EVA-MARIA EBNER

GREEN GLOBAL OFFICE BUILDING

submitted to the
FH JOANNEUM Gesellschaft mbH,
University of Applied Sciences, Graz

MASTER THESIS: GREEN GLOBAL OFFICE BUILDING

submitted by Eva-Maria Ebner, BSc
Krieselsdorf 8, 9800 Spittal an der Drau, AUSTRIA

Tutor: Arch. DI Heimo Staller
Graz, November 18th 2013

GREEN GLOBAL OFFICE BUILDING

corporate design in different climate zones

DECLARATION

“I declare that this paper is my own work and was written without literature other than the sources indicated in the bibliography. Information used from the published or unpublished work of others has been acknowledged in the text and has been explicitly referred to in the given list of references. This paper has not been submitted in any form for another degree or diploma at any university or other institute of tertiary education.”

Graz, November 18th 2013

EINLEITUNG

Das Bürogebäude ist ein wichtiger Bestandteil unserer Städte sowie unserer Wirtschaft. Obwohl sie eine relativ alte Art von Gebäuden sind, haben sie einen großen Einfluss auf unsere heutigen Städte. Sie bilden die Skyline, verändern die mikroklimatische Situation vor Ort und repräsentieren große Unternehmen. Daher stellen sie heute einen unabdingbaren Teil der Städte dar und es gibt sie in unterschiedlichsten Ausführungen weltweit.

Im ersten Teil dieser Arbeit werde ich Bürogebäude analysieren und deren Besonderheiten aufzeigen. Darüber hinaus werde ich ökologische Fragen im Zusammenhang mit Bürogebäuden in verschiedenen Klimazonen beantworten.

Um ein energieeffizientes Gebäude zu entwerfen, ist es wichtig auf die örtlichen Gegebenheiten zu achten. Wenn man Faktoren wie Solarstrahlung, Temperatur, Wind, Luftfeuchtigkeit etc. berücksichtigt, kann man viel gezielter im Entwurf eingreifen, um negative Einflüsse zu verhindern und um die Positiven hervorzuheben. Darüber hinaus hat die Gestaltung des Gebäudes, die Form, die Ausrichtung etc. große Auswirkungen auf die Energieeffizienz wie auch die allgemeinen Anforderungen an den Energiebedarf.

Daher ist das Ziel dieser Arbeit, ein nachhaltiges Bürogebäude am Standort Wien zu entwerfen, das in der Nutzung nachhaltig geführt werden kann und ökologische Gebäudetechnik aufweist. Um zu demonstrieren, wie diese Konstruktion angepasst werden muss, um in unterschiedlichen Klimata genauso zu funktionieren, werde ich vier weitere Orte rund um den Globus untersuchen, die in komplett unterschiedlichen Klimazonen liegen. Das Design werde ich dementsprechend anpassen. Um das Ergebnis numerisch zu verdeutlichen und einen Vergleich zu ermöglichen, werde ich den Energiebedarf im Programm “EnerCalC” ermitteln.

Die “Corporate Identity” vom Hauptdesign und die grundlegenden Gebäudevorgaben wie beispielsweise die Bruttogeschossfläche werden in allen Klimazonen die gleichen bleiben, aber das Aussehen wird sich aufgrund der unterschiedlichen Klimabedingungen immer ein wenig verändern.

ABSTRACT

An office building is an important component of our cities as well as of our economy. Although they are a relatively old kind of buildings, they still have huge influences on our cities today. They form the skyline, alter the microclimatic situation onsite and represent huge companies. They have become a main part of cities and they exist in a wide variety of locations all over the world.

In the first part of this thesis, I am going to analyse office buildings and explain their characteristics. Furthermore, I will have a look at the ecological issues pertaining to office buildings across different climate zones.

To design an energy efficient building it is important to take local conditions into account. If you provide factors such as solar radiation, temperature, wind, air-humidity etc, you can take action in a more powerful way to prevent negative influences and to highlight the positive ones. If you know them, the design of the building according to its shape, orientation ect. has to be adapted to it and the energy demands determined.

Therefore, the aim of this thesis is to design a sustainable office building in Vienna that is constructed in ecological manners and which is operated using alternative building systems. In order to demonstrate how this design can easily be customized to be appropriate for different environments, I am going to investigate four places around the globe, of completely different climates and match the design to these. In order to numerically quantify the results, I am going to demonstrate the environmental aspect with the tool “EnerCalC”.

The corporate identity of the main design and the basic guidelines concerning the gross floor area will remain the same through the range of climates although the building may look different because of the variety in climate conditions.


14
37
108
164
22
54
118
150
28
75
116
171
CSIC
EnerCalC2013
Werkzeug für vereinfachte Energiebilanzen in Anlehnung an DIN V 18599
Start
EnOB

CONTENT

CHAPTER I

INTRODUCTION

at the beginning of this thesis, the general requirements are described to find out what is meant by the topic **"green global office building"**. *therefore, the challenges and problems are explained, which are of great importance to design an office building in different climate zones. furthermore, each issue is illustrated seperately. it is described, why* **working worldwide** *is a topic in the 21st century and why it is to stay. why does a corporation with a lot of subsidaries need* **corporate architecture** *with its own, individual identity? and why* **bioclimatic design** *is the higher level argument in designing energy efficiently in consideration of the local climate.*

Ill. 1 | PROBLEMS AND CHALLENGES

What is important to design a green global office building.

1. PROBLEMS AND CHALLENGES

To design a “green global office building” several factors have to be considered. First of all, there is the use of the building: the office. It is important to know the definition and historical background as well as some good examples of this kind of building. The second part is the ecological aspect. Answers have to be found concerning the energy demand of an office building and energy efficient building concepts. The third challenge is to put all the just mentioned issues into a global content. Therefore you have to know the specific climate and its impacts on building structures and facades.

Last but not least, a corporate identity which works in cold and temperate climate as well as in the subtropics, the tropics and the desert should be found.

Only if there is an overlapping design for all climate zones, you have a corporate architecture, which you can compare in regard to ecology and energy efficiency.

Ill. 2 | SPREAD WORLDWIDE

One company with four subsidaries in different countries.

2. WWW | WORKING WORLD WIDE[1]

Due to the industrialization and imperialism, a lot of companies began to open subsidiaries in other countries, starting in the 19th century. After the Second World War, the importance of multinational corporations increased even more because of the growing world economy and the rise in foreign direct investment. As coherent effect of the globalization, the number of multinational corporations increased from 7,000 in 1970 to over 78,000 in 2006, including even more daughter companies. Ergo, multinational corporations account for over half of the industrial output of the world.

The list of the largest multinational companies by revenue is lead by the petrochemical firm "Royal Dutch Shell", followed by the US "ExxonMobil" and the US retail group "Walmart".

The reach of the companies is limitless. The "Royal Dutch Shell" Company, for example, is located in more than 70 countries around the world, employes about 87,000 people and there are more than 44,000 filling stations worldwide.[2]

1. Cf. WIKIPEDIA (2013): Multinationales Unternehmen. Viewed on 04/30/2013 under de.wikipedia.org/ wiki/Multinationales_Unternehmen
2. Cf. SHELL (n.y.): The Shell global homepage. Viewed on 04/30/2013 under www.shell.com

Ill. 3 | THE APPLE STORE IN NEW YORK

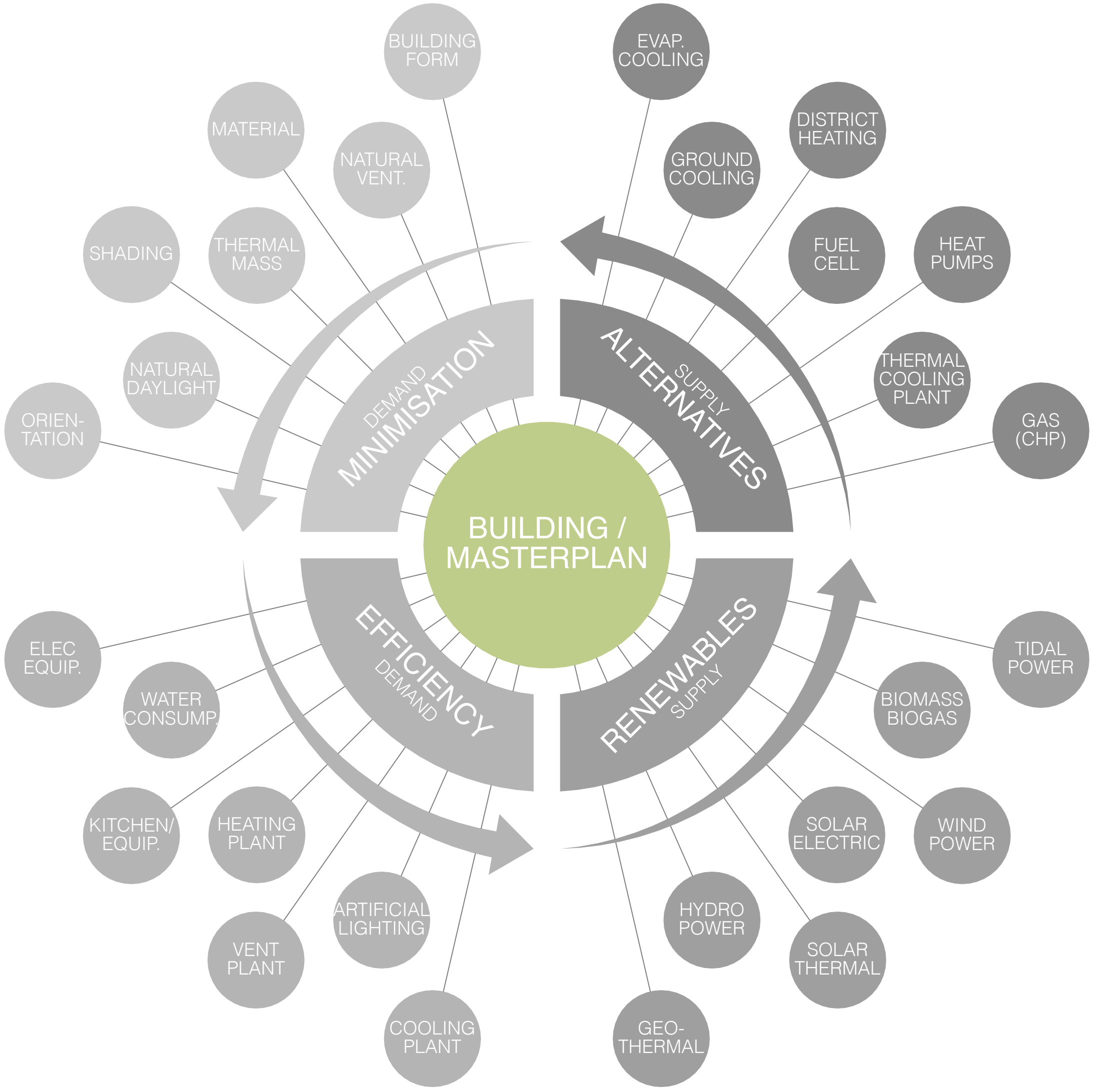
Representing a good example of corporate identity and architecture.

3. CORPORATE ARCHITECTURE

Corporate Architecture can be seen as a reaction to multinational companies. Each kind of firm regardless of its size has to represent itself in the best possible way on the local and global market. That is why corporate identity is of paramount importance and corporate architecture should be integrated with it. A well-designed building transmits trust and image, while providing insight into the innovation potential of a company. It motivates and identifies the employees of the company as well as creates corporate identity. Marketing and architecture should speak the same language and they should follow the corresponding goal. The mission statement as a part of the design can create a unique identity.[3]

A very good example of corporate identity is "Apple Inc.", which pervades all different areas, beginning from each kind of product, over the appearance of the employees, to the shape and impression of the buildings. Nowadays, simplicity is at the forefront of their design.
Apple once published the motto: "Think Different", and is now at the top of "Fortune Global 500"[4] which is a ranking of corporations by market capitalization.

3. Cf. Bratschi, Urs: Architektur als Marketinginstrument. Mehrwerte für Unternehmen durch Corporate Architecture in KMU-Magazine, No. 10 (12/2007 - 01/2008) Viewed on 04/29/2013 under http:// www.marketingarchitektur.ch/downloads/KMU- Magazin_1007.pdf
4. Cf. WIKIPEDIA (2013): List of corporations by market capitalization. Viewed on 05/01/2013 under en.wikipedia.org/wiki/List_of_corporations_by_ market_capitalization



Ill. 4 | BIOCLIMATIC MASTERPLAN OF A BUILDING

Illustrating the four strategies of environmental design.

4. BIOCLIMATIC ARCHITECTURE

Worldwide, buildings are responsible for 33 % of global CO_2 emissions and consume about 25 % of global primary energy. Also 60 % of the world's electricity goes into buildings. That is to say, that the buildings of today are the greatest polluters on earth.[5]

For this reason, ecological design, the building's environmental performance as well as bioclimatic architecture are incredibly important. It is now a global matter to reduce energy consumption and environmental impact of buildings. As the local climatic and geographic characteristics from city to city are different, building design should react to this to reduce the energy consumption. Local environmental constraints and potentials are to be recognized to develop appropriate design concepts and technology as well as creating high levels of indoor comfort.[5]

One main goal of a bioclimatic design approach is the reduction of the life-cycle costs of a building. The savings can range from 30 % to 60 %. Moreover, the building users benefit from the positive effects of sustainable design. Interior comfort rises due to a healthier internal environment, which minimizes sick leave days generating more productive working conditions.

Throughout human history a multitude of factors such as, for example, politics, culture and financing have influenced buildings. There has only been one relative constant over time – the climate. Therefore, we should bring this factor back to the core of building planning.[6]

5. Cf. Gonçalves, Joana Carla Soares / Umakoshi, Érica Mitie: The Environmental Performane of Tall Buildings. (London: Earthscan, 2010) pp. 143-145
6. Cf. Yeang, Ken: the skyscraper. bioclimatically consid- ered. (London: Academy Editions, 1996) pp. 24-26

CHAPTER II

HISTORICAL OVERVIEW OF OFFICE BUILDINGS

the second chapter deals with the historical development of the building. therefore, it is important to begin with a short definition. where does the office stem from, when is it first mentioned, and how did it change over a period of time? these are all questions, which have to be answered. that is why a **historical development** *from the antiquity to now gives an insight into the* **alteration** *of the office building. afterwards, the current office types are mentioned as well as some* **today's innovations** *are illustrated. last but not least, the chapter ends showing some good examples of* **sustainable office buildings** *of today.*

1. DEFINITION

The word office stems from the Latin "officum", and its equivalents in Middle English and Anglo-French. Interestingly, this was not necessarily a place but rather a "prescribed form or service of worship"[7]. More or less, it could be seen as a mobile "bureau" in the sense of human knowledge or even the abstract notion of a formal position.
The English form of the word first appeared in 1395 when Geoffrey Chaucer referred to a place where business is transacted in a collection called "the Canterbury Tales".

Today an office can be generally described as a room or area where people work or hold a specific position within an organization. The place of the office can be anywhere unless it is the location of someone's duty and it has an official presence to a company or organization.[8]

7. Cf. MERRIAM-WEBSTER (2013): Office. Viewed on 03/06/2013 under www.merriam-webster.com/ dictionary/office
8. Cf. WIKIPEDIA (2013): Office. Viewed on 03/06/2013 under en.wikipedia.org/wiki/Office

2. HISTORY OF OFFICE BUILDINGS

ANTIQUITY. The history of office buildings cannot be described in a consistent or even continuous way. You can find different types of offices in similar implementations from the antiquity up to now. It is definitely not an invention of the 20th century.[9]
In the classical antiquity, offices were primarily part of a palace complex or a large temple.[10] A strict separation between the palace and the administration took place in ancient Egypt between 3200 and 525 BC. According to the sociologist Max Weber[9], it was the historical forerunner of all following kinds of bureaucracy. The administration was clearly and hierarchically defined and a lot of scribes were employed to execute their work in different fractions. Comparable to our "office nomads" of today, a lot of reputable scribes often gadded around from place to place with their pen and ink to meet at the scriptoriums for an exchange of their work.[9]

During the High Middle Ages, the medieval chancery grew in importance, becoming a place where a lot of governmental letters were written and where laws were copied by order of a kingdom. As the mercantilism became strong during the Renaissance in the 15th and 16th century, it became important for the merchants to both conduct their business in the same building as well as travelling to other places of their company. The numerous existing, small and internationally located offices of trading concerns are similar to our well known "satellite offices".[10]

The main difference in historical offices and those of today is explained by the development of working in connection with particular political and social situation as well as technological progress.[9]

Ill. 5 | OFFICE-LIKE SITUATION IN ANTIQUITY

Scribes are meeting in a scriptorium.

9. Vgl. Hascher, Rainer / Arnold, Thomas: Entwurfsatlas Bürobau. (Basel: Birkhäuser, 2002) pp. 13-19
10. Vgl. WIKIPEDIA (2013): Office. Viewed on 03/06/2013 under en.wikipedia.org/wiki/Office

Ill. 6 | **LARKIN ADMINISTRATION BUILDING**

Designed by Frank Lloyd Wright.

INDUSTRIAL REVOLUTION. The 18th century represents the basis for the office buildings of today. With its rise in banking, railroads, insurance, retailing, oil and the telegraph industries, a lot of new working fields came up, which needed spaces in offices. As time went by, all the other working fields began to separate work and living, which resulted in a rise of constructing office buildings.
In classicism, you could only find two to three story buildings with a repertoire of not more than three different kinds of floor plans. There were buildings with a corridor and a stripe of offices on each side, or the offices are grouped around an areaway or they were arranged around a central room.
From the middle of the 19th century onward, stock trading grew in importance which caused a building boom. As a result, the working tasks became split up and the employees worked in strictly hierarchically separated departments with different room sizes. The "single office" became a status symbol.

The economical expansion also influenced the technical aspects of office buildings. The invention of producing steel profiles and a hydraulic elevator made it possible to expand office buildings in height with seemingly no limit. The frame construction played a leading role. Other inventions of the 1870s like the telephone, electrical light and the serial production of typewriters also increased working efficiency in offices.
In the next few years there were a lot of different solutions for plans available. You could only see differences according to building law. There were, for example, limits in height in Germany and Austria so the offices only expanded in a horizontal way. In Chicago there were no statutory provisions at all so they began to speculate about gaining the most possible profit from the building. That was why natural limits were the only ones they had to obey. Nevertheless, the depths of the rooms were about eight to ten meters, which was much more than in Europe.[11]

THE 20th CENTURY. In 1906 Frank Lloyd Wright set up new limits in designing office buildings. His plan of the Larkin Administration Building provided 1,800 employees with a great deal of space to work in huge open galleries. As he did a lot of research on corporate structure and the working process, he was able to optimize the performance of the office building. He used the latest techniques and interiors and provided places to relax during the breaks.
In the 20s the construction of office buildings changed. Standardization and systematization as well as the hierarchically organization became important to enhance the building performance. The employees as human beings lost in importance. A good example of this move is the building of the Johnson Wax Company in Buffalo designed by Frank Lloyd Wright.
At the same time in Europe, they began to construct multi-story buildings in the bigger cities. In contrast to America, they preferred the simple cellular office to the group office.
After the world economic crisis and the Second World War the construction of office buildings was stopped up to the 40s. After this time, architects tied in with the traditions of the 20s and the designs became more functional.
In the 50s the human being moved into the limelight again, which is known in theory as "Human Resources".[11]

11. Cf. Hascher, Rainer / Arnold, Thomas: Entwurfsatlas Bürobau. (Basel: Birkhäuser, 2002) p. 13

3. DIFFERENT ROOM TYPES

Room design depends on two factors: first, what should the room be used for (requirements and tasks of the room users); second, what is the shape of the whole building. Economy, social structure and the environment also influence those two criteria. Knowledge about the different types of rooms illustrates the basis for creating good working spaces.[12]

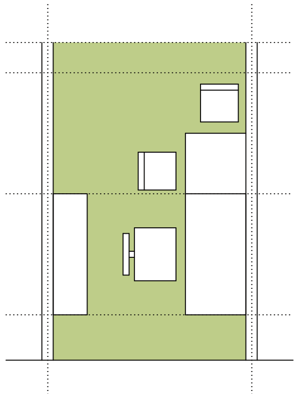
SMALL ROOM OFFICES	GROUP OFFICES	OPEN-PLAN OFFICES
individual office	small group office	
multi-person office	large group office	
cellular office	large office unit	
individual work cubicles	office environment	
within a combi	room-in-room office	
	project workshop	

SMALL ROOM OFFICES.

INDIVIDUAL OFFICE[13]

The traditional and most common form of an office is the individual one. Single occupancy is good for undisturbed and concentrated work. Moreover, it offers an opportunity for separate and private conversations with patrons or colleagues. The room should be individually equipped and adjustable. Thus, a lot of technology is needed. As the room is constricted to a space of 8 m², it is not adequate for teamwork.

Depth of the room:	4.00 – 5.50 m
Width of the room:	2.50 – 4.50 m
Depth of the building:	12 – 14 m (one or double sided construction)
Development of the room:	via corridor
Working space:	with daylight
Individuality and privacy:	high
Service Pipes:	wall ducts via consolidation or via underfloor duct systems

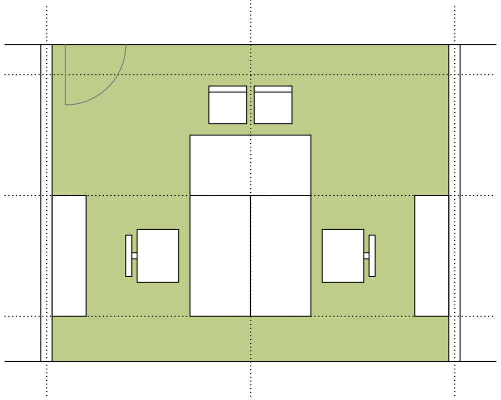


Ill. 7

12. Cf. Hagner, Alexander: Büro Raum Planung. Allgemeine Grundlagen. (Neudörfl: Neudörfler, 2004) p. 13
13. Cf. Ibid., pp. 13-14

TWO-PERSON OFFICE[14]

A two-person office is preferable if the colleagues have to work together. The flow of information is fast and efficient. Tables are positioned to face each other. Acoustical disruptions can be irritating at work requiring concentration. In this case, the tables should be oriented to the wall.



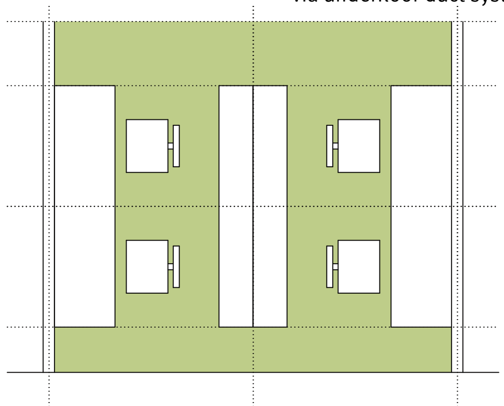
Ill. 8

GROUP OFFICES.[15]

SMALL AND LARGE GROUP OFFICES

This kind of office supports teamwork best. It offers space for 4 to 10 people in an area of up to 100 m². Working together in one unit increases the information flow and communication. It is a good opportunity for working on projects, but not for customer liaison and support, as well as highly confiding tasks. Climate and lighting conditions can not be regulated individually to fit everybody's needs. Due to the increased number of people, the acoustic level is higher. Grouping just a few tables directly towards each other can decrease the percentage of disruptions.

Depth of the room:	4.00 – 5.50 m
Width of the room:	a wide range
Depth of the building:	12 – 14 m (one or double sided construction)
Working space:	high percentage of working places with daylight
Individuality and privacy:	low
Service Pipes:	wall ducts via consolidation or via underfloor duct systems

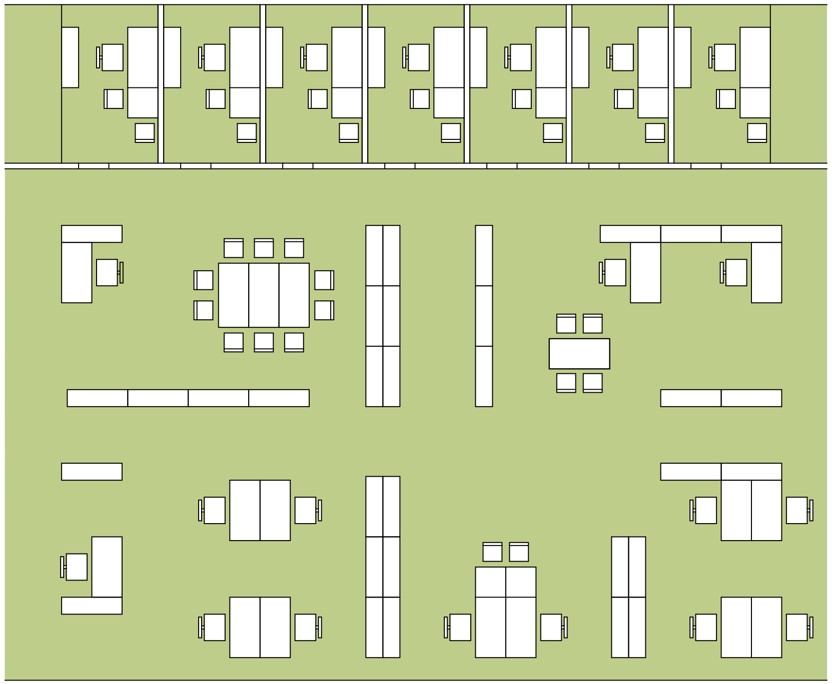


14. Cf. Ibid., pp. 15-16
15. Cf. Ibid., pp. 17-20

LARGE OFFICE UNIT[16]

Open plan offices provide space for 25 to 100 people and 15 m² per working place. Due to high building depths and heights the quality of the individual working places varies a lot. The architects are confronted with daylight and artificial light planning, as well as noise reduction and comfortable air conditioning. Modern air conditioning systems guarantee an individual regulation of about 3°C of each working place. The noise should be reduced to a volume lower than 40 dB and a consistent background noise should mask the disturbing individual noises. Although large rooms have higher costs, the flexibility of the floor plan increases.

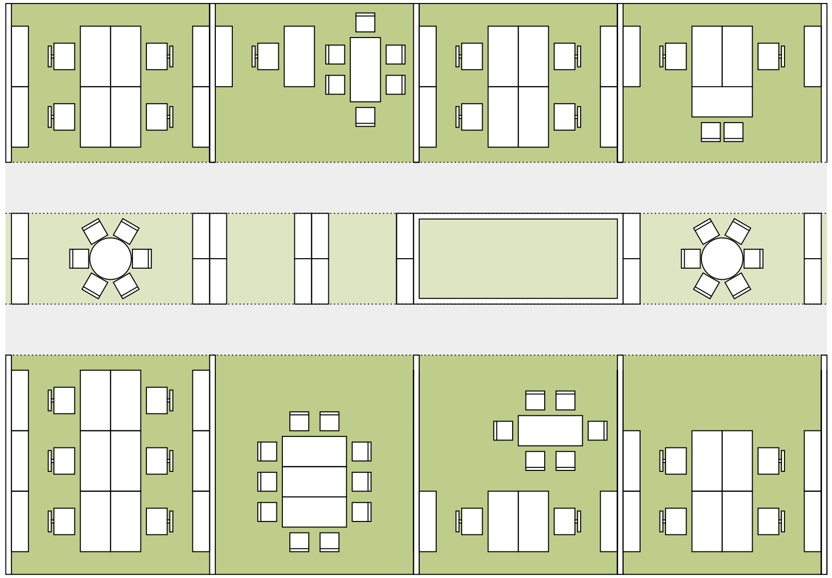
Room area:	400 – 1200 m²
Depth of the room:	20 – 30 m
Width of the room:	20 – 40 m
Working space:	low percentage of working places with daylight
Individuality and privacy:	very low
Service Pipes:	via underfloor duct systems or via double floors
Air condition:	fully air conditioned



Ill. 10 | LARGE OFFICE UNIT

16. Cf. Ibid., pp. 21-22

Ill. 11 | COMBI OFFICE



OFFICE ENVIRONMENT[17]
With the help of sound-absorbing room-dividing elements, fewer numbers of working spaces in a room, and installing plants, a large office unit can turn into an office environment. A lot of small work islands can reduce acoustical and visual disruptions and the individual working places can be better separated, which increases the feeling of privacy and security. A challenge in planning is to provide a view to the outside as well as not construct cage like systems.

COMBI OFFICE[18]
The combi-office combines, as the word says, the traditional individual offices with the open plan offices. This way, the advantages of both concepts can be realized. With this plan a good mix of concentrated work and teamwork is possible.

Depth of the room:	4,00 – 5,00 m
Width of the room:	2,40 – 3,00 m
Depth of the building:	15 – 17 m

Working space:	high percentage of working places with daylight
Individuality and privacy:	high
Service Pipes:	wall ducts via consolidation, via underfloor duct systems or via double floors
Air condition:	partly air conditioned

17. Cf. Ibid., pp. 23
18. Cf. Ibid., pp. 23-25

4. INNOVATIONS OF TODAY

Ill. 12, 13, 14 | SMART WORKING SOLUTIONS

These facitities are offered at “Google” in Zürich.

HOT DESKING.[19,20] Hot desking or also hoteling are new systems of doing office work. In this cases, the employees do not have their own desk in the office anymore, but the companies provide a pool of fully equipped desks, which the workers can occupy, if required. Several workers on different shifts share one desk. This system increases space savings, mobility, and efficiency of work places, as well as improving teamwork. The difference between hoteling and hot desking is, that hoteling is reservation-based unassigned seating. This new method of working can be seen as an extension to the flexibility of the different office types.

SMART WORKING.[21,22] To improve satisfaction of the employees and communication, and through that, the job performance of the people, selected leisure activities and relaxing possibilities are integrated into everyday’s work. A fitness studio, a smoothie-bar, a rehabilitation area as well as possibilities to play billiard and video games become a part of the office equipment. Moreover, this system offers non-office like places, where you can go to do work, if you are going stir-crazy in your office. Following the motto “turning the hobby into a career”, companies like Google and Credit Suisse are very successful with this method.

19. Cf. BUSINESS DICTIONARY (2013): Hot Desking. Viewed on 06/20/2013 under www.businessdictionary. com/definition/hot-desking.html
20. Cf. BUSINESS INSIDER (2013): Collins, Ben: “Hot Desking” Is A Big Trend -- Here’s Why A Lot Of People Hate It. Viewed on 06/20/2013 under au.businessinsider.com/hot-desking-is-a-big-trend- heres-why-a-lot-of-people-hate-it-2013-4
21. TAGESANZEIGER (2010): Google in Zürich: “Hier hätte sich auch Michael Jackson wohl gefühlt”. Viewed on 07/19/2013 under www.tagesanzeiger. ch/digital/internet/Google-in-Zuerich-Hier- haette-sich-auch-Michael-Jackson-wohl-gefue-hlt/story/31962316
22. Cf. BÜROWISSEN (2012): Innovative Bürokonzepte. Viewed on 07/19/2013 under www.buerowissen. ch/Zukunftsvisionen/Innovative-Burokonzepte- /#!prettyPhoto

Ill. 15 | INDOOR VERTICAL GARDEN

A plant structure on the wall as a design element.

VERTICAL LANDSCAPING.[23,24] Vertical landscaping is a method to integrate plants in a space efficient way on the walls. As a design element, it positively affects the mood, as well as health and productivity of the employees. Moreover, it cleans the indoor air by filtering pollutants and viruses produced by office materials, equipment and appliances. Plants also humidify the air and produce CO_2, which ensures good air.

23. Cf. IMMONET (n.y.): Die Pflanze als lebender Saubermacher für das Office. Viewed on 07/19/2013 under www.immonet.at/pflanzen.htm
24. Cf. INHABITAT (2011): Meinhold, Bridgette: Spain's Largest Vertical Garden Cleans Air Inside Office Building. Viewed on 07/19/2013 under inhabitat. com/spains-largest-vertical-garden-cleans-air- inside-office-building/

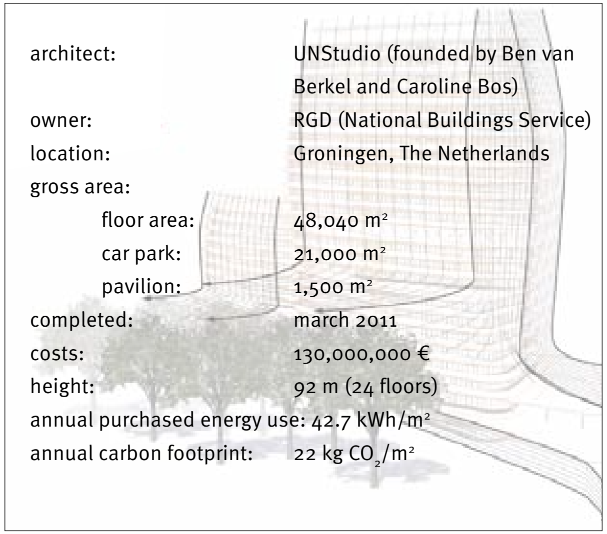
32

5. REFERENCES FOR SUSTAINABLE OFFICE BUILDINGS

Ill. 16,17,18 | DATA OF THE EEA + TAX OFFICE

These graphs show the climate data of the building area and the demand for heating and cooling.

EDUCATION EXECUTIVE AGENCY AND TAX OFFICES IN GRONINGEN.[25] The EEA + Tax Office, designed by UNStudio, was built in 2011 and can be seen as one of the most energy-efficient office buildings in Europe. Two distinct operations are housed here: the Dutch federal tax service and the Education Executive Agency. “The design of this building contains numerous new innovations related to the reduction of materials, lower energy costs and more sustainable working environments.” According to Ben van Berkel, “it presents a fully integrated, intelligent design approach towards sustainability”[26].
A complex element of the building shows the building skin, which is outfitted with soft, undulating curves. These elements are employed to meet both ecological concerns and energy efficiency by having integrated shading, wind control and daylight penetration in it’s fin-shaped elements.
The floor-to-floor heights are limited to 3.3 m to improve the building comfort. The horizontal fins keep a large amount of the heat outside the building and they are able to reduce the cooling demand. To provide the building with natural air a high-pressure ventilation system is used in the upper floors. In addition, a concrete core activation system for both cooling and heating as well as an underground long term energy storage is installed to reduce the demand for external energy sources.
Last but not least, the building has a grid of 1.2 m to make a transformation into housing possible and to provide a high level of flexibility in the future.



architect:	UNStudio (founded by Ben van Berkel and Caroline Bos)
owner:	RGD (National Buildings Service)
location:	Groningen, The Netherlands
gross area:	
floor area:	48,040 m²
car park:	21,000 m²
pavilion:	1,500 m²
completed:	march 2011
costs:	130,000,000 €
height:	92 m (24 floors)
annual purchased energy use:	42.7 kWh/m²
annual carbon footprint:	22 kg CO_2/m²

25. Cf. GREENSOURCE (2011): Dumiak, Michael: Education Executive Agency and Tax Offices. Viewed on 05/15/2013 under greensource.construction.com/green_building_projects/2011/1109_Education_ Executive.asp
26. ARCHDAILY (2011): Cilento, Karen: EEA + Tax Office / UNStudio. Viewed on 05/17/2013 under www. archdaily.com/130671/eea-tax-office-unstudio/

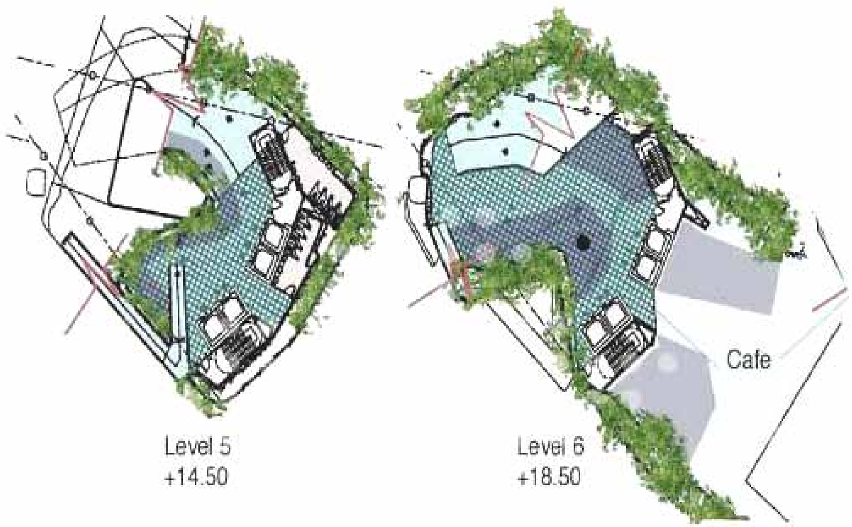
Ill. 19 | EEA + TAX OFFICE IN GRONINGEN

An energy-efficient buiiding designed by UNStudio.

EDITT TOWER IN SINGAPORE.[27] The EDITT Tower is an abbreviation for "Ecological Design In The Tropics" and it was designed by TR Hamzah & Yeang. The 26-floor high-rise building sets out a new approach in ecological tower design.
The building is constructed using many recycled and recyclable materials and it includes a recycling system on each floor.
Reacting to the site's ecology, the building includes organic mass in its design to increase the biodiversity onsite, and rehabilitate the local ecosystem. The vegetation covering half of the buildings surface responds to the microclimate of the site, as well as to each individual height zone at the tower. Moreover, it is important to connect the street-level activities with those of the upper floors. Landscaped ramps are installed up to the first 6 floors to pin the streetscope to the upper floors. Furthermore, bridges connect the tower with neighboring buildings for greater urban connectivity, and views are created to the surroundings.
The building collects rainwater and integrates a grey-water system with an estimated self-sufficiency of 55%. For the rainwater collection there are installations at the facade to catch the running water off its side.
To gain energy, photovoltaic panels are used that create 2.04 kWh/m^2 per day and provide 39.7 % of the building's energy needs. To increase the comfort inside, natural ventilation and mixed-mode servicing with ceiling-fans and wind-walls are integrated into the building design. The building also includes the ability to convert sewage into biogas and fertilizer for the plants.

architect:	TR Hamzah & Yeang
owner:	URA (Urban Redevelopment Authority)
	EDITT (Ecological Design in The Tropics)
	NUS (National University of Singapore)
location:	Singapore, Singapore
gross area:	6,033 m^2
completed:	pending
costs:	130,000,000 €
height:	26 floors

27. Cf. T.R. Hamzah & Yeang (n.y.): Editt Tower. Viewed on 05/26/2013 under www.trhamzahyeang.com/ project/skyscrapers/edit-tower01.html



Ill. 20, 21 | EDITT TOWER IN SINGAPORE

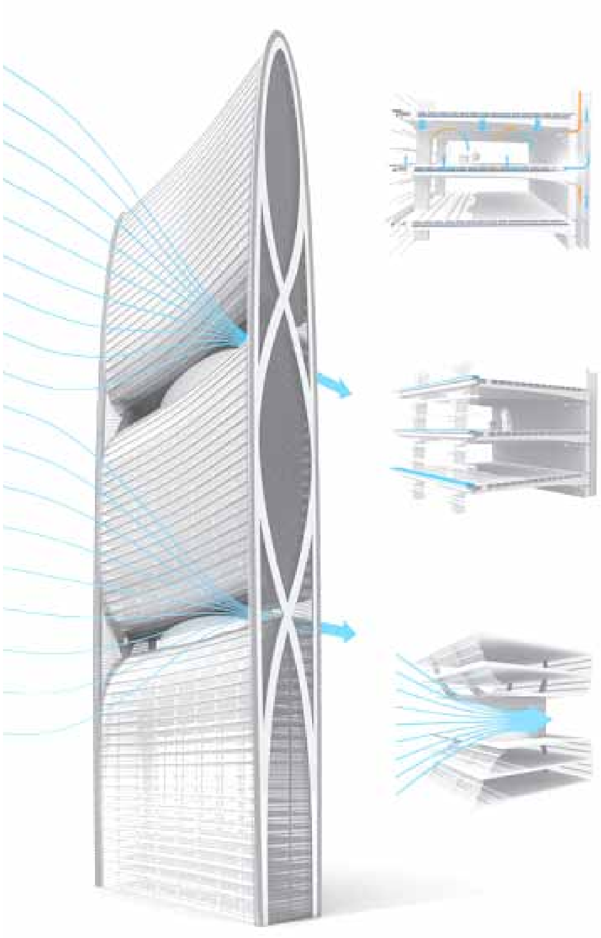
Floor plans and a visualisation of the design by TR Hamzah & Yeang.

PEARL RIVER TOWER IN GUANGZHOU.[28] Due to very bad air pollution in Guangzhou / China, the main goal of the architects Skidmore Owings & Merill was to design a very energy efficient building. Their strategy can be summarized in 4 categories: reduction, reclamation, passive absorption and generation.

“Reduction” includes cooling via concrete core activation, displacement ventilation coming from a raised access floor as well as integrated high-efficiency lighting and water conservation systems into the building. Moreover, photovoltaic on the facade directly powers a motorized blind system, that follows the track of the sun. The second part “Reclamation” deals with heat recovery coming from a chiller, generator and exhausted air. They use the thermal mass of the building for cooling during the night and harvested water humidifying the indoor air, as well as for watering the plants and flushing toilets. The third category is about “absorbing the energy” through wind and solar technologies. That is why photovoltaic and solar panels play an important role in the design of the building. Four vertical-axis wind turbines are integrated, to produce energy even during the night. The forth part is generation. A system of linked micro turbines is turning the tower into a mini power plant, and thus, the building into a zero energy building.

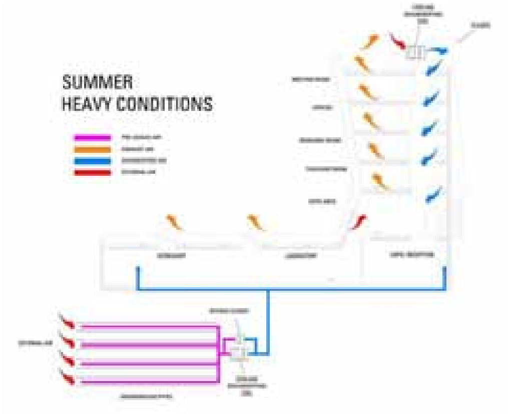
architect:	Skidmore Owings & Merril
owner:	China National Tobacco Company
location:	Guangzhou, China
gross area:	212,165 m²
completed:	march 2011
height:	310 m (71 floors)

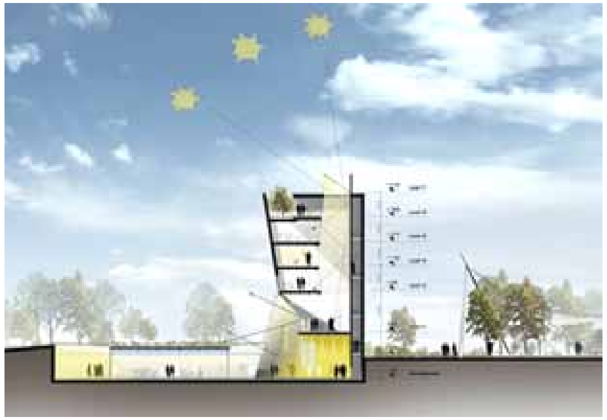
28. Cf. JOSRE (n.y.): Pearl Ricer Case Study China. Viewed on 07/29/2013 under www.josre.org/wp-content/ uploads/2012/09/Pearl-River-Case-Study-China.pdf



Ill. 22, 23, 24 | PEARL RIVER TOWER

These pictures show the facade, the ventilation system and a visualization.





Ill. 25, 26 | BUILDING CONCEPTS

Illustrating the ventilation and lighting solutions.

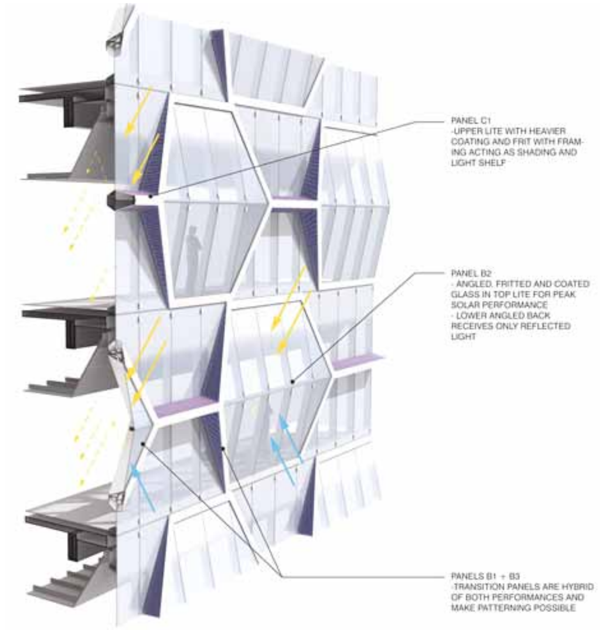
CENTRE OF SUSTAINABLE TECHNOLOGIES IN NINGBO.[29,30] The CSET is an energy efficient building at the campus of the Nottingham University in Ningbo / China. The main function of the building is a research laboratory for the staff and post-graduate students, but there are also workshop, office and exhibition spaces provided. The appearance is similar to a beacon or Chinese lantern. Triangle elements made out of printed glass twist and distort towards the sky, allowing a lot of different views and a uniform skin. The design also employs various environmental strategies. Thus, the tilted, glazed facade elements, for example, correspond to the needs of natural light inside by avoiding direct solar radiation on the other side. Moreover, there are several skylights to bring natural light from the roof all the way down to the basement area. Simultaneously, it creates a flue effect to allow efficient natural ventilation and geothermal energy to cool or heat the building. The goal of this system is to guarantee a high indoor comfort without using mechanical air-conditioning systems. Furthermore, the building is capable generating its own energy from renewable sources, as well as storing rainwater and re-using grey water appropriate. The environmental impact of the building is minimized as much as possible, so the energy demands in heating and cooling will be low and met by renewable sources.

architect:	Mario Cucinella Architects
owner:	University of Nottingham
location:	Ningbo, China
gross area:	1,300 m²
completed:	in 2008
costs:	5,000,000 €
height:	6 floors
annual heating energy demand:	10 kWh/m²
annual cooling energy demand:	30 kWh/m²
annual carbon footprint:	0 $kgCO_2/m^2$

29. Cf. http://www.mcarchitects.it/project/cset-1 am 29.07.2013 um 19:48
30. Cf. http://en.urbarama.com/project/centre-for-sustainable-energy-technologies-cset-ningbo am 29.07.2013 um 19:33

Ill. 27 | CSET IN NINGBO

A perspective view of the centre of sustainable technologies.



Ill. 28 | THE FACADE

Showing the different angles and shapes of the facade elements.

V ON SHENTON IN SINGAPORE.[31] The twin tower complex “V on Shenton” by UNStudio will replace the former UIC building that used to dominate the skyline of Singapore. Due to redevelopment of the area, there will be the company UIC in the 23-storey tower and there will be housing in the 53-storey tower additionally. While the office towers match the environment, the residential tower is an accentuated contrast.
The specialty of the two towers is their facades which corresponds to the function and comfort inside. So the towers’ facades are different. However, the basic shape of the hexagon is the same. These elements are designed to increase the performance of the facade. They feature different angles and materials to meet the best solution for shading and reflection. Ben van Berkel says: “The pattern of the facade comprises four to five different textures, each varying depending on the programme. At times the glass of the facade creates texture through the relief effect and the coloured side lighting, whilst the volumetric balconies of the residences create a deep texture in the total volume of the building.“[32]
Both towers are framed by chamfers to create a united appearance. During the night the frame lights up to highlight the form and be present in the city. Moreover, skygardens are integrated into the building to provide good views to the city and what is more, to improve the city climate by providing fresher and cleaner air.

architect:	UNStudio (founded by Ben van Berkel and Caroline Bos)
owner:	UIC Investments (Properties) Pre Ltd
location:	Singapore, Singapore
gross area:	85,507 m^2
completed:	in progress
height:	237 m

31. Cf. DEZEEN (2012): Frearson, Amy: V on Shenton By UNStudio. Viewed on 07/29/2013 under www. dezeen.com/2012/08/01/v-on-shenton-by- unstudio/
32. ibid.

Ill. 29 | V ON SHENTON IN SINGAPORE

A visualization of the building designed by UNStudio.

CHAPTER III

DESIGN OF OFFICE BUILDINGS

in the **designing phase** *of a building you have to think about a lot of factors: how could the building be* **constructed** *without falling apart, why can you not place each building every-where, which parts of the building need ener-gy the most, how can the building be designed in an* **energy efficient** *way and how can the building concept work? that is why this chapter finds answers to these questions according to the* **demands and needs** *of an office building.*

1. CONSTRUCTION[33]

If you construct a high-rise building, you have to consider the materials, the bearing structure as well as the dynamic loads.

CONSTRUCTION MATERIALS.

Ferroconcrete: This construction material is a combination of concrete and steel where the materials complement one another's positive aspects. Steel takes on the tractive forces while concrete withstands pressure. Therefore steel bars or mats are embedded in concrete. The steel elements have to be calculated prior to find the right dimensions and positions in the concrete to withstand the traction. Moreover, the concrete protects the steel against corrosion and against excessive heating in the case of fire. Ferroconcrete achieves good results in construction. It is also possible to use pre-fabricated elements. However, ferroconcrete made on-site reaches better values. So in comparison to other construction materials, it needs a lot of time to build up walls and ceilings.

Steel: Steel can be easily prefabricated as well as installed on-site. The single elements are connected to each other with screws, rivets or they can be fused. If the elements are fused together, it has to be done carefully, because heat harms the carrying capacity of steel. So in the case of fire, the material expands, which causes pressure and makes the steel break. Moreover, joints are likely to break down.

Composite construction: This way of construction uses both ferroconcrete and steel. It is a combination of both constructions. That is to say, the carrying steel frames are embedded in concrete to take over the carrying part together and to protect the steel against heating up too much. The concrete can be reinforced additionally. The composite construction elements can be widely prefabricated. If the concrete is added on-site the steel is capable of carrying although the concrete is not hardened yet and the construction of the building can be continued straight away.

BEARING STRUCTURE.

Ceiling structure: Normal massive ceilings are constructed in ferroconcrete and they rest on a regular column grid of up to 7.50 m using a ceiling thickness of 30 cm. If there are higher span lengths needed, or if the dead load of the construction should be reduced, it is advantageous to dissolve the massive construction by using, for example,

33. Cf. AXXIO (n.y.): Konstruktionsweisen für den Hochhausbau. Viewed on 07/19/2013 under www. axxio.net/highrise/Tragwerk/tragwerke.htm

reinforced-concrete-ribbed-ceilings. These kind of ceilings use a beam structure filled with tensile-loaded iron bars which carry compressive forces in a distance to the ceilings and the room between the ribs can be used for installations.

Bracing structure: Depending on the height and slenderness of a building there are several systems for bracing structures available and necessary. In most cases floor-high frames and timber frames are enough. If a building has more than 50 floors, the bracing structure combines several floors to mega-structures.

Spatial structure: Considering spatial structures, you can distinguish between core-bearing structures and pipe-bearing structures. Core-bearing structures could be anywhere in the building, in the middle or at the edge. Mostly, they contain the development of the building and they are very thin structures. That is why they do not brace the building horizontally, but they can carry vertical loads. More efficient are pipe-bearing structures. The difference to the core-bearing structures is, that they have bigger dimensions to get a bigger inner lever-arm and to support the bracing of the building.

DYNAMIC LOADS.
Wind loads: Gust of winds can cause vibrations in a high-rise building. If the frequency of the vibration is close to the eigenfrequency of the building, it can constitute a resonance disaster.
Earthquake loads: Loads caused by earthquakes are not predictable and assessable in the extent in advance. That is why in earthquake prone areas, they have to be expected, and possible occurring loads have to be calculated.

Attenuation of dynamic loads: Vibrations caused by dynamic loads have to be limited by installing a “vibration mass”, an additional mass, at several places of the building to act restrainingly.

2. THE BUILDING SITE

The building site influences the building the most. The climate situation onsite is the guideline for the whole design, construction system and building service concepts. Thus, it has to be said, that one specific building cannot be built everywhere on earth. That is why the next topic deals with the definition of climate, the climate elements, the climate factors and the climate zones.

DEFINITION.[34] The word climate stems from the ancient Greek verb "klínein" which means to incline and it describes the tilt oft the Earth's axis. Not to mix it up with the weather, the climate refers to a statistically determined state of the Earth's atmosphere over a longer period of time.
There are statistics available either for a location, a region or the whole Earth.

CLIMATE ELEMENTS. Simply put, the climate elements describe the climate. The most important elements according to architecture are solar radiation, air temperature, air humidity, precipitation as well as wind.

