidification	56	kWh/(m²a)
DHW demand including distribution:	0.0	kWh/(m²a)
Biomass contingent (PER):	20	kWh/(m²a)

Energy demand referred to treated floor area	Efficiency Calcula-tion -	 User defined -	Useful energy Covered fraction	Final energy demand kWh/(m²a)	PER PER factor kWh/kWh	 PER demand kWh/(m²a)	PE PE factor kWh/kWh	 PE demand kWh/(m²a)	CO_2 Emission factor (CO_2-eq) kg/kWh	 CO_2eq emissions kg/a
							1-PE factors (non-renewable) PHI Certification		1-CO2 factors GEMIS (Germany)	
Heating			100%							
Electricity (HP compact unit)					1.35		2.60		0.363	
Electricity (heat pump)	4.84		100%	0.3	1.35	0.3	2.60	0.7	0.363	169
Other (heating)					1.35		2.60		0.363	
Boiler					0.00					
District heating					0.77		0.30		0.000	
Solar thermal system										
Aux. electricity (heating, wintertime ventilation)				0.0	1.35	0.0	2.60	0.0	0.363	1
Total heating						**0.3**		**0.7**		**170**
Cooling and dehumidification					PER		PE		CO_2	
Electricity cooling (HP)	2.58			18.6	1.55	28.8	2.60	48.3	0.363	12403.4
Electricity dehumidification (HP)	2.00			4.1	1.60	6.6	2.60	10.8	0.363	2765.5
Auxiliary electricity cooling, ventilation summer				6.0	1.55	9.3	2.60	15.6	0.363	4005.0
Auxiliary electricity (dehumidification)					1.60		2.60		0.363	
Total cooling and dehumidification						**44.75**		**74.71**		**19173.87**
DHW generation			100%		PER		PE		CO_2	
Electricity (HP compact unit)					1.25		2.60		0.363	
Electricity (heat pump)			100%		1.25		2.60		0.363	
Electricity (direct)					1.25		2.60		0.363	
Boiler					0.00					
District heating					0.79		0.30		0.000	
Solar thermal system										
Aux. electricity (DHW + solar DHW)					1.25		2.60		0.363	
Total DHW						**0.0**		**0.0**		**0**
Occupant electricity + auxiliary electricity (other)					PER		PE		CO_2	
User electricity (lighting, electrical devices, etc.)				17.2	1.25	21.5	2.60	44.7	0.363	11461
Auxiliary electricity (other)					1.25		2.60		0.363	
Total user electricity and auxiliary electricity						**21.5**		**44.7**		**11461**
Additional gas demand					PER		PE		CO_2	
Drying/Cooking				0.0	1.75	0.0	0.00	0.0	0.000	
Total additional gas demand						**0.00**		**0.00**		**0**
Total PER demand without bioenergy budget						**66.6**				
Bioenergy utilisation						**-9.8**	The bioenergy budget will be used with 16.6 kWh/(m²a).			
Total energy demand kWh/(m²$_{TFA}$ a)					PER:	**56.8**	PE:	**120.0**	CO_2:	**30805** kg/a

Energy generation referred to projected building footprint	Final energy Final energy generation kWh/a	 Final energy generation kWh/(m²$A_{Projected}$*a)	PER PER factor kWh/kWh	 PER generation kWh/(m²$A_{Projected}$a)	PE PE factor kWh/kWh	 PE generation kWh/(m²$A_{Projected}$a)	CO_2 Emission factor (CO_2-eq) kg/kWh	 Emissions generated kg/a	 Emissions saved kg/a
PV electricity	98014	64.6	1.00	64.6	0.00	0.0	0.13 I 0.363	12742	22837
Solar thermal system	0	0.0	-	0.0	0.00	0.0			
		0.0							
Total energy production kWh/(m²$_{Projected\ building\ footprint}$ a)			PER:	**64.58**	PE:	**0.00**	CO_2:	**12742**	**22837**

Verification Passive House/EnerPHit standard



Classes in subdivisions: Current value:				PHI Criteria Low Energy Building	Criteria Passive House : Classic	 Plus	 Premium	Achieved class
Heating demand referred to TFA	**1**	kWh/(m²a)	≤	30		15		Premium
Heating load referred to TFA	**8**	W/m²	≤	-		10		
Cooling and dehumidification demand referred to TFA	**51**	kWh/(m²a)	≤	66		51		Premium
Airtightness n_{50}	**0.6**	1/h	≤	1		0.6		Premium
PER demand referred to TFA	**57**	kWh/(m²a)	≤	75	60	45	30	Classic
PER generation referred to projected building footprint	**65**	kWh/(m²a)	≥	-	0	60	120	
PE demand (non-renewable primary energy)	**120**	kWh/(m²a)	≤	120		120		Classic

Energy standard of the whole building — With the selected verification method PER (renewable) the following class can be reached: **Classic**

Standard criteria

Summary Different final energy sources are added up here. Though this is not scientifically correct, it is required by other single verifications.	Final energy MWh/a	PER (renewable primary energy) MWh/a	PE (non-renewable primary energy) 1-PE factors (non-renewable) PHI Certification MWh/a	CO2eq emissions 1-CO2 factors GEMIS (Germany) kg/a	CO_2eq substitution 1-CO2 factors GEMIS (Germany) kg/a
Demand	**84.9**	**104.3**	220.64	30805	30805
Generation	**-98.0**	**-98.0**	0.00	12742	-22837
Cumulated demand and generation (annual balance)	**-13.15**	**6.32**	220.64	43547	7968
Demand without occupant electricity consumption	53.29	64.87	138.55	-21037423	-21037423
Demand without occupant electricity consumption, accumulated generation	-44.73	-33.15	138.55	-21024681	-21060260

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