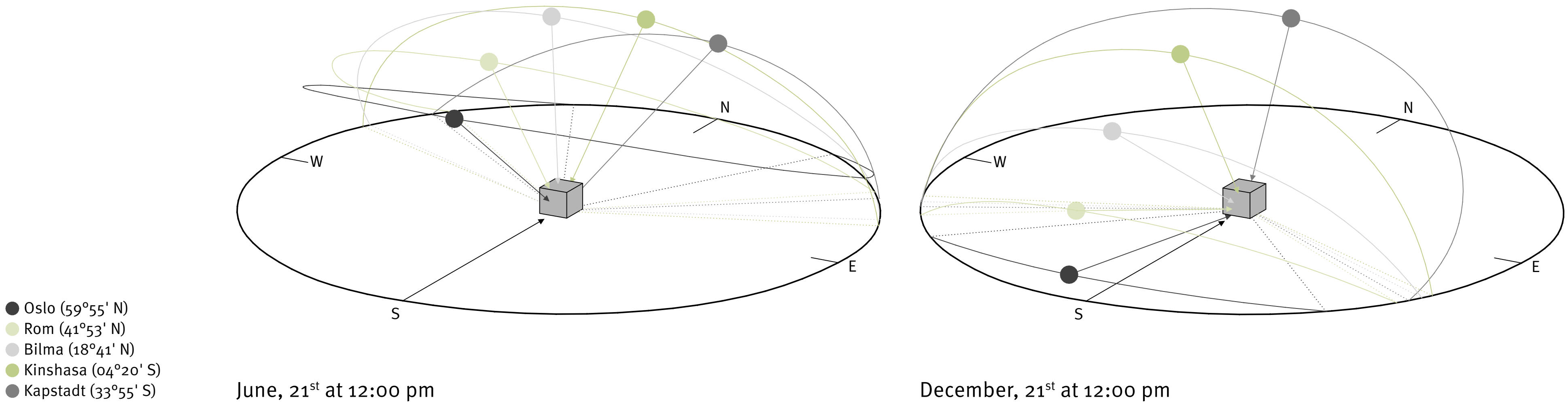
Solar radiation [W/m^2][35]: Solar radiation plays an important role in planning. It is the natural source of light and energy and has huge influences on both room climate and daylight provision. The solar radiation varies in the different climate zones according to latitudes. The length of the day, the angle of radiation incidence, the orientation of the building as well as the type and intensity of solar radiation received throughout the year, affect the heating and cooling energy demand.

Temperature [°C][35]: Both solar radiation and the temperature of incoming air are factors for changing the outdoor air temperature. Additionally, the average temperature over the year affects the configuration of a building, as well as its heat protection, ventilation and cooling systems.
The change in temperature throughout the day provides a lot of possibilities for passive cooling strategies.

Air humidity [g/kg][36]: Air humidity is subdivided into two different kinds of measurements: relative and absolute air humidity. Absolute air humidity is a location-specific factor and it is primarily influenced by the proximity to the ocean and precipitation levels. It affects the room climate as well as the outflow of moisture from indoor spaces. As the minimum value of absolute air humidity is on cold days, the maximum value appears at high temperature.
Relative air humidity is affected by temperature and it regulates the need of either dehumidifying or humidifying the airflow.

Wind[36]: Regarding wind, you have to deal with pressure and suction [N/m^2] to the building skin and with airflow around a building [m/s]. The micro-climatic situation onsite is of primary importance. As the meteorological data provides the wind direction and the wind strength, the microclimate regards the terrain and the topography of the site, the shape and proximity of the surrounding buildings and the surrounding vegetation. This is why local winds play a more important role in planning than the regional ones to provide natural ventilation systems.

34. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 12
35. Cf. Ibid., p. 14
36. Cf. Ibid., p. 16



Ill. 30 | ALTITUDE OF THE SUN

These two images show the altitude in summer and winter on different longitudes.

CLIMATE FACTORS.[37] Climate factors can be described as processes and situations that produce, maintain or alter a specific climate. The sun plays the most important role determining the daily and seasonal changes caused by the intensity and angle of solar radiation. The latitude, distribution of land and sea, the local and trans-regional wind system and the altitude of a location are also major factors.

Latitude: Latitude describes the Northern or Southern distance from any point of the surface to the equator. As the Earth’s axis is inclined by just over 23.5° either the Northern or the Southern part of the Earth which is closer to the sun experiences summer. Moreover, the Earth travels around the sun on an elliptical course. Thus, during the Northern hemisphere’s winter the Earth is closest to the sun, and on the Northern hemisphere’s summer the distance is furthest from the sun. That is why the temperature on the Northern hemisphere is less subject to seasonal changes than on the Southern hemisphere.

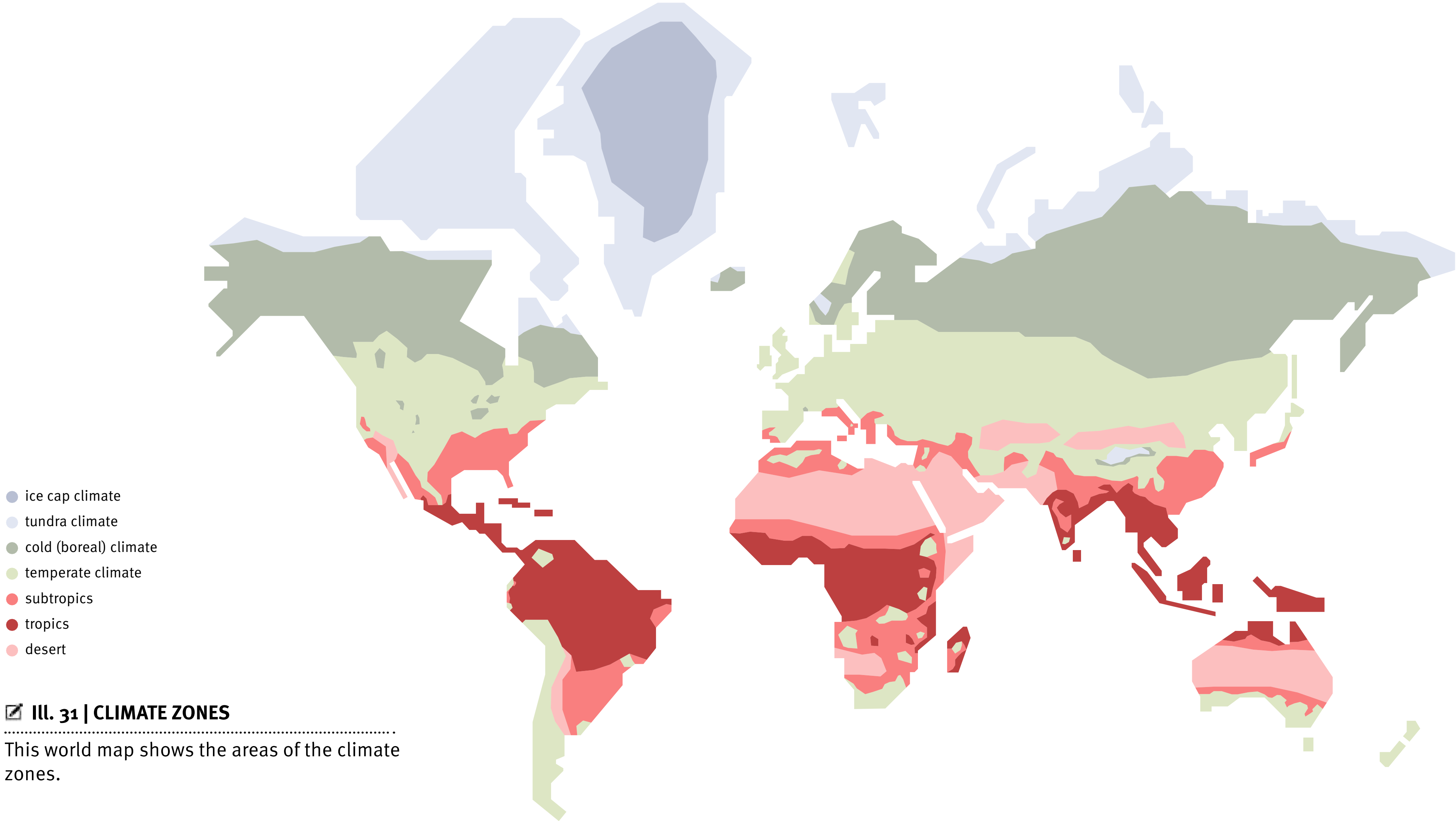
Proximity to the ocean and continentality: As more than 70 % of the Earth’s surface is covered by ocean and the average temperature of the seawater is 3.8 °C, the climate on two locations can be very different although being on the same latitude. The reason for this effect is the higher specific heat capacity of water compared to the one of land. Additionally, the reflection capacity of surfaces on land is much higher than on the water. Therefore, the average temperature close to the sea is much more consistent than the further inland. Moreover, the interior in continental situations is lower and so is the air humidity.

Altitude: Mountains often alter the climate according to their height and expanse. In the windward of a mountain, clouds are formed and it is more likely to rain as on the lee side. The higher a mountain the higher the wind speeds and solar radiation. What is more, the rises and falls of air always cause changes in temperature. Every kind of gas gets cooled down, if the pressure on it is released, and if the pressure increases the gas heats up. That causes a specific circulation of mountain and valley winds.

City climate: The climate in cities differs from the surroundings because of natural and anthropogenic factors. The natural ones contain the geographical position, terrain, altitude as well as any natural undeveloped areas. The anthropogenic factors include the type and density of the buildings, the heat storage capacity of different kinds of building materials, and the degree of surface sealing. Emissions from industry, household and traffic alter the climate by producing insulating smog over the city. According to the position of the building, you can find both low wind speeds because of the warm air rising from cities and the compression of the cooler air, as well as high wind speeds because of jet effects in straight streets. The temperature in cities is usually also higher and heat islands can develop. As a result, the evaporation is higher.

CLIMATE ZONES. The surface of the world is divided into five standardized climate zones which show the connections between the different climate factors.
Those climate zones are: cool climate, temperate climate, the subtropics, the tropics and the deserts.

37. Cf. Ibid., p. 20



Ill. 31 | CLIMATE ZONES

This world map shows the areas of the climate zones.

cold climate
- warm or hot summers
- cold winters
- continental and on high latitude
- heating and humidification demand in winter

temperate climate
- warm summers
- cold or cool winters
- climate without extremes
- heating energy demand in winter

subtropics
- hot and humid or warm summers
- wet and cold or cool winters
- short transitional periods
- cooling and dehumidification demand in summer

tropics
- hot and humid summers
- hot and humid winters
- constant high temperature
- cooling and dehumidification demand in summer and winter

desert
- extreme hot summers
- warm winters
- hardly any rainfall
- cooling (dehumidification) demand in summer and winter

3. ENERGY DEMAND[38]

An office building can only function, if the energy demands are covered. The influencing factors on the energy demand are the location and local climate, the design, the construction, and the function of the building. If those factors are considered carefully the demands for heating, cooling, ventilation, hot water and electricity can be lowered to a certain degree.

First of all there are three different levels of energy demands[39]: the effective energy demand, the end energy demand and the primary energy demand. The effective energy demand is the amount of energy, which has to be brought up or taken off to reach good thermal indoor comfort. It is mostly influenced by the design of the building. The end energy demand considers the losses in providing the necessary effective energy. Therefore, the building service systems play an important role. Last but not least, the primary energy demand is distinguished by the energy carrier itself. This can be, for example, petroleum, natural gasoline, biomass and so on. It includes the whole life-cycle of the energy carrier from the extraction to the transport to the conversion into fuel such as pellets or electricity.

HEATING. Heating is only needed in areas, where the outdoor air temperature sinks so much, that the indoor comfort could not be held upright anymore on its own. The comfort indoor temperature of rooms range from 15 - 18° C in corridors to 20 - 23° C[40] in habitable rooms. Thus, heating could be done with several building concepts such as using radiators, convectors, a heated floor or ceiling or concrete core activation.
Beyond that, there are also possibilities to lower the heating energy demand itself by using qualitatively good and enough insulation, by installing good windows with high-quality glass, by designing a compact building, by avoiding thermal bridges and by providing an air-tight building envelope. Those factors provide thermal comfort especially close to the facade and to working places close to windows.

COOLING. Depending on the climate, solar radiation, solar gain through the window, heat input through the building envelope, heat input through the incoming air and intern heat inputs from machines, people and lighting, can increase the cooling demand dramatically. Simple solutions such as reducing the glazing percentage or considering the orientation and quality of the windows and sun protection can have positive effects on the indoor comfort. If more cooling is needed, the thermal mass or passive cooling should be integrated. However, passive cooling through night cooling is only possible, if the outdoor air temperature during the night is below 21°C. Otherwise concrete core activation using groundwater or soil is also a good solution. Another one is active cooling via air-conditioning plants.

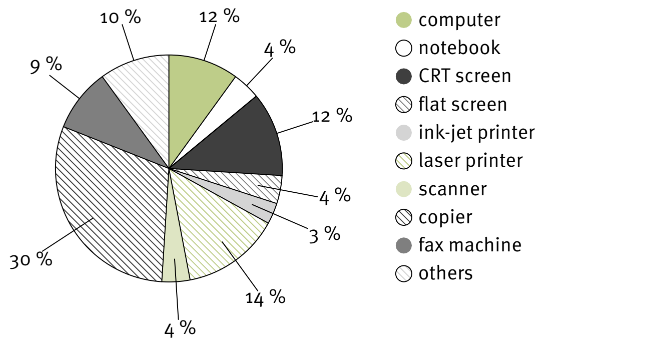
VENTILATION. In office buildings it is important to ensure good air quality and enough fresh air, as well as to keep the indoor temperature in the range of the thermal comfort. To achieve that, several possible air conditioning concepts are available: the mechanical, the natural and the mix of both systems. The natural air-conditioning concepts are preferable, as they do not need energy in the utilization phase of the building.
The air quality in office buildings is often polluted because of the interior, the furniture, office machines and cleaning agents. The humidity of the indoor air is influenced by the one of the outside. So if the air exchange rate is high, you have to dehumidify or humidify the air additionally. Strategies to limit the pollution can be to reduce the pollution sources, to limit the density of people using the same office room, to prohibit smoking indoor, to use low-emission interiors, to use eco-friendly cleaning agents and decentralizing office gadgets with high emissions.

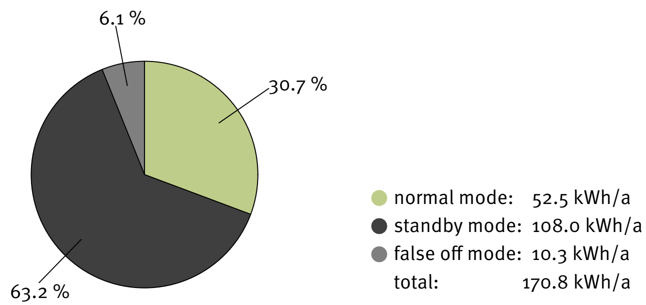
38. Cf. Universität Karlsruhe: Effiziente Energienutzung in Bürogebäuden. Planungsleitfaden. (Augsburg: Bayrisches Landesamt für Umwelt, 2008) Viewed on 07/21/2013 under http://www.hannover.ihk.de/fileadmin/pdf/ihk/themen/umwelt_energie/energieeffizienzbuerogebaeude.pdf
39. Cf. Staller, Heimo: Energetik im Entwurf WS 2011. [Unpublished paper.] p. 44
40. Cf. BAULINKS (n.y.): Wohlfühltemperatur / Humidex im RLT Magazin. Viewed on 07/23/2013 under http://www.baulinks.de/raumlufttechnik/wohlfuehltemperatur.php

HOT WATER. The need of hot water is not that high in office buildings. So the energy demand is very low. Producing hot water with solar panels can be easily integrated into the building concept.

LIGHTING. Natural light and artificial lighting are very important factors in rooms with working places, as they have huge influences on comfort and concentration of the people. Especially daylight is essential, because the employees spend a lot of time at work and daylight has a lot of positive effects on the organism. In the past, a lot of office buildings were designed without integrating daylight in lighting planning. The reason for that was, that most of the people sit in front of the computer and the main goal was to avoid glare. But, if you do so, the primary energy demand of the building concepts increases up to 30%. Also the cooling energy demand gets up to at least 30%, because lighting heats up the air. To improve the lighting situation, there are several factors that should be considered soon in the planning phase. This includes the distance to nearby buildings, the orientation of the office rooms, the form of the building, the position and size of the windows, the quality of the glass and the quality of the lighting itself. Nevertheless, there are strict regulations for lighting in offices that have to be fulfilled. To give you an example: The illuminance at a working place in front of a computer should be at least 500 Lux[41] and an energy efficient lighting system should be lower than 15 W/m^2.[42]

POWER FOR THE EQUIPMENT.[42] A small office building features an energy consumption between 30 to 80 $kWh/(m^2a)$ for equipment and lighting, but energy efficient working places should not need more than 200 KWh per year. Using energy efficient office equipment is not the only solution for success, but a good way to start. The equipment should also be used in an efficient way. So the users should be aware of their energy consumption and should be motivated to reduce it in a way, they could do it. The power management function of computers, printers and other office machines should, for example, be activated. In addition, they should be turned off when not used. Taking such measures, you can save up to 65 % of electricity per machine and year. Moreover, the standby-time should be avoided by using switchable multiple socket outlets or automatically, central deactivation during the night or weekend. Also the use of certain machines should be reconsidered as well as actions such as printing and copying.





Ill. 32, 33 | POWER CONSUMPTION

The first chart illustrates the percentage of different office equipments and the second one different modi.

41. Cf. BG BAU (n.y.): 7.4.2. Beleuchtung. Viewed on 07/23/2013 under www.bgbau-medien.de/zh/ z418/7_4_2.htm
42. Oehlinger, Christine / Egger, Christiane / Stieger, Johann / Dell, Gerhard: Strom sparen Schritt für Schritt im Büro. Wie Sie Ihren Stromverbrauch ohne große Investitionen um 10% senken können. (Linz: O.Ö. Energiesparverband, 2010) Viewed on 07/23/2013 under http://www.stromsparenjetzt. at/fileadmin/redakteure/ESV/Info_und_Service/ Publikationen/Strom_sparen_Buero_2010.pdf

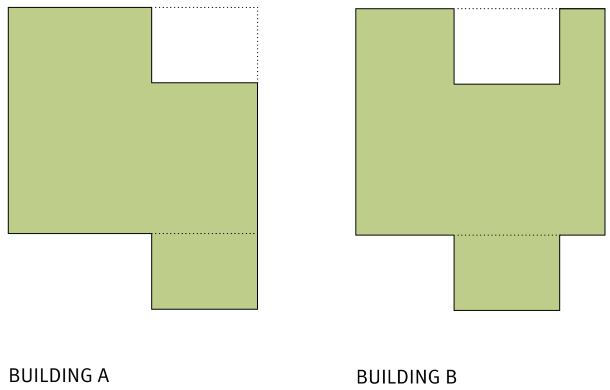
4. ENERGY EFFICIENT DESIGN

The design of a building influences its energy demand dramatically. That is why you have to consider a lot of factors such as compactness, glazing percentage, orientation, sun protection elements, thermal mass and passive cooling straight away in the designing phase. These factors should be taken into account individually and as a whole, because they depend on and influence each other to a great extent.

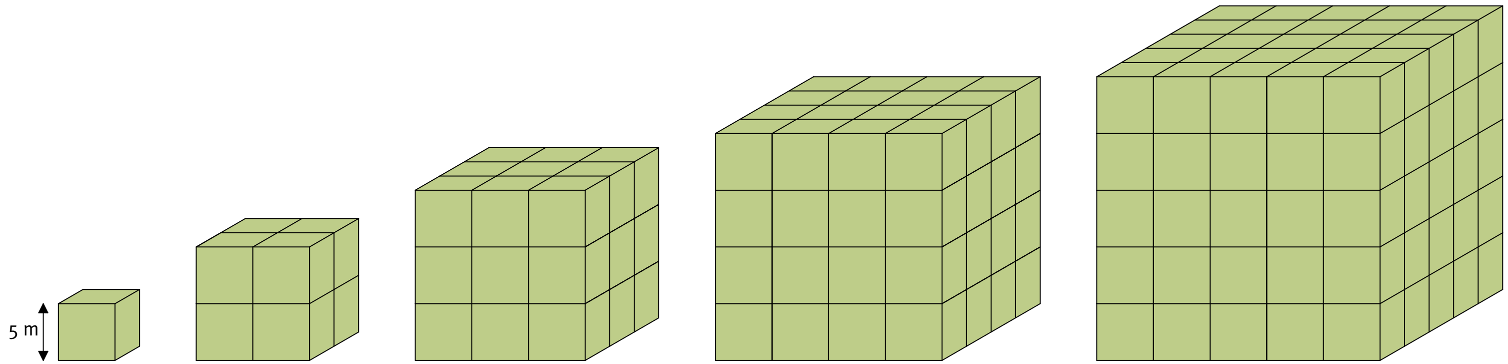
COMPACTNESS | CHARACTERISTIC LENGTH.[43,44]
The compactness of a building is described by the surface-to-volume ratio. The lower the ratio the more compact and energy efficient is the building. It is a very important factor for the heating energy demand. If the surface is bigger, the heat has more possibilities to get out of the building. You can reduce the surface-to-volume ratio, if you avoid cantilevers, oriels, jutties and all other add-ons and cut-outs of a building. An interesting fact is, that the most compact form is the ball. So in architecture the igloo achieves the best outcome, otherwise cubic and block elements should be aspired. Moreover, bigger buildings, whether in height or width, have the better ratio than smaller ones. A more compact building also reduces the building costs. Energy efficient office buildings are bars, ridge structures, atriums, point blocks and slab blocks.

Ill. 34 | SHAPE OF BUILDINGS

Although the two buildings have the same floor area, there have to be applied 2 cm more insulation to building A and 4 cm to building B than to a cubical building.



43. Cf. ENERGIE SPARHAUS (n.y.): A/V-Verhältnis, Kompaktheit von Gebäuden. Viewed on 07/22/2013 under www.energiesparhaus.at/ fachbegriffe/azuv.htm
44. Cf. BAUNETZ WISSEN - NACHHALTIG BAUEN (n.y.): Gebäudeform. Viewed on 07/22/2013 under http://www.baunetzwissen.de/standardartikel/ Nachhaltig-Bauen_Gebaeudeform_662875.html



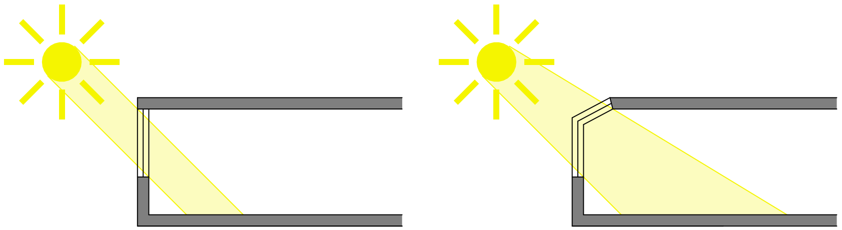
BUILDING ENVELOPE	[m²]	600	1,350	2,400	3,750
VOLUME	[m³]	1,000	3,375	8,000	15,625
SURFACE TO VOLUME RATIO	[m⁻¹]	0.6	0.4	0.3	0.24
CHARACTERISTIC LENGTH	[m]	1.7	2.5	3.3	4.2

Ill. 35 | DIFFERENT BUILDING SIZES

This graph shows the interaction between different building parameters.

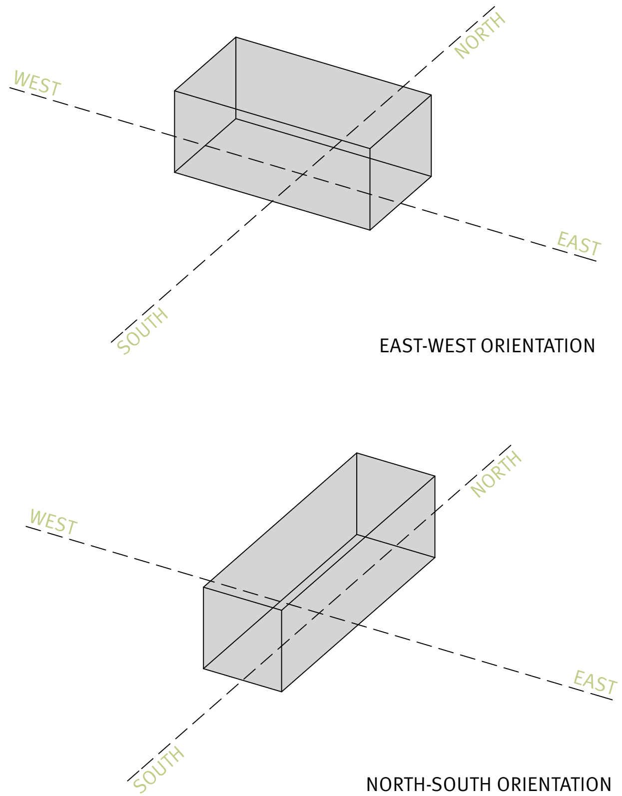
Ill. 36 | DIFFERENT WINDOWS AND POSITIONS

The higher the window lintel, the deeper the sun comes into the room.



GLAZING PERCENTAGE AND POSITION OF THE GLAZING ELEMENTS.[45] Depending on the climate zone and function of the building, a high glazing percentage can have positive or negative effects. If you consider housing in temperate climate, it is advantageous, if there are huge windows at the Southern side of the building. Due to that, the heating energy demand can be reduced in winter. Regarding an office building, the glazing percentage should be lower because of higher internal loads (which reduce the heating energy demand in winter anyway) and the cooling energy demand in summer. Moreover, the working places should be antiglare.
To guarantee natural daylight also in the back of the room, the window lintel should be as high as possible or a skylight should be installed. Furthermore, the form of the windows plays an important role regarding the light distribution in a room. It is better to install wide windows or even a window ribbon at medium height or a couple of narrow but high windows, than normal cubic windows.

ORIENTATION.[46] In areas with a lot of heating degree days, the orientation plays an important role for the solar gain. An East-West orientation and a big distance to nearby buildings are therefore recommended, to reduce the heating energy demand. If you consider areas, where cooling is the main challenge and solar gain has to be avoided, the best orientation is also towards the South. At the South, the sun reaches its highest point and the shading system works the best. Therefore, the buildings should be positioned close to each other and cantilevers should be added.



Ill. 37 | ORIENTATION OF THE BUILDING

An American East-West orientated building accords with the Austrian “Südausrichtung”.

45. Cf. BAUNETZ WISSEN - TAGESLICHT (n.y.): Verglasungs- und Fensterflächenanteil. Viewed on 07/22/2013 under www.baunetzwissen.de/ standardartikel/ Tageslicht_Verglasungs-und- Fensterflaechenanteil_167222.html
46. Cf. BAUNETZ WISSEN - NACHHALTIGES BAUEN (n.y.): Gebäudeorientierung und Zonierung. Viewed on 07/22/2013 under www.baunetzwissen.de/ standardartikel/Nachhaltig-Bauen_Orientierung- und-Zonierung_662877.html

SUN PROTECTION.[47] Sun protection elements in the area of a window are a method to protect against the sun. These elements can be attached to the exterior of the windows, between the panes or indoor.

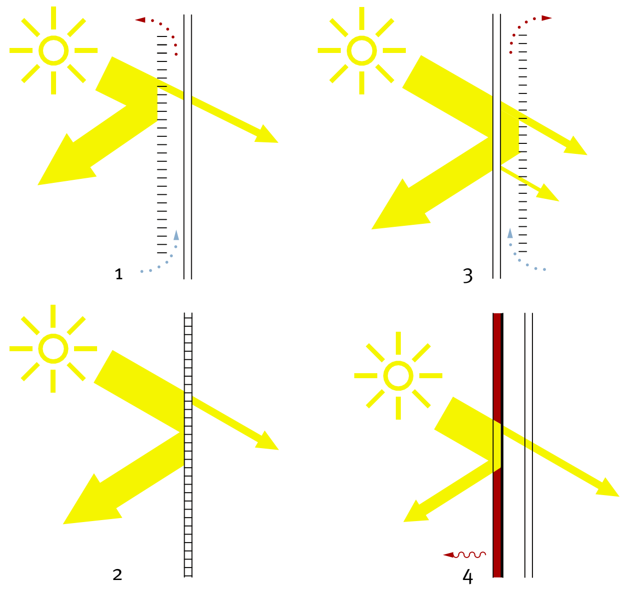
External sun protection (1): Attaching sun protection at the outside is the most efficient possibility. Just 10 % to 50 % of the sun can get into the room depending on the configuration. There are movable or rigid systems available which have both positive and negative attributes. The advantage is, that the thermal radiation does not come into the room because it is reflected or absorbed in front of the facade. The disadvantage is, that it is not resistant against all weather conditions.

Sun protection between the panes (2): Sun protection between the panes of a window can be rigid, rotatable and/or movable. The problem of that system is, that 15 % to 40 % of the irradiated energy of the solar radiation reaches the room behind the glass sheet. If the system is rigid, the view is blocked. If it is movable, it is more prone to failure and failure means to replace the whole window assembly.

Interior sun protection systems (3): Sun protecting elements at the inside can reflect 40 % to 70 % of the solar radiation and they are resistant to any weather conditions. They can either be blinds, roller blinds or screens. Their weakness is, that they reflect solar radiation inside, so the heat stays inside.

Sun protection glass (4): The principles of reflection, transmission and absorption play an important role for sun protection glass. The percentage of thermal radiation of the sunlight should get reflected while the daylight provision is still remaining.

	EXTERNAL	BETWEEN	INTERIOR	SP GLASS
USABILITY	+++	+	+++	++
ATTENDANCE	+	++	+++	+++
PRICE	+	+++	+	+++



Ill. 38 | SUN PROTECTION

This graph shows different possibilities to avoid solar radiation.

47. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 132

THERMAL MASS.[48] Thermal mass should be considered in the planning phase. It lowers the heating energy demand in winter, because it is capable of storing sun energy. In the hot summer months it works as an air conditioning system, because it keeps high temperatures inside and as a result, the indoor climate is more constant. In comparison to buildings with low thermal mass, the buildings heat up more often and also during the heating degree days.

ATRIUM | WINTER GARDENS.[49,50] Atriums and winter gardens are highly glazed spaces in a building which are surrounded by two or more sides of the building. The development is often integrated into the atriums. Furthermore, atriums create thermal zones to optimize energy consumption. In winter, they can reduce the energy demand of the adjacent rooms. Moreover, they bring daylight into the building and they cause natural ventilation. With the help of air outlets in the roof, thermal buoyancy and a natural climate in the building can be supported. To keep the temperature constant in the atrium, thermal mass should be integrated into it.

Ill. 39 | AN ATRIUM

This picture shows a modern example of an atrium in the Mont' Kiara Retail Mall in Spain.

48. Cf. N.Ed.: Hoch gedämmte Häuser brauchen Speichermassen. Vorteile im Sommer und im Winter in Aktuell Bauen mit Mauerwerk + Beton, No. 10 (10/2006) Viewed on 07/22/2013 under http://www.gfg24.de/download/Human-Healthy-Speichermasse.pdf
49. Cf. BAUNETZWISSEN - TAGESLICHT (n.y.): Atrien und Lichthöfe. Viewed on 07/22/2013 under www. baunetzwissen.de/standardartikel/Tageslicht_ Atrien-und-Lichthoefe_167206.html
50. Cf. BAUNETZWISSEN - NACHHALTIGES BAUEN (n.y.): Atrien. Viewed on 07/22/2013 under www. baunetzwissen.de/glossarbegriffe/Nachhaltig- Bauen-Atrien_664128.html?bid=577089&index=A

5. BUILDING CONCEPTS[51]

If you plan a building, you have to consider the changing climatic elements such as temperature, solar radiation, absolute air humidity and wind speed over the course of a month or even a day. Moreover, you have to analyze extreme values and connections between those elements.
The site of a building is affected by the climate, the local climate and the microclimate. They all have huge influences on energy-related and room climate-related aspects of building planning. The concept of a building must react to local conditions.

FACADE CONCEPT.[51] The building skin is the interface between indoor and outdoor. Factors such as glazing percentage, window geometry, sun protection and heat protection have to be adapted to achieve the requirements according to energy, room climate and daylight. In addition, the building's relationship to its surrounding environment and individual regulation concerning ventilation and sun protection are also important parameters.

ROOM CONDITIONING CONCEPT.[52] Room conditioning concepts depend on the building's function, the facade type and the local climate conditions to provide specific comfort requirements wich are needed.

OPERATIVE ROOM TEMPERATURE	20 - 26 °C
ABSOLUTE HUMIDITIY	max. 12 g/kg
AIR SPEED	0.2 - 0.8 m/s
FRESH AIRFLOW RATE (per person)	25 - 30 m^3/h
LUMINANCE	300 - 500 lux

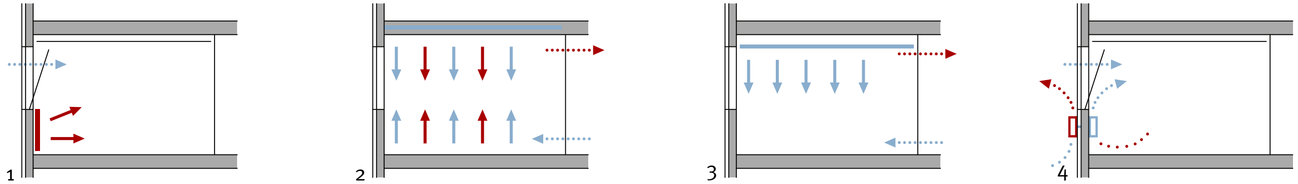
Radiator and convector (1)[53]: If natural ventilation is possible, the best price to performance ratio features a radiator or convector for heating. To add cooling, a blower convector is necessary. If mechanical ventilation or heat recovery is required, an earth duct can be used for passive cooling and preheating incoming air.

Concrete core activation (2)[53]: This heating and cooling system uses the massive ceilings or walls to control the temperature. Water flows through pipes to cool or heat the concrete as a transmitting medium.[54] The system temperature does not have to be high but cooling performance and adjustability are limited. Measurements for acoustics as well as mechanical ventilation with incoming air dehumidification in humid climates are required.

51. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 40
52. Ibid., p. 41
53. Ibid., p. 134
54. Cf. BAUNETZWISSEN - HEIZUNG (n.y.): Bauteilaktivierung. Viewed on 03/21/2013 under www.baunetzwissen.de/glossarbegriffe/ Heizung-Bauteilaktivierung_675251. html?bid=584747&index=B

Ill. 40 | ROOM CONDITIONING SYSTEMS

1. radiator/convector | 2. concrete core activation | 3. cooling ceiling | 4. split unit



Suspended cooling ceiling(3)[55]: Like the concrete core activation, the suspended cooling ceiling is a surface cooling and also heating system. It transmits cold or heat mainly as radiation and can achieve high performances. The cooling output is limited because the system temperature should not be lower than 16°C. Otherwise condensation water can appear. If the soil temperature is low, renewable cooling sources can be used in the soil.

Split units (4)[56]: Split units are decentralized systems that are installed on the facade of a building. The room conditioning can be adjusted differently in each room. It is an electrically operated room climate system used for heat and cold production. To a certain extent, they can also be used for dehumidification and they work at all levels of humidity. In comparison to the central systems, it is less efficient but they have a high level of adjustability.

Underfloor heating/cooling[57]: Loops filled with water run beneath the floor covering to use the floor as a transmitting medium. The system temperatures are limited according to the surface temperature of the floor but it can be easily combined with renewable energy sources. Also, cooling via the floor is restricted according to comfort criteria.

Night ventilation[57]: As far as night ventilation is concerned, a lot of factors have to be taken into account. There has to be enough thermal mass or phase change material in the building, the outdoor air temperature has to be low during the night, the degree of airflow should be high, and a lot of ventilation openings in the facade should be provided.

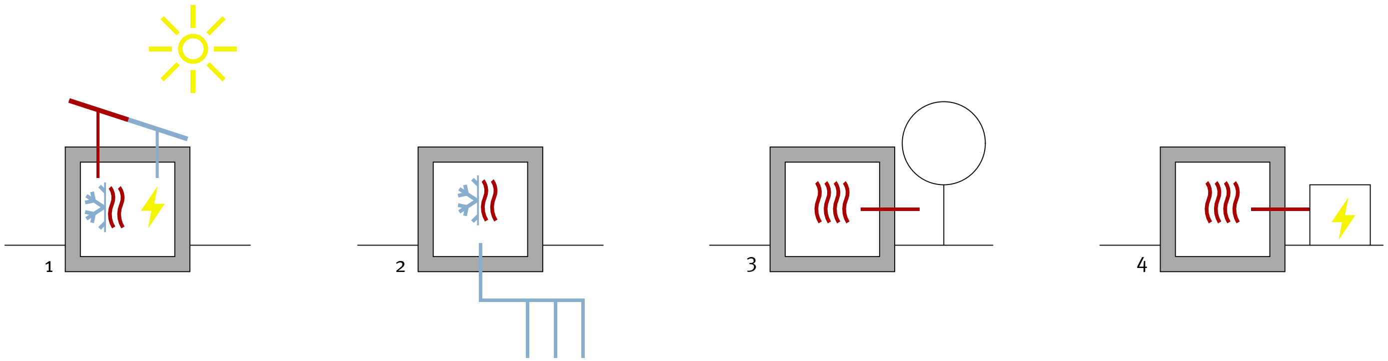
Decentralized ventilation system[57]: A decentralized ventilation system is a regenerative heat exchanger installed directly on the facade. The heat exchanger warms the outdoor air coming through a ventilation system. Heat recovery can also be added if exhaust air is handled via this system. If cooling is requested or outdoor air is moist, condensate drainage is necessary.

ENERGY GENERATION CONCEPT.[58,59] Energy generation concepts should be chosen in regard to heating, cooling and dehumidifying demands, the required capacities and the system temperatures of the room conditioning.

55. Cf. WIKIPEDIA (2013): Kühldecke. Viewed on 03/21/2013 under de.wikipedia.org/wiki/Kühldecke
56. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 134
57. Cf. Ibid., p. 152 | 58. Cf. Ibid., p. 41 | 59. Cf. Ibid., p. 136

Ill. 41 | ENERGY GENERATION SYSTEMS

1. solar energy | 2. geothermal energy | 3. bioenergy | 4. cogeneration



Solar energy (1)[59]: With the help of solar collectors, global radiation can be captured and converted to heating energy to be used for heating water, and to support heating or cooling. There are several different kinds of collectors which can be used in different areas and differ in their degrees of efficiency. Nevertheless, the output is high and the heat can be generated up to 90 °C. Solar collectors can also be used for solar cooling in combination with a high cooling capacity. Cooling with collectors is most efficient in areas, where it can be used for heating during the winter months. Regarding energy production, photovoltaic elements can be used to convert solar radiation directly into electricity with a performance of approximately 15 %. These elements can be easily integrated into the facade but performance suffers under dust in the air.

Geothermal energy (2)[59]: Geothermal energy can be captured using a heat pump to raise the temperature of energy from the soil or from groundwater. This method is most efficient with surface heating systems and low system temperatures. In summer the heat pump can function as a refrigeration unit for cooling. The geothermal energy can be used to prewarm or precool the incoming air via a register in the ventilation system or it can be fed into the surface heating or cooling system.

Bioenergy (3)[60]: This form of energy is extracted from biomass. Renewable products such as wood, soft commodity or organic waste materials are used for central heating. The use of bioenergy removes fossil fuels step by step and helps to preserve the environment.

Combined heat and power plan (4)[59]: The difference between a central heating system and a combined heat and power plant system, short CHP, or in other words cogeneration is, that it uses the waste heat to generate electricity which is generally fed into the main grid. The initial investment and maintenance costs are very high. That is why it is only economically efficient, if it has a running time of over 5,000 hours a year. This system should only be installed, if heat is needed throughout the year.

Cooling tower[59]: A cooling tower can be used for direct cooling of the outdoor air. The outdoor air temperature has to be low during the night so it can be stored in a concrete core activation system. Cooling towers can also provide recooling for refrigeration units.

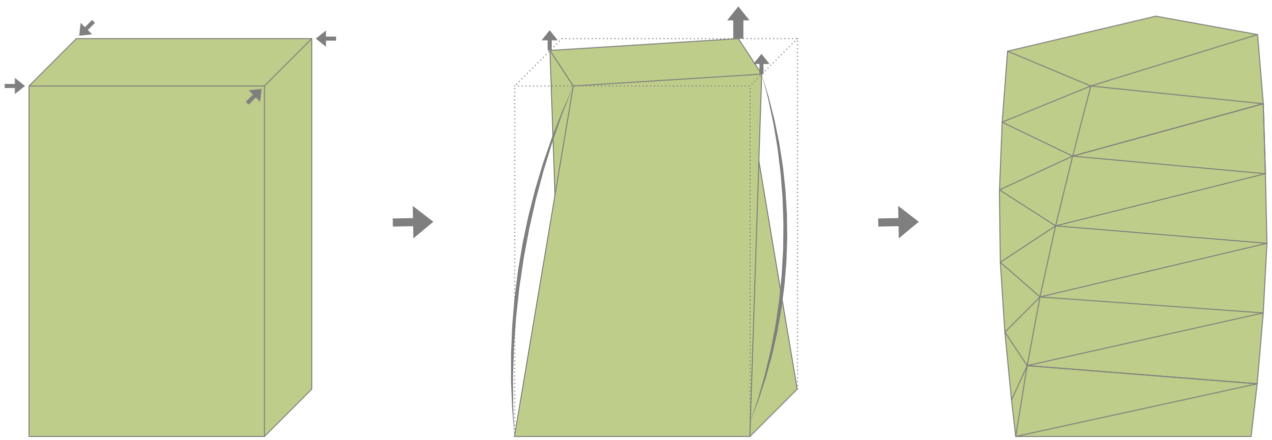
60. Cf. WIKIPEDIA (2013): Bioenergy. Viewed on 04/26/2013 under de.wikipedia.org/wiki/ Bioenergie


CONSUMPTION
KILOWATT
POLLUTION
ENVIRONMENT
PROVING
GLOBAL WARMING
ENERGY
SOLAR RADIATION
TEMPERATURE
AIR-HUMIDITY
PASSIVE HOUSE
PRODUCTION
ELECTRICITY
COOLING ENERGY DEMAND
EFFECTIVE
ECONOMIC
ENERGY
HEATING DEGREE DAYS
ELECTRICITY LIGHTING
RENEWABLE
PERFORMANCE
THERMAL
ENERCALC
BRIDGE
DISCHARGING GAIN
INPUT OUTPUT
TRANSMISSION
ACTIVE
LATITUDE
PROXIMITY TO OCEAN
WATER
BUFFER ZONE
HEAT LOSS
INTERIOR GAINS
TOPOGRAPHY
ALOCATION
THERMAL MASS
INSULATION
ECOLOGICAL
CONSUMTION
HOT WATER
ELECTRICITY
VENTILATION
GREEN
INDOOR COMFORT
LIGHTING
CO2 EMISSIONS
CONCRETE CORE ACTIVATION
SUN PROTECTION
CONSTRUCTION
COMPACTNESS
ORIENTATION
SHAPE
ACTIVE
PASSIVE
ENERGY DEMAND
COOLING
HEATING
CLIMATE
PHOTOVOLTAIC
SUSTAINABILITY
ELECTRICITY LIGHTING
RENEWABLE
CONSTRUCTION
DAY
GLAZING PERCENTAGE
LIGHT
TOPOGRAPHY
CO2
SOLAR RADIATION
TEMPERATURE
AREA
MEETING ROOM
STORAGE ROOM
CONFERENCE ROOM
CORPORATE ARCHITECTURE
CA
MARKETING
JOB HOLDER
TRUST
IMAGE
CANOPY
CANTILEVER
SMART WORKING
TEAMWORK
HUMAN RESOURCES
FLEXIBILITY
IMAGE
HOT DESKING HOTELING
TEAMWORK
CI
ATRIUM
REVERS
SKY
LINE
ABILITY
OFFICE
BARRIER-FREE
SMALL ROOM OFFICE
TWO-PERSON OFFICE
OFFICE ENVIRONMENT
INDIVIDUAL OFFICE
LARGE OFFICE UNIT
GROUP OFFICE
COMBI OFFICE
RISE
INTERNATIONAL CAREER
JOB
BUSINESS
VERTICAL LANDSCAPING
INNOVATION
POTENTIAL
HIGH
BUILDING
SUCCESS
RISE
RELAXING CORNER
WAITING AREA
SUBSIDIARY
REVERSABILITY
EMPLOYEES
CA
MULTINATIONAL CORPORATIONS
ELEGANT MODERN
WIND
TEMPERATURE
CI
ECONOMY
CAREER
CITIES
VIENNA
BANGKOK
CHICAGO
HANOI
DUBAI
PROMOTION
MARKETING
GLOBAL
STRUCTURE
INNOVATION
AIR-HUMIDITY
DESERT
BIOCLIMATIC ARCHITECTURE
SUBTROPICS
ENVIRONMENTAL PERFORMANCE
OCEAN
TROPICS
CONTINENTAL
MULTINATIONAL CORPORATION
TEMPERATE
CLIMATE
COLD
SUMMER
WINTER
MISSION STATEMENT
CITIES
SUBSIDIARIES
BUSINESS
INNOVATION POTENTIAL
SKYLINE
IMAGE
VERTICAL LANDSCAPING

CHAPTER IV

THE DESIGN

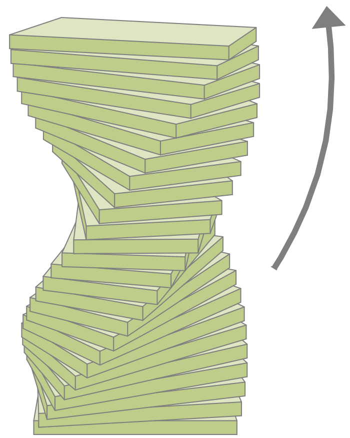
1. THE IDEA



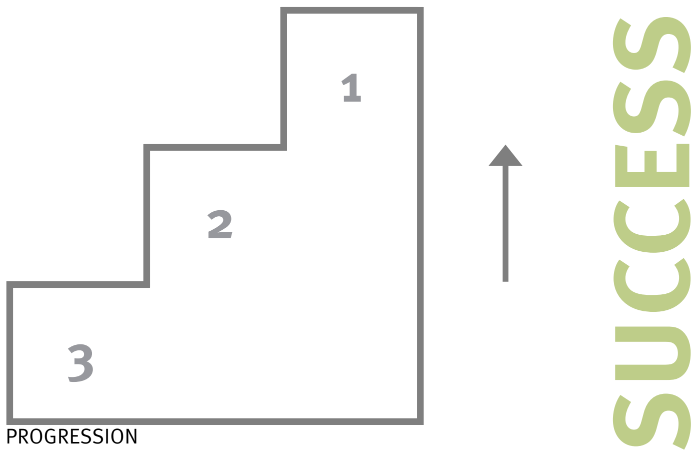
CUBE TWISTING DETAILING

The starting positing of the design can be described as a simple cuboid. In the next step, each floor rotates about 2.1 degrees around the center. In this case, the surface-to-volume ratio is inauspicious and the building is prone to thermal bridges. Therefore, four floors form a unit, which is connected via triangle facade elements. This creates both a solid volume and a domestic appearance. Moreover, this concept can easily be transformed to all climate zones and create a corporate architecture with high recognition value.
In short, the design levels are:
CUBE - TWISTING - DETAILING.

The folding of the facade is the direct answer to a staircase. It is a constant upward movement, which literally stands for well-doing business and the pursuit of success. With every step you take, you achieve something and you get closer to your goal. A project of a company consists of a lot of steps, and sometimes the requirements during a project change but in the end there could only be one straight and clear outcome. If you transfer this metaphor to the building, the floors illustrate the steps, which is emphasised by the rotation. Moreover, the twisting shows the changes of a project, as the facades also change directions.



TOWARDS THE SKY



PROGRESSION

2. TARGET GROUP

It is also important to know the target group for the design of a building. There are the employees and their clients. As it is an office building, both groups are between 18 and 65 years old. To emit success, the appearance is important. So, men primarily wear suits, while women wear costumes or pantsuits. As they are dressed very appropriately, the appearance of the building and interior design should also respond to them. Moreover, it should be elegant and chic as well as neat and well structured.

3. CORPORATE DESIGN

SYMBOL

LOGO

COLORS

C:28 M:8 Y:58 C:0

C:30 M:24 Y:24 C:0

C:43 M:35 Y:32 C:1

C:0 M:0 Y:0 C:100

4. THE LOCATION

The locations for the design are spread all over the Northern hemisphere of the world. The main location is in temperate climate. Therefore, I chose Vienna in Austria. Moreover, there are designs for Chicago / United States of America in cold climate, for Hanoi / Vietnam in the subtropics, for Bangkok / Thailand in the tropics and Dubai / United Arab Emirates in the desert. The locations are all on the Northern hemisphere of the world to make a comparison of the designs more comprehensible as the seasons are at the same time of the year.

1 | CHICAGO
latitude: 41°51’ N
longitude: 87°39’ W
height above sea level: 179 m

2 | VIENNA
latitude: 16°22’ N
longitude: 48°12’ E
height above sea level: 171 m

3 | HANOI
latitude: 21°02’ N
longitude: 105°52’ E
height above sea level: 16 m

4 | BANGKOK
latitude: 13°44’ N
longitude: 100°34’ E
height above sea level: 20 m

5 | DUBAI
latitude: 25°15’ N
longitude: 55°20’ E
height above sea level: 5 m

Ill. 47 | LOCATIONS

The five locations which I designed buildings for.

5. SPACE ALLOCATION AND FUNCTIONAL PROGRAM[61]

Ill. 49 | OFFICE ROOM SOLUTIONS

These graphics show different office room sizes.

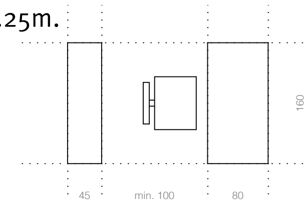
For my design, I used the space allocation and functional program of the EU-wide competition called “1030 Wien Rasumofskygasse - Büro- und Geschäftsgebäude” as a guideline. The calculated net floor space of the program corresponds to the Austrian “ÖNORM” or more specifically to the ÖNORM B 1800-2002.

EXTERNAL DEVELOPMENT. The main entrance to the office should be clearly visible and it should be designed in a manner encouraging people to enter the building as well as welcoming them from the outside. The external development should be simple and clearly orientated.

INTERNAL DEVELOPMENT. The main entrance should welcome both the employees of the company and the visitors. That is why the central located foyer should distribute the people right away at the entrance of the building. The vertical development should be carried out via several peripheral building cores. All execution paths and orientation through the building should be easy and speak for themselves. Furthermore, it should be hierarchically ordered and executed barrier-free. In other words, the main paths should connect the cores with each other and the minor paths should lead to the office areas and link the working spaces.

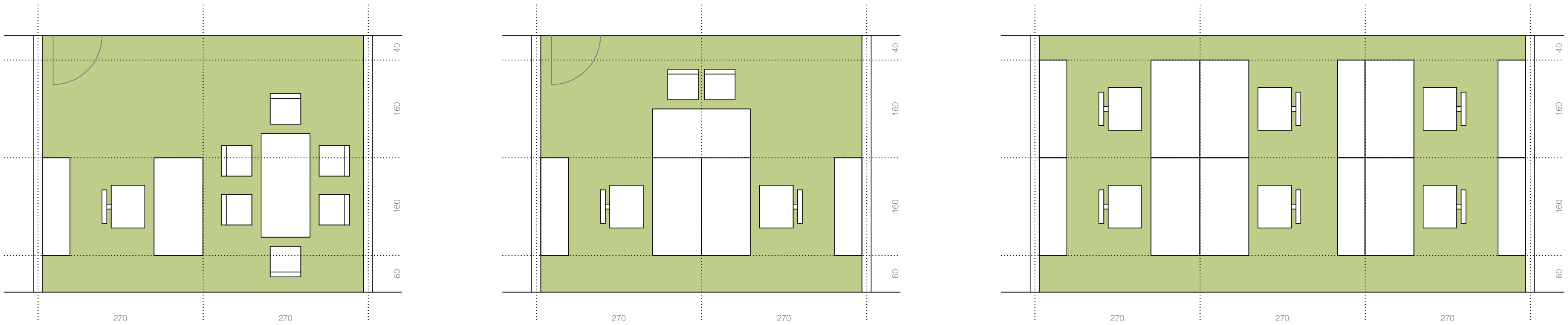
FUNCTIONAL PROGRAM. The concept of the building should be open to single tenant as well as multiple tenant use. This requires a lot of flexibility and reversibility. That is why a good structure with a planning grid is necessary which allows organizational changes all the time. Demands regarding concentrated single work as well as teamwork should be integrated into plan solutions. In order to make multiple tenant use possible, independent areas should be included in the concept.

Basic module of a working place:
This is the smallest module of an office unit. The dimensions are 1.60m to 2.25m.



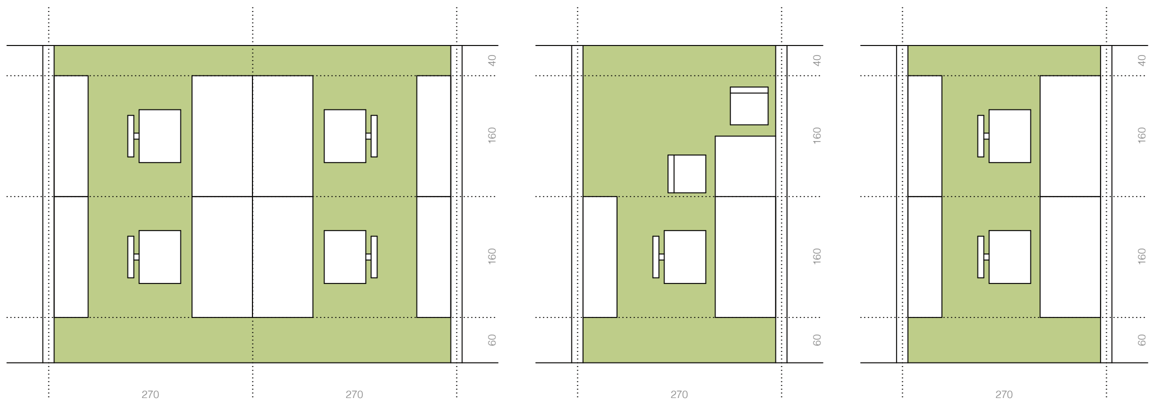
Ill. 48

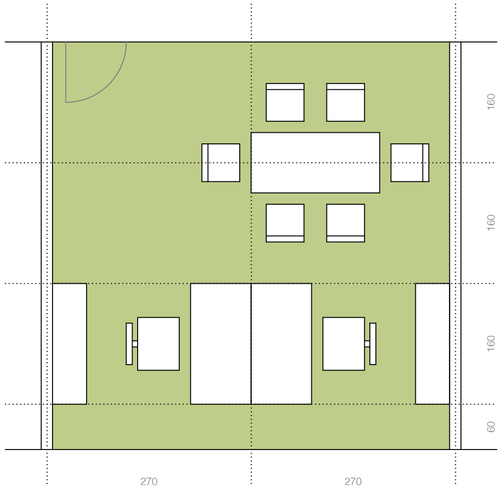
61. Cf. Österreichische Post AG: 1030 Wien Rasumofskygasse- Büro- und Geschäftsgebäude. EU-weiter offener zweistufiger anonymer Generalplanerwettbewerb (Realisierungswettbewerb). Auslobungsunterlagen 1. Fassung. Teil D Funktionale Gebäudequalität. [Unpublished paper.]

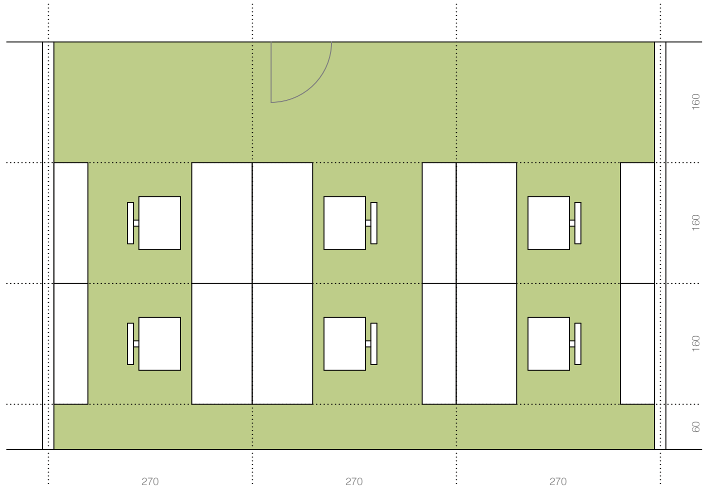


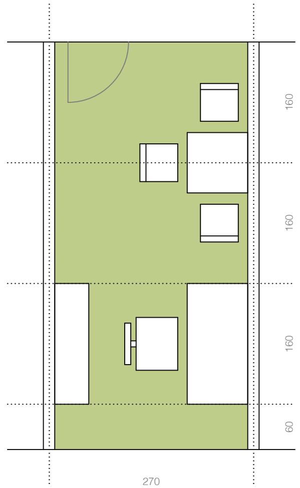
Dimensions between axes and building depths:
According to efficiency, flexibility and comfort as well as in due consideration of law and norms the best dimension between axes measures 2.70 m. This also allows building depths of 4.20 m, 5.40 m and 6.25m. All axes should have an individual access to infrastructure such as, for example, heating, cooling, lighting etc.

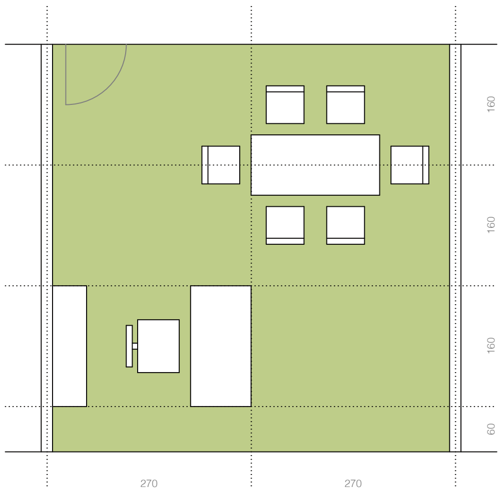
Building area | planning grid:
The planning grid can be seen as the third design level beside the basic module of a working place and the dimensions between the axes. An open structure is recommended to improve communication. The working places can be zoned with dividing walls, movable walls or closets.



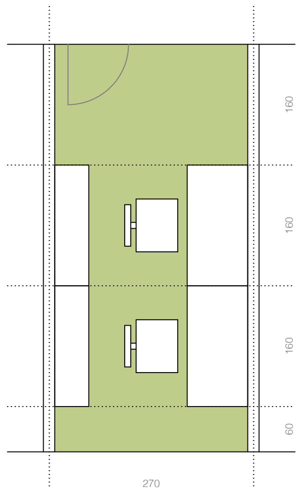

160
160
160
60
270
270

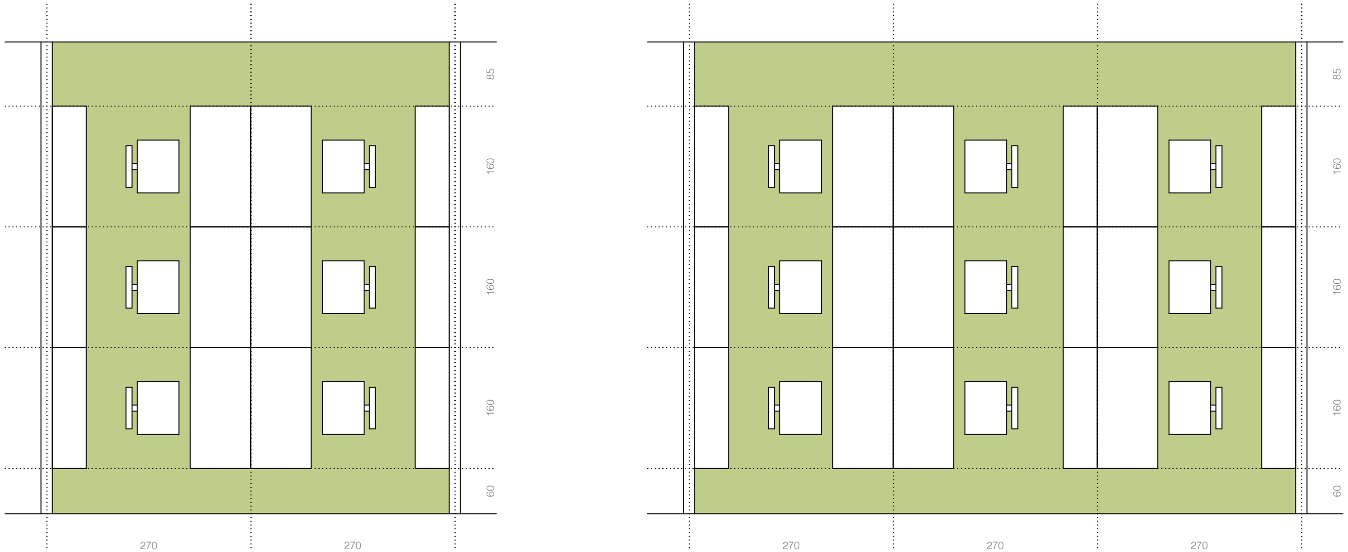

160
160
160
60
270
270
270


160
160
160
60
270


160
160
160
60
270
270

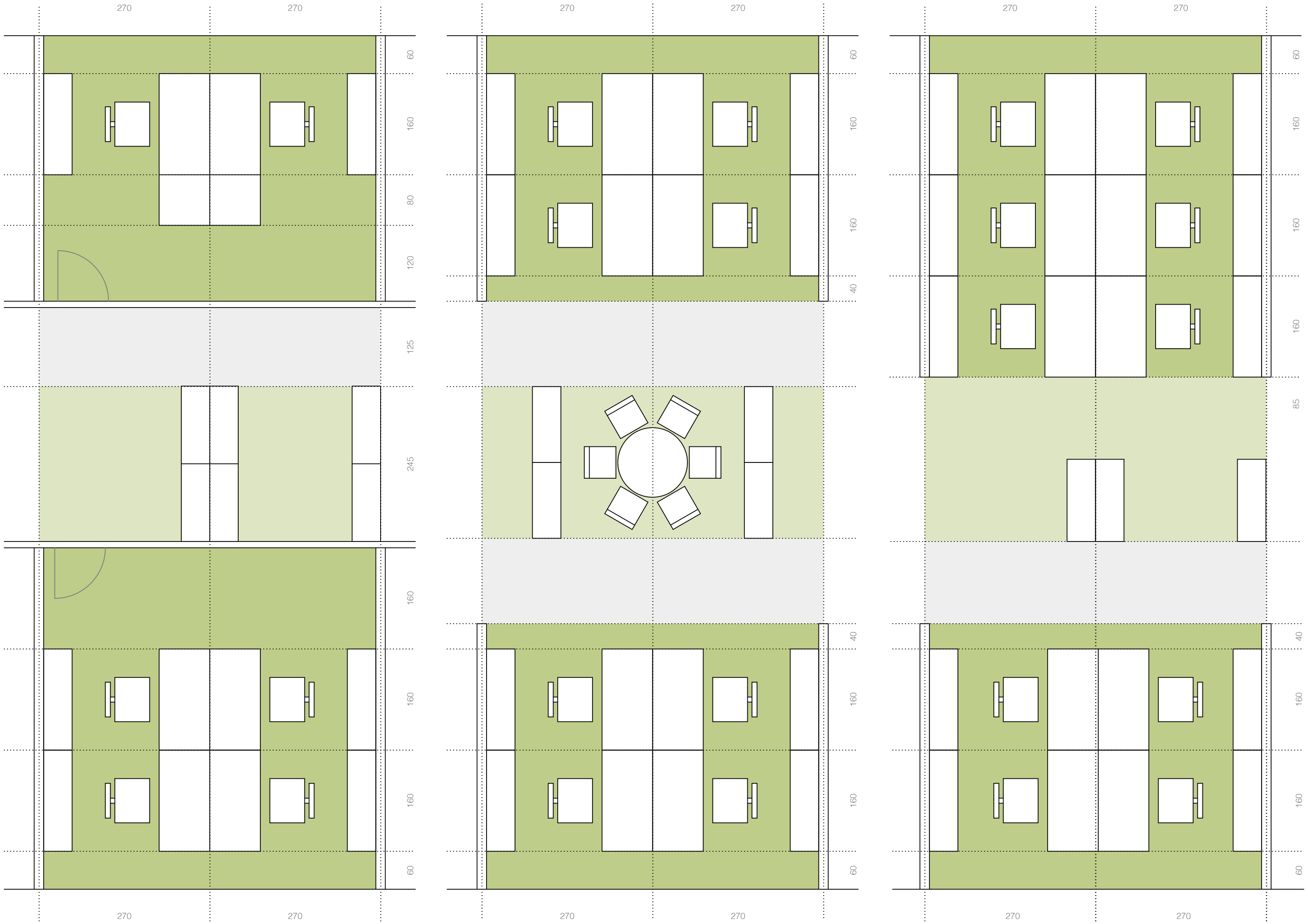

160
160
160
60
270
270


160
160
160
60
270



Ill. 50 | OFFICE ROOM SOLUTIONS

These graphics show different office room sizes.


270
270
60
160
80
120
125
245
160
160
160
60
40
85

Ill. 51 | MULTIFUNCTIONAL ZONES

These graphics show different office rooms in combination with multifunctional zones in the middle.

Multifunctional Zones:
There should be room for joint use between the working places. This includes waiting areas, printing areas, a wardrobe, communication areas as well as additional or special working places.

Building cores:
The building core is a carrying element and it assumes the function of the vertical access through the building. As a static element a lot of other functions such as, for example, kitchenettes or restrooms, are connected to it. It has to fulfill fire protection demands, but nevertheless, it should be a welcoming, lucent and pleasant area.

Building core areas:
Kitchenette (about 15 m^2): The small kitchens should be fully furnished with two fridges, two microwaves, a sink, a dishwasher, storage room for a coffee machine, dishes, waste separation and some general space. There should be one kitchen per floor and core. Moreover, a table with up to 6 seats should be available.

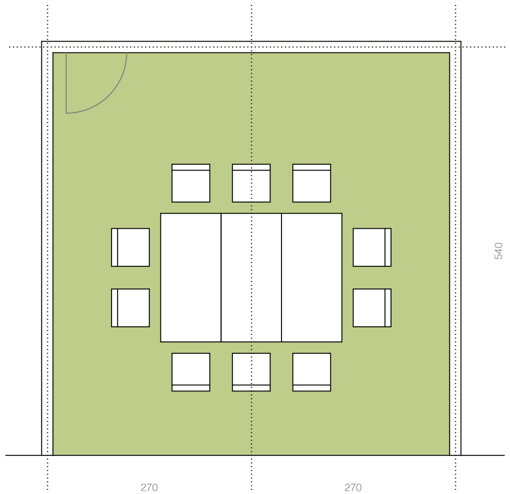
Storage room for cleaning material (about 7 m^2): The storage room for cleaning material should be equipped with a sink and it should provide space for a cleaning trolley. There should be a storage room on each floor and it should be connected to each core.

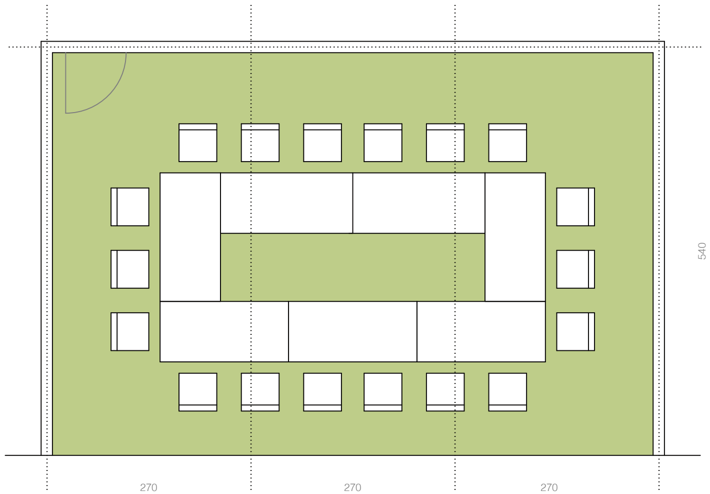
LAN room (about 7 m^2): The plenum for data and telephone cables should be in the LAN room. Each floor and core should be featured with its own LAN room.

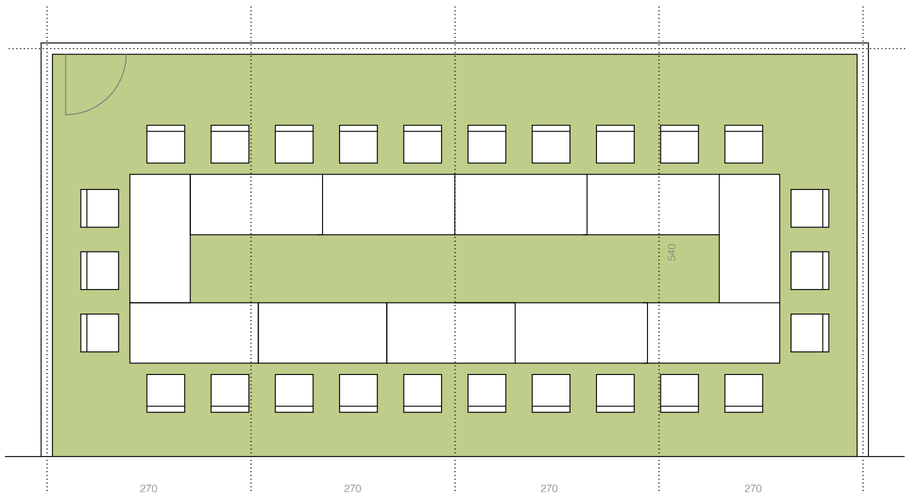
Restrooms (about 20 m^2 + 5 m^2): There should be enough restrooms close to each core according to the number of employees working there. The ratio of restrooms for women and men should be 50:50. Moreover, a handicapped accessible restroom is demanded.

Staircase / elevators (about 50 m^2): The staircase should be designed in a way that animates people to walk instead of to use the elevator. Thus, daylight as well as a connection to the outside should be provided.

Supply slots: Connected to the core, there should be supply slots for the cords and sewing system.


270
270
540


270
270
270
540


540
270
270
270
270

Ill. 52 | MEETING ROOMS

These graphics show different sizes of meeting rooms.

Additional core areas:
Lounge (about 30 m²): Additional to the small kitchens there should be comfy lounge areas. They should be equipped with a soda machine as wells as a coffee dispenser and should invite to meet and talk. An access to a balcony would also be very desirable. If that is not possible, a smoking cabin should be added.

Decentralized meeting rooms (about 30 m²): A good mix of naturally and artificially lighted meeting rooms should be installed in each floor and they should be located close to the core. They should offer space for up to 10 people.

Project rooms (about 30 m²): A project room should have the same size as a meeting room. But it also has to have an excellent daylight provision.

Management area and management press area: The management area as well as the management press area should be located under the roof with an access to a terrace. The whole interior should be high standard. Moreover, there should be an open reception with a waiting area offering seating as well as a wardrobe for both the management area and the management press area. Connected to the reception there should be a meeting room for the management with high standard interior. Additionally, it should be good for holding videoconferences.

In the management area space should be provided for four management offices, two offices for management assistants, two additional provision offices, an office for externals, an office for the personal drivers and restrooms. In addition, a room for first aid, a doctor's room and a resting room should adjoin to the reception.
The management press area should include a large and a small press conference room, a lounge with a buffet space, a storage room and an engineering room.
The whole area should be secured with an access control system. Visitors should not have access to the office areas. Thus, the elevators should provide a convenient circuit logic.

ROOMS	AREAS WITH DAYLIGHT	AREAS WITHOUT DAYLIGHT
offices		
basic module (room depth = 4.2)	12	
basic module (room depth = 5.4)	15	
basic module (room depth = 6.25)	17	
building core area		
kitchenette		15
storage room for cleaning material		7
LAN room		7
restrooms		25
staircase / elevators		50
additional core area		
lounges	30	
decentralized meeting rooms	30	
project rooms	30	
centralized special areas		
meeting room for 20 persons	60	
meeting room for 10 persons	45	
office for external people	30	
kitchenette and storage room		40
lounge area		60
printing area		10

ROOMS	AREAS WITH DAYLIGHT	AREAS WITHOUT DAYLIGHT
management area		
reception / waiting area / wardrobe	100	
meeting room for management	40	
management office	60	
management assistant office	60	
additional provision office	60	
office for external people	60	
reserve / room for personal driver	30	
management press area		
large press conference room	70	
small press conference room	45	
reception / waiting area / wardrobe	80	
lounge	100	
buffet and preparation space	80	
storage room	30	
engineering room	15	

Ill. 53 | SPACE ALLOCATION PLAN

This is a list of the needed rooms with their areas.

6. REFERENCE OF THE CONSTRUCTION

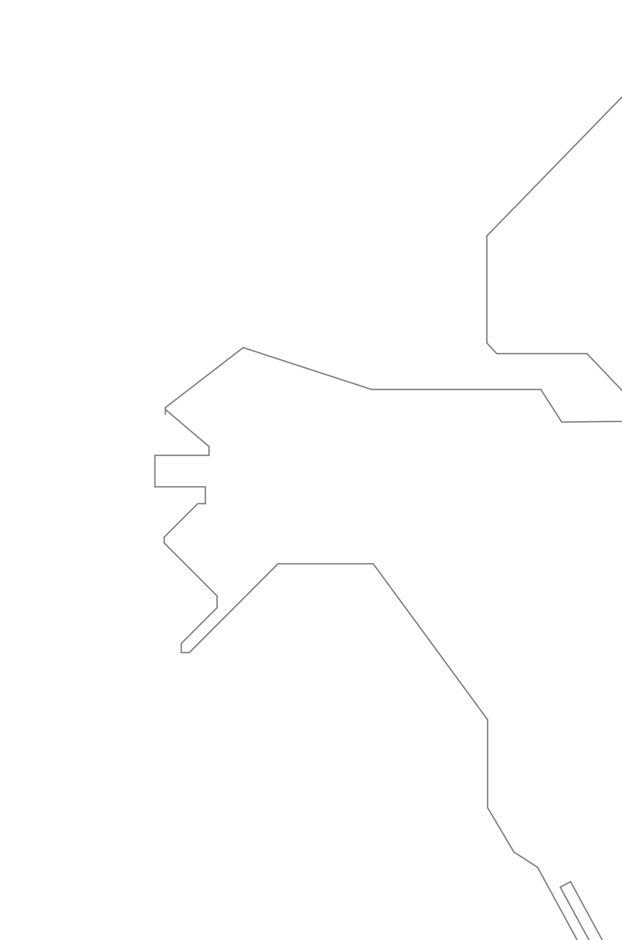
WUHAN MARINE SCIENCE AND RESEARCH TOWER.[62]
The Marine Science and Research Tower in Wuhan / Central China shows a frozen expression of twisting water. The 461 meter tall tower is designed by ACID + AaL + Studio méta- and offers about 14,800 m² of space for research and development. Each floor is rotating at the central core of the building and it is scaling down by moving up vertically. This system provides balcony zones at each office level.

As I am designing a building which is rotating towards the sky, I used the construction of the Wuhan Marine Science and Research Tower as my reference for the static system. There is a central carrying core in the middle and carrying columns. As there is this twisting of the building, the columns are tilted. In this case, it is good, because they can absorb both horizontal as well as vertical forces. These forces can be transferred to the core. To strengthen the system, the ceilings should be thicker than usually.

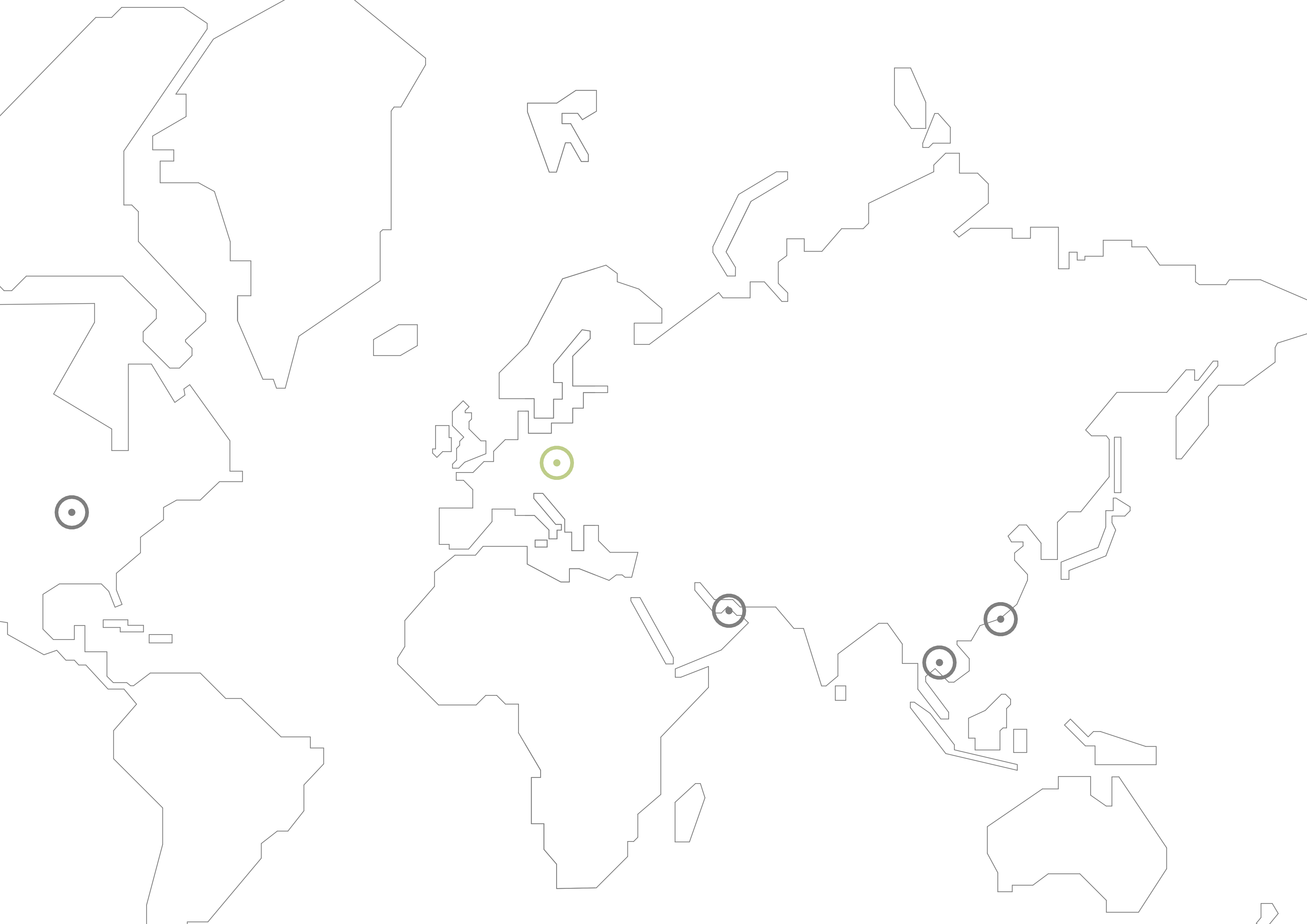
Ill. 54, 55 | REFERENCE FOR THE CONSTRUCTION

These two pictures show the Wuhan Marine Science and Research Tower.

62. Cf. ARCHDAILY (2012): Furuto, Alison: Wuhan Marine Science and Research Tower Proposal / ACID + AaL + Studio méta-. Viewed on 08/03/2013 under www. archdaily.com/306256/wuhan-marine-science-and- research-tower-proposal-acid-aal-studio-meta/



vienna



Ill. 57 | **PANORAMA OF VIENNA**

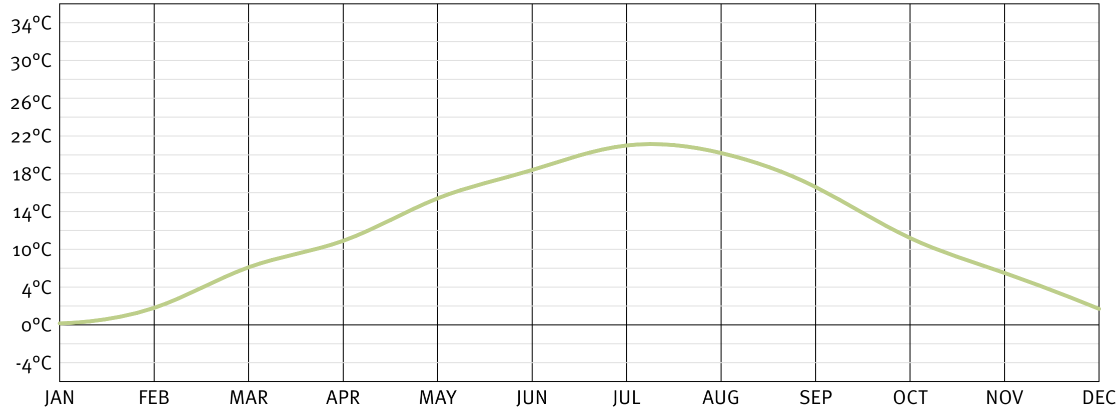
View from the North to the South.

7.1. TEMPERATE CLIMATE[63]

The temperate climate is defined by its seasons without extreme values in outdoor air temperature and air density. That is why it is also called the intermediate climate. This zone predominates on the Northern hemisphere between the 35th and 60th latitude from the Eastern part of North America to the Western part of the Eurasian land mass. The seasons in this zone are distinct in regard to long springs and autumns. There are four different kinds of temperate climate depending on the closeness to the ocean or to the continent.

The climate in Vienna is very typical of a temperate climate zone. Temperature and solar radiation fluctuate considerably throughout the year. Energy is required for heating as well as for cooling.

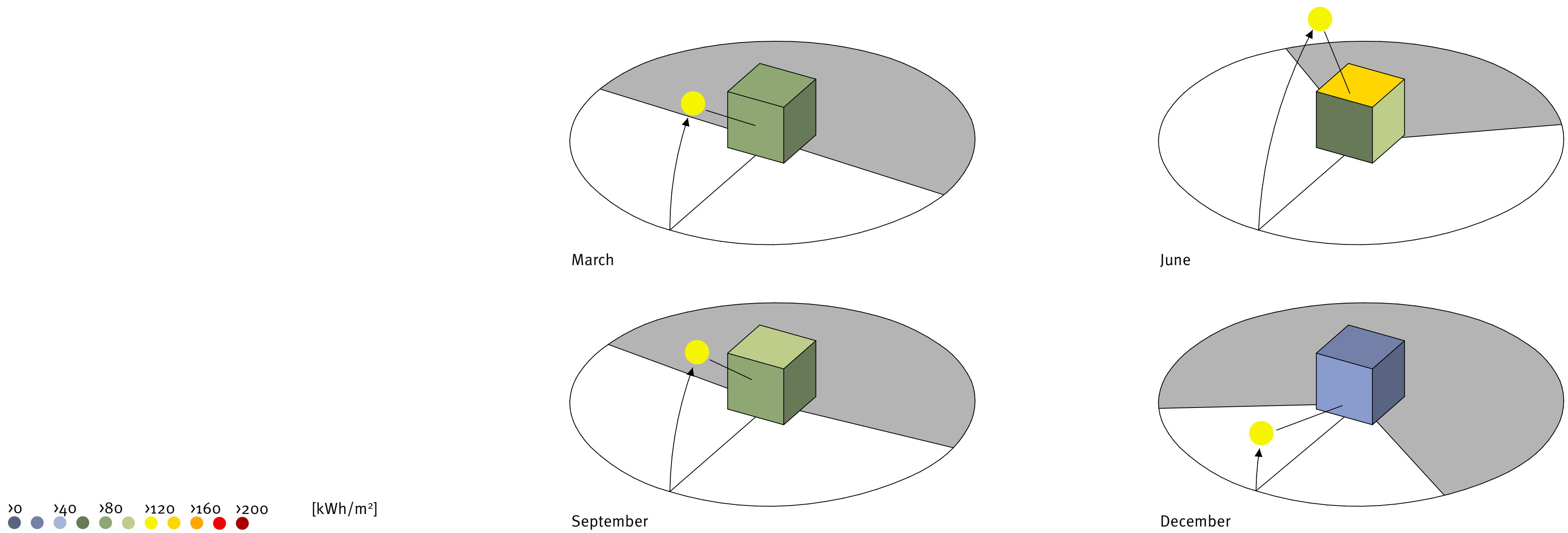
Ill. 58 | TEMPERATURE CURVE OF VIENNA



Climate data[64]:	
Average temperature:	11.4 °C
Average max. temperature:	15.3 °C
Average min. temperature:	8.3 °C
Maximum temperature:	37.0 °C
Minimum temperature:	-17.6 °C
Sum of level of rainfall:	547.9 mm
Sum of hours with sunshine:	1883.6 h
Average wind speed:	3.9 m/s

Average relative humidity 7 am:	80.8 %
Average relative humidity 2 pm:	63.2 %
Days with frost (max. temp. < 0.0°C):	50.4 d
Hot days (max. temp. ≥ 30.0 °C):	17.9 d
Heating degree days:	2,989.7 Kd/a[65]
Cooling degree days:	497.2 Kd/a

63. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p.62
64. Cf. ZAMG (n.y.): Klimadaten von Österreich 1971- 2000. Viewed on 03/16/2013 under www.zamg. ac.at/fix/klima/oe71-00/klima2000/klimadaten_ oesterreich_1971_frame1.htm
65. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p.160

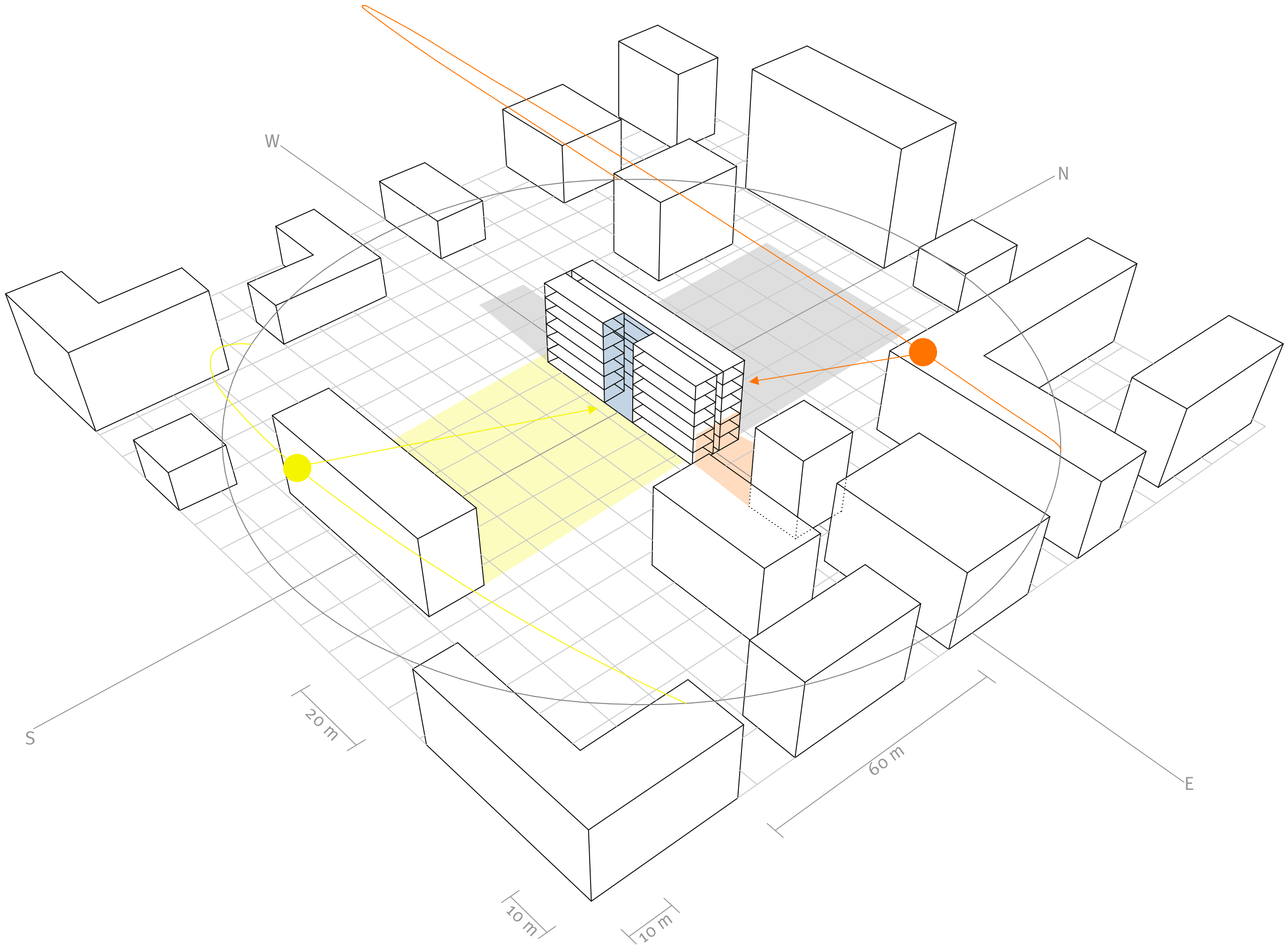


Ill. 59 | SOLAR RADIATION IN VIENNA

These graphics show the solar radiation reaching facade surfaces in different seasons.

7.2. BUILDING STRUCTURE[66]

The most important parameters in the temperate climate are the building's orientation, the building's shape as well as the height of nearby buildings and the distance to already existing buildings.
Planners are challenged as far as the finding of good surface-to-volume ratio compromises between transmission heat loss, daylight provision and natural ventilation. All of these design variables can be reached by a few simple implements such as using thermal buffers or moderate depths and heights for a building. An atrium or conservatory can reduce heat transmission, and height can decrease wind loads and the demand on technical systems. An East-West orientation allows the most effective amount of solar gain. A Southern facade also enables the best shading possible. The distance to nearby buildings should be highest to the South and can be lower to the East and West according to solar loads in summer, but nevertheless, good daylight use should be assured.



Ill. 60 | BUILDING STRUCTURE OF VIENNA

Far distance to nearby buildings, an atrium in the South and a moderate building depth are the main characteristics for a buidling in temperate climate.

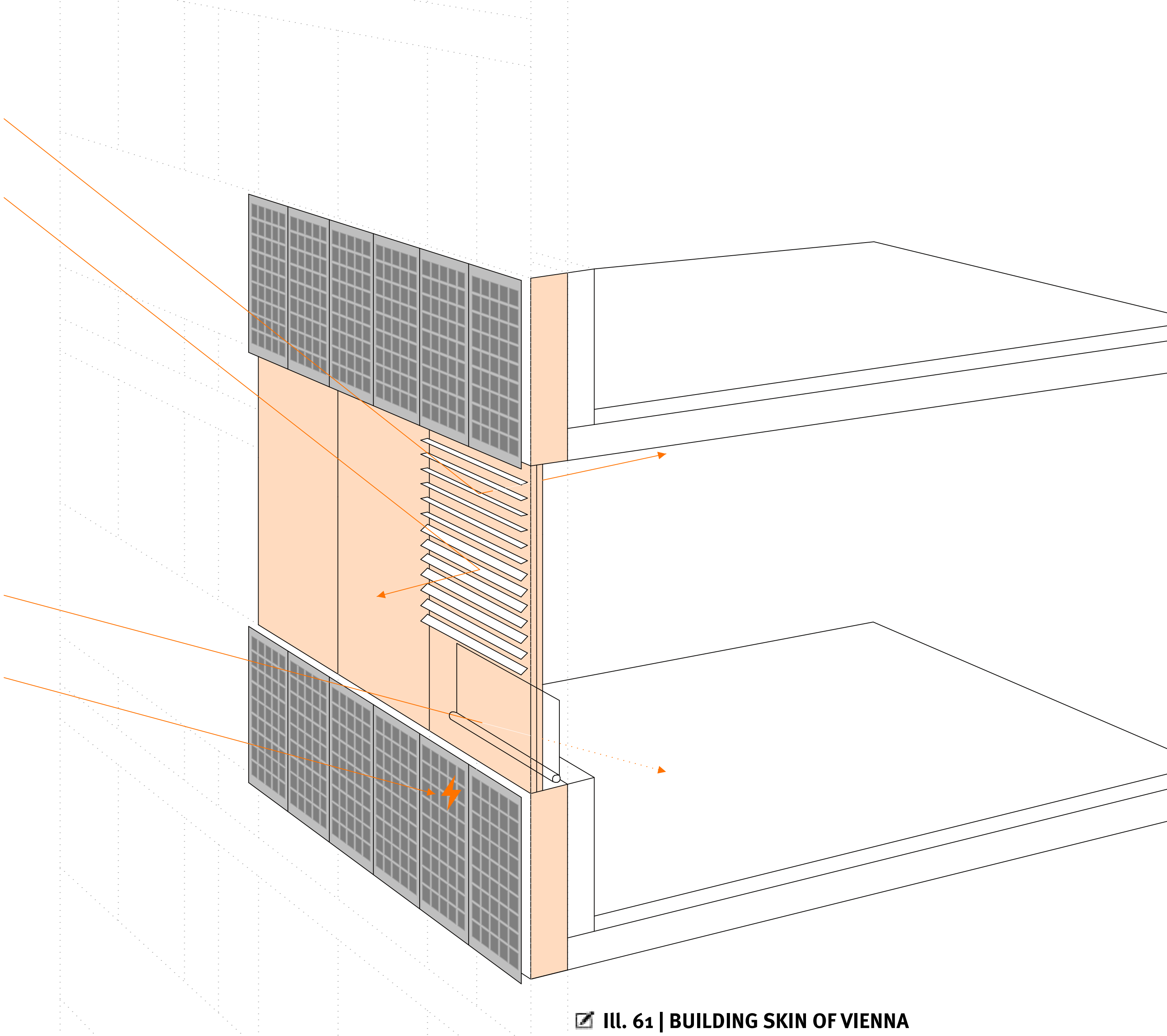
66. Cf. Ibid., p.68

7.3. BUILDING SKIN[67]

In Vienna the facade should avoid heat input in summer but it should support solar gain in winter. That is why a good thermal protection with a thickness of 20 cm is recommended. Additionally, the use of sun protection coatings as well as photovoltaics is useful.

The glazing percentage of a building should be optimized to avoid heat loss in winter and solar input in summer. It depends on the U-value of the building skin, the transmission factor (g) and the arrangement and functions of the rooms inside.[68] The glazing percentage of a building should be planned according to its orientation and to the track of the sun.

In Vienna the glazing percentage should be between 50 % and 70 % depending on the orientation. The glass which is used should be made out of triple thermal protection glazing with low-e coating and gas filling to achieve a U-value as low as 0.7 W/(m²K).



Ill. 61 | BUILDING SKIN OF VIENNA

Photovoltaics on the facade, high glazing percentage and external sun protection are essential in temperate climate.

67. Cf. Ibid., p.70
68. Cf. Sahner, Georg / Drittenpreis Julia: Bauherreninformation für das Baugebiet Kornburg Nord. (Nürnberg: Umweltamt und Stadtplanungsamt der Stadt Nürnberg, 2008) Viewed on 03/19/2013 under http://www.nuernberg.de/ imperia/md/bau-referat/dokumente/planen/ bauherreninformation_kornburgnord.pdf

7.4. DESIGN

The building for Vienna could be located in the so called Donau-City. Thereby, it is important that the adjacent buildings do not shade the building too much.

The design for Vienna is very compact and every floor rotates about 2.1° around the centre. So the main building's facade ranges from South-West to South-East. The core is East-West orientated.

The office building consists of 21 regular floors and 3 floors in the roof area. In total, the building reaches a height of about 80 meters.

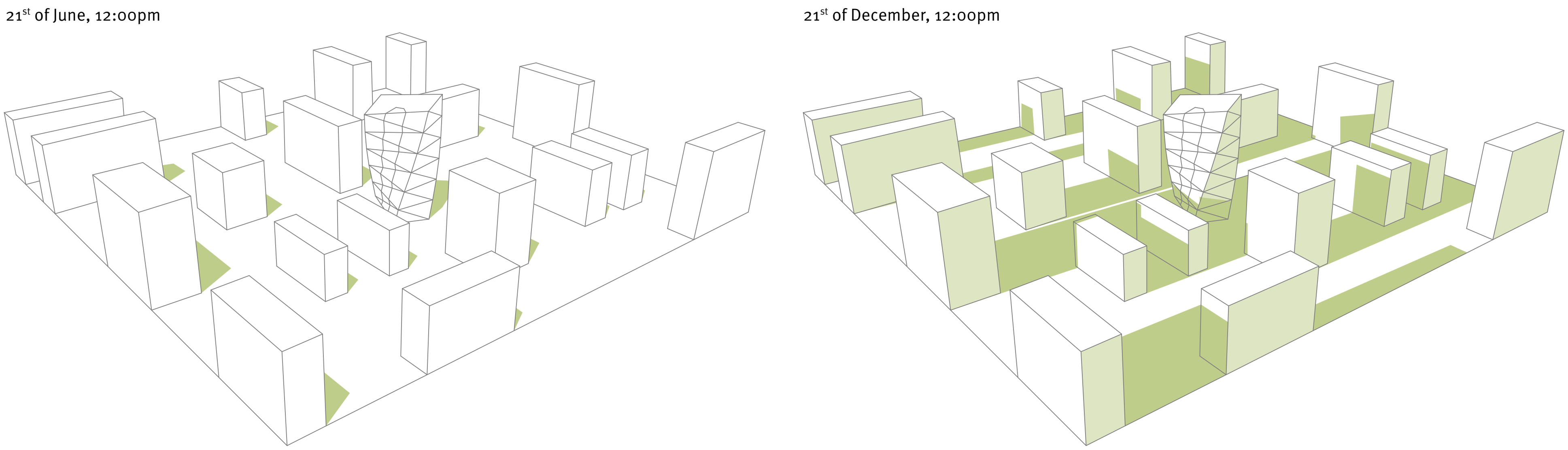
The facade consits of triangle elements which unite 4 floors. Those elements are connected to each other in an angle considering the rotation of the building.

The special characteristic of the design for Vienna is the atrium towards the South. It is both a thermal buffer zone as well as a design element. It can be seen as a vertical development but also as a refreshing and relaxing area. Small, individual platforms connect the staircases to create a monumental figure. The atrium is surrounded by glass walls, so the adjacent office rooms have a great view into the atrium.

On the first floor a canopy which protrudes from the atrium marks the entrance. On this floor only the atrium is open to ensure a good wind shield. If you enter the building, you directly arrive at the reception. Then you could either go to the developing core or to a small café. Moreover, two small shops can be found on the first floor.

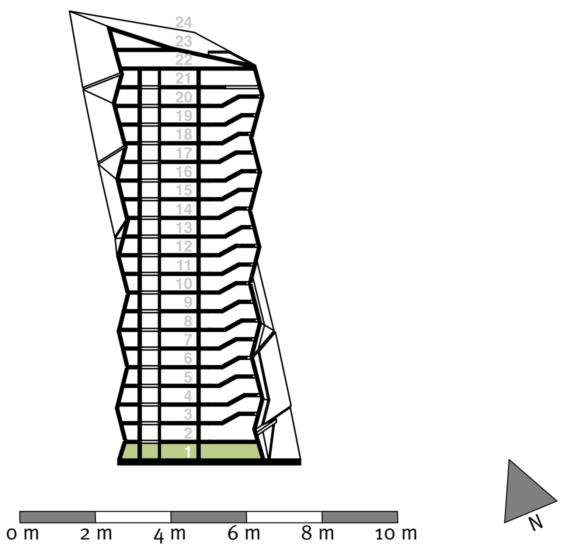
The second to the twenty-first floor are for office use. The obtuse and acute angled rooms are a specialty on these floors, and can be seen as a reaction to the core, as they are parallel to it.

The pitch of the roof runs from the twenty-first to the twenty-fourth floor. So the floors get smaller and smaller. The meeting-rooms with a buffet zone are on the twenty-second floor. It can be used for bigger events too. Therefore, it is directly connected to a restaurant on the upper floor. From there you can go to a small relaxing area at the rooftop.



Ill. 62 | SHADING STUDY

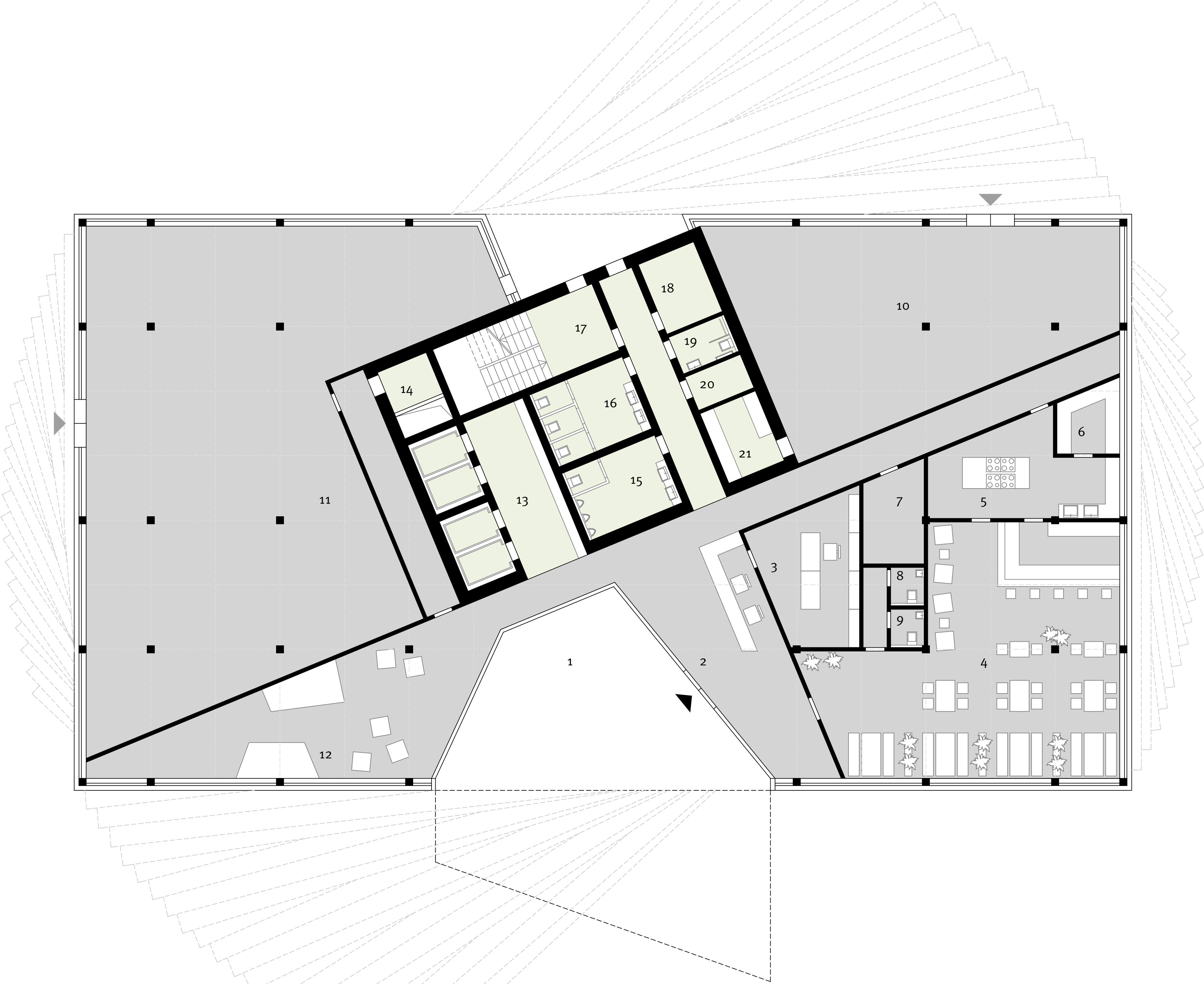
External shading of Vienna on the 21st of June and on the 21st of December.



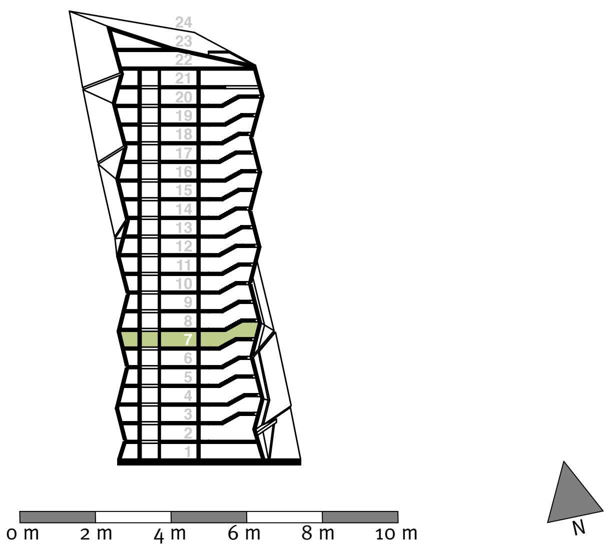
Ill. 63 | VIENNA | FIRST FLOOR | M 1:200

In the first floor, there is the entrance area with its reception, a small cafeteria and two shops.

1 porch
2 reception
3 back office
4 café
5 kitchen
6 cold storage room
7 storage room
8 restroom men
9 restroom women
10 shop 1
11 shop 2
12 relaxing area
13 elevetor waiting area
14 engineering room
15 restroom men
16 restroom women
17 staircase
18 storage room
19 restroom for the disabled
20 LAN-room
21 storage room



1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21



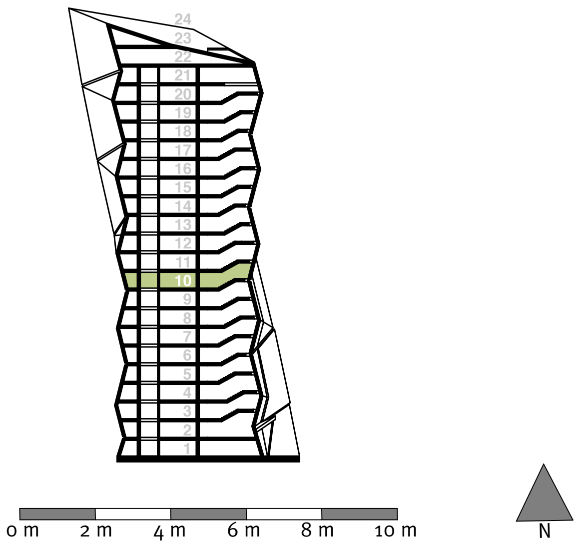
Ill. 64 | VIENNA | SEVENTH FLOOR | M 1:200

The seventh floor shows a regular floor for office use including different office sizes and meeting rooms.

1 elevetor waiting area
2 engineering room
3 restroom men
4 restroom women
5 staircase
6 kitchenette
7 LAN-room
8 restroom for the disabled
9 storage room
10 office room
11 office room
12 atrium
13 sitting area
14 relaxing corner
15 office room
16 office room
17 office room
18 office room
19 office room
20 meeting room
21 office room
22 office room
23 office room
24 storage room
25 office room
26 office room
27 office room
28 office room
29 office room
30 meeting room
31 office room

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31

92



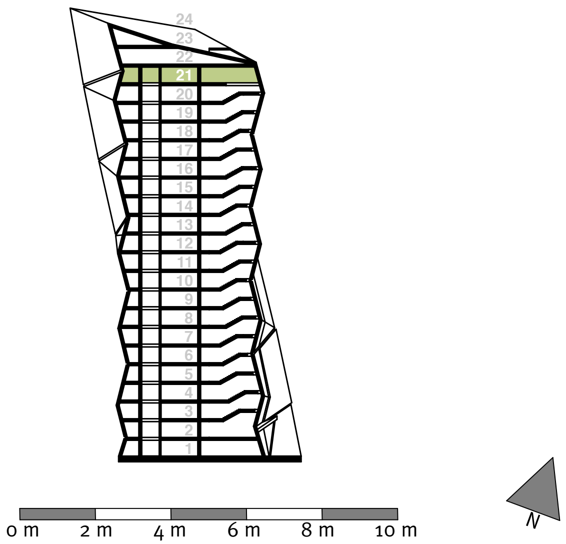
Ill. 65 | VIENNA | TENTH FLOOR | M 1:200

The tenth floor is in the middle of the building and it also shows an office floor.

1 elevetor waiting area
2 engineering room
3 restroom men
4 restroom women
5 staircase
6 kitchenette
7 LAN-room
8 restroom for the disabled
9 storage room
10 office room
11 office room
12 atrium
13 sitting area
14 office room
15 office room
16 meeting room
17 office room
18 office room
19 office room
20 storage room
21 storage room
22 office room
23 office room
24 office room
25 office room
26 office room
27 office room

21
20
2
5
9
23
22
19
18
17
8
24
26
4
7
1
3
6
27
25
13
16
12
10
11
14
15

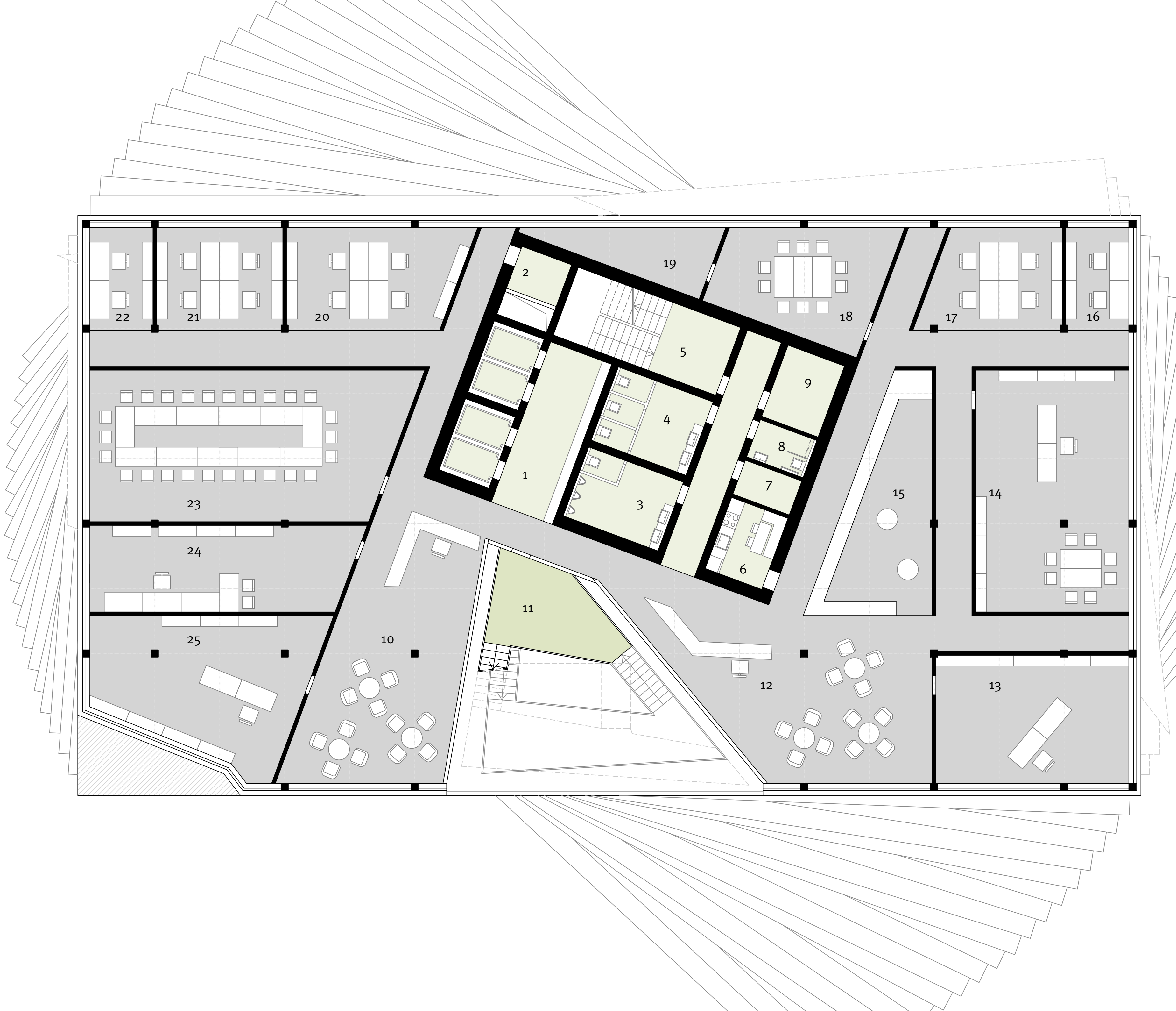
94



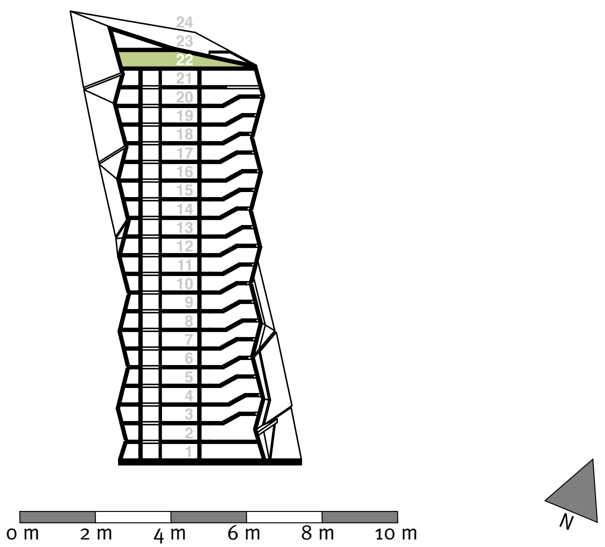
Ill. 66 | VIENNA | TWENTYFIRST FLOOR | M 1:200

In the 21st floor there is the offices for the management and management press area.

1 elevetor waiting area
2 engineering room
3 restroom men
4 restroom women
5 staircase
6 kitchenette
7 LAN-room
8 restroom for the disabled
9 storage room
10 reception and waiting area
11 atrium
12 reception and waiting area 2
13 office room
14 office room
15 relaxing area
16 office room
17 office room
18 office room
19 storage room
20 office room
21 office room
22 office room
23 meeting room
24 office room
25 office room



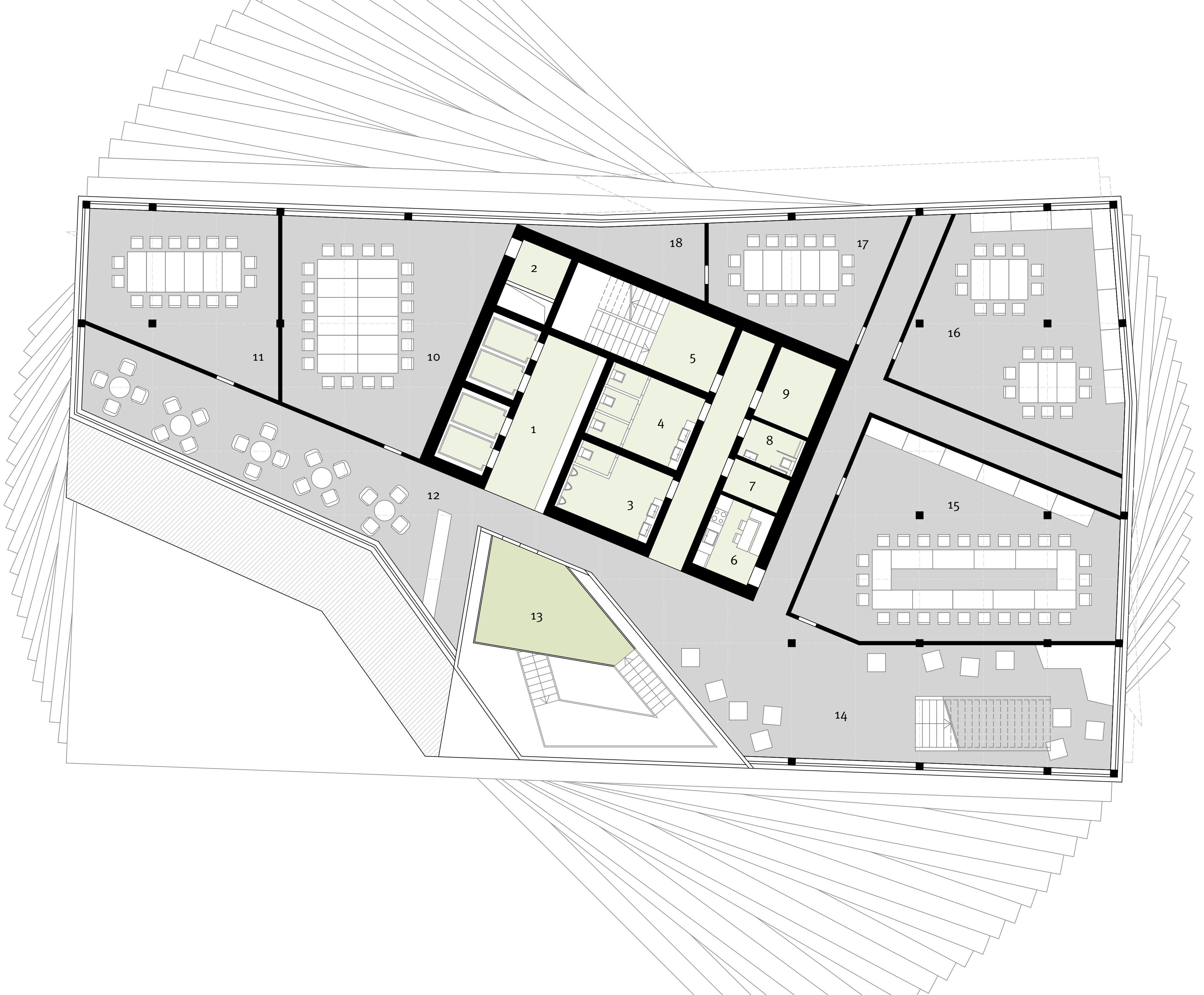
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25



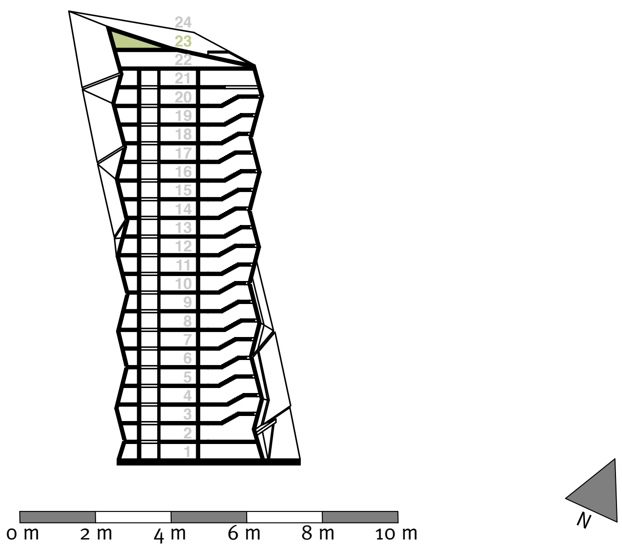
Ill. 67 | VIENNA | TWENTYSECOND FLOOR | M 1:200

In the 22nd floor, there are the meeting rooms for the management and management press area.

1 elevetor waiting area
2 engineering room
3 restroom men
4 restroom women
5 staircase
6 kitchenette
7 LAN-room
8 restroom for the disabled
9 storage room
10 meeting room
11 meeting room
12 buffet zone
13 atrium
14 sitting area | gallery
15 meeting room
16 meeting room
17 meeting room
18 storage room



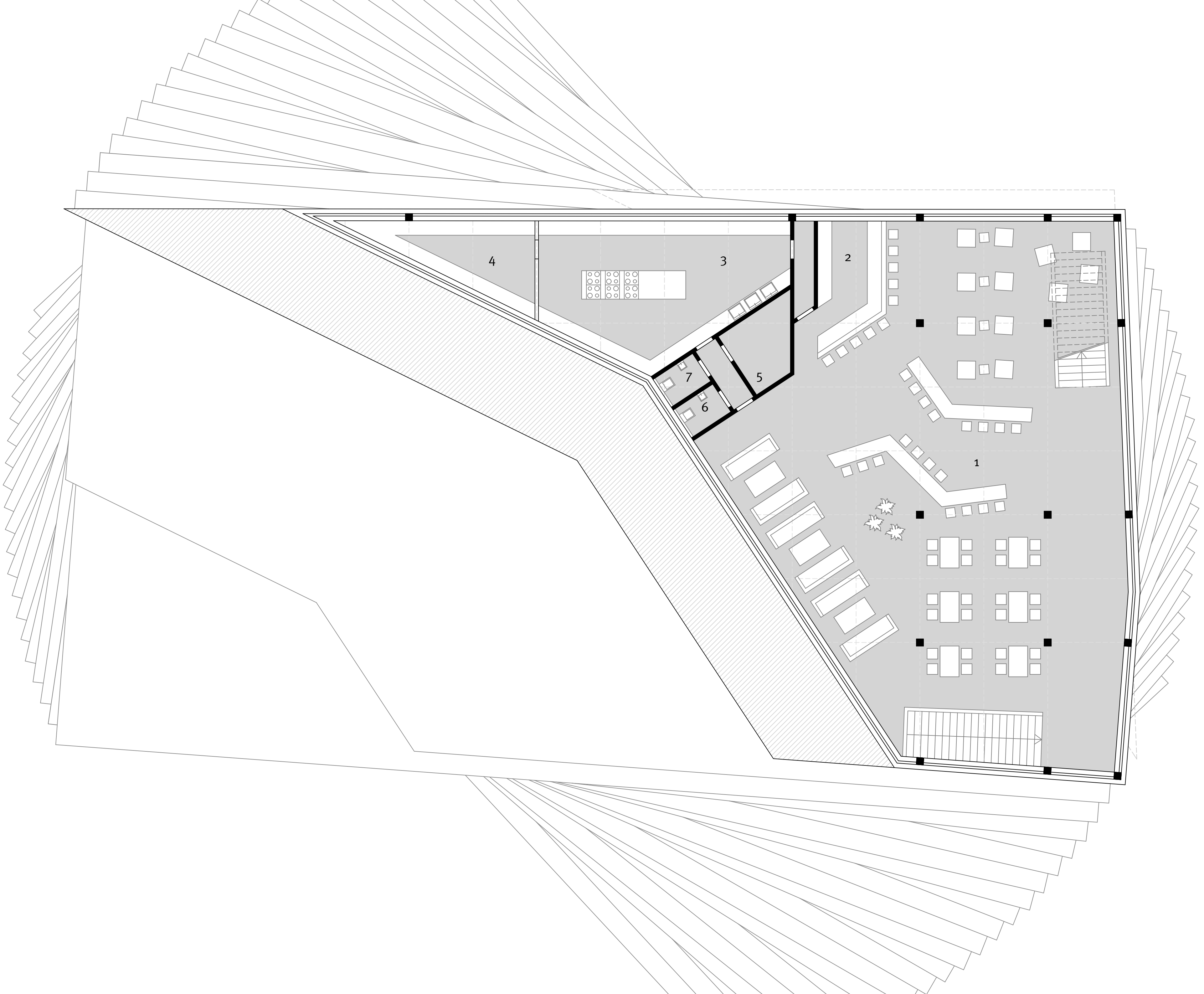
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18



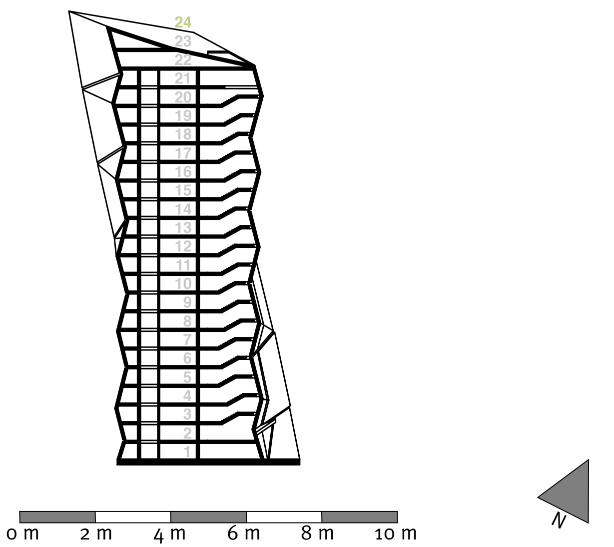
Ill. 68 | VIENNA | TWENTYTHIRD FLOOR | M 1:200

In the 23rd floor, there is a restaurant which is connected to meeting room area in the 22nd floor.

1 restaurant
2 bar
3 kitchen
4 cold storage room
5 storage room
6 restroom for women
7 restroom for men



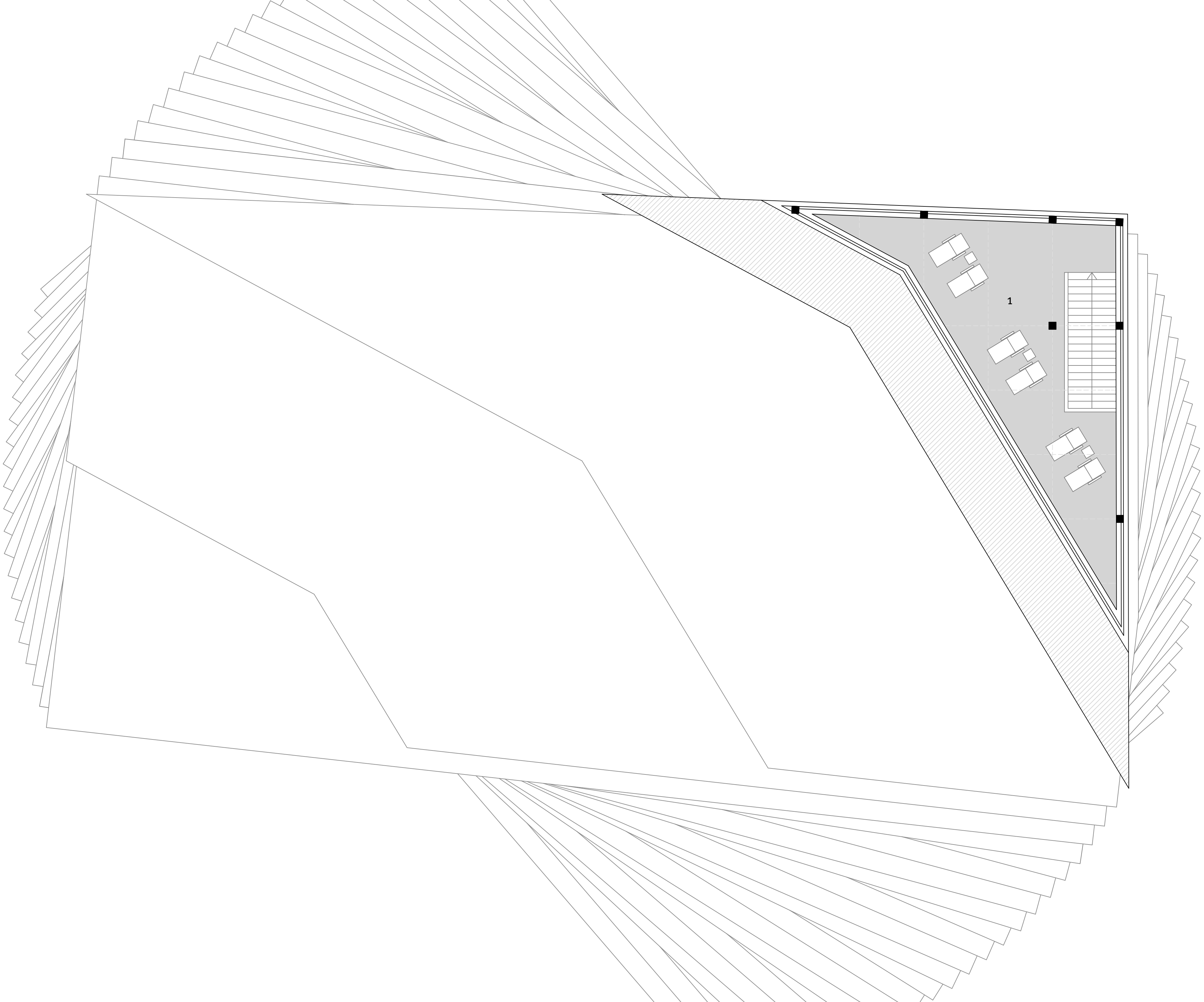
4
3
2
7
5
6
1



Ill. 69 | VIENNA | TWENTYFOURTH FLOOR | M 1:200

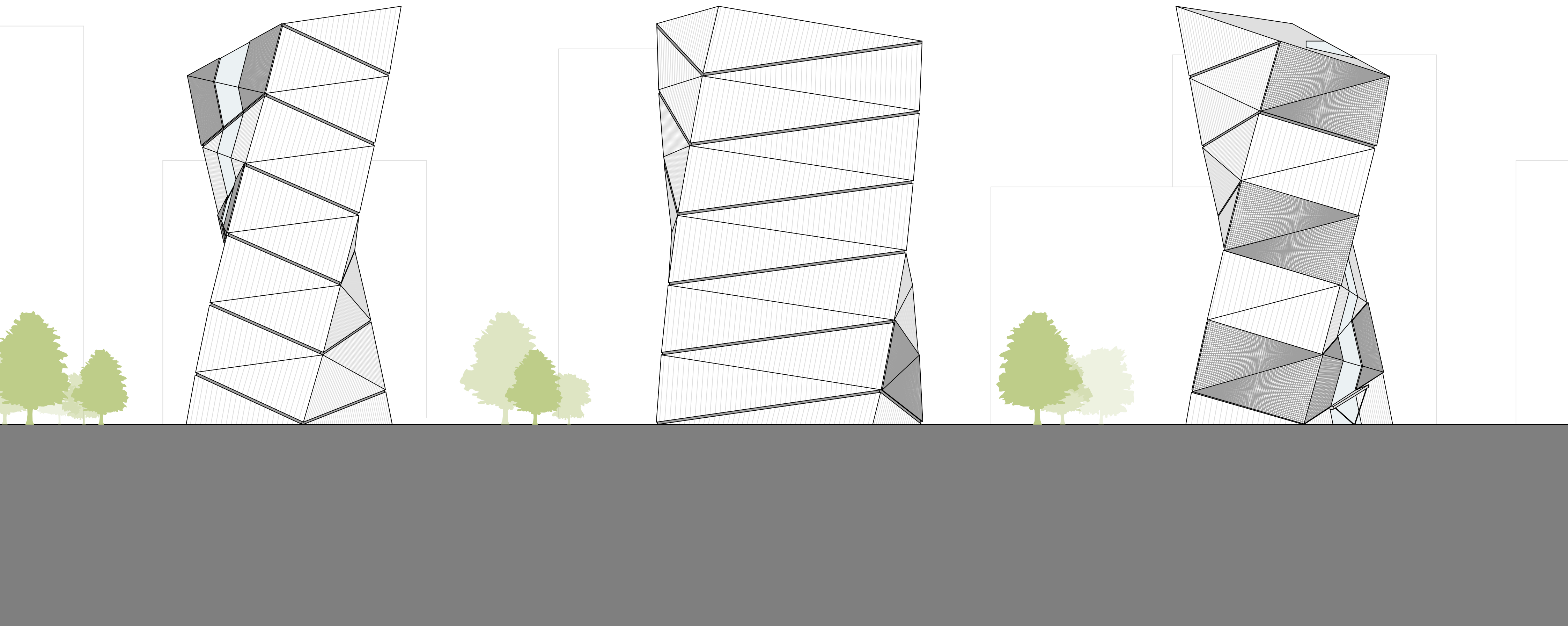
A small relaxing area can be found in the attic floor of the building.

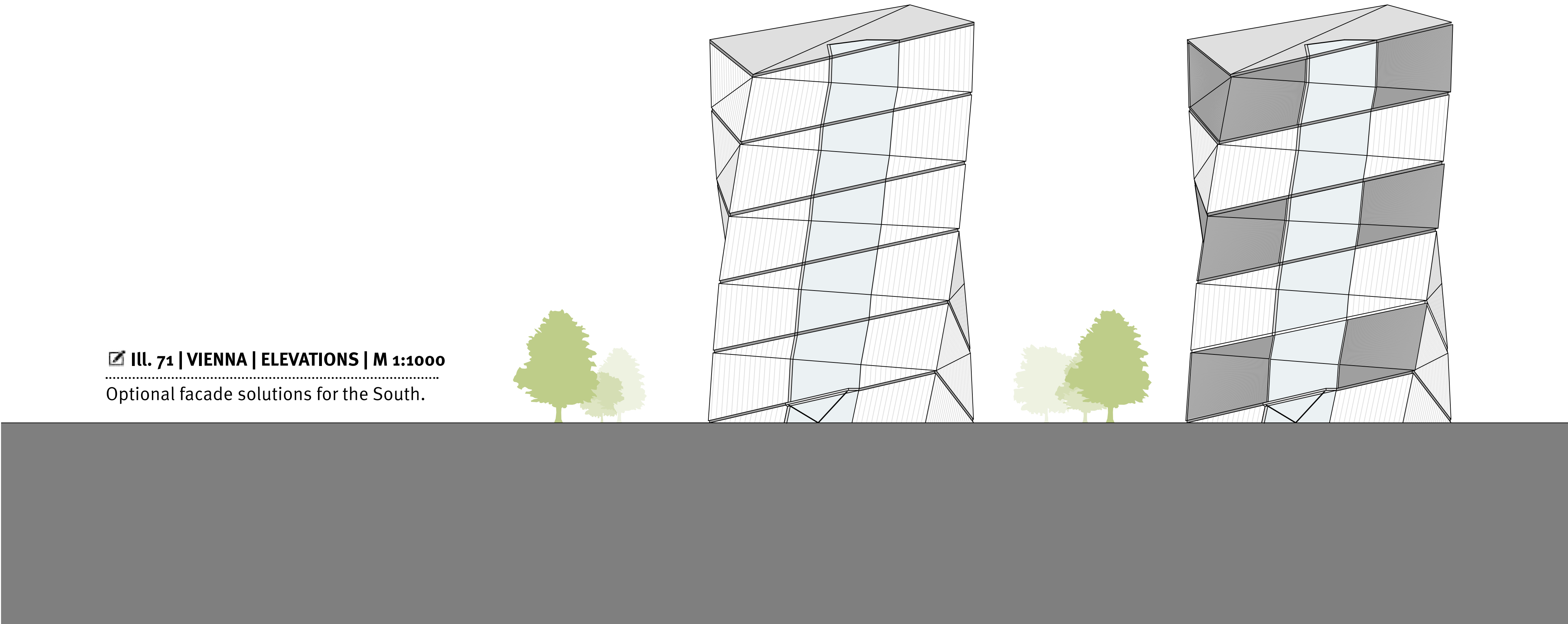
1 rooftop


1

Ill. 70 | VIENNA | ELEVATIONS | M 1:1000

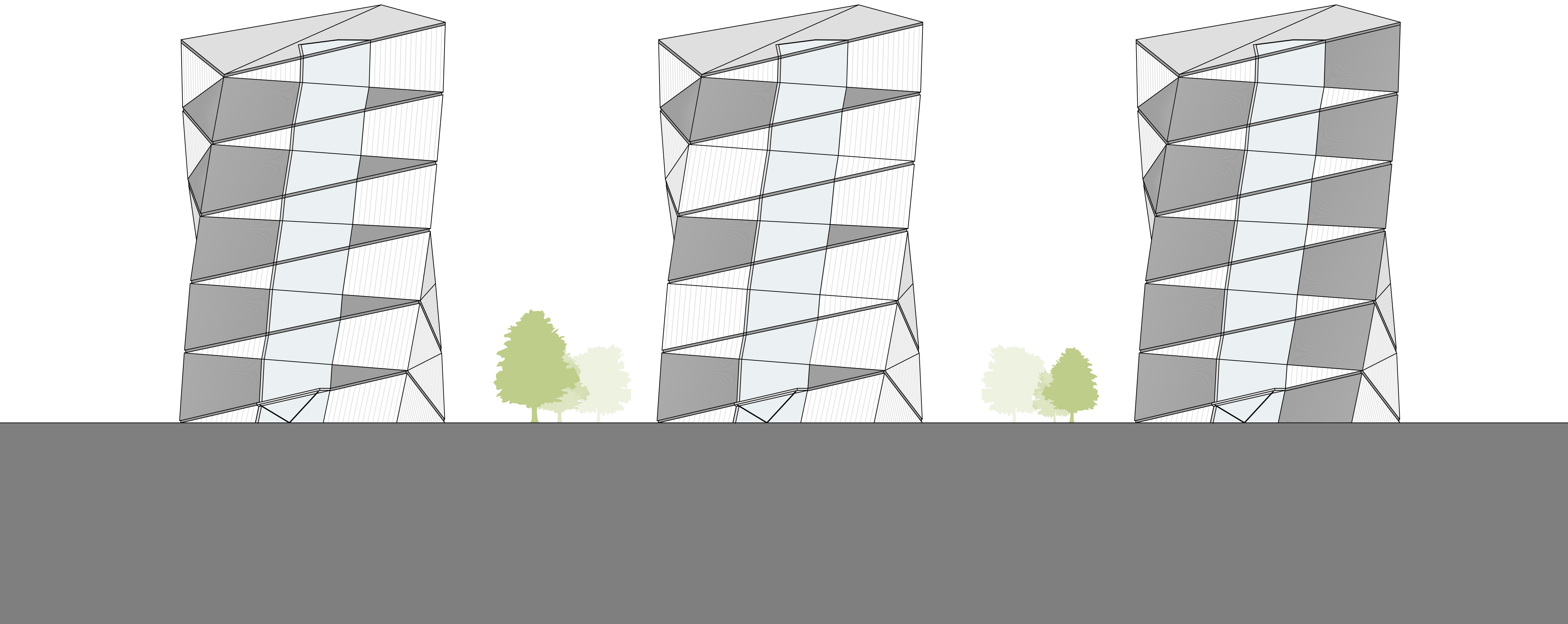
South | West | North | East

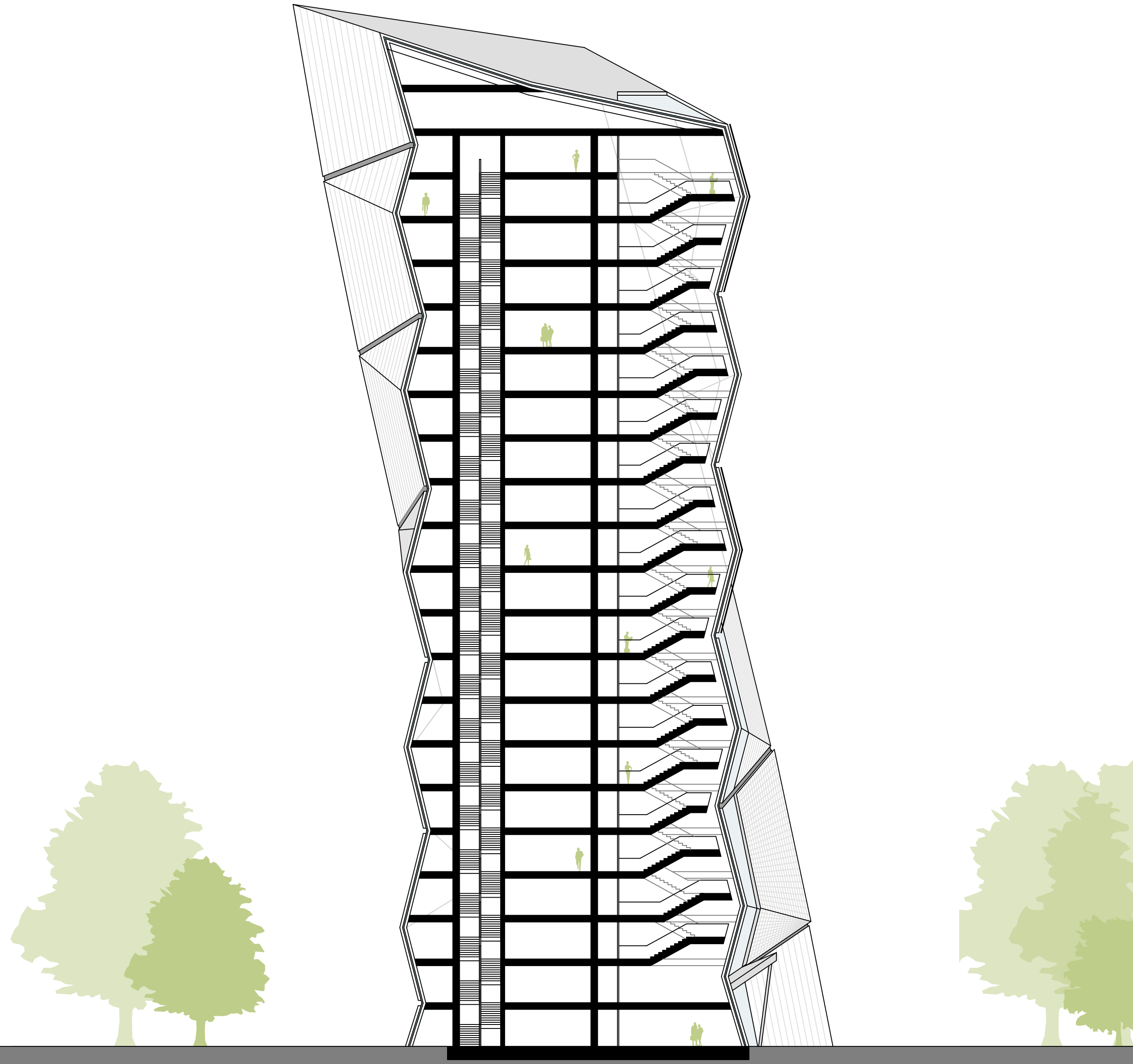




Ill. 71 | VIENNA | ELEVATIONS | M 1:1000

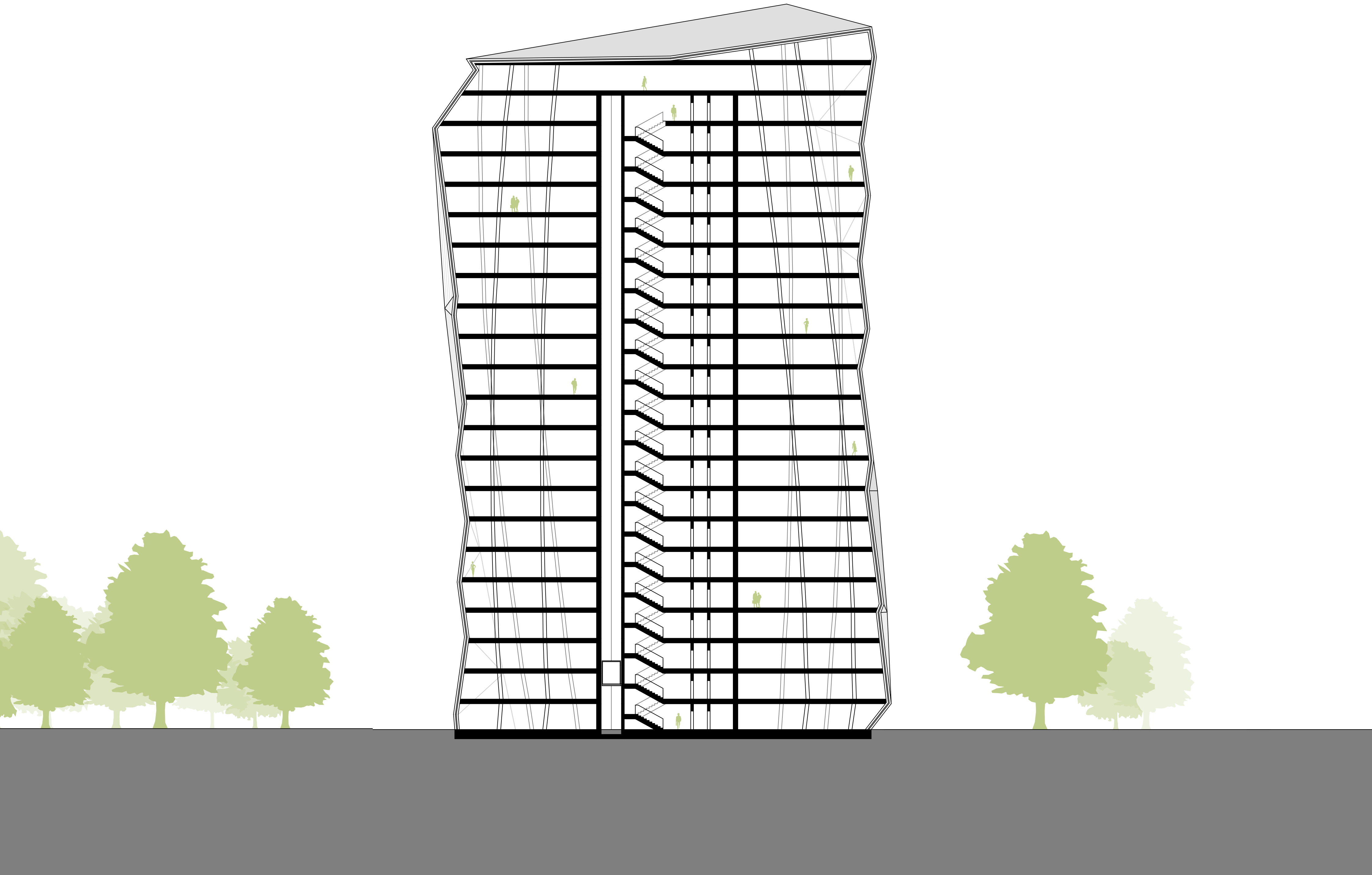
Optional facade solutions for the South.





Ill. 72 | VIENNA | SECTIONS | M 1:500

Horizontal - East-West orientated and vertical - North-South orientated section through the core.



108

Ill. 73 | VISUALIZATION

An image of the waterside to the Donau-City.



dress
Desigual

Ill. 75 | VISUALIZATION

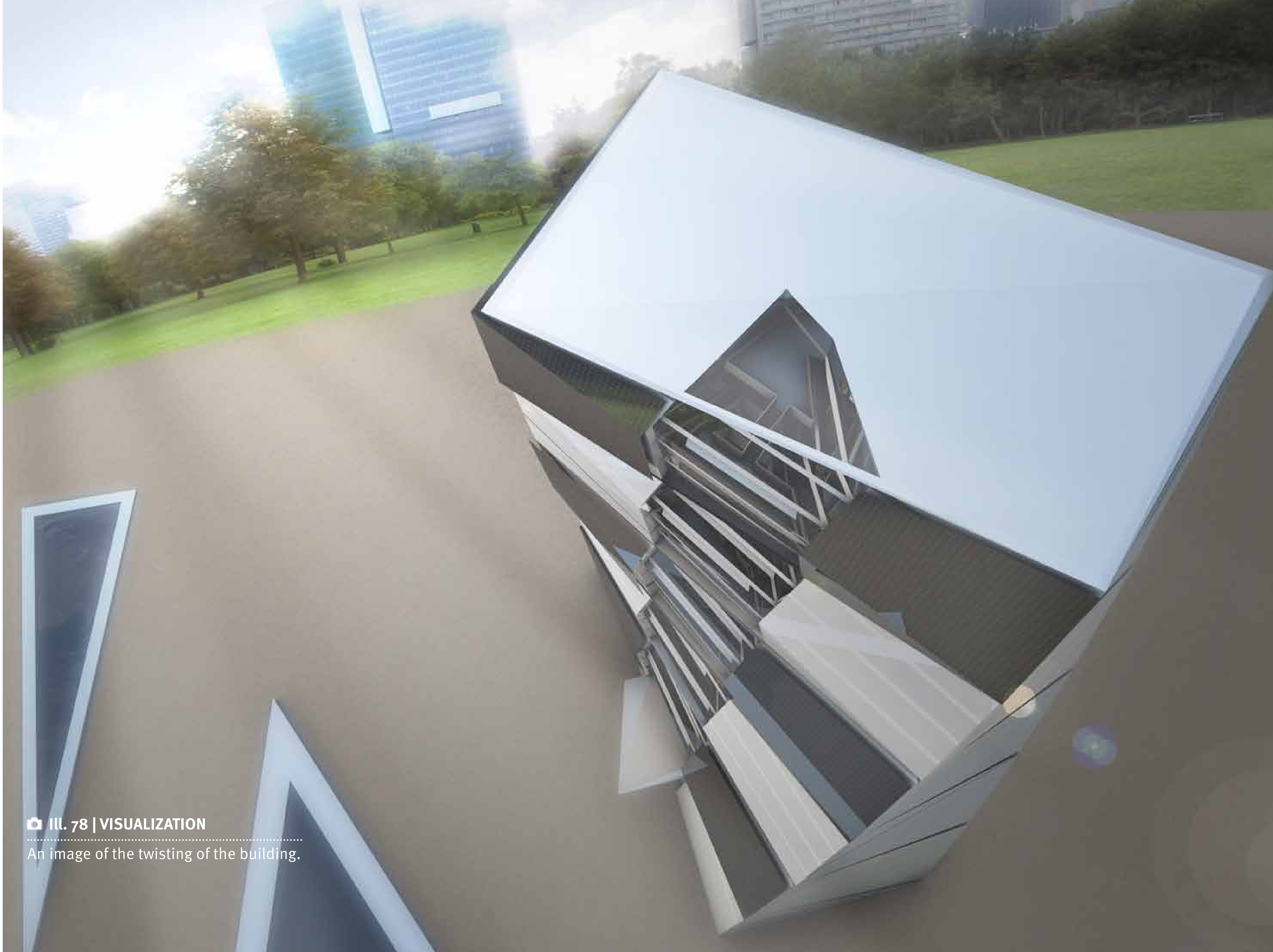
An image of the front side of the building.

Ill. 76 | VISUALIZATION

A detail of the facade with the photovoltaic panel.

Ill. 77 | VISUALIZATION

An image of the back side of the building.



Ill. 78 | VISUALIZATION

An image of the twisting of the building.

Ill. 79 | VISUALIZATION

View from the top of the staircase to the bottom.

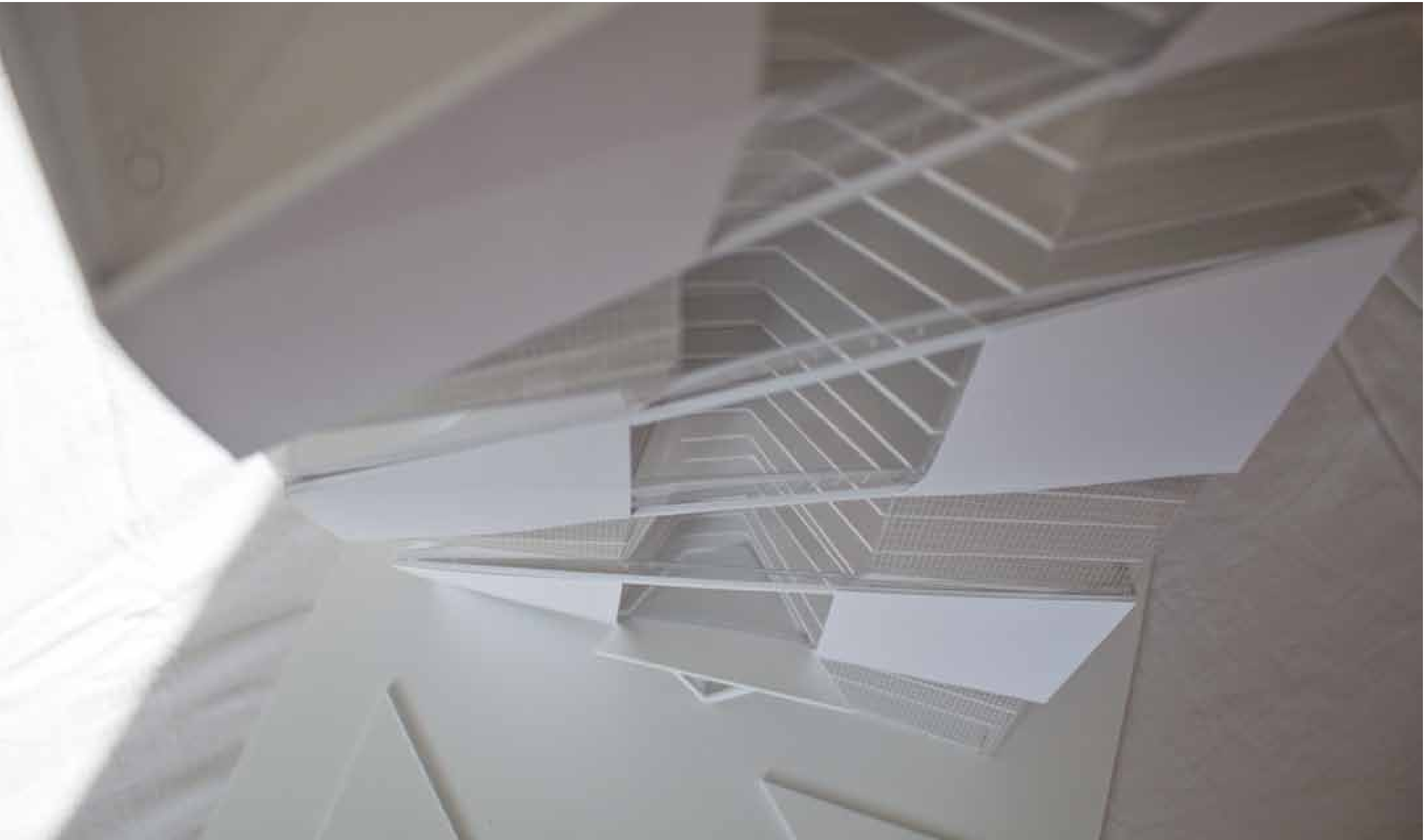
Ill. 80 | VISUALIZATION

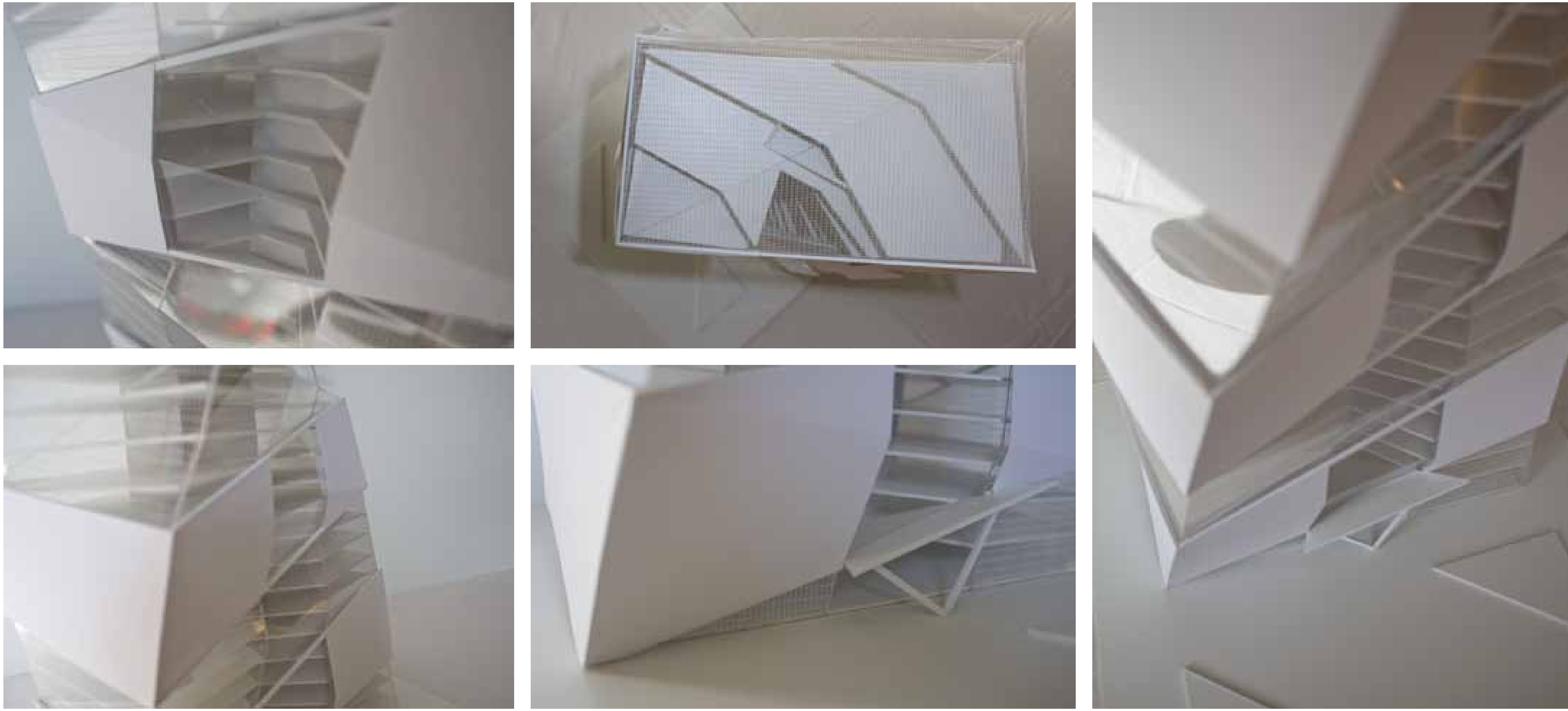
View from the staircase to an office room.

Ill. 81 | PICTURES OF THE MODEL

South | East | North | West | South-East view



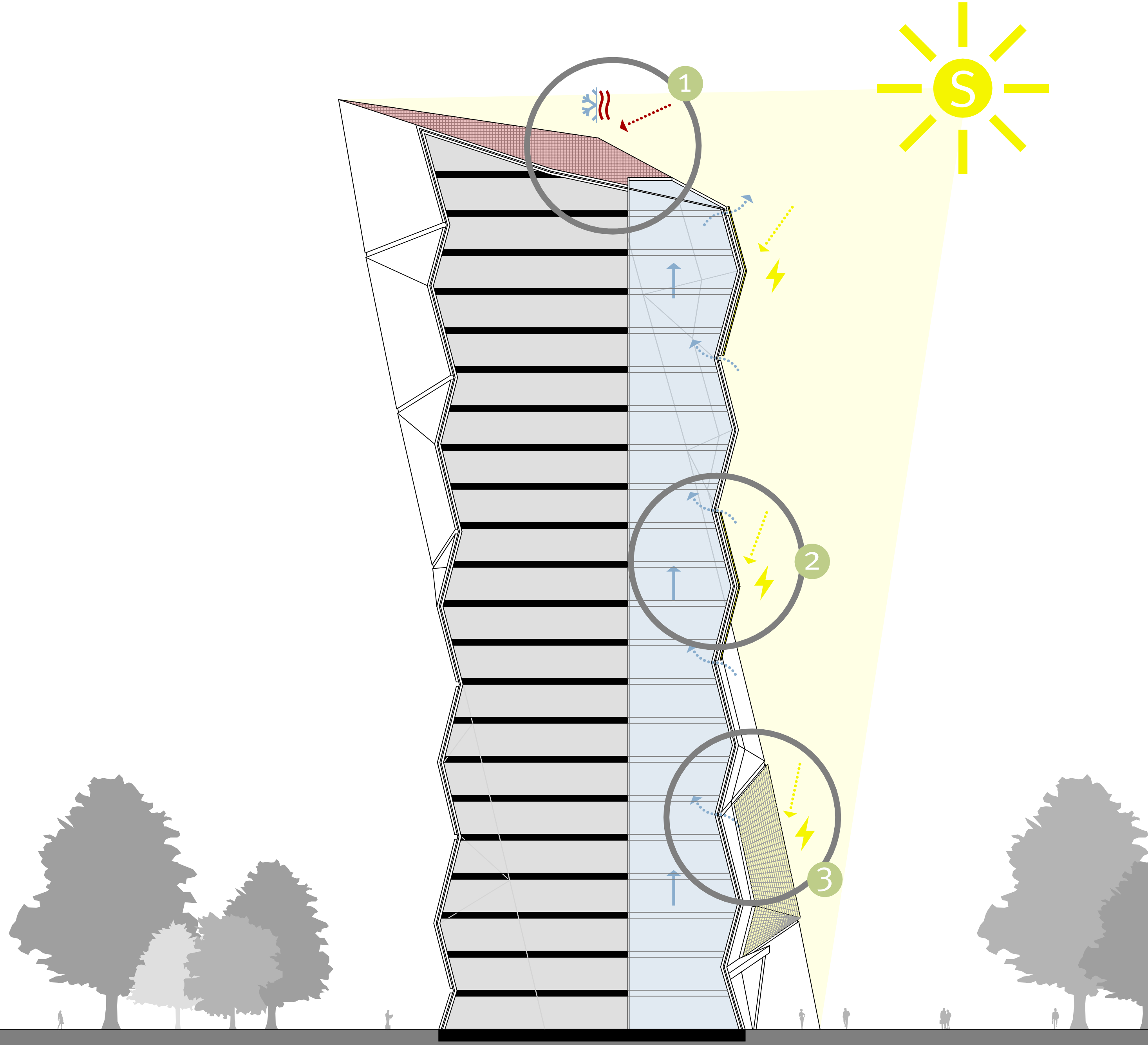




Ill. 82 | PICTURES OF THE MODEL

Various detail views of the building.

8. ECOLOGICAL ASPECTS



S sun from the South

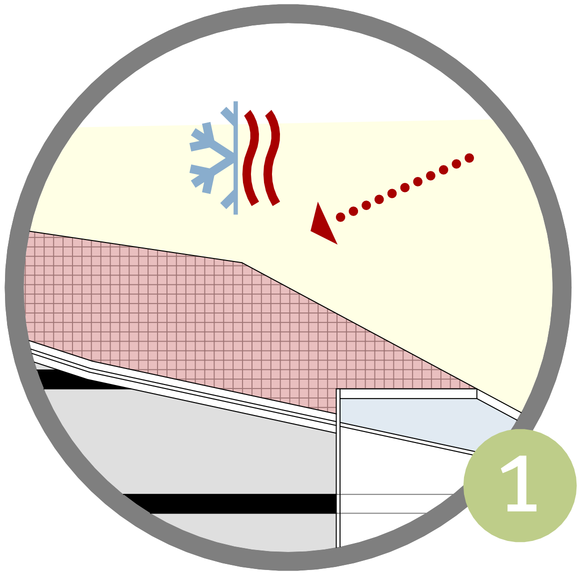
photovoltaic system

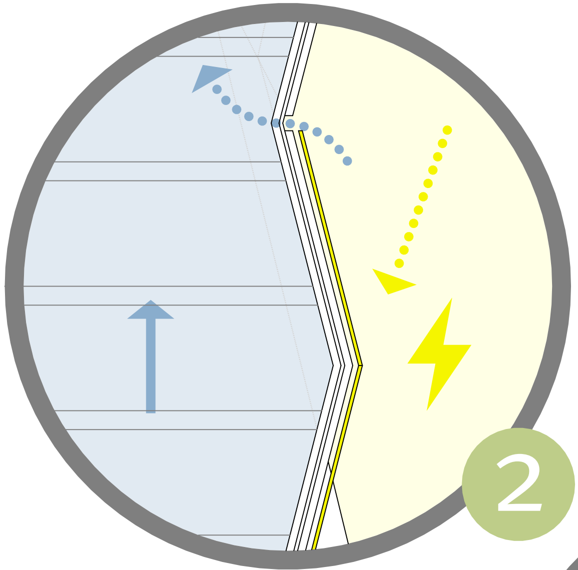
solar system

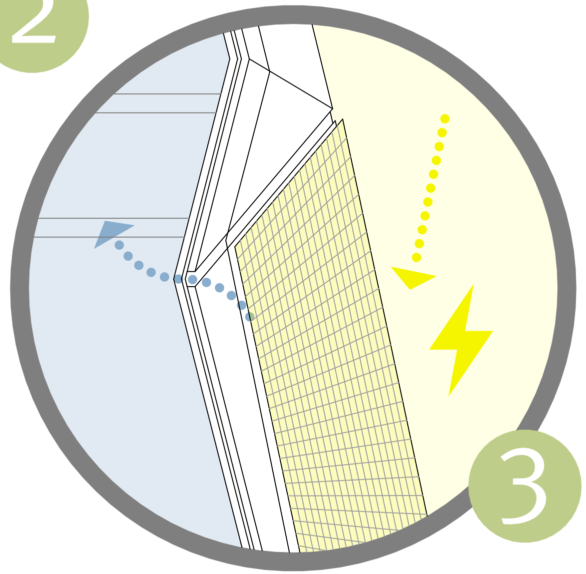
natural ventilation

Ill. 83 | SECTION | M 1:500

This section shows the ecological parameters of the building.



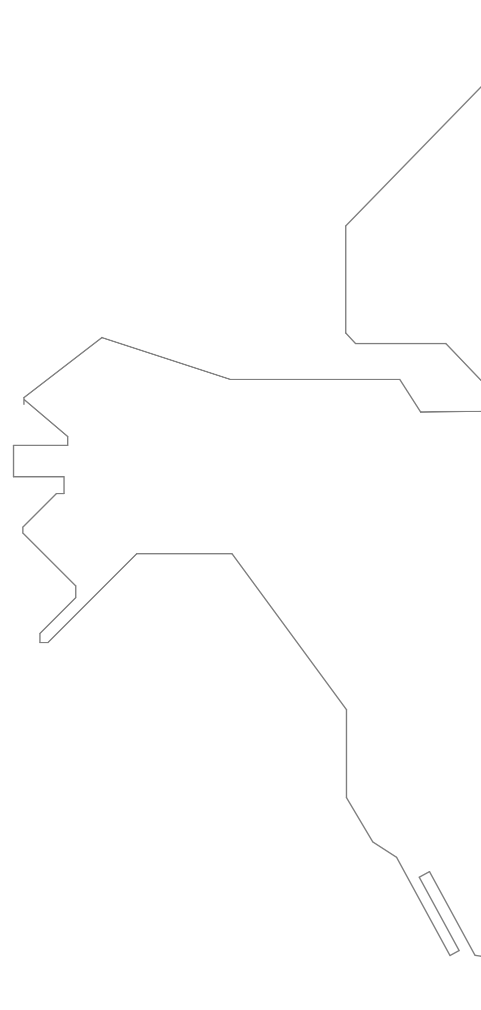




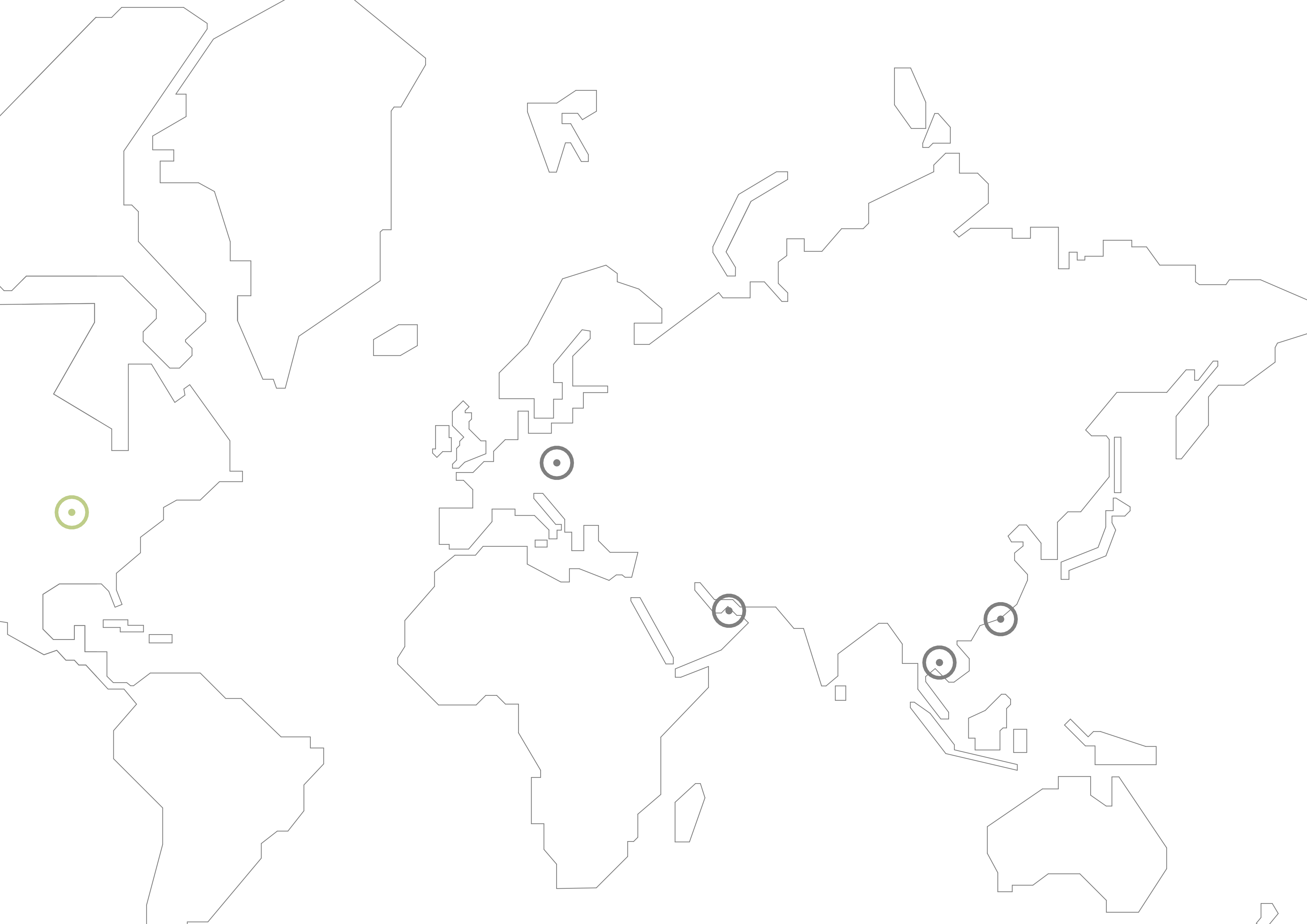
1 **Solar panel.** At the roof, there should be installed a solar panel for hot water as well as additionally for heating or cooling.

2 **Natural ventilation.** To improve the indoor air comfort of the building, there are openings in the facade to provide natural ventilation.

3 **Photovoltaic system.** As there is a lot of space directly on the facade, photovoltaic elements are added to produce electricity on-site.



chicago

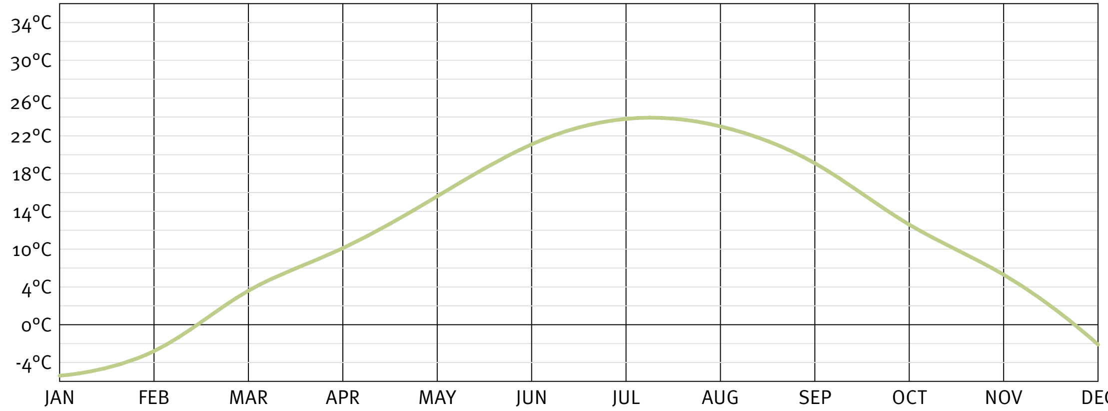


9.1. COOL CLIMATE[69]

A cool continental climate is restricted to the Northern hemisphere only as the Southern one does not have as large land masses. It ranges from the 40th to the 60th latitude and is defined by extreme temperate fluctuations between summer and winter as well as large diurnal temperature shifts. The landmasses greatly heat up during summer. The result of that are convective rainfalls. In winter the precipitation level is lower and it occurs mainly in the form of snow. According to the sun's position the days are very long during the summer months and the average annual sum of sunlight is quite high.

The huge challenge in a cool climate such as at Chicago, is to reduce the heating energy demand. The cooling energy demand is low but renewable cold sources can easily be used for it.

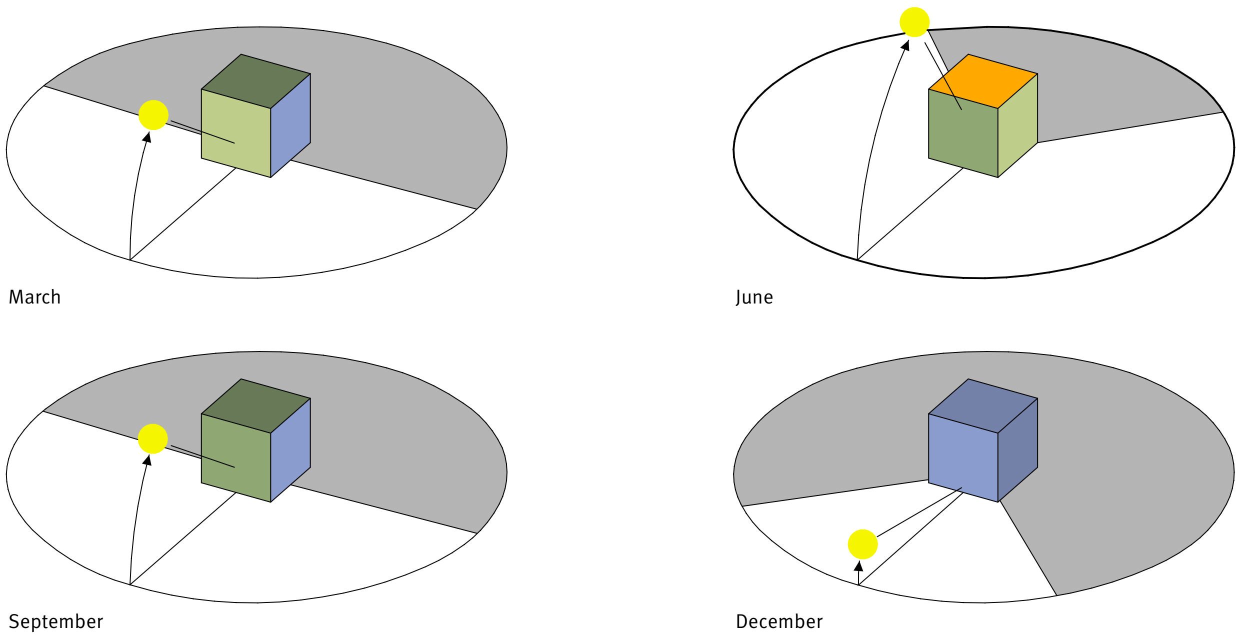
Ill. 85 | TEMPERATURE CURVE OF CHICAGO



Climate data[70]:	
Average temperature:	9.4 °C
Average max. temperature:	14.8 °C
Average min. temperature:	4.2 °C
Maximum temperature:	28.7 °C
Minimum temperature:	-10.6 °C
Sum of level of rainfall:	909 mm
Sum of hours with sunshine:	2611 h[71]
Average wind speed:	4.6 m/s

Average relative humidity 7am:	80 %[72]
Average relative humidity 2pm:	57 %
Days with frost (max. temp. < 0,0°C):	131 d
Hot days (max. temp. ≥ 30,0 °C):	17 d
Heating degree days:	3,809.6 Kd/a
Cooling degree days:	497.9 Kd/a[73]
Annual average Snowfall:	955 mm

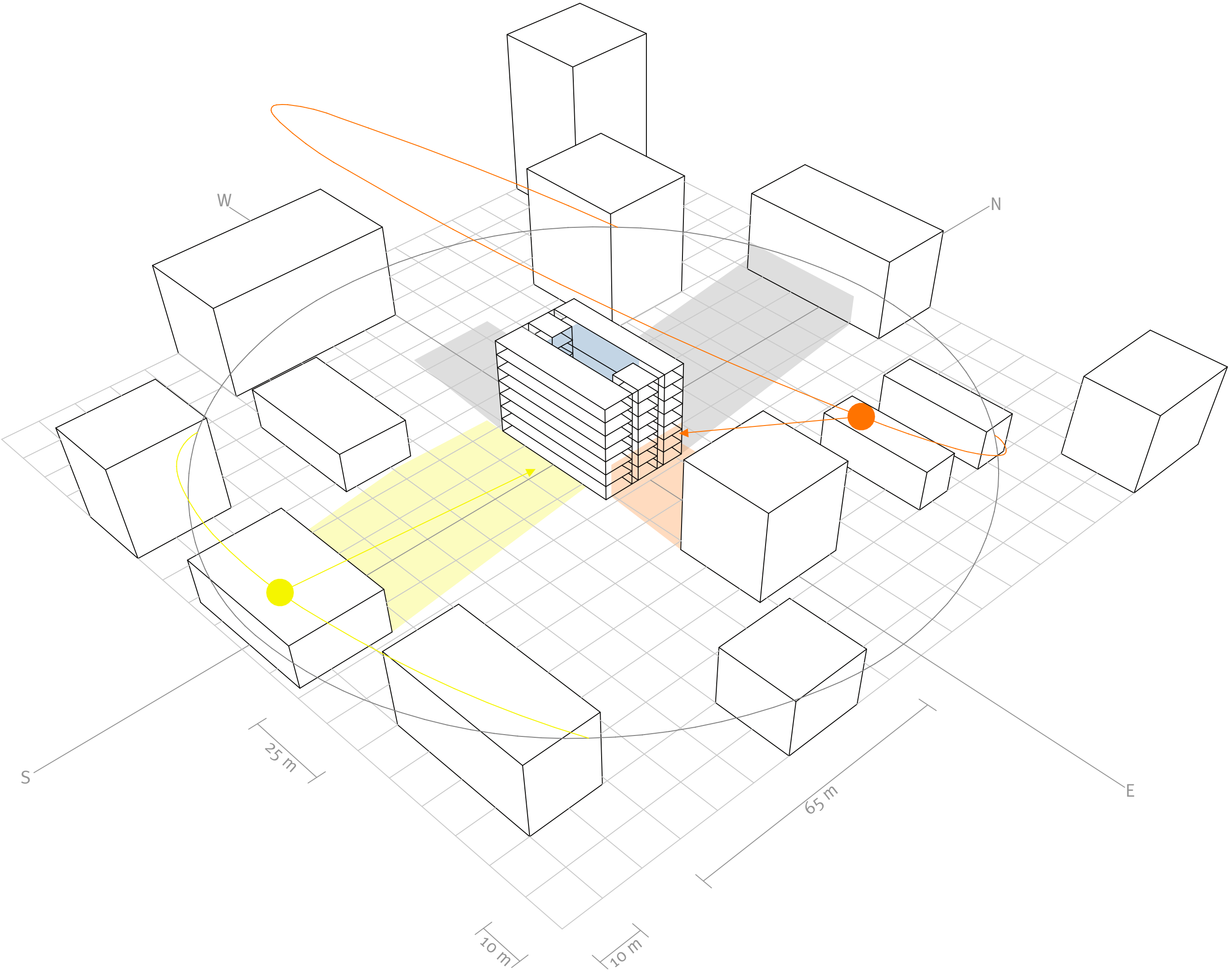
69. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 46
70. Cf. CLIMATE ZONE (n.y.): Chicago. Viewed on 04/15/2013 under www.climate-zone.com/climate/ united-states/illinois/chicago/
71. Cf. US CLIMATE DATA (n.y.): Climate - Chicago - Illinois. Viewed on 04/15/2013 under www.usclimatedata. com/climate.php?location=USIL0225
72. Cf. CURRENT RESULTS (n.y.): Annual Average Relative Humidity in US Cities. Viewed on 04/15/2013 under www.currentresults.com/Weather/US/humidity- city-annual.php
73. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 158



Ill. 86 | SOLAR RADIATION OF CHICAGO

These graphics show the solar radiation reaching facade surfaces in different seasons.

9.2. BUILDING STRUCTURE[74]



The most important parameter in cool climate is transmission heat loss. Thus, a compact building form is appropriate. To reduce the surface-to-volume ratio the building's depths can be higher and atrium or other buffer zones can be used. The higher the building the greater the wind loads as well as an adverse effect on the heating energy demand in winter.
To optimize solar gain in winter, the building should be East-West oriented with no shading from buildings to the South. During summer the South facade can easily be shaded with horizontal sun protection elements. The distance to nearby buildings on the Eastern and Western side can be lower.

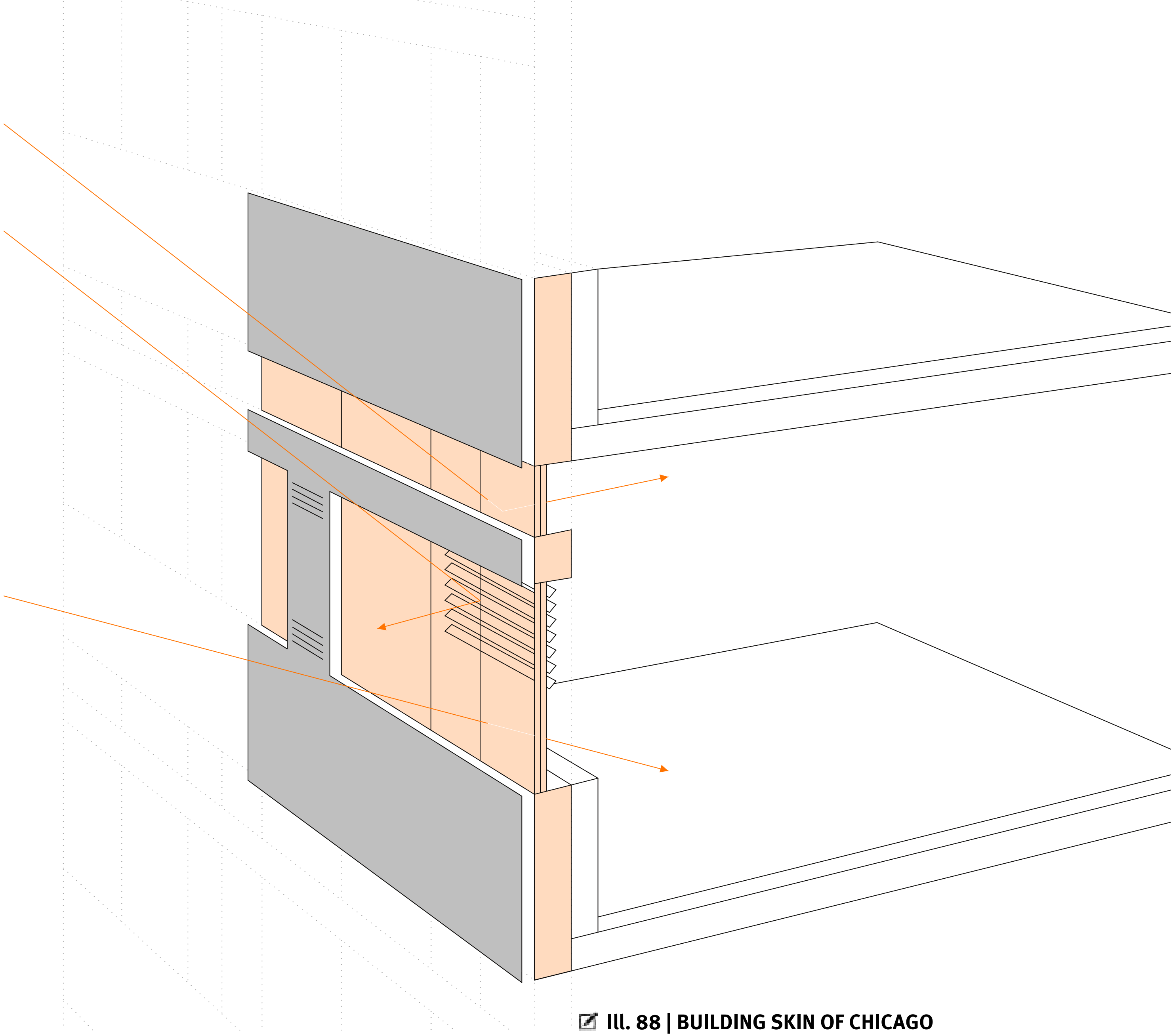
Ill. 87 | BUILDING STRUCTURE OF CHICAGO

Far distance to nearby buildings, an atrium in the center and a compact form are the main characteristics for a buidling in cool climate.

74. Cf. Ibid., p. 52

9.3. BUILDING SKIN[75]

In winter the facade for Chicago has to minimize heat loss and make passive solar gain possible. That is why the building should be designed with about 20 to 30 cm of insulation. Thermal bridges have to be avoided and the material of the installed glass should reach a U-value lower than 0.7 W/(m²K). The challenge in summer is to avoid thermal gain but that can be easily solved with an external mobile sun protection system. If the window surface areas are smaller there is also an internal sun protection feasible. Ideally, the best glazing percentage on the North, East and West facade should be between 30 % and 40 %. At the Southern facade it could be up to 50 %, which has a good effect on the heating energy demand in winter. The position of the window lintel should be high or a skylight should be installed.



Ill. 88 | BUILDING SKIN OF CHICAGO

A high window lintel and external sun protection are important on facades in cool climate.

75. Cf. Ibid., p. 54

9.4. DESIGN

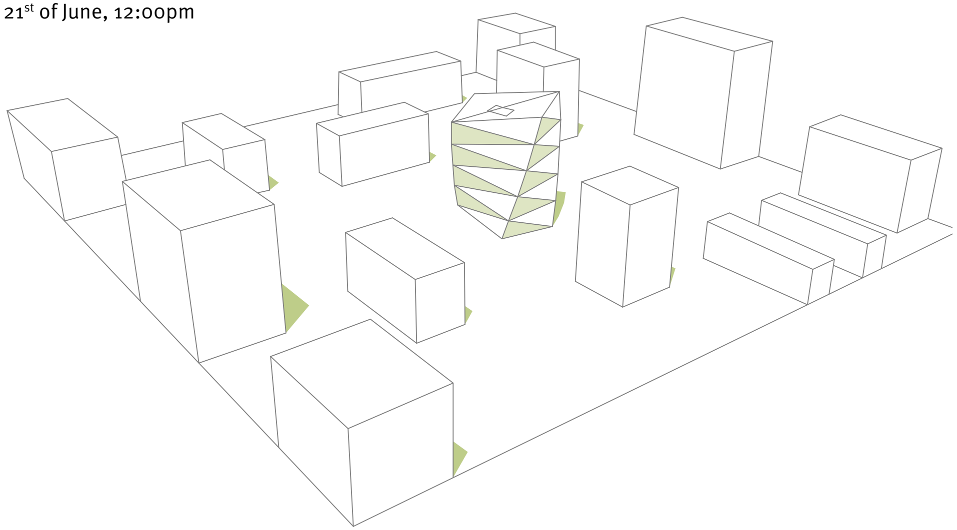
Ill. 89 | CHICAGO
A city view at the chicago river.

The design for Chicago is compact and simple. It is very similar to the design for temperate climate, with the exception, that the atrium is at the center of the building. That is why a higher building depth is possible. The atrium is rectangular and parallel to the core. The base area of the atrium is almost 100 m^2 to provide daylight inside the building.

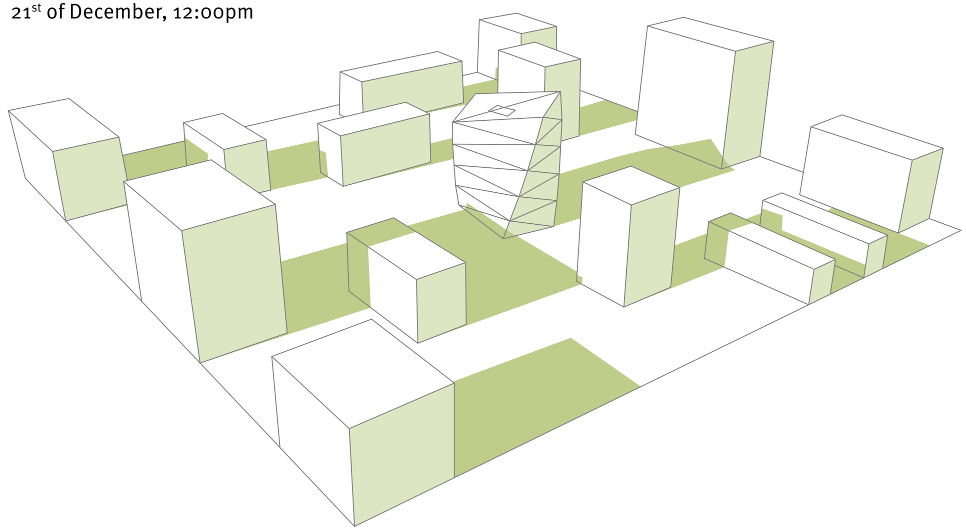
The area of the whole floor is 1,388 m^2 including the atrium. It consists of 17 regular floors and 3 floors in the canted roof area. This results in a building height of about 66 meters.

The adjacent buildings should have a greater distance to the building as the solar radiation is not that high and the winter sun is very deep with long shadows. External shading should be avoided as well as possible to guarantee solar gains in winter.

21st of June, 12:00pm



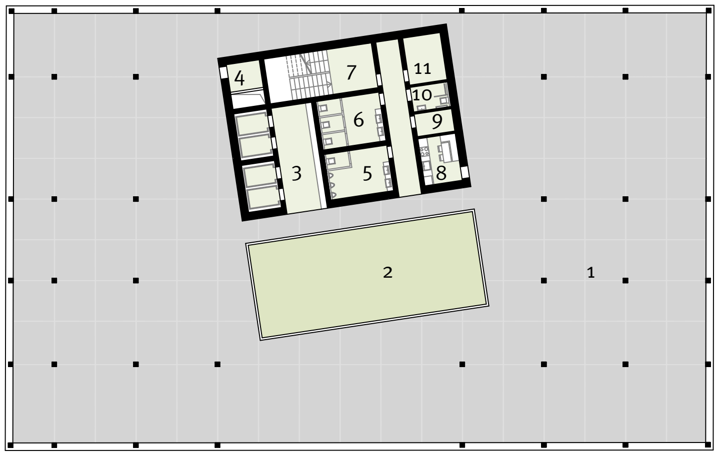
21st of December, 12:00pm



Ill. 90 | SHADING STUDY

External shading of Chicago on the 21st of June and on the 21st of December.

1st Floor



5th Floor

Ill. 91 | CHICAGO | M 1:500

The atrium in the center signifies the design for Chicago.

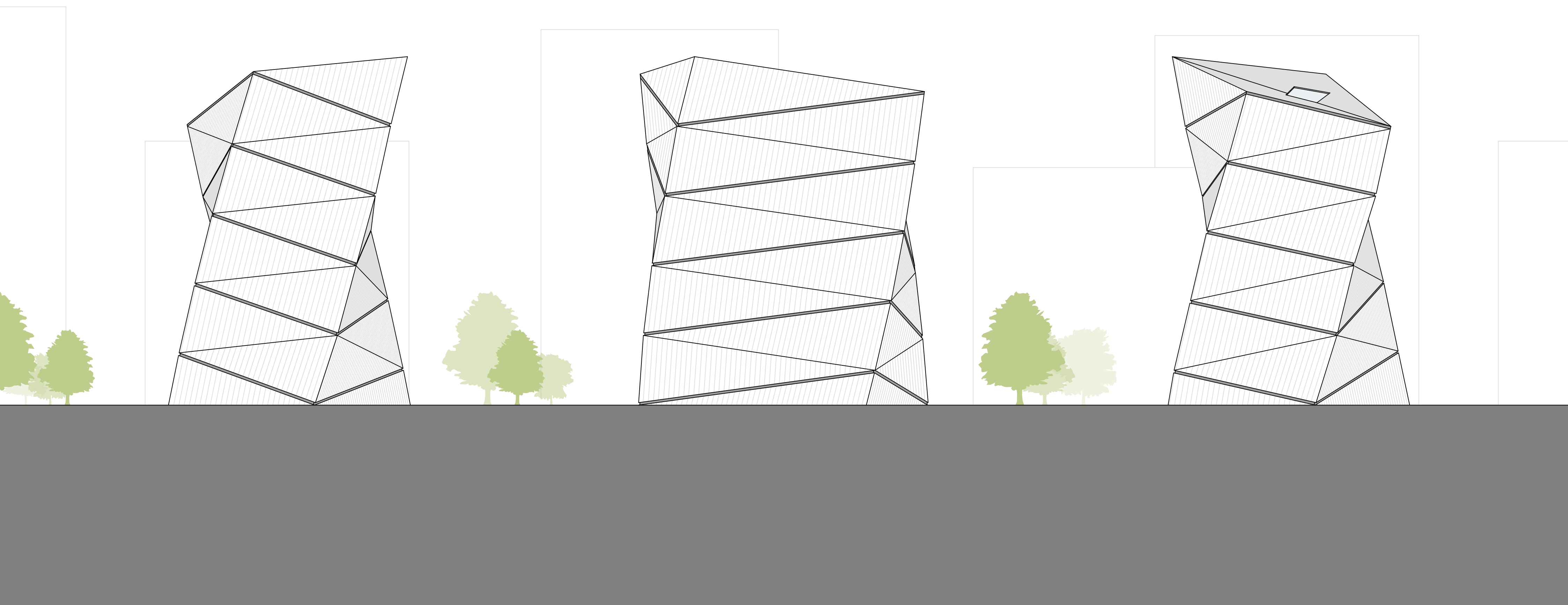
9th Floor

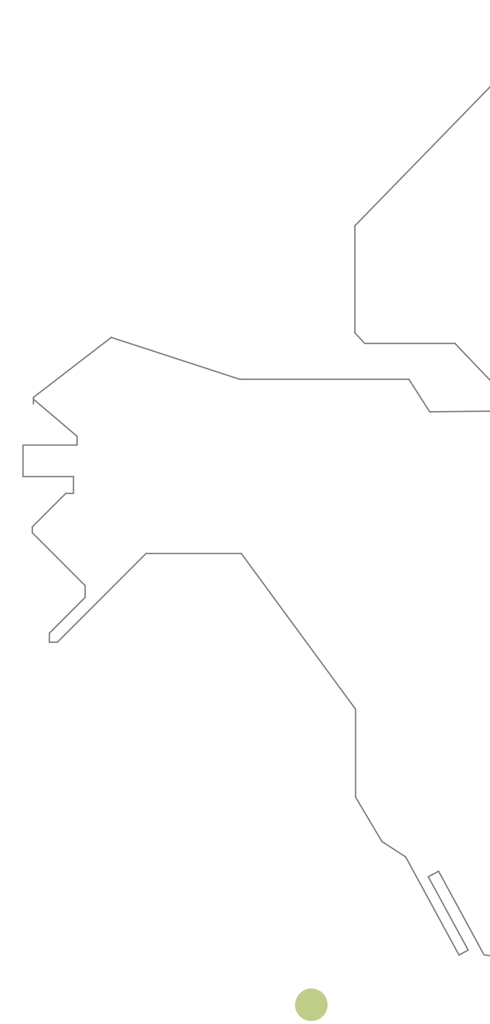
17th Floor

1 office area
2 atrium
3 elevator waiting area
4 engineering room
5 restroom for men
6 restroom for women
7 staircase
8 kitchenette
9 LAN-room
10 restroom for the disabled
11 storage room

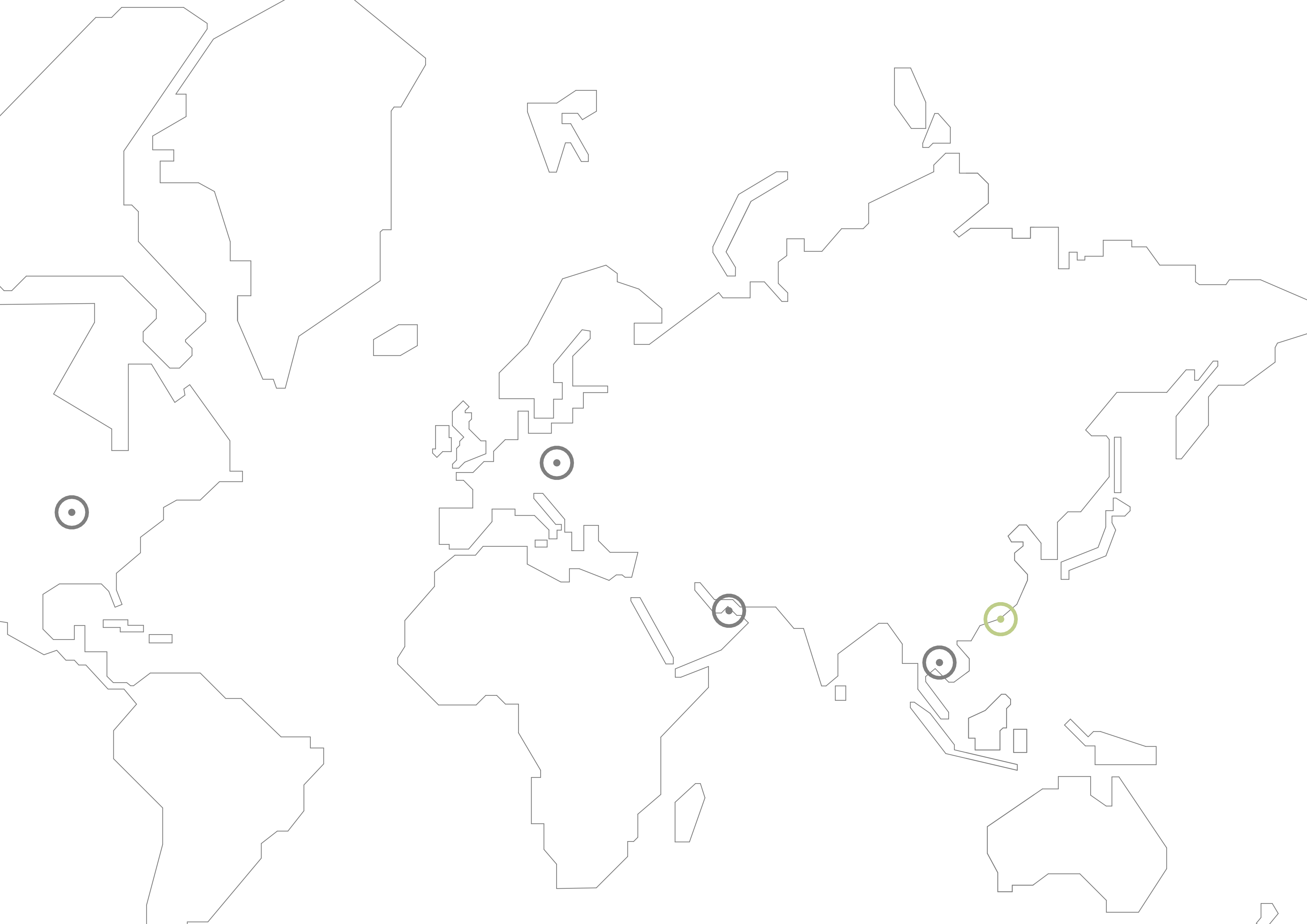
Ill. 92 | CHICAGO | ELEVATIONS | M 1:1000

South | West | North | East





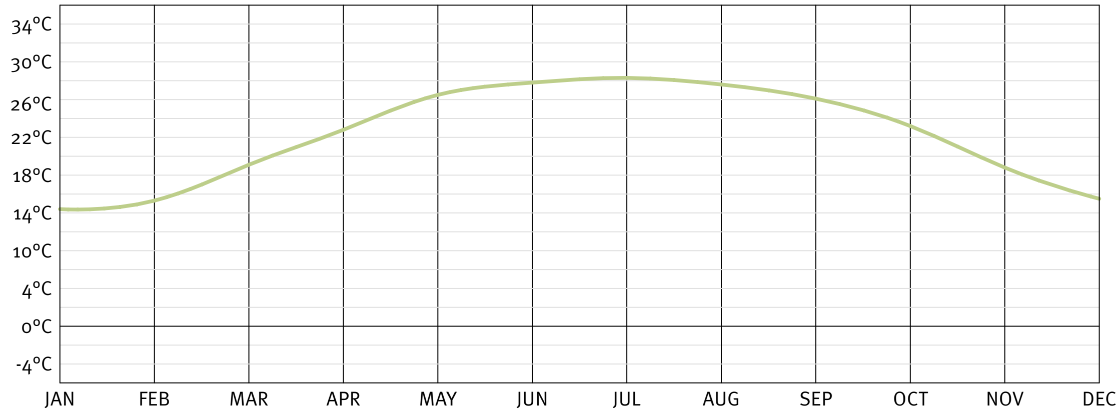
hanoi



10.1. SUBTROPICS[76]

Hanoi is a good example of the warm humid subtropical climate zone. The summers get really hot and humid while the winters can get relatively cold and dry. Throughout the year, the precipitation level is continuously high. Humid air streams from the oceans to the continental areas and causes heavy rainfalls during the summer months. In winter, cool and dry winds coming from the landmasses dominate. These kinds of winds are called monsoons. The natural vegetation of the subtropics consists of lush rainforests along the coast and at the windward side of mountains. In more continental areas where the precipitation level is not quite as high, wet evergreen forests and laurel forests abound.

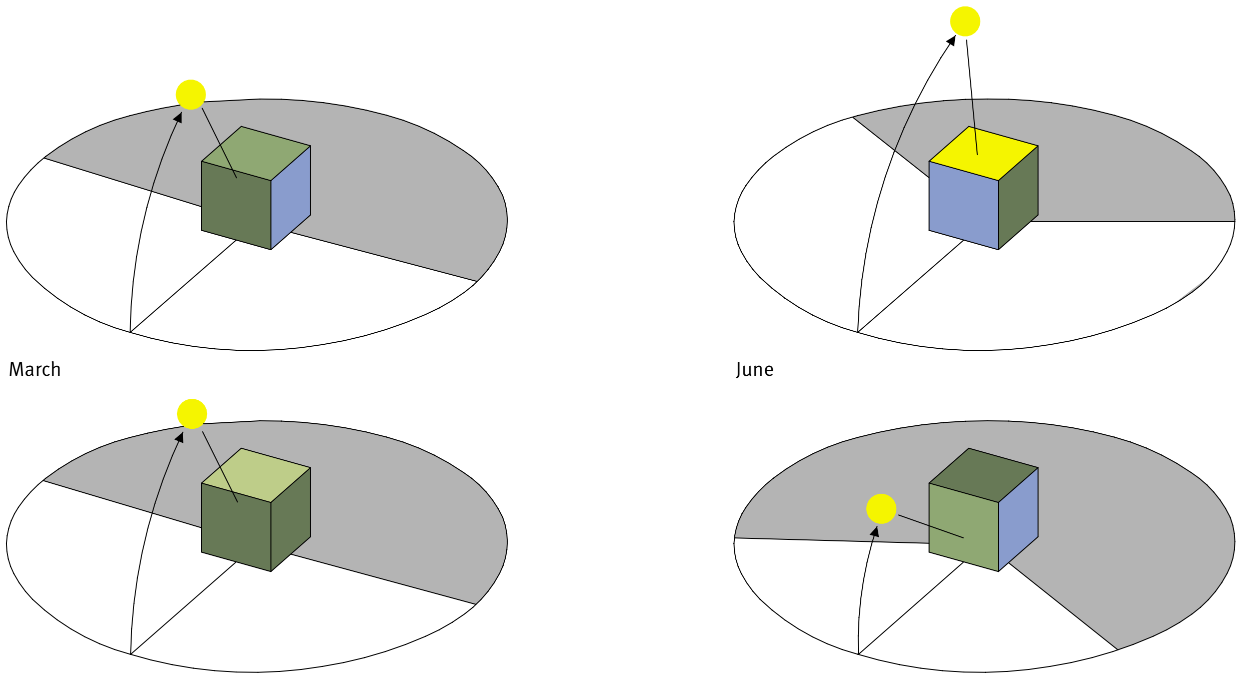
Ill. 94 | TEMPERATURE CURVE OF HANOI



Climate data[77]:	
Average temperature:	24.0 °C
Average max. temperature:	27.8 °C
Average min. temperature:	20.6 °C
Maximum temperature:	42.8 °C
Minimum temperature:	5.6 °C

Sum of level of rainfall:	1,682 mm
Sum of hours with sunshine:	1,167 h
Average wind speed:	1.97 m/s[78]
Average relative humidity 2pm:	75 %

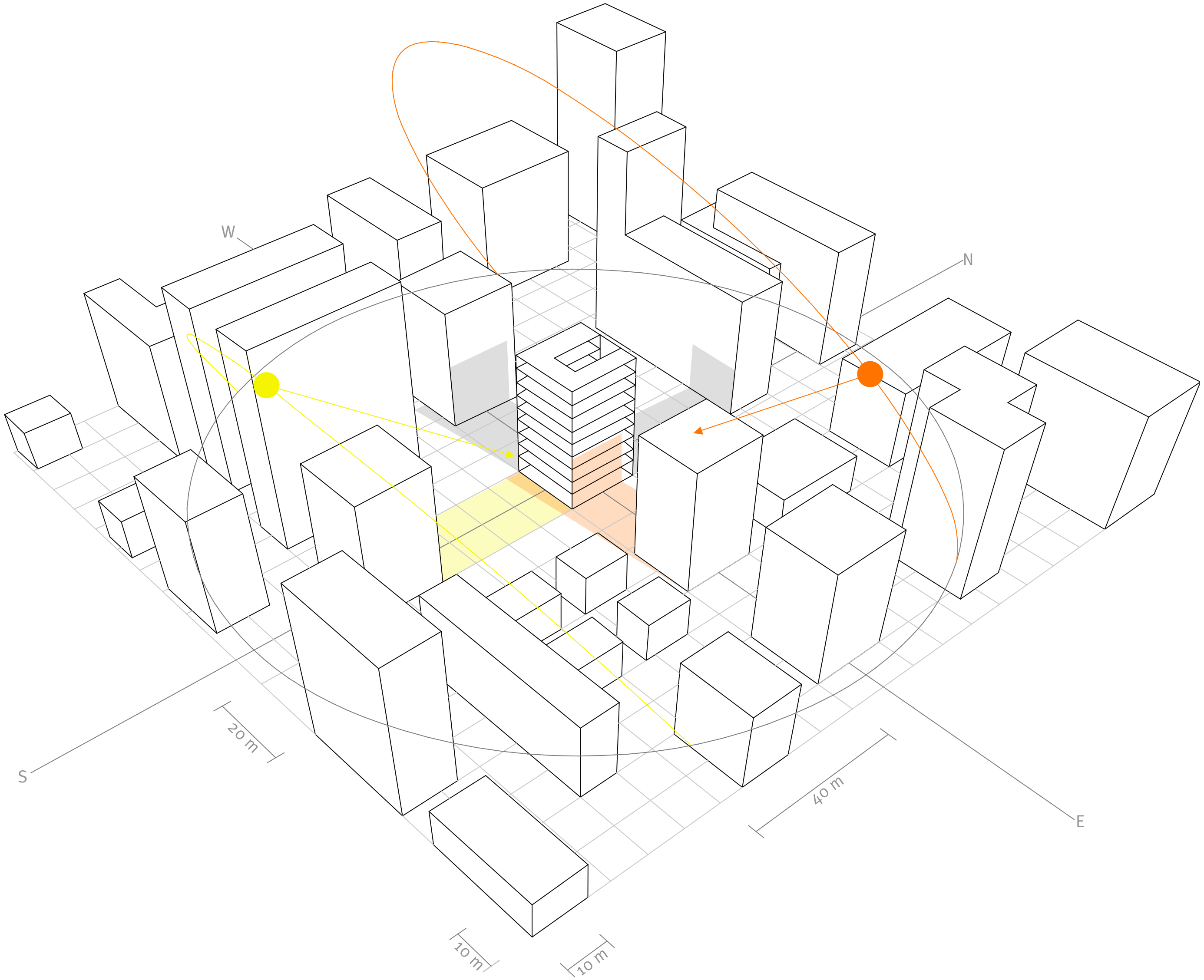
76. Cf. WIKIPEDIA (2013): Hanoi. Viewed on 07/29/2013 under en.wikipedia.org/wiki/Hanoi
77. Cf. STADTKLIMA (1983): Hanoi. Viewed on 04/15/2013 under www.stadtklima.de/cities/asia/vn/hanoi/ hanoi.htm
78. Cf. WEATHER ONLINE (n.y.): Hanoi. Viewed on 04/28/2013 under www.weatheronline.co.uk/ Vietnam/Hanoi.htm



Ill. 95 | SOLAR RADIATION OF HANOI

These graphics show the solar radiation reaching facade surfaces in different seasons.

10.2. BUILDING STRUCTURE[79]



Compared to the aforementioned climates, the building for the subtropics does not have to be as compact as the others. It is even advantageous to make it less compact due to improving the daylight provision and natural ventilation. Nevertheless, the building's depth should be low and it should be orientated to the South. To avoid solar gain, vertical shading is very important. Nearby buildings should be closer to the building but not too close considering to daylight provision.

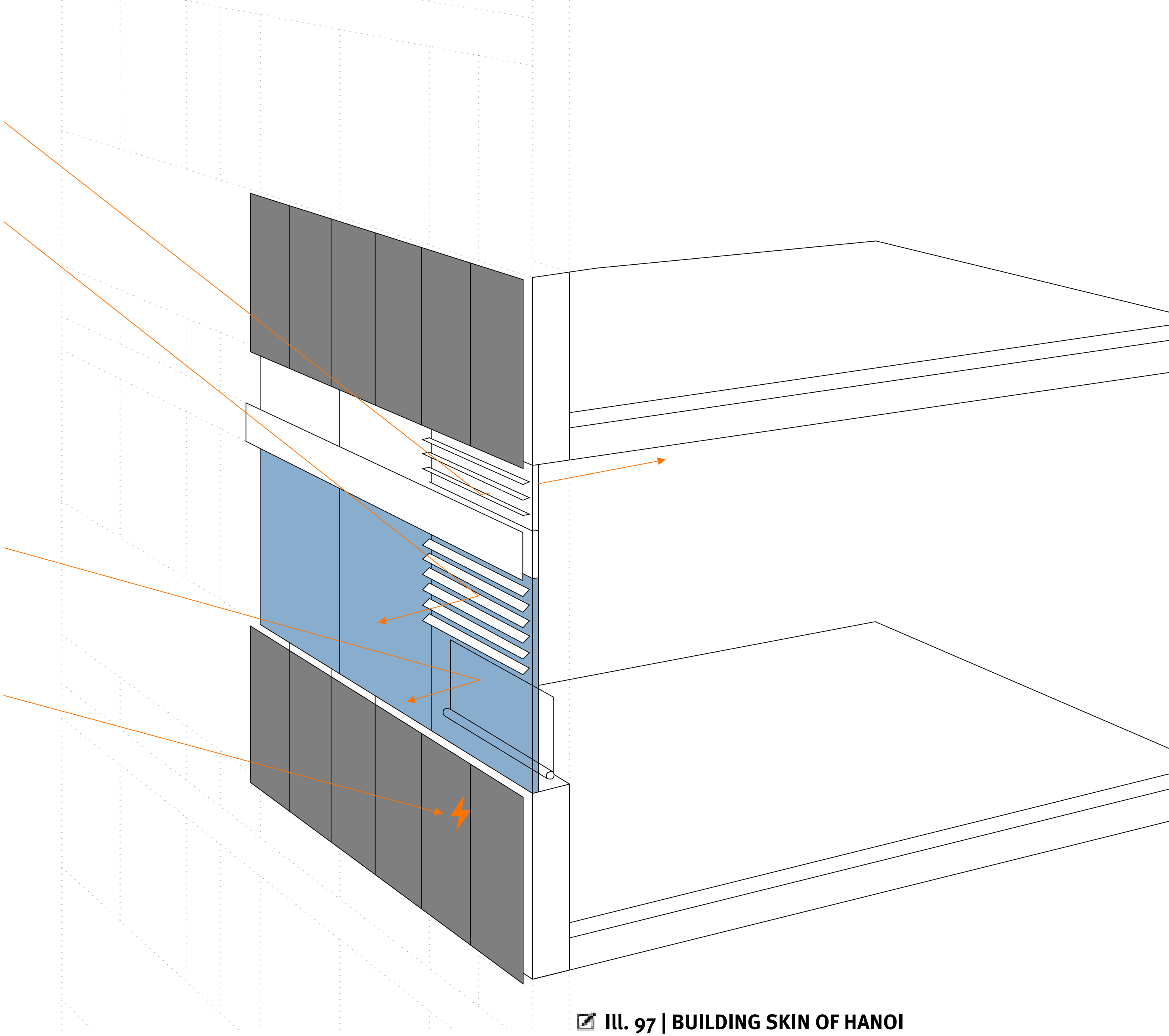
Ill. 96 | BUILDING STRUCTURE OF HANOI

Low building depths and closer distances to nearby buildings are preferable in the subtropics.

79. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 84

10.3. BUILDING SKIN[80]

In the subtropics the percentage of diffuse radiation is very high. External sun protection elements have to be installed on the East, South and West facades. The glazing percentage should also be chosen due to solar input and daylight illumination and should not be higher than 60 %. The glazing material itself should be made out of sun protection glass with additional low-e coating. The g-value should be lower than 0.4 and the U-value under 1.4 W/(m²K). The upper part of the windows should not be covered with sun protection coating to provide daylight more efficiently.
Due to transmission heat loss, a thermal protection of about 5 cm is recommended. In addition, amorph photovoltaic elements on the facade are highly adviced.



Ill. 97 | BUILDING SKIN OF HANOI

External sun protection and photovoltaic panels play an important role in the subtropics.

80. Cf. Ibid., p. 86

10.4. DESIGN

Ill. 98 | HANOI
Skyline of the city at night.

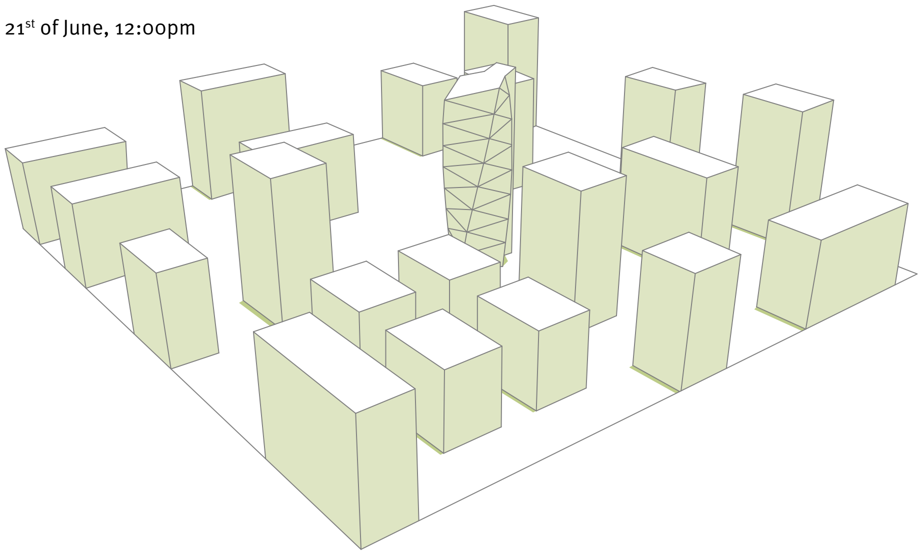
The highest building can be found in Hanoi. It is a tower with 29 regular floors and 3 floors in the canted roof area. So the building reaches a height of about 106 meters.

The building consists of two parts: the static core in the North and the twisting office area in the South.

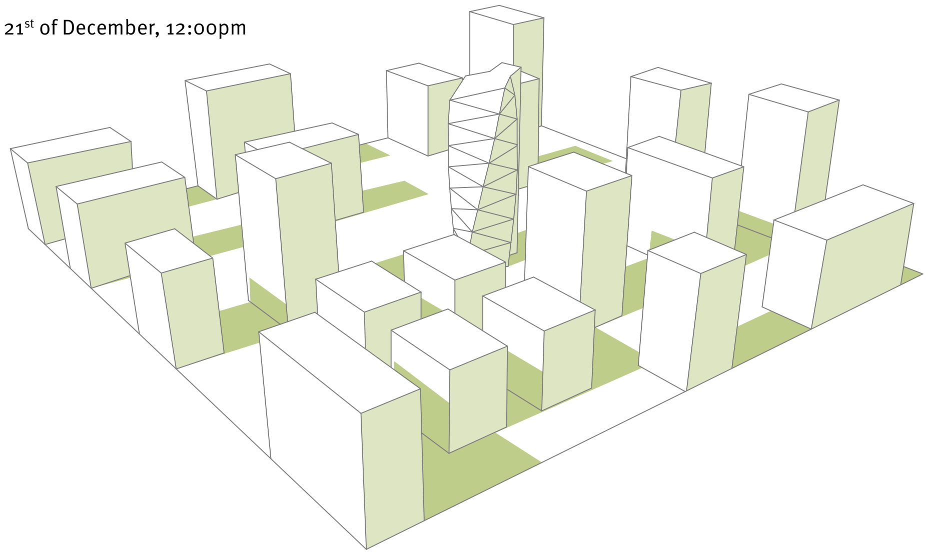
The building's depth is low with about 24 m to improve daylight provision and natural ventilation. In relation to the aforementioned designs, the distance to nearby buildings can be closer.

The floor plan design is a lot different compared to the ones for Vienna and Chicago. In Hanoi there is no atrium and the building is rather square shaped without big building depths in both directions.

21st of June, 12:00pm

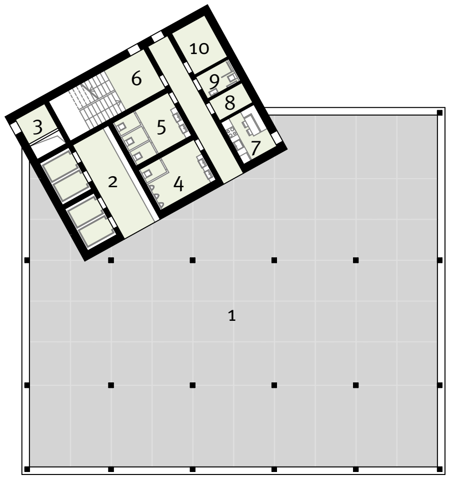


21st of December, 12:00pm

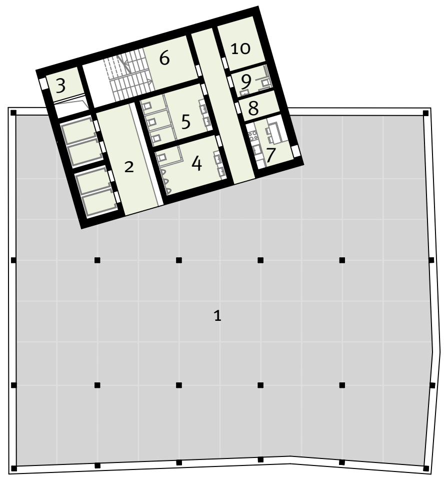


Ill. 99 | SHADING STUDY

External shading of Hanoi on the 21st of June and on the 21st of December.



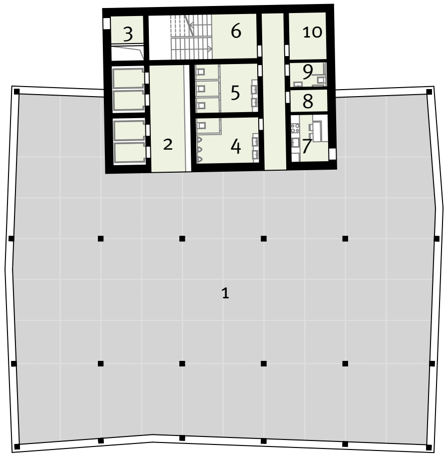
1st Floor



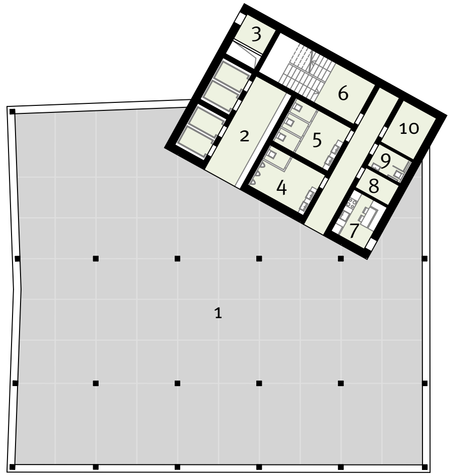
7th Floor

Ill. 100 | HANOI | M 1:500

The office use area spins around the statical core.



14th Floor

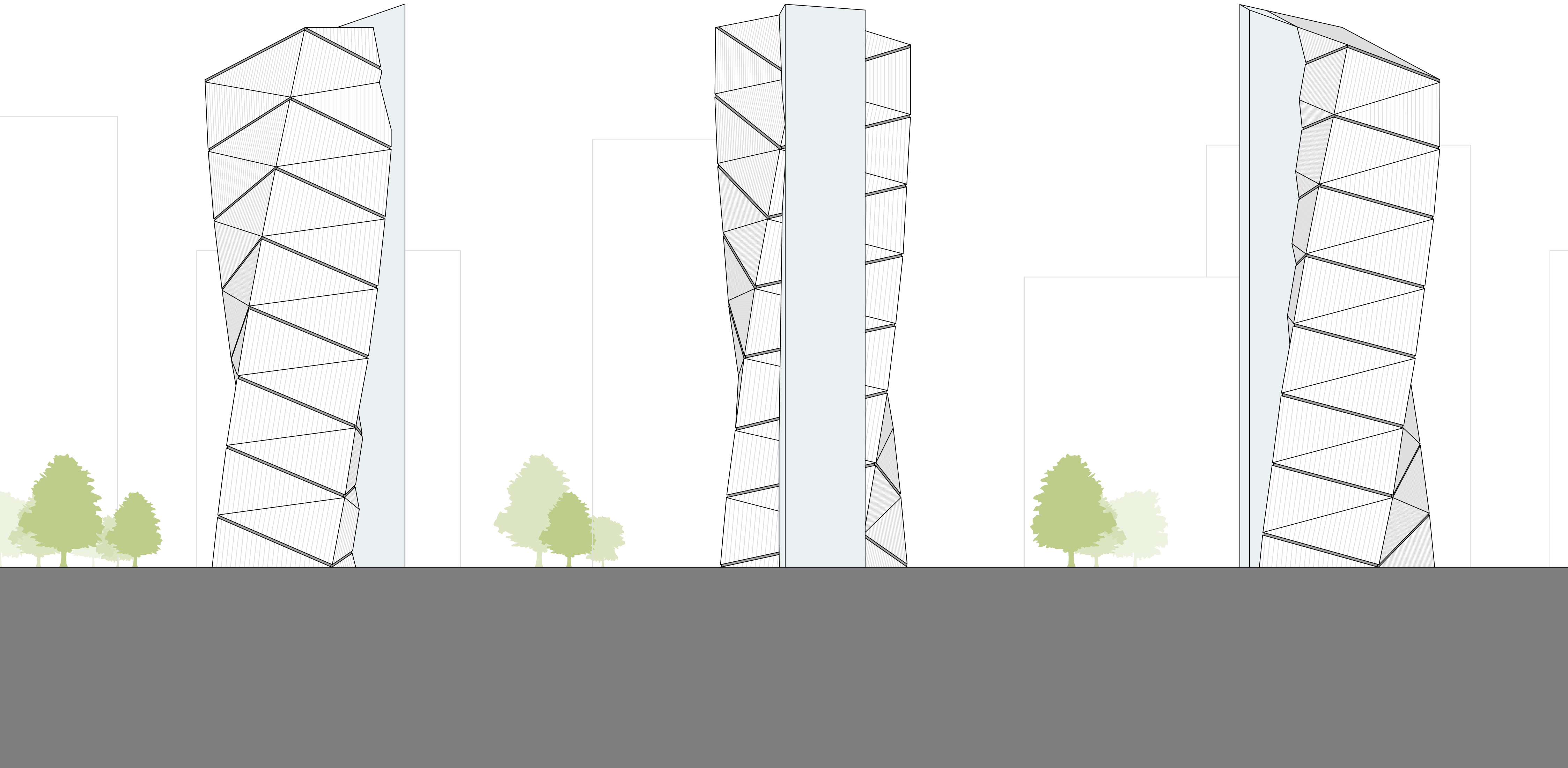


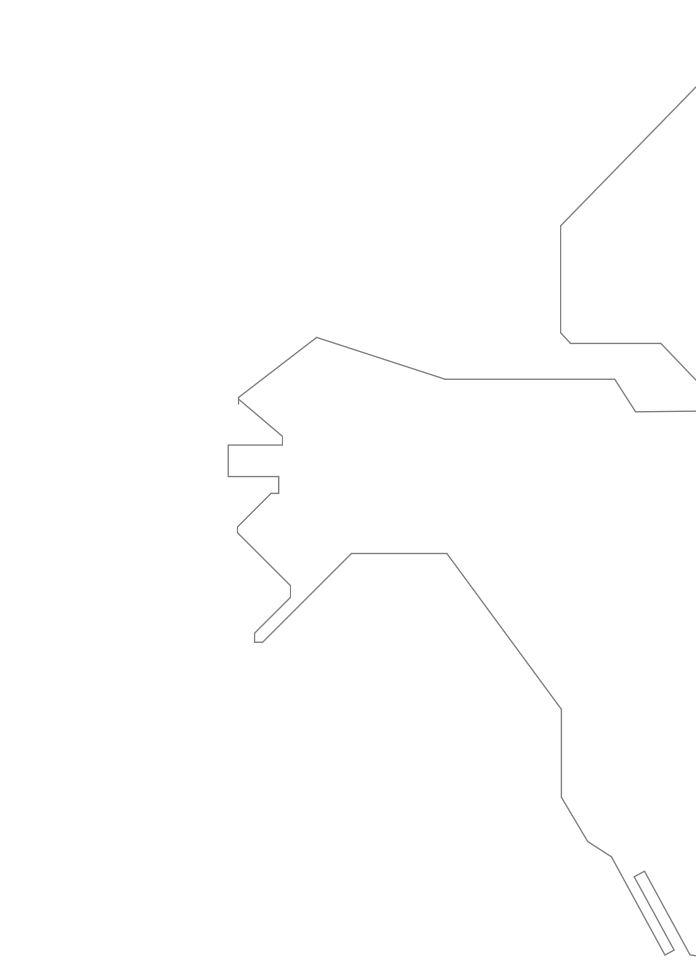
28th Floor

1 office area
2 atrium
3 elevator waiting area
4 engineering room
5 restroom for men
6 restroom for women
7 staircase
8 kitchenette
9 LAN-room
10 restroom for the disabled
11 storage room

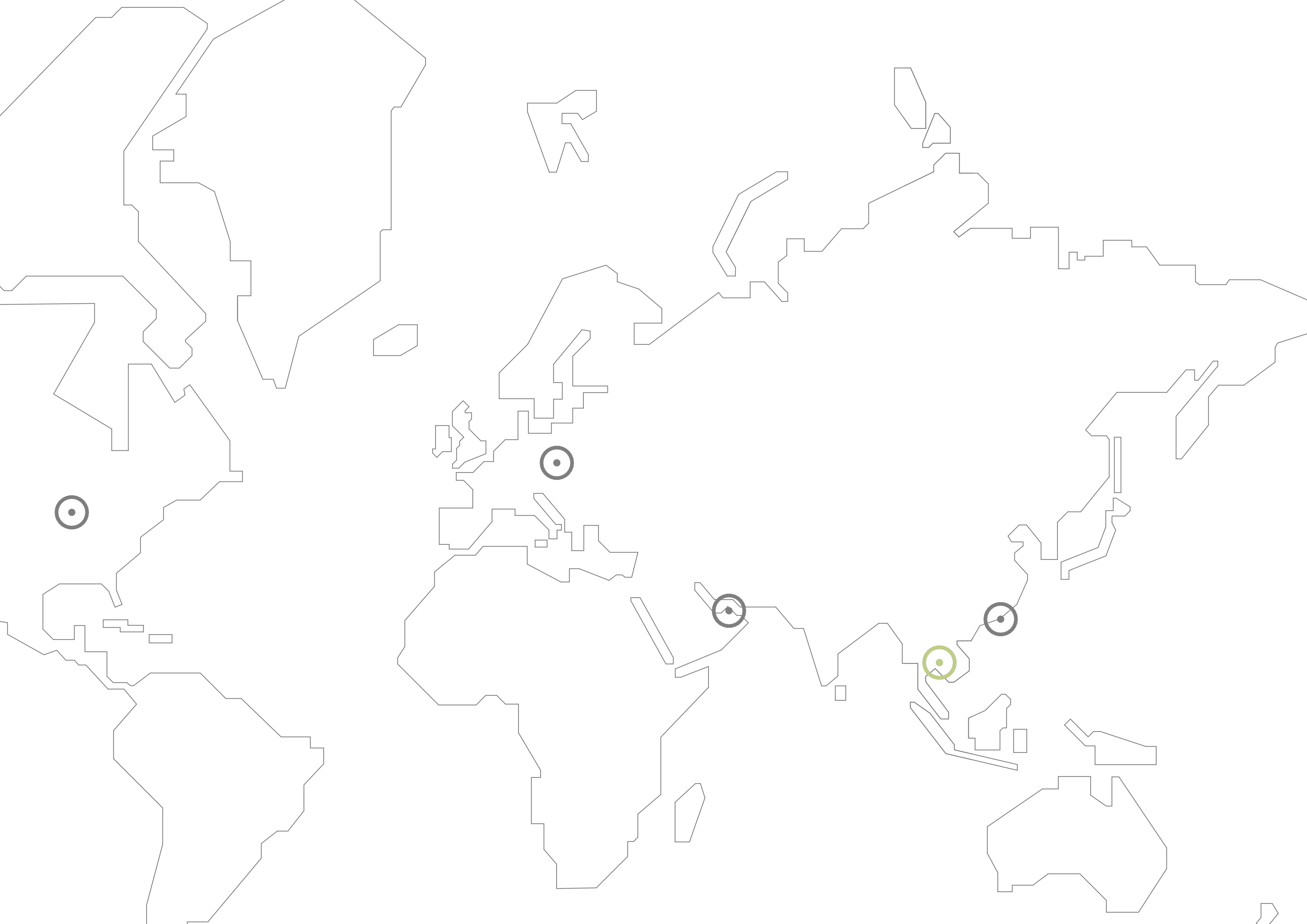
Ill. 101 | HANOI | ELEVATIONS | M 1:1000

South| West | North | East





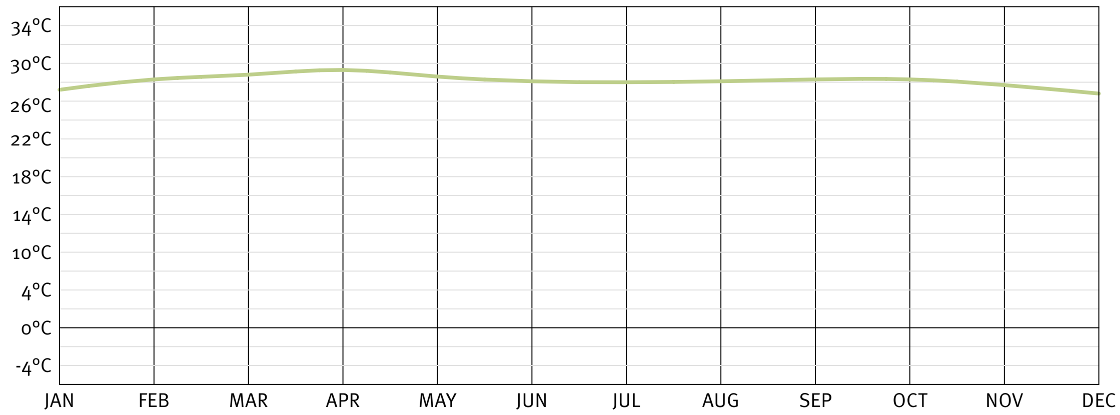
bangkok



11.1. TROPICS[81]

The tropics stretch from the tropical rainforests at the equator to the dry areas of the tropics on both hemispheres. The temperature in these areas is continuously hot all over the year but the summers can be very wet due to the rainy season. The peak of the temperature is always prior to the rainy season and the lowest one is during the dry season. The vegetation in the tropics is characterized by grassland with some trees and bushes.

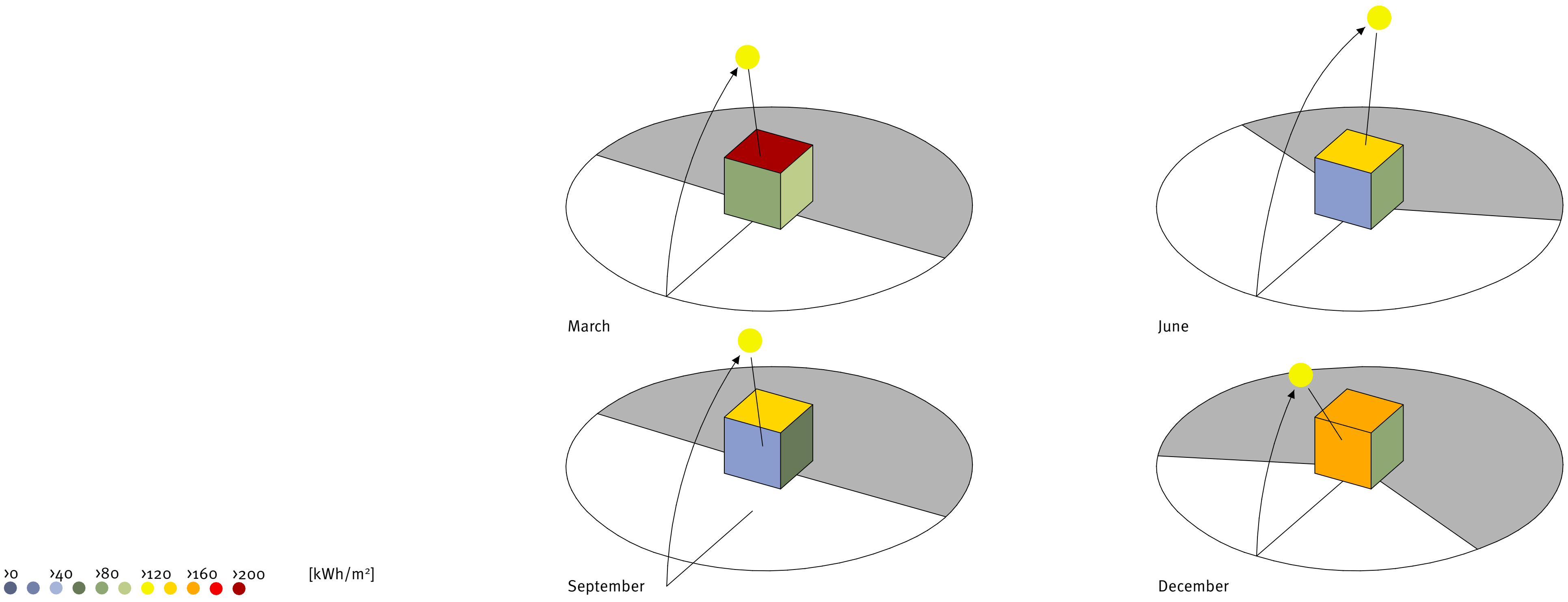
Ill. 103 | TEMPERATURE CURVE OF BANGKOK



Climate data[82]:	
Average temperature:	27.8 °C
Average max. temperature:	32.7 °C
Average min. temperature:	24.1 °C
Maximum temperature:	40.0 °C[83]
Minimum temperature:	10.5 °C

Sum of level of rainfall:	1,497 mm
Sum of hours with sunshine:	2,630 h
Average wind speed:	4.5 m/s[84]
Average relative humidity 7am:	87.5 %[85]
Average relative humidity 2pm:	59.3 %

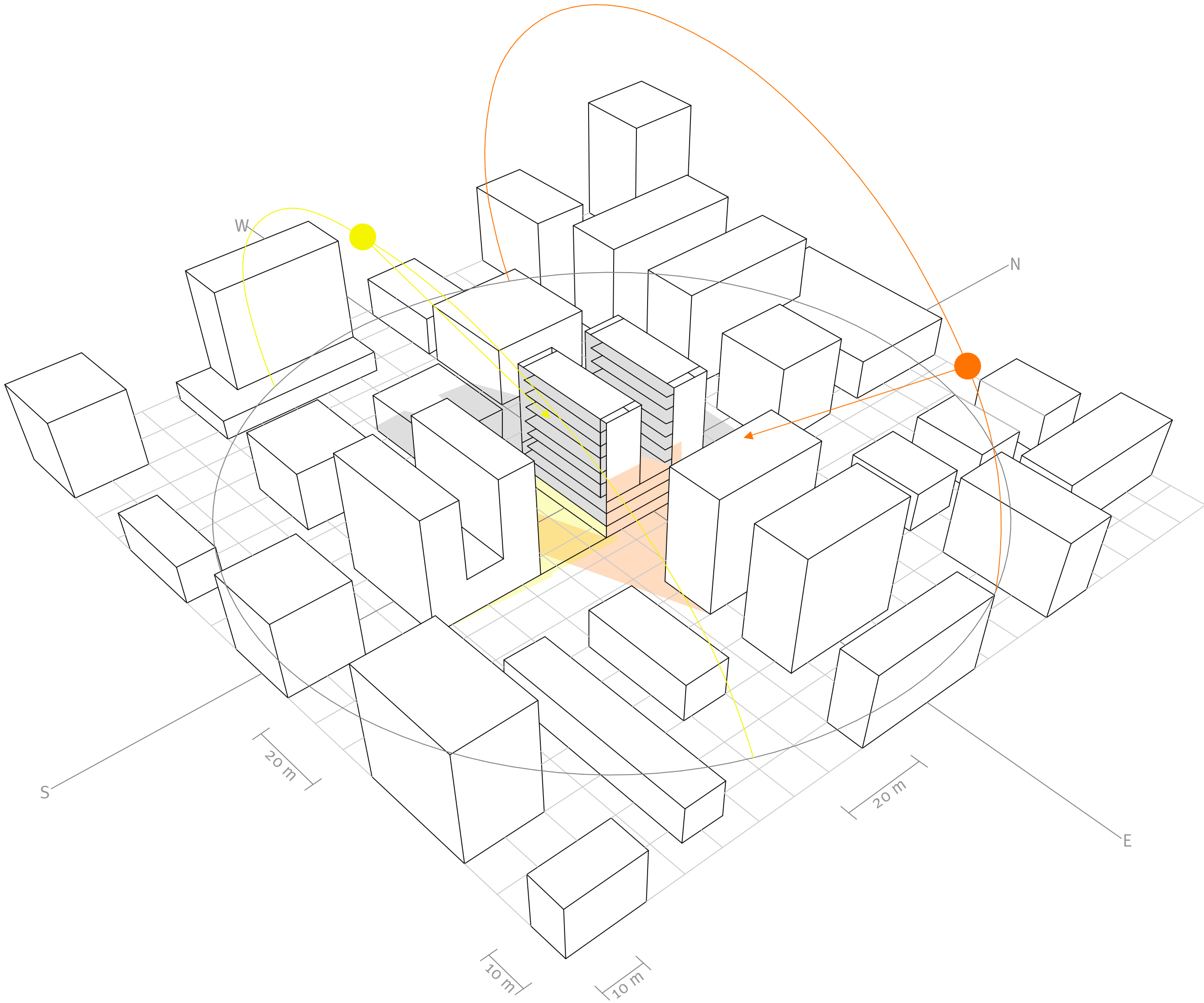
81. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 94
82. Cf. CLIMATE CHARTS (n.y.): Bangkok, Thailand. Viewed on 04/29/2013 under www.climate-charts.com/ Locations/t/TH48455.php
83. Cf. WIKIPEDIA (2013): Bangkok. Viewed on 04/29/2013 under en.wikipedia.org/wiki/Bangkok
84. Cf. WINDFINDER (n.y.): Wind- & Wetterstatistiken Bangkok Pilot. Viewed on 0429/2013 under www. windfinder.com/windstats/windstatistic_BANGKOK. htm
85. Cf. MY FORECAST (n.y.): Bangkok, Thailand. Viewed on 04/29/2013 under www.myforecast.com/bin/climat e.m?city=75672&metric=true



Ill. 104 | SOLAR RADIATION OF BANGKOK

These graphics show the solar radiation reaching facade surfaces in different seasons.

11.2. BUILDING STRUCTURE[86]



In the tropics the buildings should have an open and non-compact plan, they should be staggered and East-West orientated as well as positioned closer to each other due to natural ventilation and radiation input. To improve the room climate, the East and West facades should have limited openings. The building's depth is restricted to optimizing daylight provision.

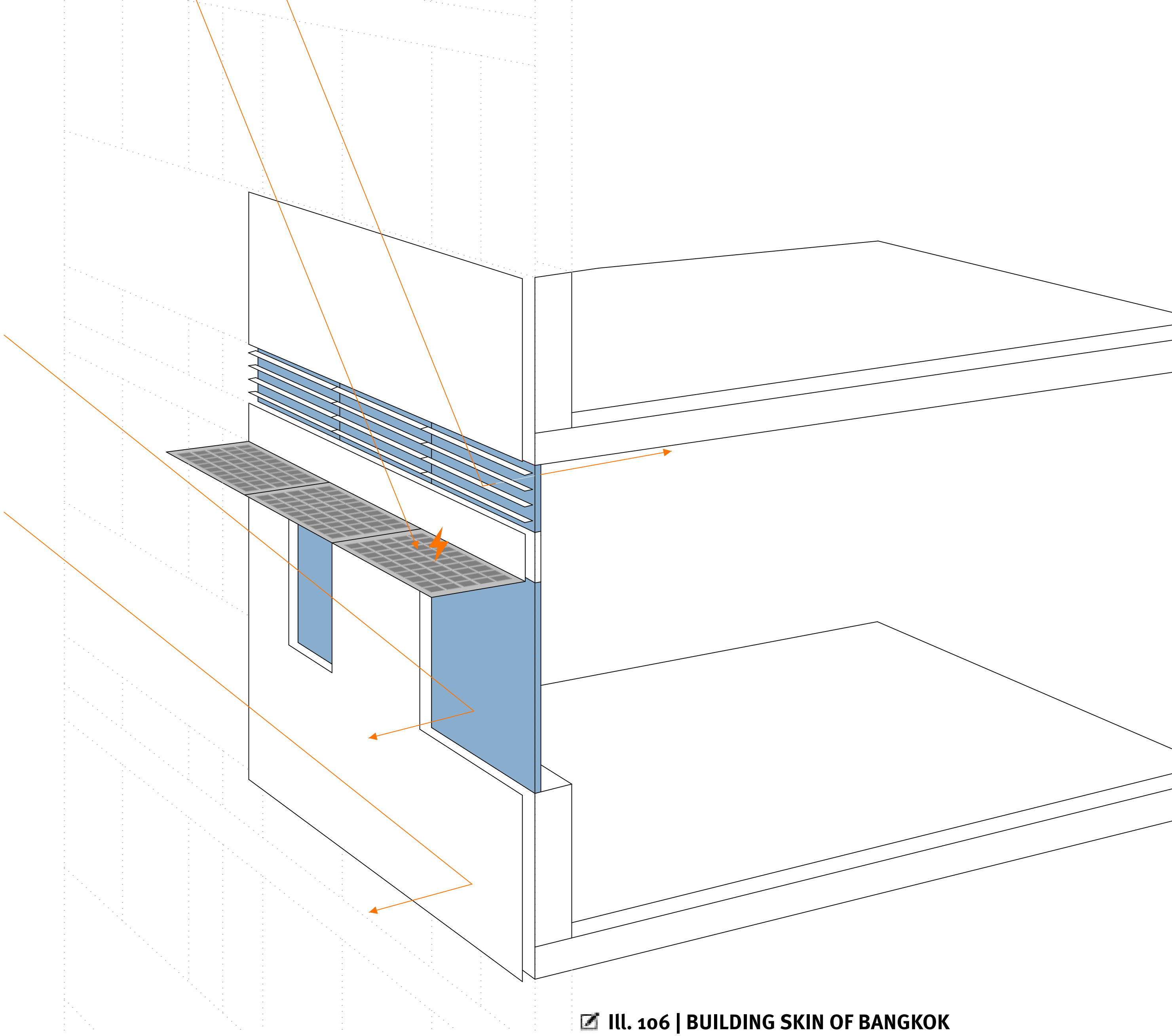
Ill. 105 | BUILDING STRUCTURE OF BANGKOK

Non-compact forms, low building depths and shading by adjacent buildings are the most important parameters in the tropics.

86. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 100

11.3. BUILDING SKIN[87]

The facade for the tropics has to be designed in a way to avoid solar input. Glazing percentage should be around 30 % to 40 % and sun protection glazing is highly recommended to reach a g-value under 0.4. Moreover, sun protection systems are a big issue. While the Southern facade has to deal with the low morning and evening sun during winter months the Eastern and Western facade should prevent direct gain and diffuse radiation all over the year.
To avoid transmission heat gain a thin layer of thermal protection should be added and to produce energy, photovoltaic elements can be mounted.



Ill. 106 | BUILDING SKIN OF BANGKOK

Low glazing percentages, sun protection glazing and photovoltaics play an important role in the tropics.

87. Cf. Ibid., p. 102

11.4. DESIGN

Ill. 107 | BANGKOK
The skyline of the city at night.

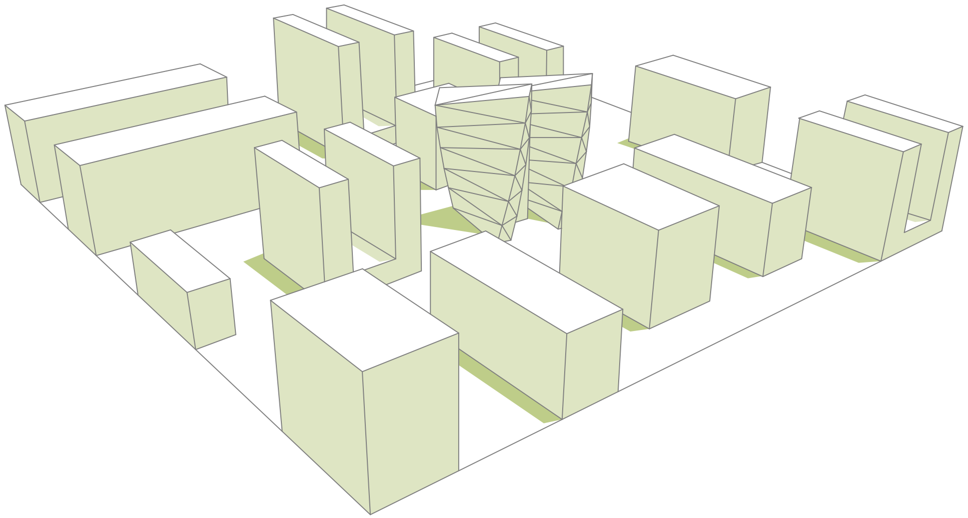
The design for Bangkok is more non-compact than the aforementioned designs.

According to high solar radiation, it is important that the building is shaded. This can be accomplished by nearby buildings but also by itself. That is why the building consists of 3 parts: the core at the center and one office area to the North and one to the South. The core remains static but the office areas are rotating. Those three parts are connected via bridges which are always at a right angle to the core.

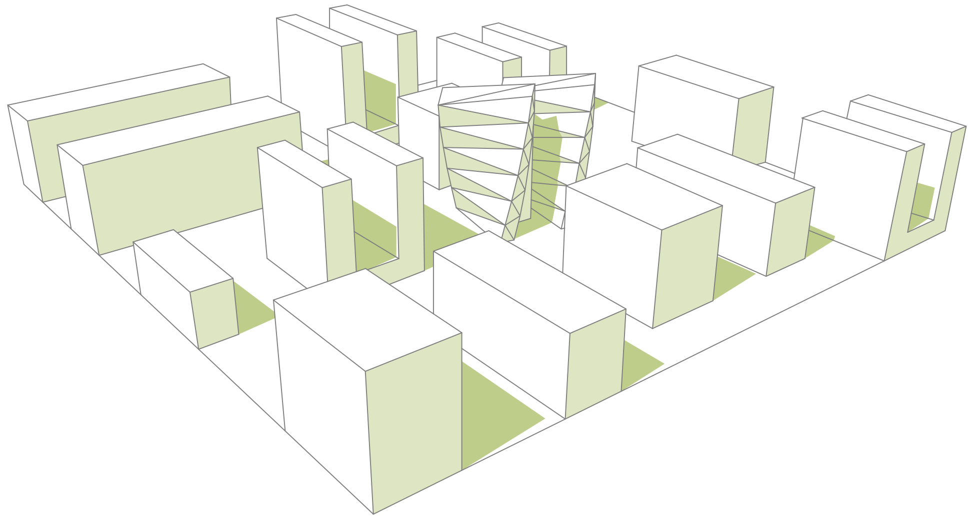
The building consists of 21 regular floors and the office areas have 3 additional floors in the canted roof area. The building's height of 80 m is the same as for Vienna.

The shape of the office areas is very thin but long. They have a dimension of 8.8 m x 49.6 m.

21st of June, 12:00pm

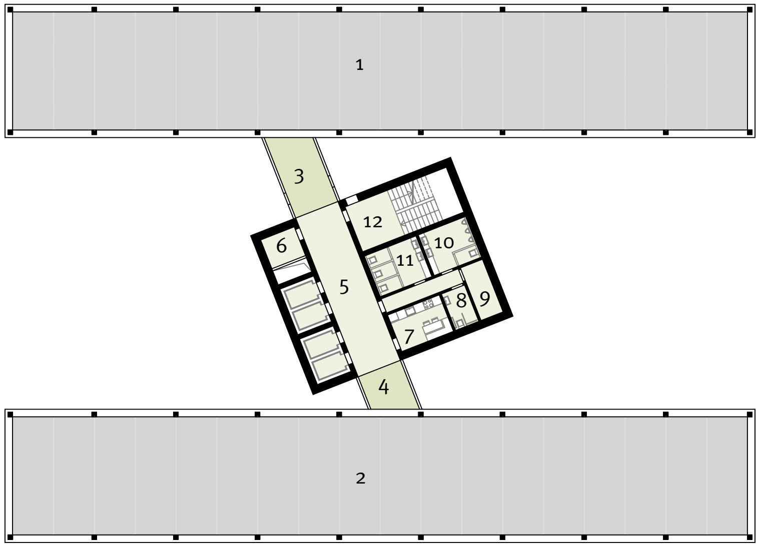


21st of December, 12:00pm

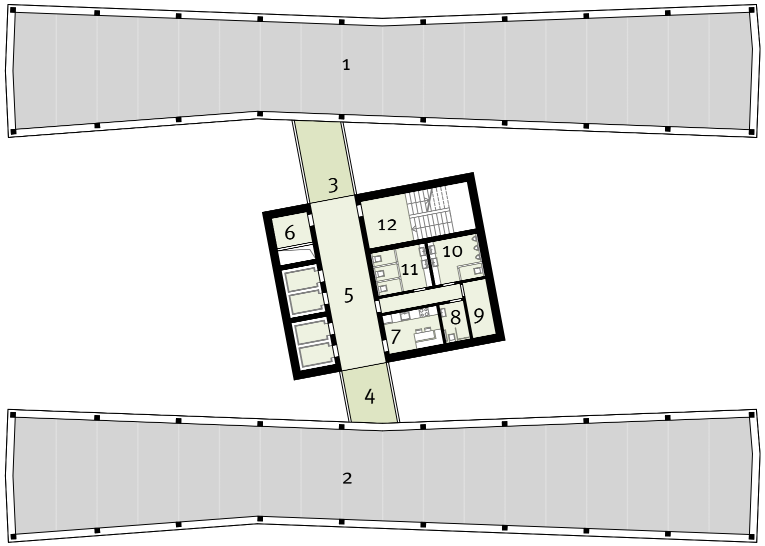


Ill. 108 | SHADING STUDY

External shading of Bangkok on the 21st of June and on the 21st of December.



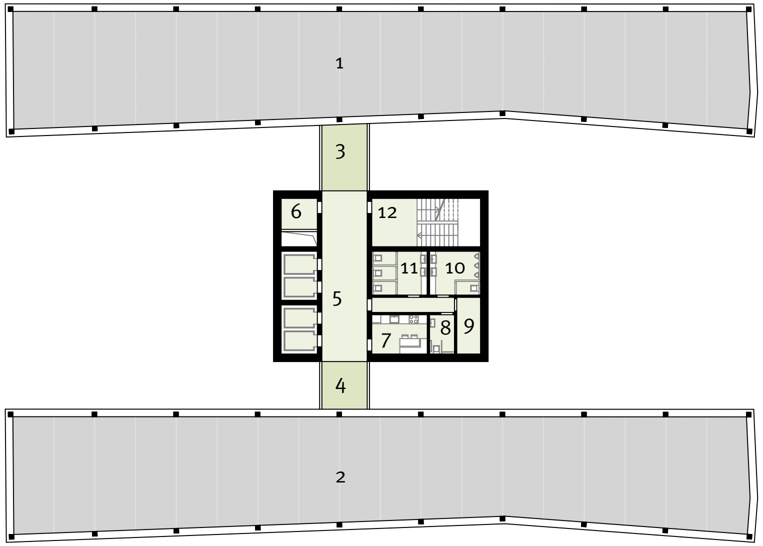
1st Floor



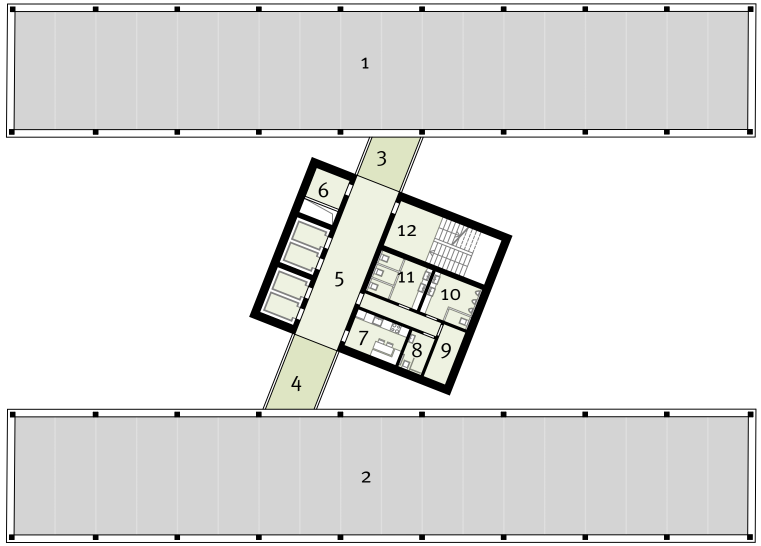
5th Floor

Ill. 109 | BANGKOK | M 1:500

One static core in the middle and two towers with office use on the Northern and Southern side.

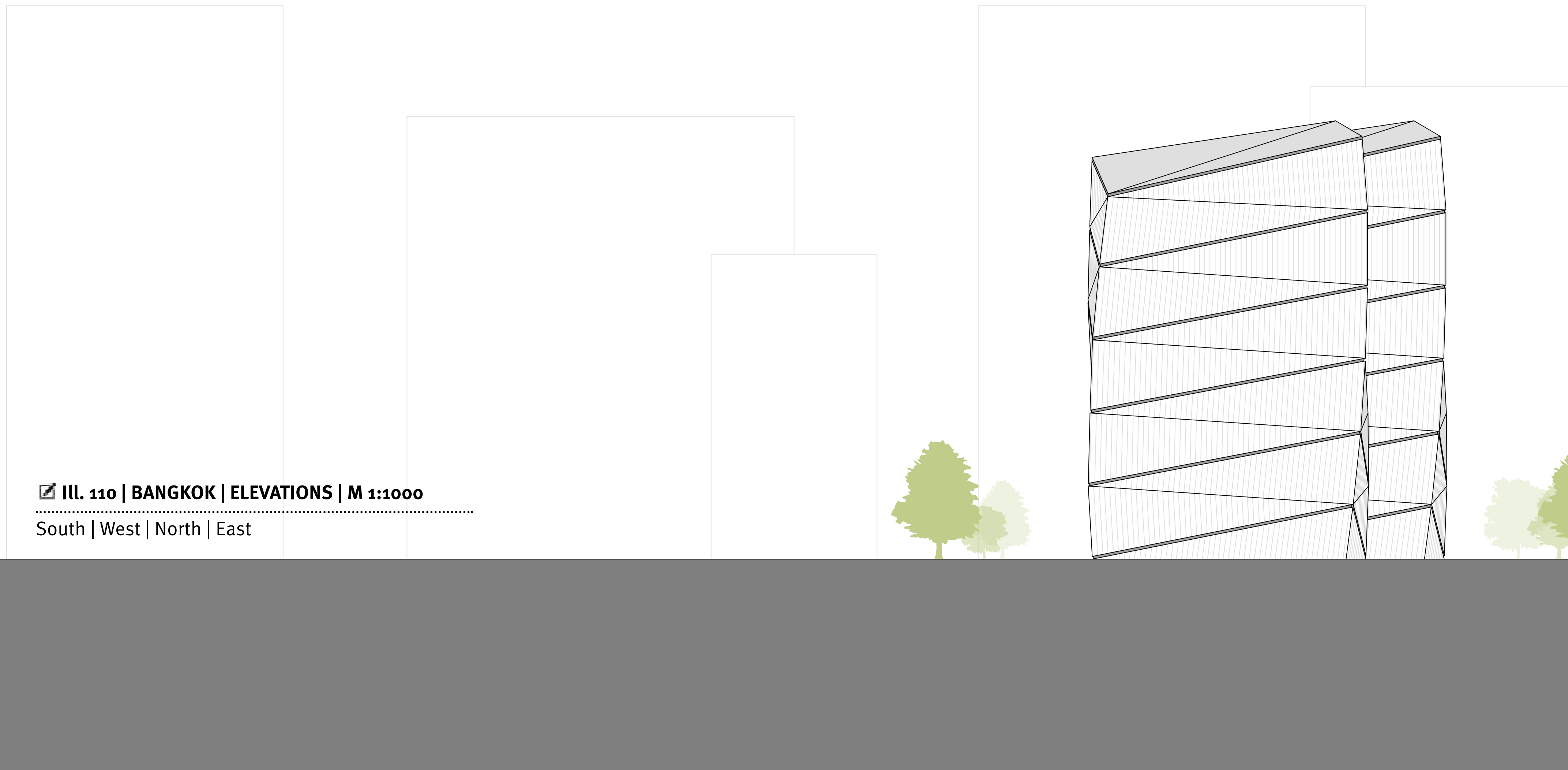


11th Floor



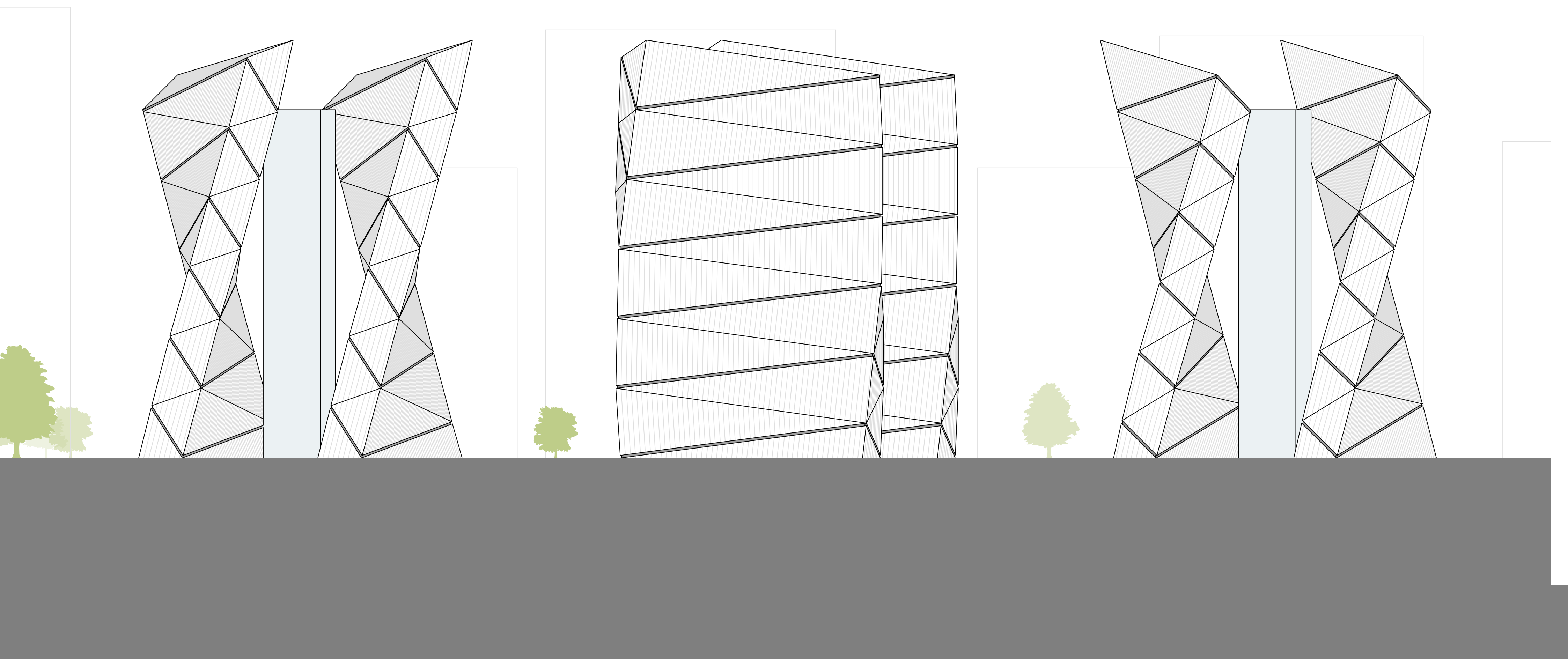
21st Floor

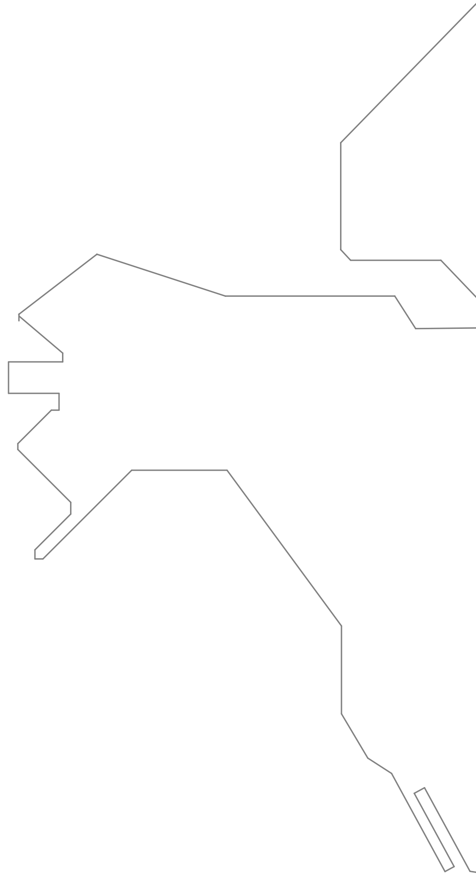
1 office area - North
2 office area - South
3 development - North
4 development - South
5 development zone
6 engineering room
7 kitchenette
8 restroom for the disabled
9 LAN-room
10 restroom men
11 restroom women
12 staircase



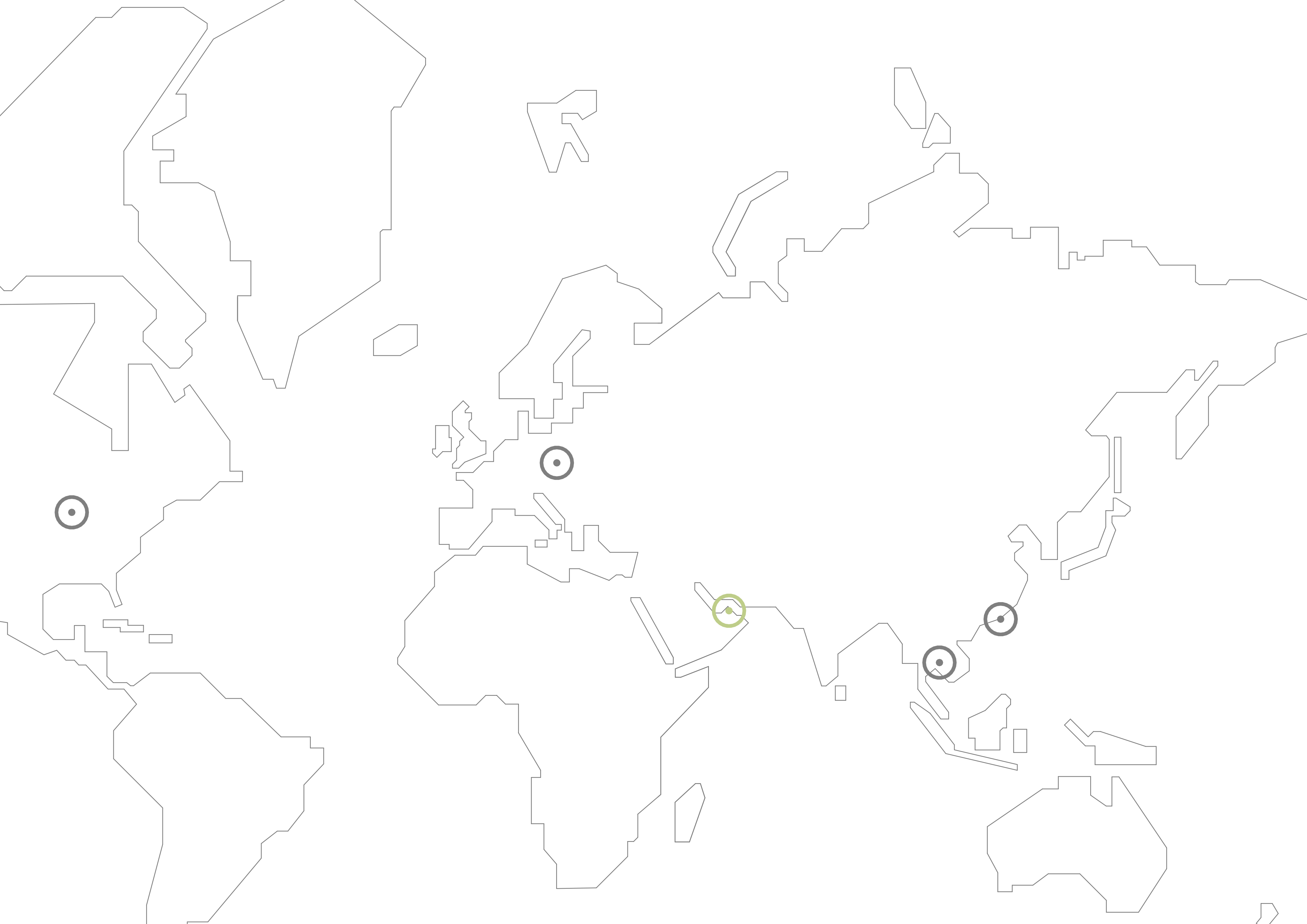
Ill. 110 | BANGKOK | ELEVATIONS | M 1:1000

South | West | North | East





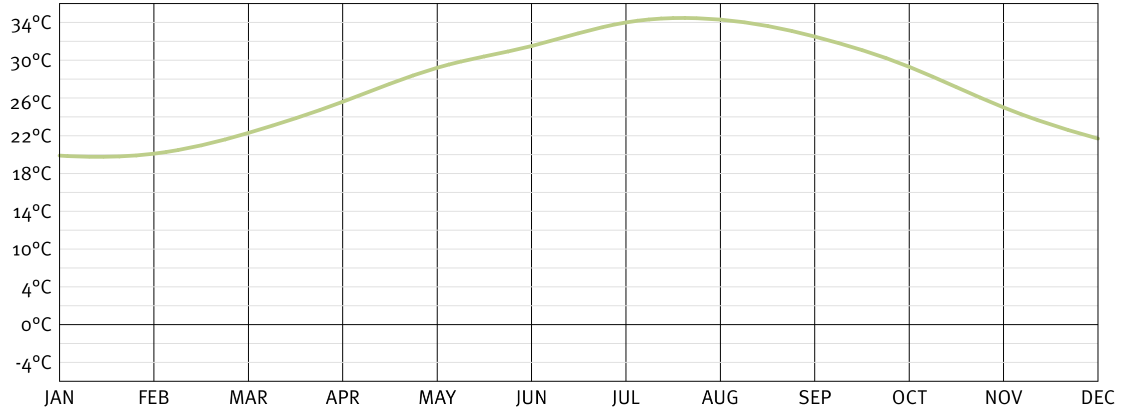
dubai



12.1. DESERT[88]

Extremely high outdoor air temperatures combined with very high or very low absolute air humidity define this climate. It is located at the Northern and Southern tropics between the 15th and 30th latitude. The annual rate of global radiation in this area is higher than in areas closer to the equator because of its belt of high pressure. This produces clear skies, a high proportion of direct radiation and very low precipitation levels. The ground is dried out and strongly reflects the radiation. In summer temperature is very high and air humidity very low in continental areas. That is why the temperature fluctuates over the course of a day.
The vegetation of deserts is constricted to patches of grass and bushes. The areas get greener only close to rivers or in areas with groundwater. In a city such as Dubai the vegetation gets artificially watered, so it appears green all over the year.

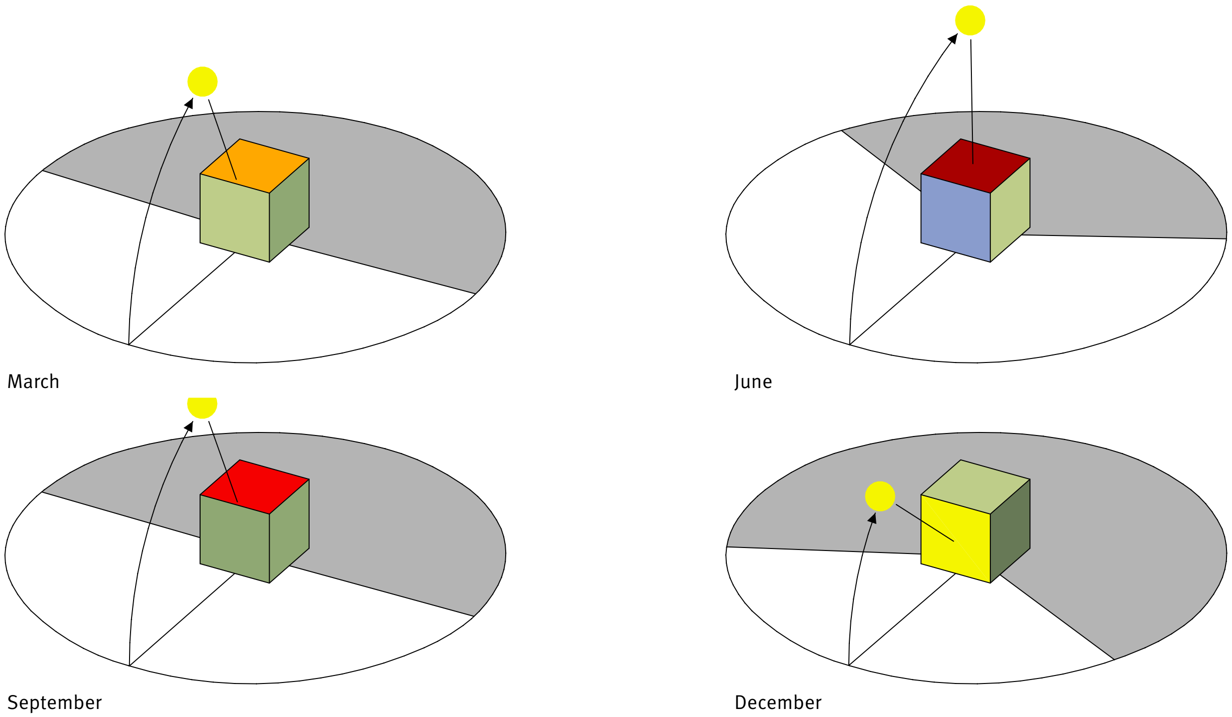
Ill. 112 | TEMPERATURE CURVE OF DUBAI



Climate data[89]:	
Average temperature:	26.9 °C
Average max. temperature:	33.0 °C
Average min. temperature:	21.3 °C
Maximum temperature:	40.6 °C
Minimum temperature:	13.7 °C

Sum of level of rainfall:	93.8 mm
Sum of hours with sunshine:	3,511.4 h[90]
Average wind speed:	5.3 m/s[91]
Average relative humidity 7am:	81 %
Average relative humidity 2pm:	36 %

88. Cf. Ibid., p. 62
89. Cf. CLIMATE CHARTS (n.y.): Dubai, United Arab Emirates. Viewed on 04/28/2013 under www. climate-charts.com/Locations/u/UE41194.php
90. Cf. WIKIPEDIA (2013): Climate of Dubai. Viewed on 04/28/2013 under en.wikipedia.org/wiki/Climate_ of_Dubai
91. Cf. EOS WEB (n.y.): Viewed on 04/28/2013 under eosweb.larc.nasa.gov

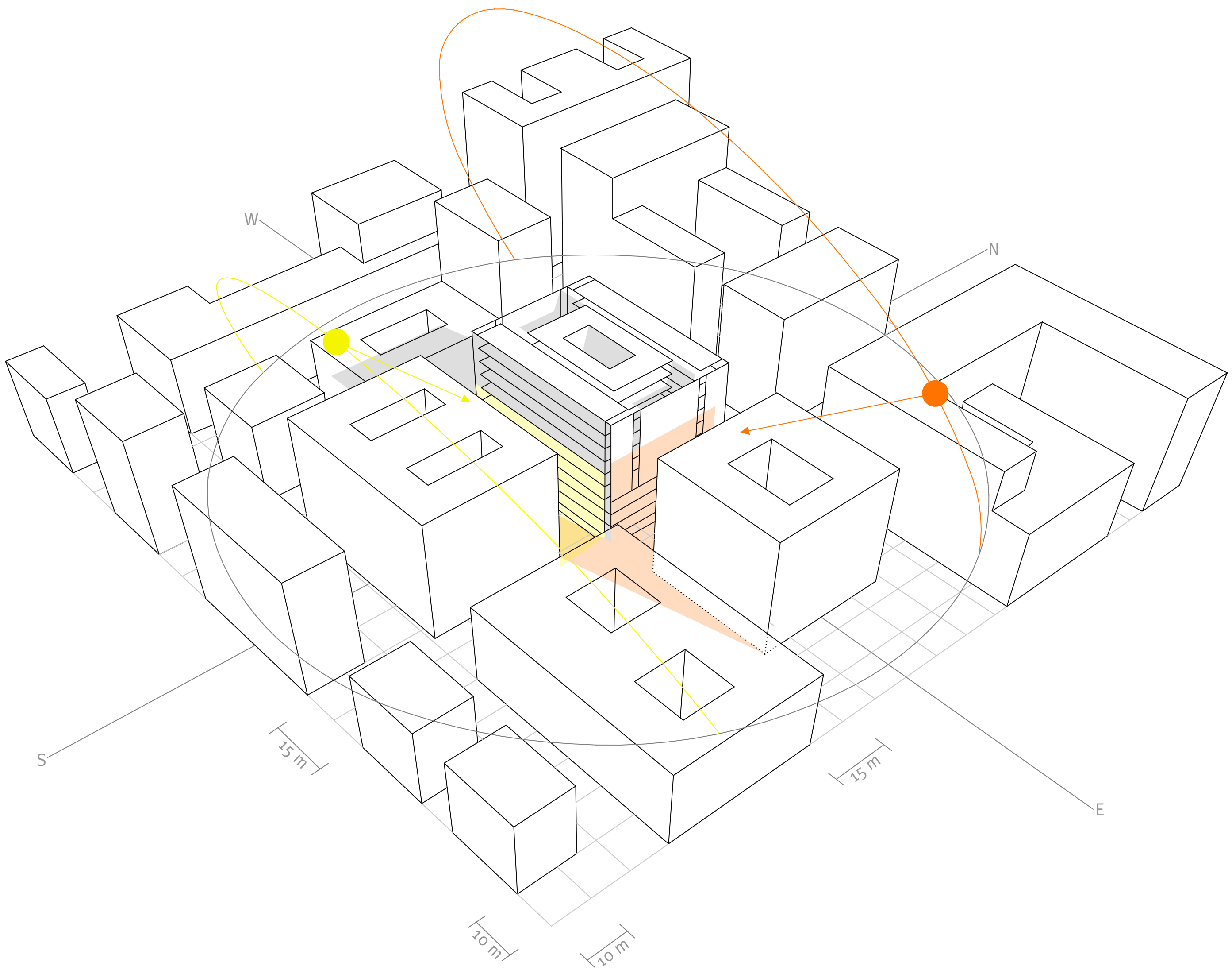


Ill. 113 | SOLAR RADIATION OF DUBAI

These graphics show the solar radiation reaching facade surfaces in different seasons.

12.2. BUILDING STRUCTURE[92]

The more compact a building the better the building structure. A low surface-to volume-ratio with greater building depth should be pursued to lower the cooling energy demand. Moreover, the buildings should be placed closer at the Eastern and Western side to shade each other. The Southern facade can additionally be shaded with well placed projections. Due to high environmental illuminance and high degree of reflection from surrounding facades, the daylight provision can be provided passively.

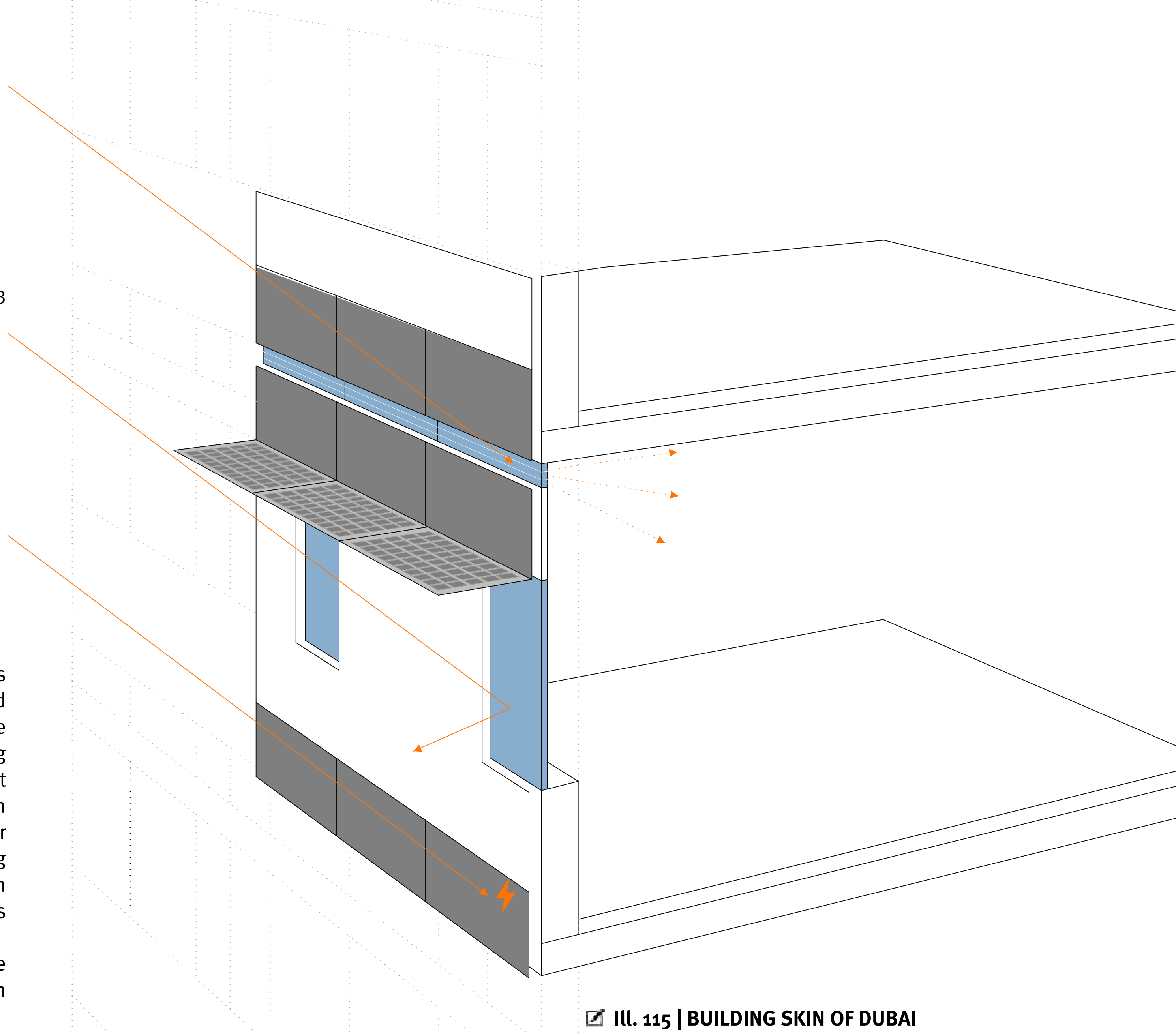


Ill. 114 | BUILDING STRUCTURE OF DUBAI

Low building depths and shading by adjacent buildings are the main characters in the desert.

92. Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 116

12.3. BUILDING SKIN[93]



The most important challenge of a desert facade is to deal with the solar input. There is no way around using external sun protection, which can reduce the cooling energy demand by 20%. The glazing percentage should not be higher than 30 % at each side and the glazing itself should have a sun protection coating and the g-value should be lower than 0.3. If you reduce the g-value to 0.2, the cooling demand decreases by 10%. To avoid transmission heat gain, a minimal thermal protection of 5 cm is very meaningful.
Amorph photovoltaic panels installed on the facade and crystalline ones as a shading element can reach high outputs.

Ill. 115 | BUILDING SKIN OF DUBAI

Low glazing percentages, sun protection glazing and photovoltaics play an important role in the desert.

93. Cf. Ibid., p. 118

12.4. DESIGN

Ill. 116 | DUBAI

The downtown of the city with the tower Burj Khalifa.

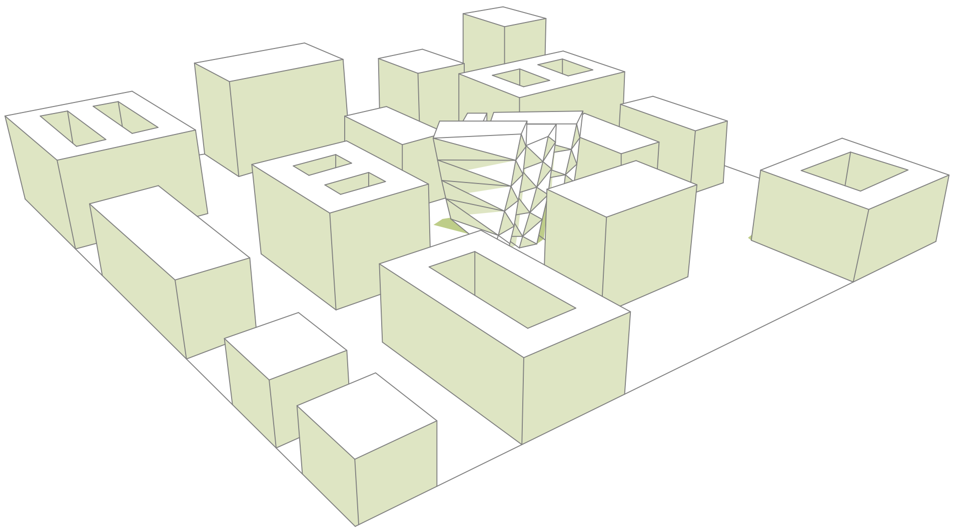
The design for Dubai is quite similar to the one for Bangkok.

It consists of 5 parts: 2 long office areas in the North and South, 2 short ones in the East and West and the central core. All of the office areas are twisted and the core remains static.

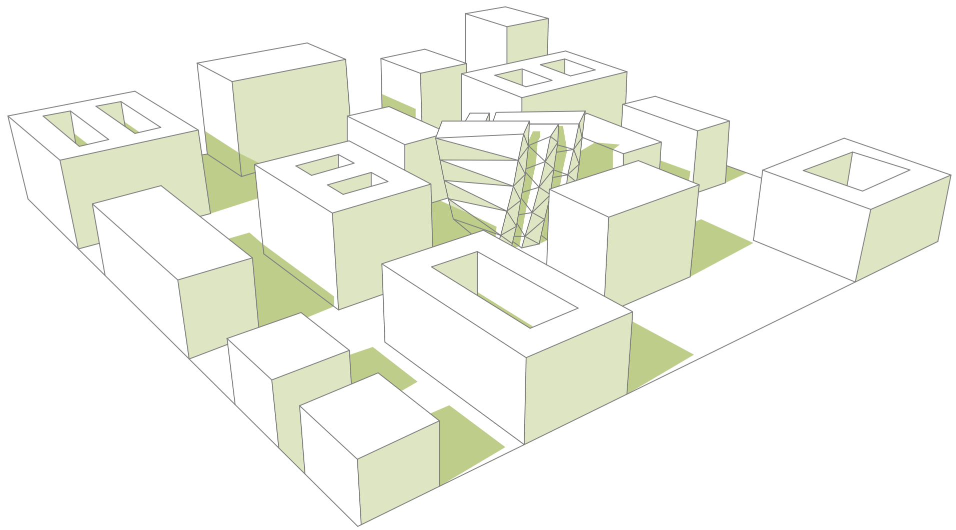
The small office areas are linked to the long ones and the long ones are connected to the core. So the bridges connecting the office areas are rotating with the short office areas and the bridges to the core stay static.

The long office areas have a dimension of 49.6 m x 8.8 m and the short office areas 11.8 m x 10.9 m. The building consists of 17 regular floors and 3 floors in the canted roof area. The height of the building measures 66 meters.

21st of June, 12:00pm

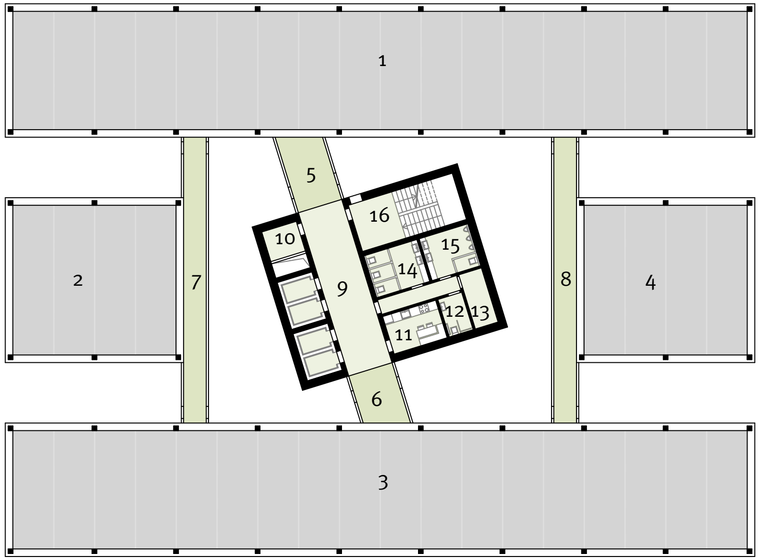


21st of December, 12:00pm

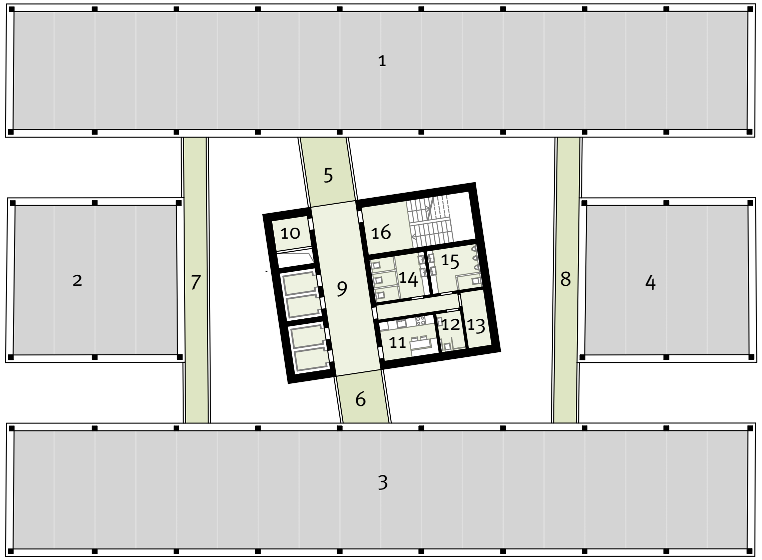


Ill. 117 | SHADING STUDY

External shading of Dubai on the 21st of June and on the 21st of December.



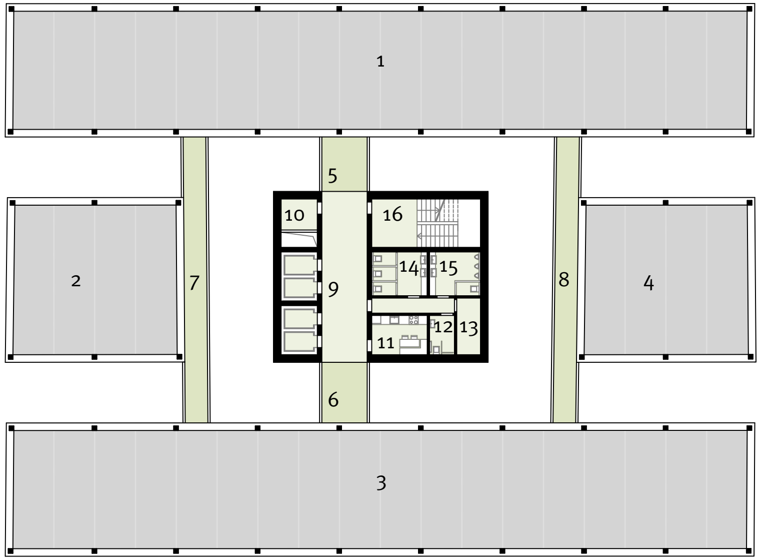
1st Floor



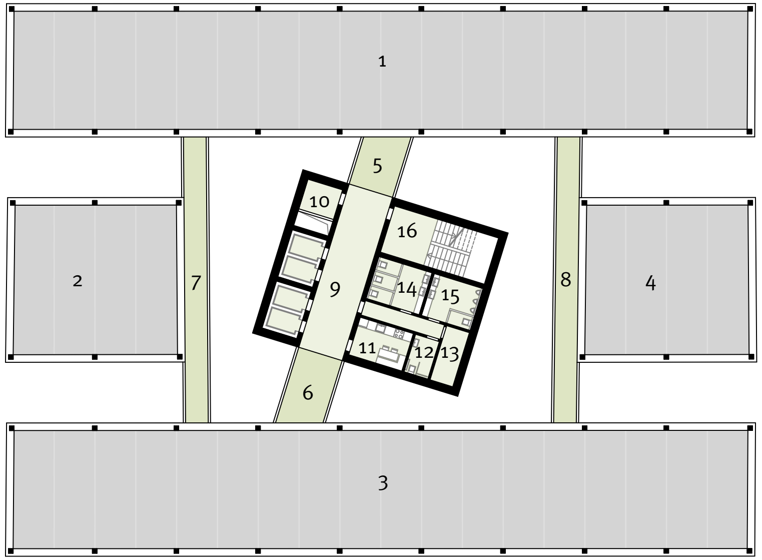
5th Floor

Ill. 118 | DUBAI | M 1:500

One static core in the middle with four towers for office use around it.

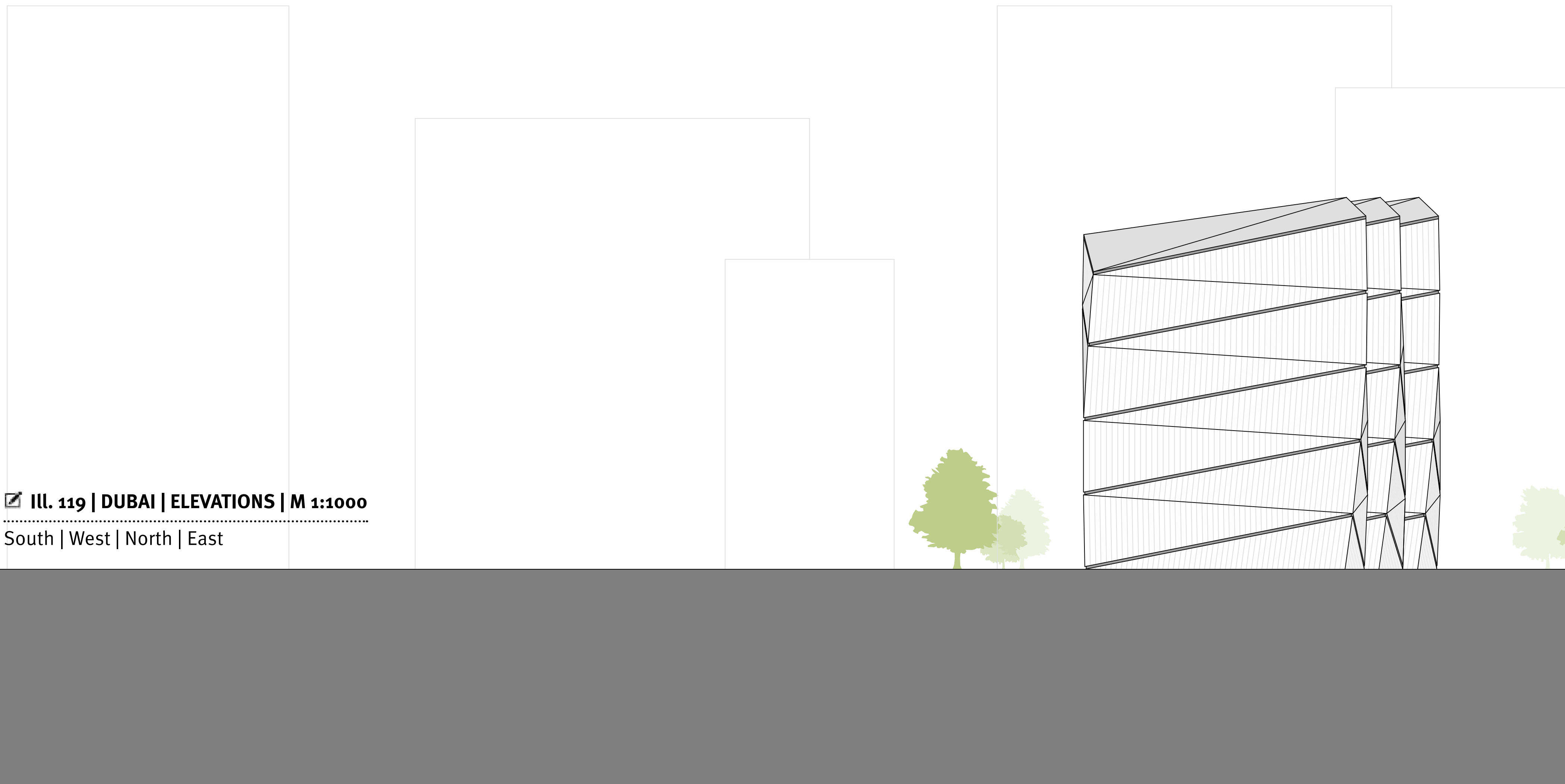


9^{th} Floor



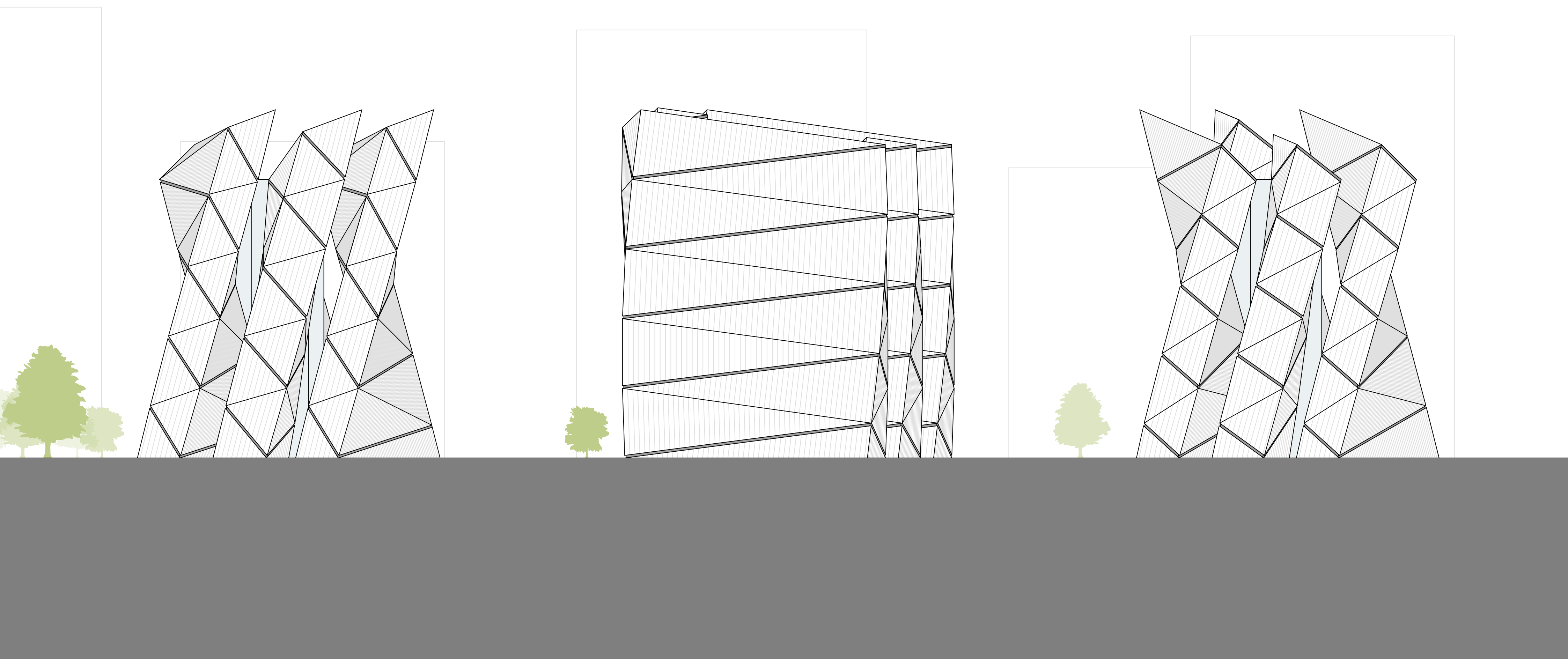
17^{th} Floor

1 office area - North
2 office area - West
3 office area - South
4 office area - East
5 development - North
6 development - South
7 development - East
8 development - West
9 development zone
10 engineering room
11 kitchenette
12 restroom for the disabled
13 storage room
14 restroom women
15 restroom men
16 staircase



Ill. 119 | DUBAI | ELEVATIONS | M 1:1000

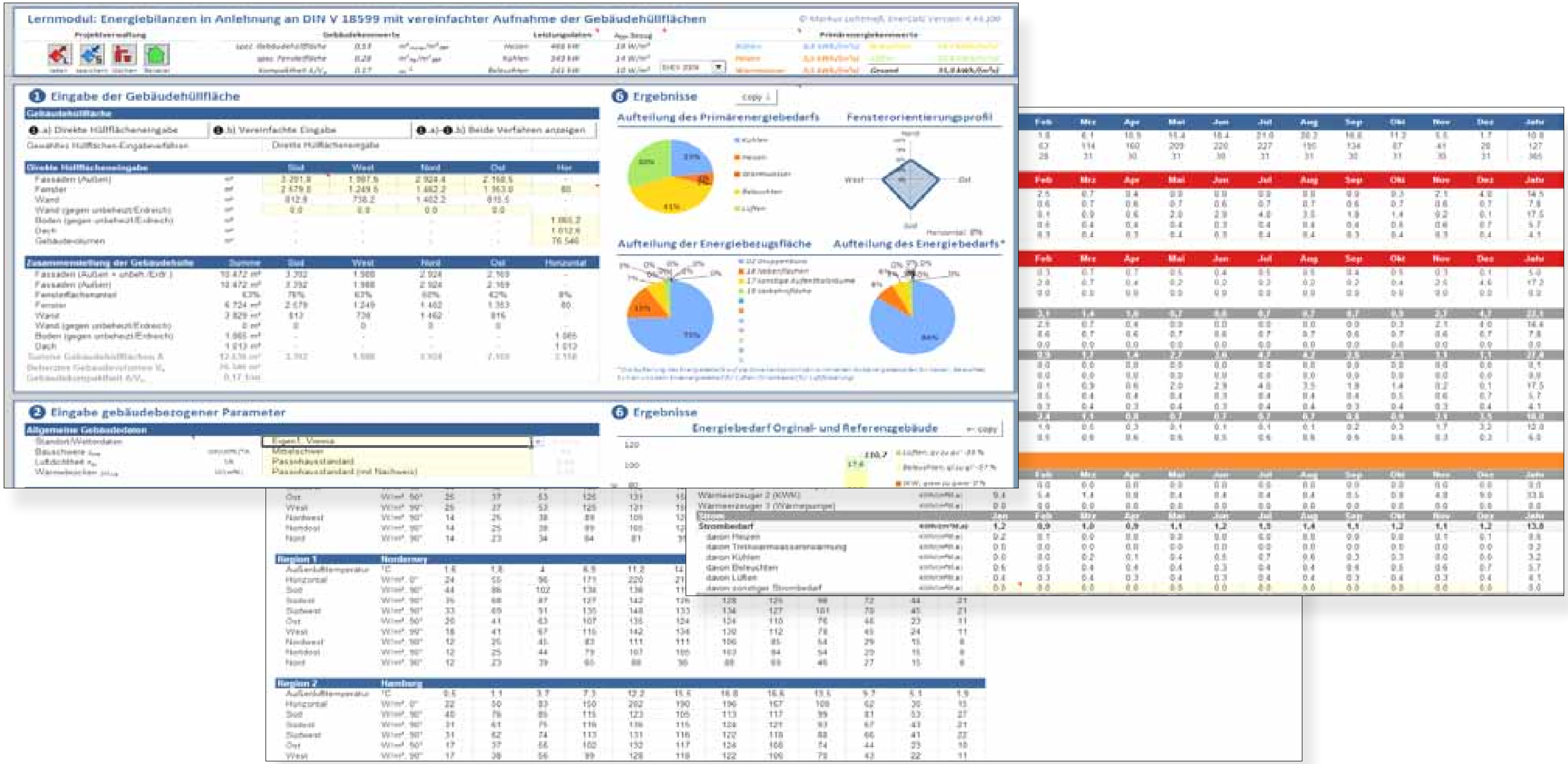
South | West | North | East



CHAPTER V
THE PERFORMANCE

the last chapter is about proving the designs of the different climate zones according to their **energetic and ecological performance**. *for that reason, the data of the buildings are put into the program* **enercalc**. *at first, i begin with the main design for vienna. i change the parameters of the program to fit the design and climate of vienna. At the next step, i put the building with the same parameters into the other four climate zones and* **analyze the result**. *as a consequence of that, i put the climate-specific designs into the climate which is provided for it and analyze these results.*

174



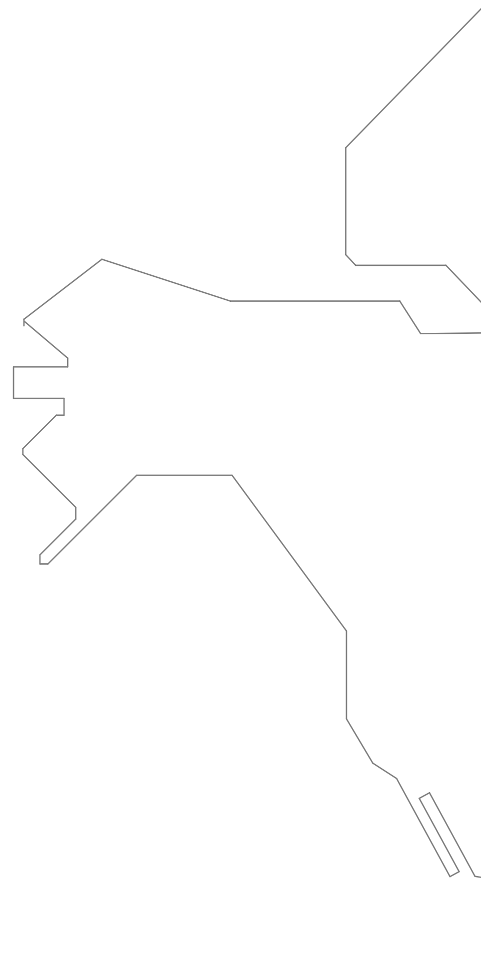
Ill. 120 | ENERCALC

These pictures show screenshots of the program.

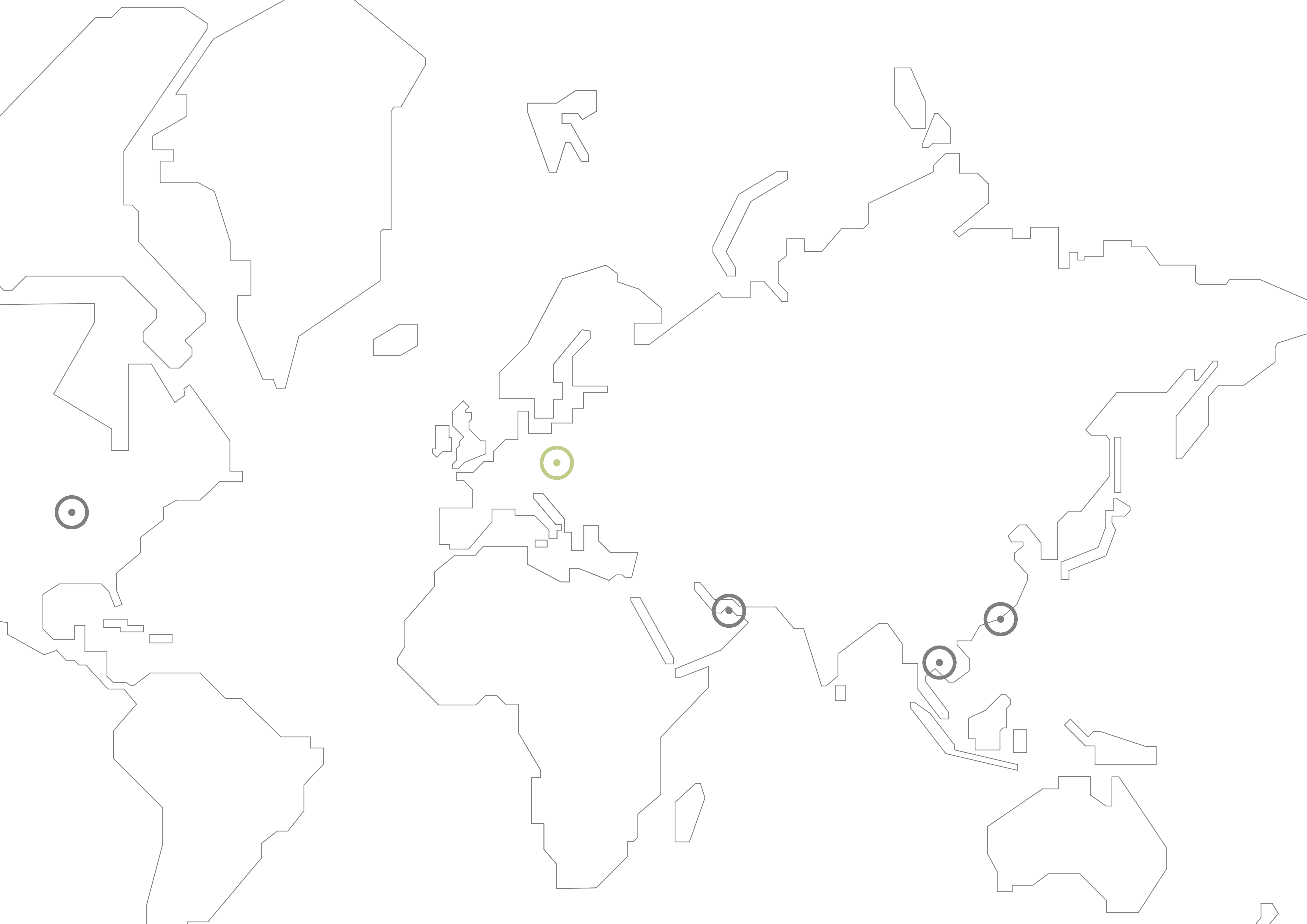
1. THE PROGRAM ENERCALC[94]

In this thesis the program EnerCalC^{2013} is used to prove the energetic and ecological performance of the designs and to compare them to each other. EnerCalC is a software based on Microsoft Excel to calculate the energy demand of buildings except residential buildings. The program gives you an overview about the energy performance and Co$_2$-emissions of a building. It is based on the German norm “DIN V 18599” but in a more simplified way. It is possible to fill out building specific data as well as to divide the building into different zones. Moreover, you can add simplified building service systems and photovoltaic installations. The specialty of this program is, that it includes the use of solar energy and cogeneration.

94.Cf. ENOB (n.y.): EnerCalC 2013 – Vereinfachte Energiebilanzen nach DIN V 18599. Viewed on 04/26/2013 under www.enob.info/de/software- und-tools/projekt/details/enercalc-vereinfachte- energiebilanzen-nach-din-v-18599/



vienna

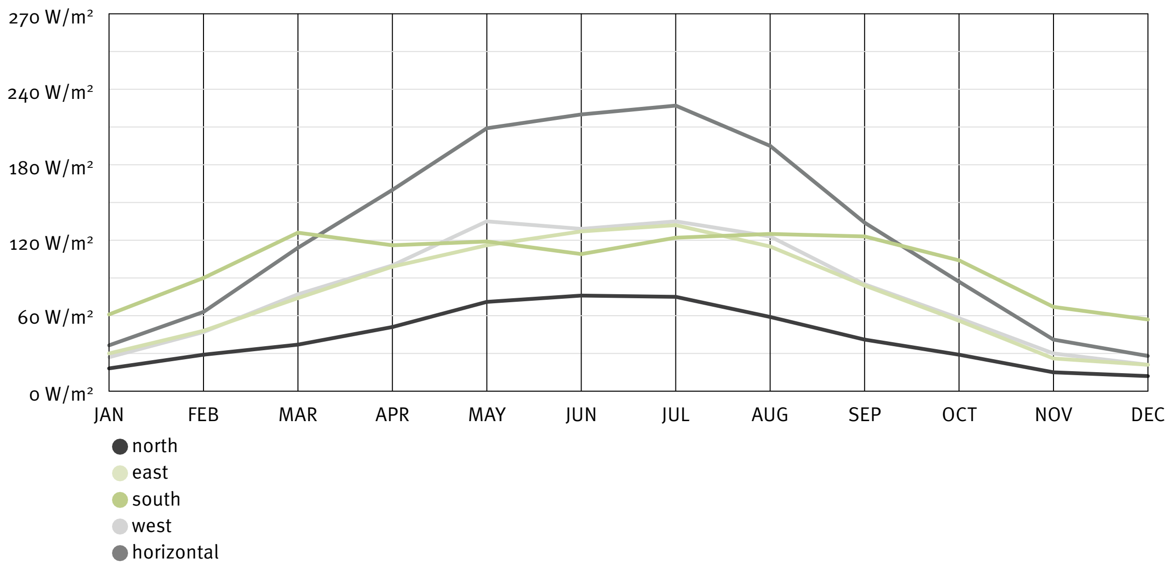


2.1. BUILDING | VIENNA

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	TEMPERATURE	°C	0,1	1,8	6,1	10,9	15,4	18,4	21,0	20,2	16,6	11,2	5,5	1,7
SOLAR RADIATION	HORIZONTAL	W/m²	36	63	114	160	209	220	227	195	134	87	41	28
	SOUTH	W/m²	61	90	126	116	119	109	122	125	123	104	67	57
	SOUTH-EAST	W/m²	50	74	106	115	122	124	134	128	110	85	50	43
	SOUTH-WEST	W/m²	47	73	110	116	138	126	137	134	112	89	55	44
	EAST	W/m²	30	48	74	99	116	127	132	115	84	56	26	21
	WEST	W/m²	27	47	77	100	135	129	135	123	85	58	30	21
	NORTH-WEST	W/m²	19	30	45	69	101	102	103	87	54	33	16	12
	NORTH-EAST	W/m²	19	30	45	69	90	101	102	82	54	33	15	12
	NORTH	W/m²	18	29	37	51	71	76	75	59	41	29	15	12

DATA OF THE BUILDING. The building for Vienna consists of 21 regular floors and 3 floors in the canted roof area. The floor's height amounts to 3.30 meters and a regular floor has a gross floor area of about 1,050 m². The total gross floor area of the building is 24,000 m² and the building's volume is 76,500 m³. The glazing percentage in the South is calculated with 70 % excluding the atrium. Of course, the atrium features 100 % of glass. The Eastern and Western side account for 60 % and in the North the proportion is 50:50. The data of the building's envelope is taken from the 3D-model in SketchUp.

Ill. 122 | SOLAR RADIATION OF VIENNA



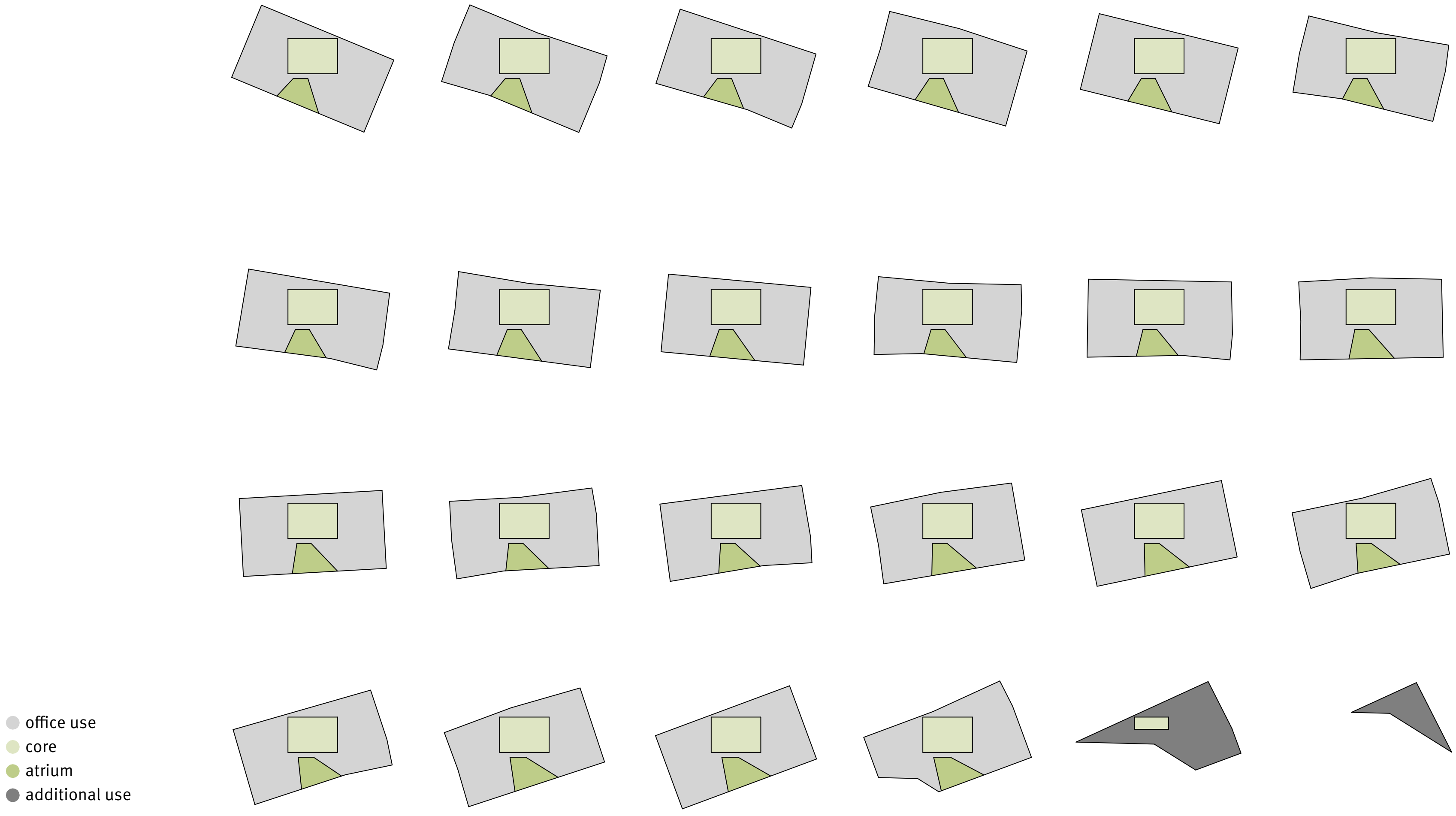
BUILDING PARAMETERS. To get a realistic result, you have to fill out certain building parameters in the program EnerCalC such as the general data about the building and the climate, the U-values of the construction, methods about shading and sun protection as well as general data about ventilation systems. To compare the building of Vienna with the designs for the other climates, I chose to keep the data as similar as possible. Of course, there are some changes due to climate factors to make the result more rational.

A short summary of the parameters of Vienna: The design can be seen as a "moderate construction", as it consists of a bearing core, lightweight walls and suspended ceilings. To fulfill the highest standards of energy-efficient buildings, the airtightness and thermal bridges should aim for reaching "passive house standards". The windows are made out of triple insulated glazing reaching a U-value of 0.68 W/(m^2K). The U-Value of the facade is calculated with 0.12 W/(m^2K), the roof with 0.10 W/(m^2K) and the base plate with 0.15 W/(m^2K). There are external sun protection elements installed on all windows, which are controlled in respect to radiation. Furthermore, there are additional light-conducting glare shields on the windows. Last but not least, the efficiency of the ventilation system is with 75 % heat recovery the highest which is possible.

BUILDING ZONES. The building is divided into four zones: the office part, the core, the atrium and the so called additional use. The office parts include every area except the atrium and the core. To compare it more easily to the other designs, I limited this area to 18,000 m^2. The remaining area can be found in the zone called additional use.

BUILDING SERVICE SYSTEMS. As the building is for temperate climate it focuses on both heating and cooling. Underfloor heating powered by geothermal energy captured via heat pumps is used for heating. Heat recovery is added in form of CHP (combined heat and power plant) to conserve energy. It amounts to 40 %. This causes a remarkable output of 31.2 kWh/(m^2a).
The zone for office use is mechanically ventilated and it is also connected to the heat recovering system. Concrete core activation using groundwater as a cooling source should be used for reaching a thermal indoor comfort during summer. Moreover, the climate demands night ventilation openings in summer as well as thermal mass. But you cannot integrate these factors into the program. The drinking water capacity depends on the office use area of 18,000 m^2 and it can be provided centrally without circulation. Solar thermal collectors should be added for hot water as well as for heating or cooling. Supplementary photovoltaic panels on the facade can reduce the energy demand of the building remarkably, if the performance is calculated with 200 kWp. This results at a yearly output of 16.5 kWh/(m^2a) in Vienna.

PRIMARY ENERGY DEMAND. The building's form, the denoted zones and the filled-out building's service parameters caused a yearly primary energy demand of 35.9 kWh/(m^2a). As the building is capable of producing its own electricity through photovoltaics and CHP, it is becoming a "plus energy building". A credit of 46.8 kWh/(m^2a) reduces the primary energy demand to incredible -10,9 kwh/(m^2a).

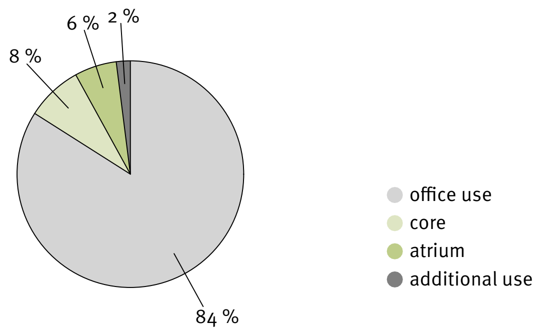


Ill. 123 | AREAS OF THE BUILDING

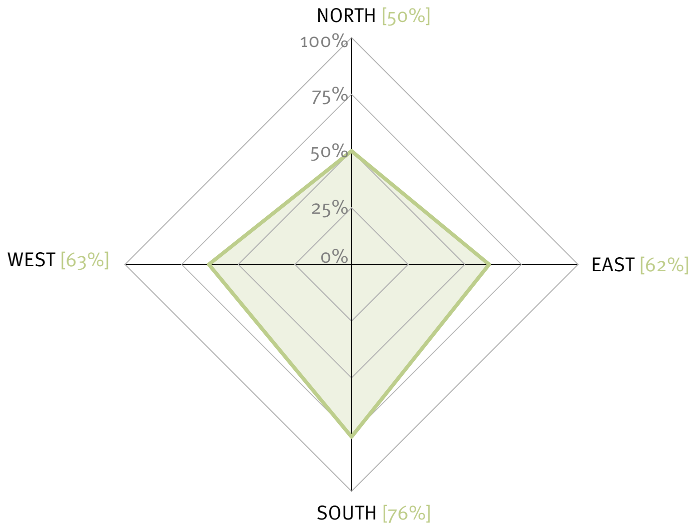
Showing each single floor with its zones.

		SOUTH	WEST	NORTH	EAST	HORIZ.
FACADE	m²	3,391.8	1,987.6	2,924.4	2,168.5	-
WINDOWS	m²	2,579.0	1,249.5	1,462.2	1,353.0	80.0
WALL	m²	812.8	738.2	1,462.2	815.5	-
BASE PLATE	m²					1,065.2
ROOF	m²					1,012.6
VOLUME	m³					76,546.0

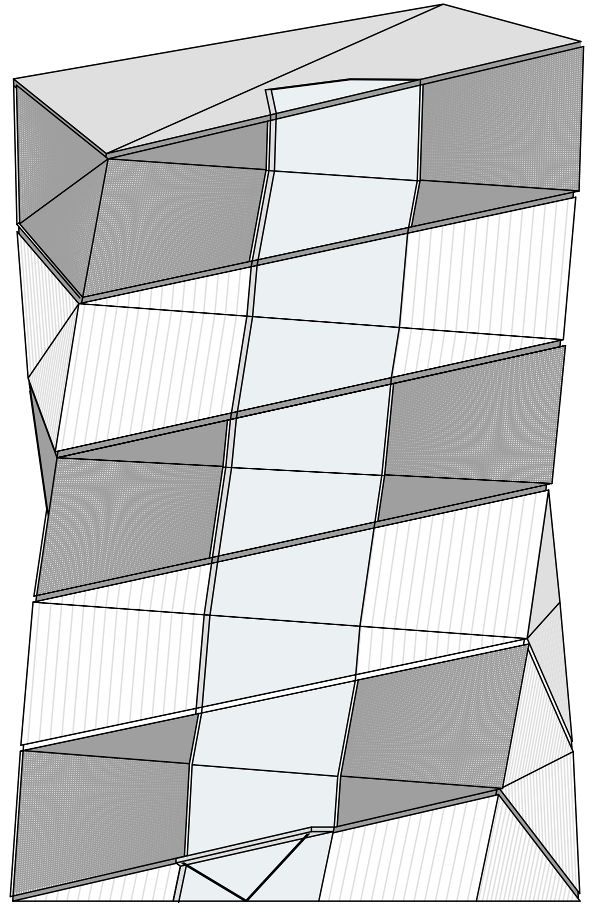
AREAS OF THE BUILDING



DISTRIBUTION OF ENERGY CONSUMING ZONES



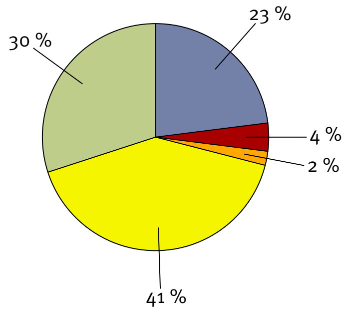
ORIENTATION OF THE WINDOWS



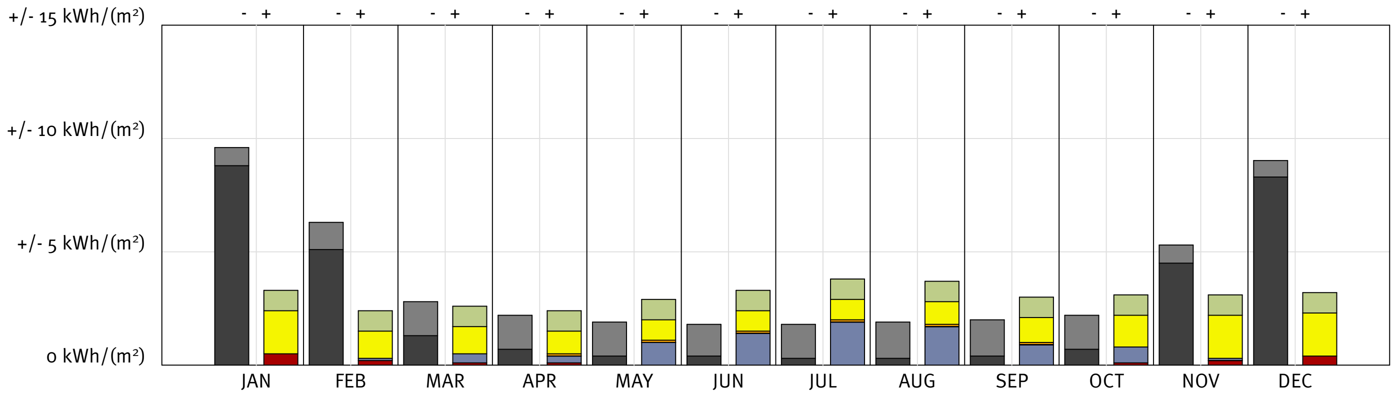
SOUTH ELEVATION OF THE BUILDING

2.2. CHARTS | VIENNA

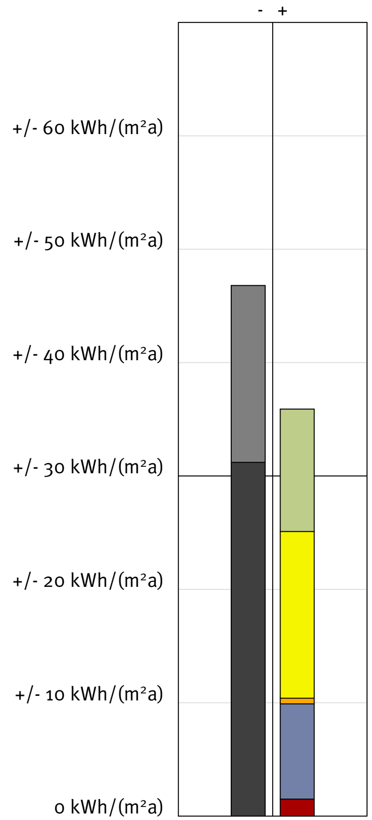
- heating
- cooling
- hot water
- lighting
- ventilation
- electricity from CHP
- electricity from photovoltaic



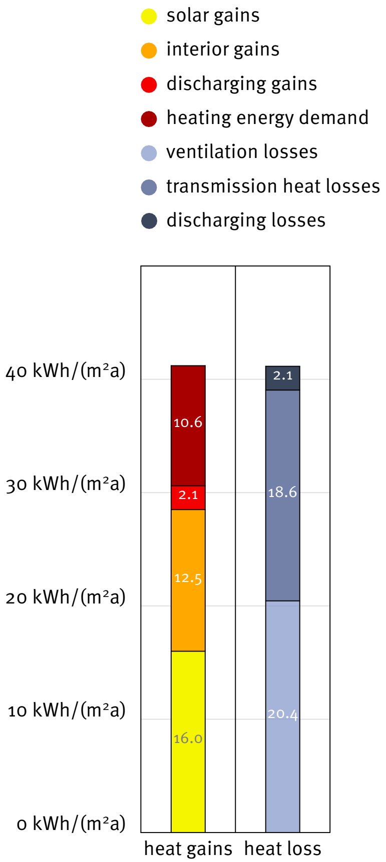
DISTRIBUTION OF PRIMARY ENERGY DEMAND



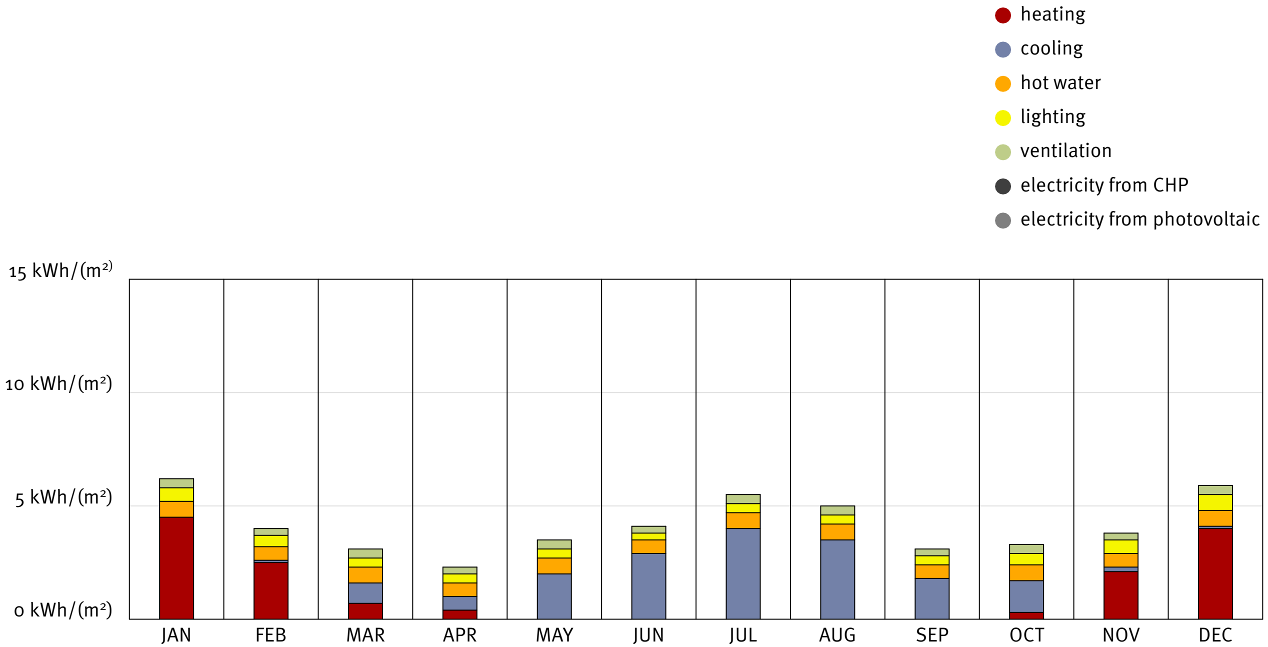
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER MONTH



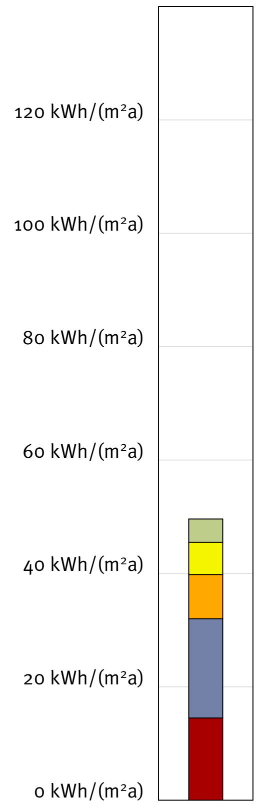
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER YEAR



HEATING ENERGY BALANCE



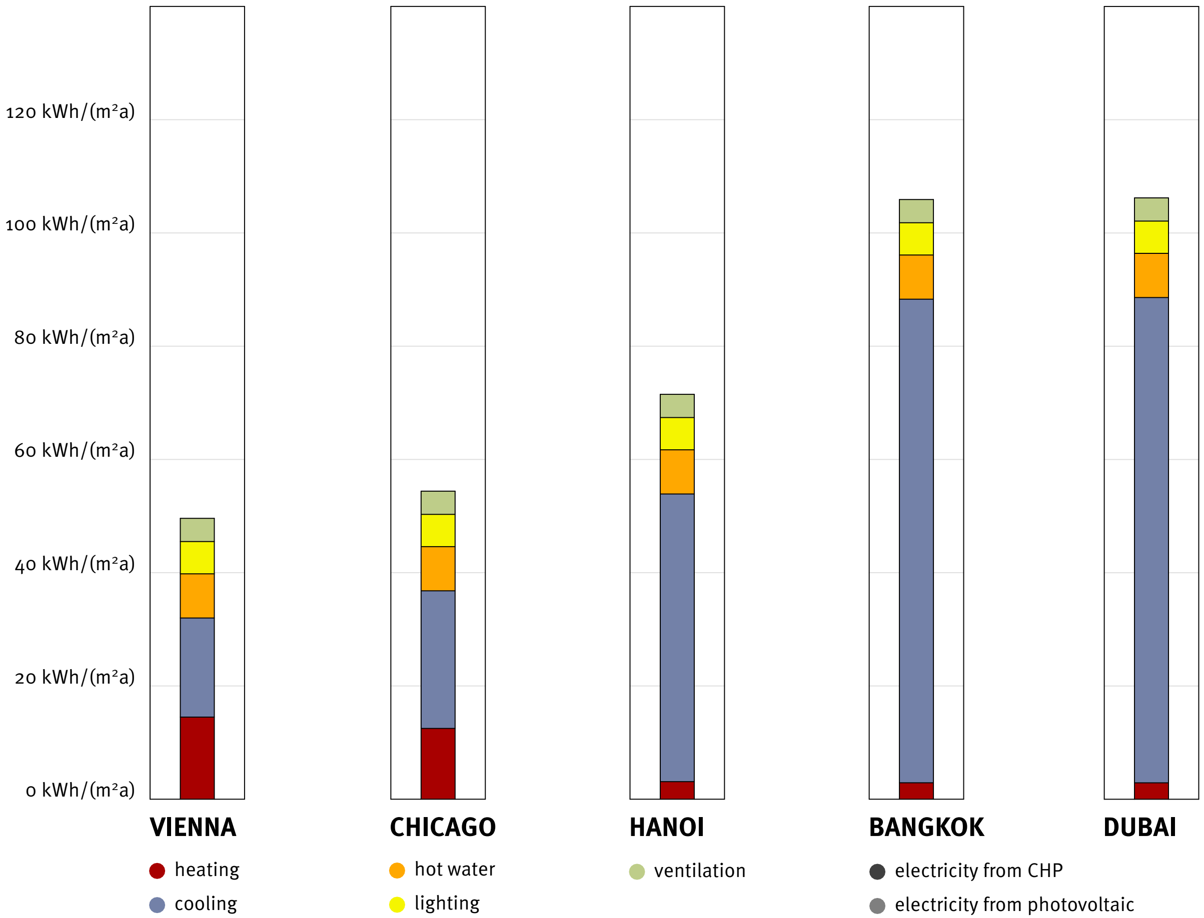
EFFECTVE ENERGY PER MONTH



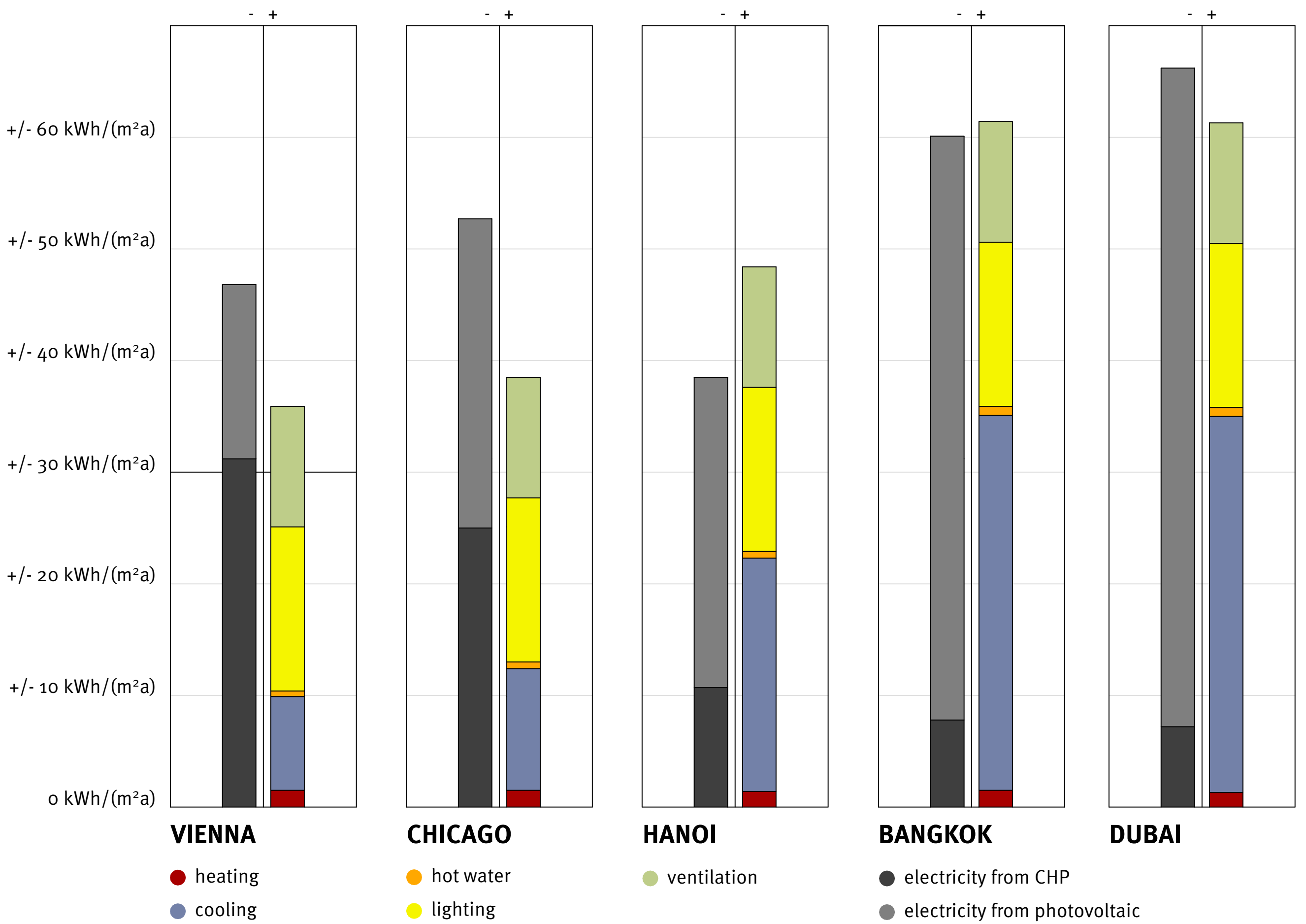
EFFECTVE ENERGY PER YEAR

3. COMPARISON

ANALYSIS. It has to be said, that the comparison of the buildings is on a high level of energy efficiency and ecology. As the building's parameters and service systems of the design for Vienna is at the highest level which is possible, the building, if transferred to other climates, also reaches good values.
That is why a comparison of the effective energy consumption per year gives you a good insight into the energy consumption of the building's design without considering the building's service systems. You can see, that especially the energy demand for cooling varies a lot. Also the energy demand for heating diversifies a little bit. The value for hot water, air conditioning and lighting remain the same, so do the areas and zones. Moreover, the program EnerCalC does not consider the environmental illuminance and the degree of reflection from surrounding facades. This would reduce the energy demand for lighting in Bangkok and Dubai.
The second chart shows a comparison of the primary



EFFECTIVE ENERGY CONSUMPTION PER YEAR



PRIMARY ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER YEAR

energy demands of the building in different climate zones. Noticeable is, that the energy demand for cooling, heating and hot water can be lowered due to building's service systems, while the energy demand for lighting and ventilating slightly increases. The primary energy demand for heating is always between 1.3 and 1.5 kWh/(m²a), because the efficiency of the heat recovery is denoted with 40 %. If there was no heat recovery it would be nearly 10 times higher in Vienna while it would only increase three times in hot climates such as Bangkok. The cooling energy demand in Vienna is the lowest. Even in Chicago it is higher, because of Vienna's temperate climate without extremes. The summers of Chicago get warmer than the ones of Vienna and therefore, there are more cooling degree days. In warmer climates such as Hanoi, the cooling energy demand rises to 21.1 kWh/(m²a) and in hot climates such as Bangkok and Dubai it is almost 4 times higher. Moreover, the building is capable of producing its own electricity. On the one hand, it has integrated heat recovery in form of CHP. Unfortunately, the program only connects heating and the producing of hot water to heat recovery. That is why the output is higher in climates with more heating degree days. To counteract, there are photovoltaic elements installed on the facade which are more efficient in hot climates such as Bangkok and Dubai.

COMPARISON OF THE PRIMARY ENERGY DEMANDS AND CO_2 EMISSIONS

PRIMARY ENERGY DEMAND	35.9 kWh/(m²a)
HEATING	1.5 kWh/(m²a)
COOLING	8.4 kWh/(m²a)
HOT WATER	0.5 kWh/(m²a)
VENTILATION	10.8 kWh/(m²a
LIGHTING	14.7 kWh/(m²a)
ENERGY PRODUCTION ON-SITE	-46.8 kWh/(m²a)
TOTAL PRIMARY ENERGY DEMAND	**-10.9 kWh/(m²a)**
CO2 EMISSIONS	8.7 kgCO2/(m²a)
CO2 EMISSIONS CREDIT	-11.4 kgCO2/(m²a)
TOTAL CO2 EMISSIONS	**-2.7 kgCO2/(m²a)**

VIENNA

PRIMARY ENERGY DEMAND	38.6 kWh/(m²a)
HEATING	1.5 kWh/(m²a)
COOLING	10.9 kWh/(m²a)
HOT WATER	0.6 kWh/(m²a)
VENTILATION	10.8 kWh/(m²a)
LIGHTING	14.7 kWh/(m²a)
ENERGY PRODUCTION ON-SITE	-52.7 kgCO2/(m²a)
TOTAL PRIMARY ENERGY DEMAND	**-14.2 kgCO2/(m²a)**
CO2 EMISSIONS	9.4 kgCO2/(m²a)
CO2 EMISSIONS CREDIT	-12.8 kgCO2/(m²a)
TOTAL CO2 EMISSIONS	**-3.4 kgCO2/(m²a)**

CHICAGO

PRIMARY ENERGY DEMAND	48.4 kWh/(m^{2}a)
HEATING	1.4 kWh/(m^{2}a)
COOLING	20.9 kWh/(m^{2}a)
HOT WATER	0.6 kWh/(m^{2}a)
VENTILATION	10.8 kWh/(m^{2}a)
LIGHTING	14.7 kWh/(m^{2}a)
ENERGY PRODUCTION ON-SITE	-38.6 kgCO_2/(m^{2}a)
TOTAL PRIMARY ENERGY DEMAND	**9.8 kgCO_2/(m^{2}a)**
CO_2 EMISSIONS	11.8 kgCO_2/(m^{2}a)
CO_2 EMISSIONS CREDIT	-9.4 kgCO_2/(m^{2}a)
TOTAL CO_2 EMISSIONS	**2.4 kgCO_2/(m^{2}a)**

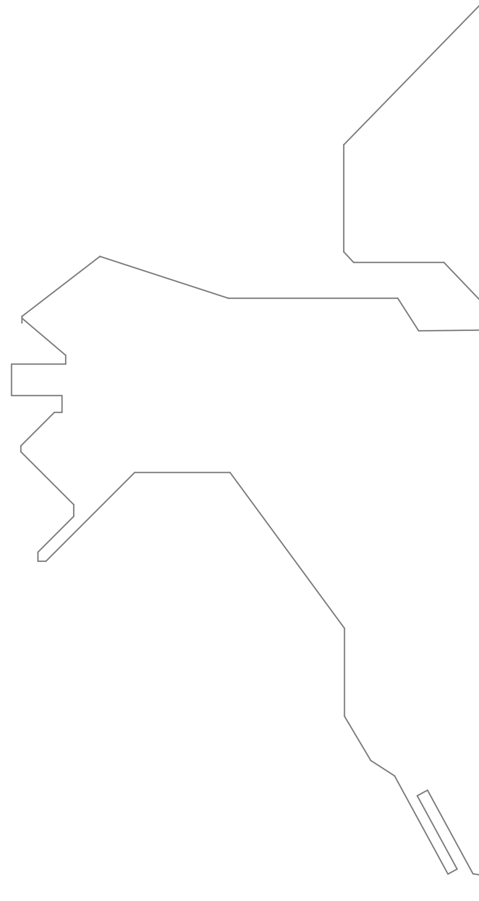
HANOI

PRIMARY ENERGY DEMAND	61.2 kWh/(m^{2}a)
HEATING	1.4 kWh/(m^{2}a)
COOLING	33.6 kWh/(m^{2}a)
HOT WATER	0.8 kWh/(m^{2}a)
VENTILATION	10.8 kWh/(m^{2}a)
LIGHTING	14.7 kWh/(m^{2}a)
ENERGY PRODUCTION ON-SITE	-60.1 kgCO_2/(m^{2}a)
TOTAL PRIMARY ENERGY DEMAND	**1.1 kgCO_2/(m^{2}a)**
CO_2 EMISSIONS	14.9 kgCO_2/(m^{2}a)
CO_2 EMISSIONS CREDIT	-14.6 kgCO_2/(m^{2}a)
TOTAL CO_2 EMISSIONS	**0.3 kgCO_2/(m^{2}a)**

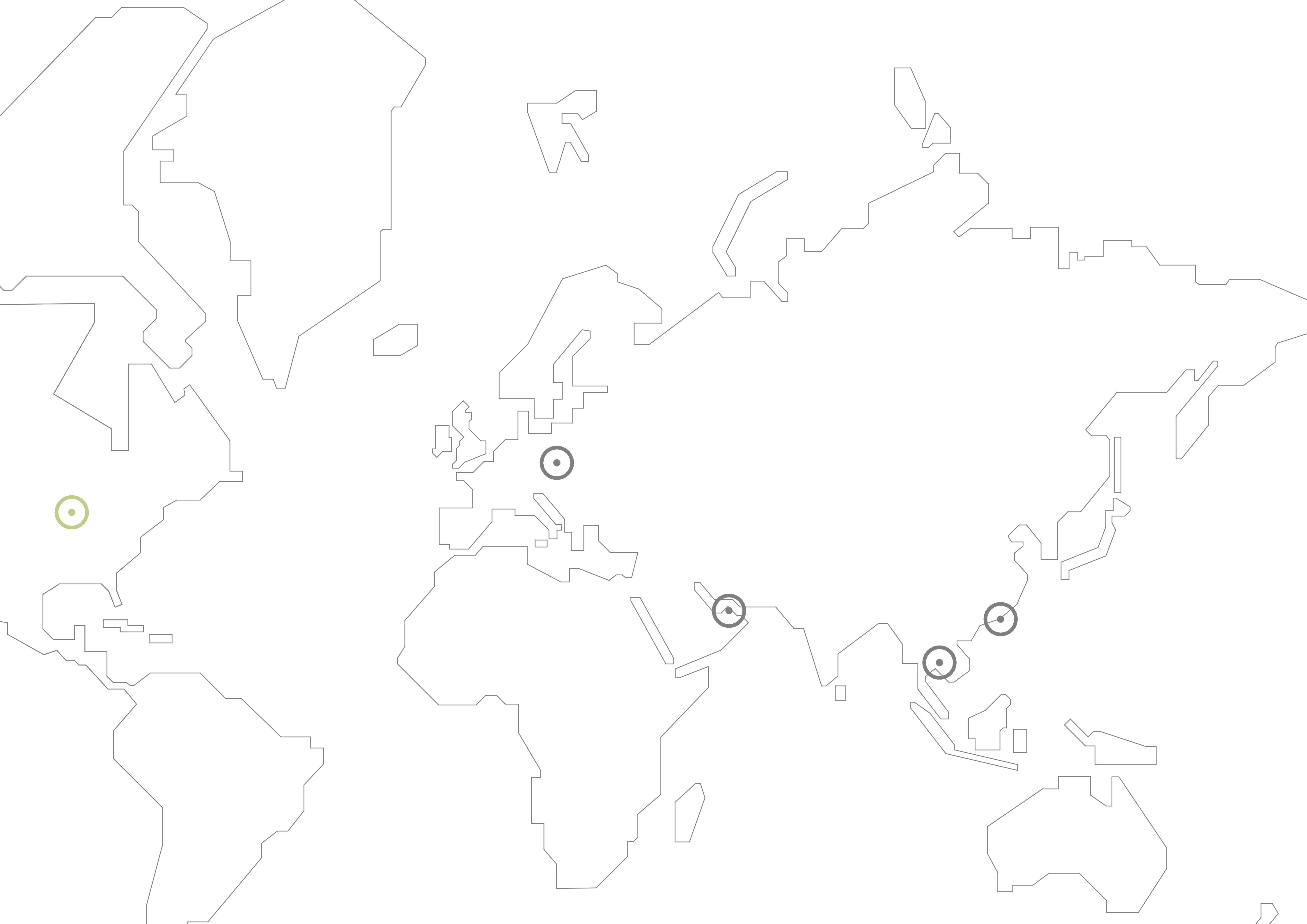
BANGKOK

PRIMARY ENERGY DEMAND	61.4 kWh/(m^{2}a)
HEATING	1.3 kWh/(m^{2}a)
COOLING	33.7 kWh/(m^{2}a)
HOT WATER	0.8 kWh/(m^{2}a)
VENTILATION	10.8 kWh/(m^{2}a)
LIGHTING	14.7 kWh/(m^{2}a)
ENERGY PRODUCTION ON-SITE	-66.1 kgCO_2/(m^{2}a)
TOTAL PRIMARY ENERGY DEMAND	**-4.7 kgCO_2/(m^{2}a)**
CO_2 EMISSIONS	14.9 kgCO_2/(m^{2}a)
CO_2 EMISSIONS CREDIT	-16.1 kgCO_2/(m^{2}a)
TOTAL CO_2 EMISSIONS	**-1.2 kgCO_2/(m^{2}a)**

DUBAI



chicago

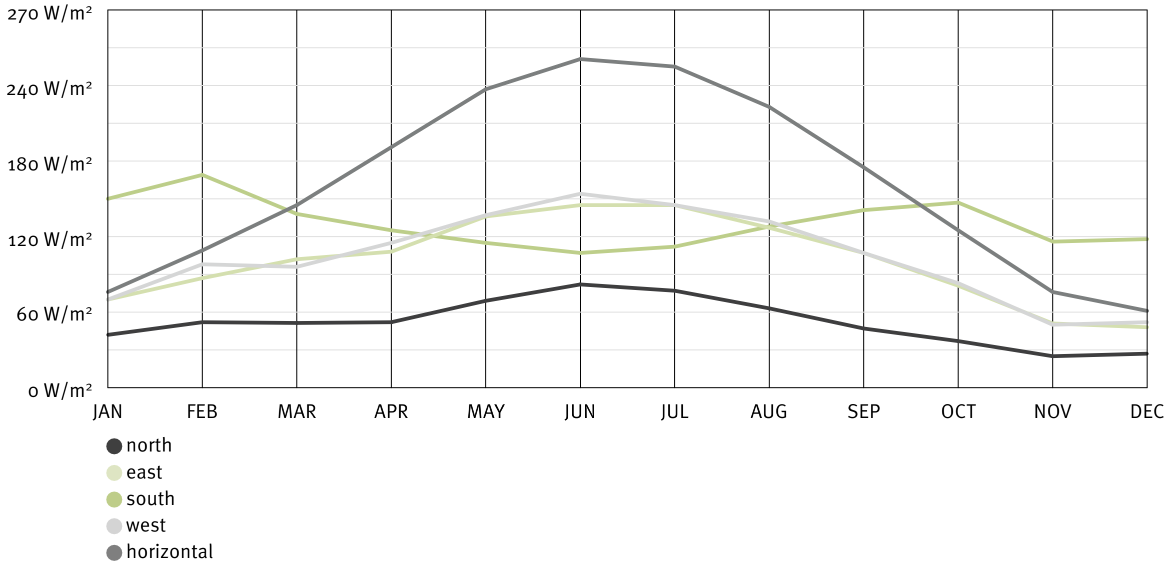


4.1. BUILDING | CHICAGO

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	TEMPERATURE	°C	-5,4	-2,8	3,6	10,1	15,6	21,1	23,8	23,0	19,1	12,6	5,3	-2,1
SOLAR RADIATION	HORIZONTAL	W/m²	76	109	145	191	237	261	255	223	175	125	76	61
SOLAR RADIATION	SOUTH	W/m²	150	169	138	125	115	107	112	128	141	147	116	118
SOLAR RADIATION	SOUTH-EAST	W/m²	120	133	129	124	134	135	138	137	133	122	92	90
SOLAR RADIATION	SOUTH-WEST	W/m²	119	146	123	131	136	139	137	140	133	125	90	95
SOLAR RADIATION	EAST	W/m²	70	87	102	108	136	145	145	127	107	81	51	48
SOLAR RADIATION	WEST	W/m²	70	98	96	115	137	154	145	132	107	83	50	52
SOLAR RADIATION	NORTH-WEST	W/m²	43	58	63	77	103	124	113	95	67	45	26	28
SOLAR RADIATION	NORTH-EAST	W/m²	43	56	65	74	103	115	113	91	67	45	26	28
SOLAR RADIATION	NORTH	W/m²	42	52	51	52	69	82	77	63	47	37	25	27

DATA OF THE BUILDING. The building for Chicago counts 17 regular floors and 3 floors in the canted roof area. The floor's height is with 3.3 meters the same as for Vienna but the gross floor area is 1,375 m². The total gross floor area of the building is 25,700 m² and the building volume is 81,400 m³. The glazing percentage is also the same as for Vienna: South 70 %, West and East 60% and North 50%. It is the same, because otherwise the lighting energy demand would increase more than the cooling energy demand would sink.

Ill. 136 | SOLAR RADIATION OF CHICAGO

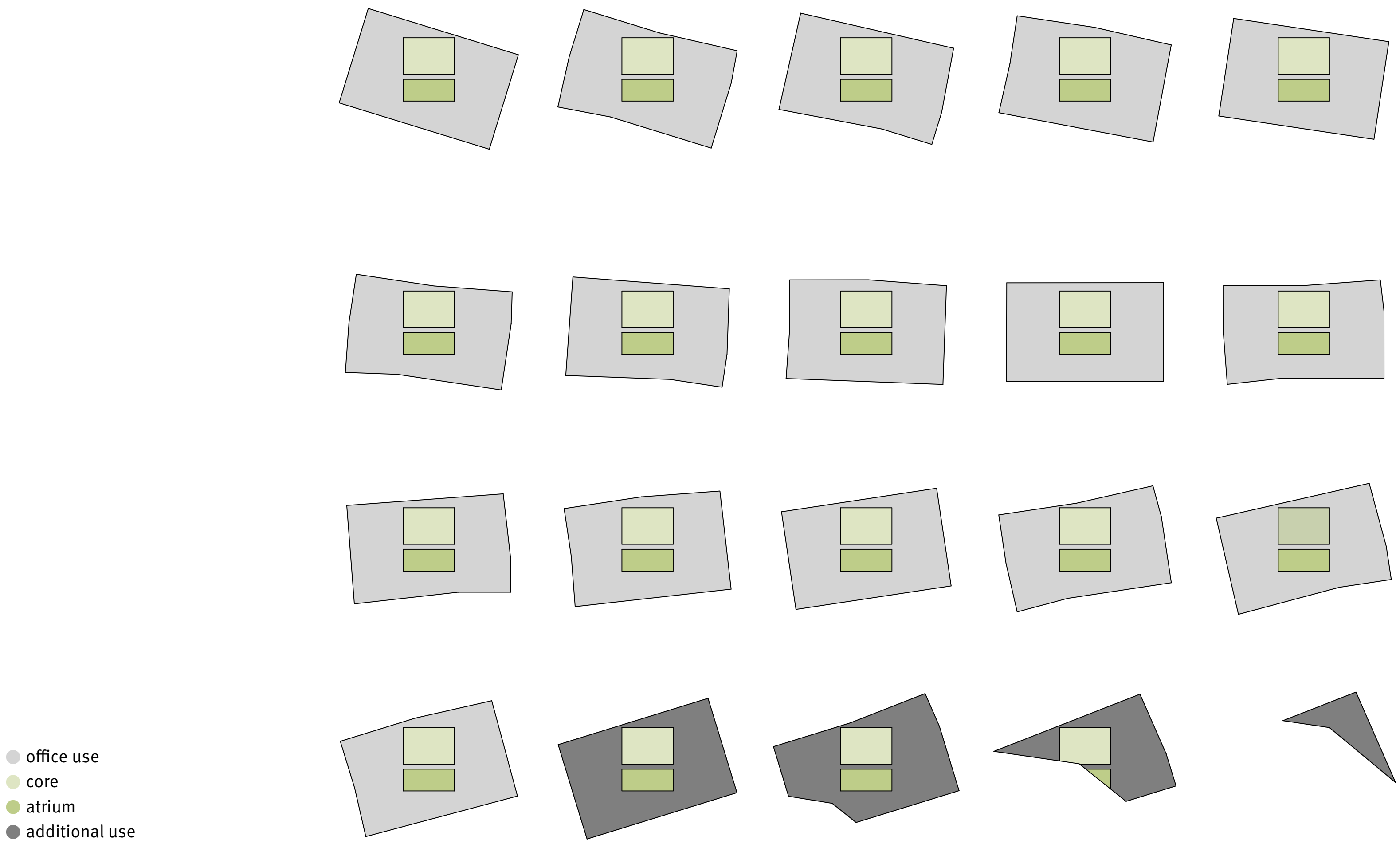


	DESIGN CHICAGO	DESIGN VIENNA
EFFECTIVE ENERGY DEMAND	**52.9 kWh/(m²a)**	**54.4 kWh/(m²a)**
HEATING	12.7 kWh/(m²a)	12.5 kWh/(m²a)
COOLING	23.9 kWh/(m²a)	24.3 kWh/(m²a)
HOT WATER	7.4 kWh/(m²a)	7.8 kWh/(m²a)
VENTILATION	3.9 kWh/(m²a)	4.1 kWh/(m²a)
LIGHTING	5.0 kWh/(m²a)	5.7 kWh/(m²a)

	DESIGN CHICAGO	DESIGN VIENNA
PRIMARY ENERGY DEMAND	36.1 kWh/(m²a)	38.6 kWh/(m²a)
HEATING	1.5 kWh/(m²a)	1.5 kWh/(m²a)
COOLING	10.9 kWh/(m²a)	10.9 kWh/(m²a)
HOT WATER	0.6 kWh/(m²a)	0.6 kWh/(m²a)
VENTILATION	10.1 kWh/(m²a)	10.8 kWh/(m²a)
LIGHTING	13.1 kWh/(m²a)	14.7 kWh/(m²a)
ENERGY PRODUCTION ON-SITE	-51.1 kgCO2/(m²a)	-52.7 kgCO2/(m²a)
TOTAL PRIMARY ENERGY DEMAND	**-15.0 kgCO2/(m²a)**	**-14.2 kgCO2/(m²a)**
CO2 EMISSIONS	8.8 kgCO2/(m²a)	9.4 kgCO2/(m²a)
CO2 EMISSIONS CREDIT	-12.4 kgCO2/(m²a)	-12.8 kgCO2/(m²a)
TOTAL CO2 EMISSIONS	**-3.6 kgCO2/(m²a)**	**-3.4 kgCO2/(m²a)**

ANALYSIS. If the building's parameters and building's service systems are identically to the ones for Vienna, the new design with the atrium at the center would reduce the primary energy demand by 1.6 kWh/(m²a), but the cooling energy demand would increase a little bit. To counteract, a suspended cooling ceiling is preferable for Chicago. The atrium at the center has a positive effect on the lighting energy demand and also on the ventilation system.
Although the climate is colder, a well-developed solar thermal system can be used for water heating as well as for heating support during the transitional periods. Also a photovoltaic system should be considered.

If you compare the effective energy demand of the design for Chicago with the one for Vienna in the cold climate, the energy demand for cooling, hot water, ventilation and lighting is lower. Only the energy demand for heating is higher with 0.2 kWh/(m²a), because a Southern atrium is preferable in summer but in all other cases the middle atrium is the better choice.

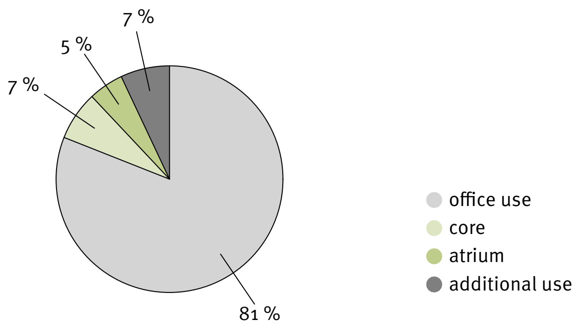


Ill. 137 | AREAS OF THE BUILDING

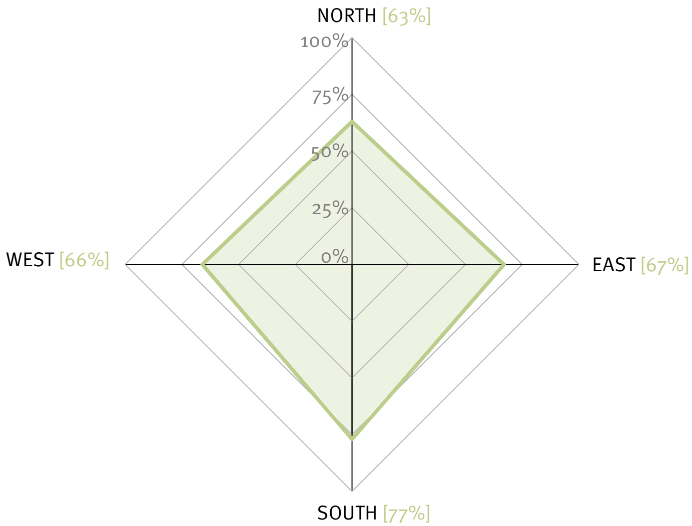
Showing each single floor with its zones.

		SOUTH	WEST	NORTH	EAST	HORIZ.
FACADE	m^2	3,818.8	2,455.1	2,597.9	2,209.2	-
WINDOWS	m^2	2,939.9	1,628.0	2,254.5	1,480.5	102.0
WALL	m^2	878.9	827.1	1,373.4	728.7	-
BASE PLATE	m^2					1,407.0
ROOF	m^2					1,331.5
VOLUME	m^3					81,417.0

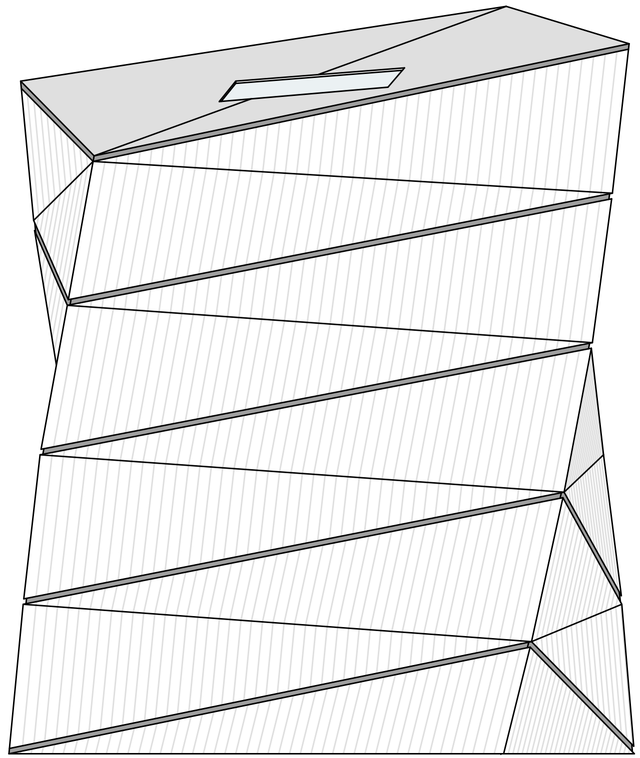
AREAS OF THE BUILDING



DISTRIBUTION OF ENERGY CONSUMING ZONES

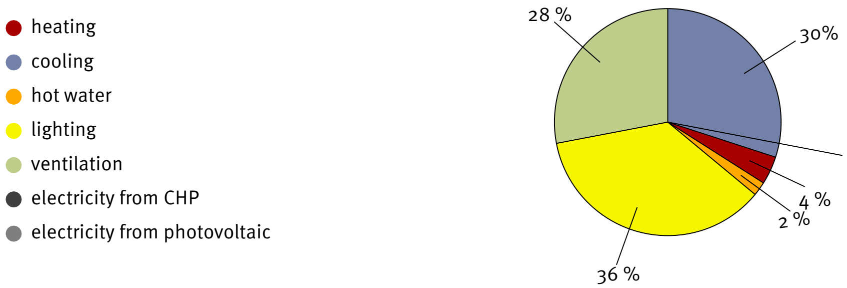


ORIENTATION OF THE WINDOWS

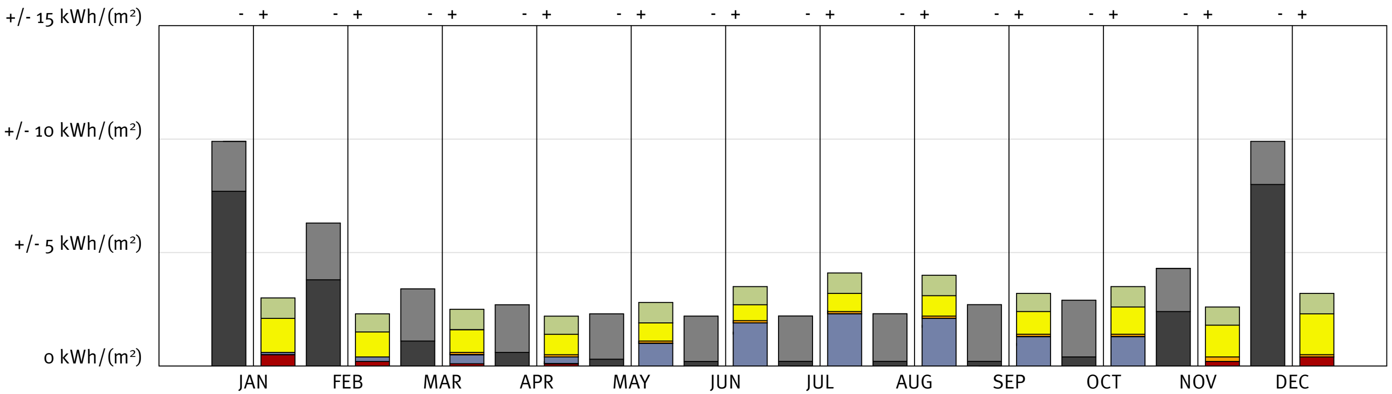


SOUTH ELEVATION OF THE BUILDING

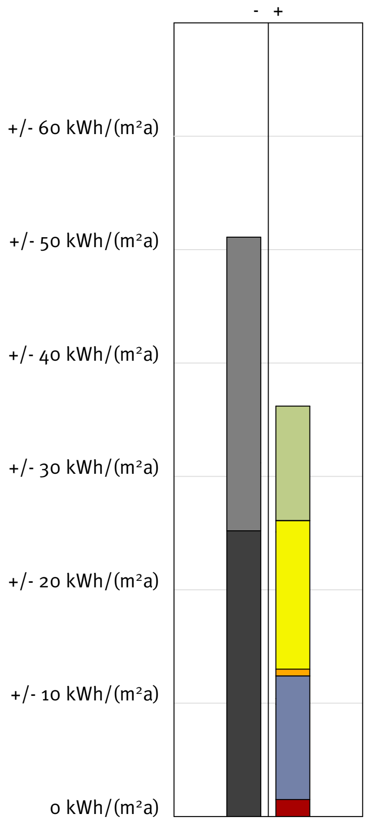
4.2. CHARTS | CHICAGO



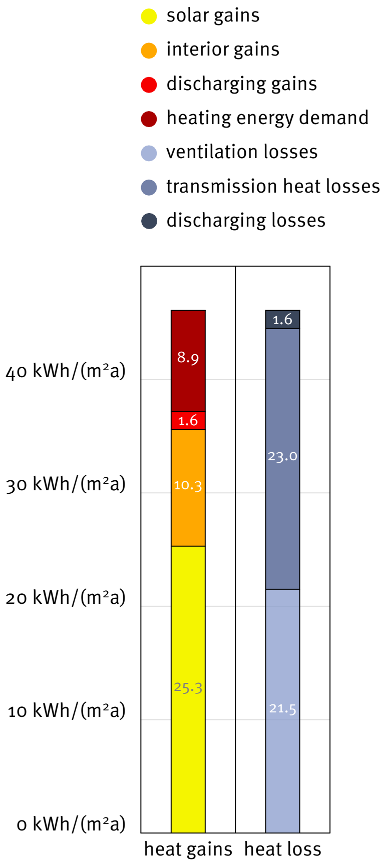
DISTRIBUTION OF PRIMARY ENERGY DEMAND



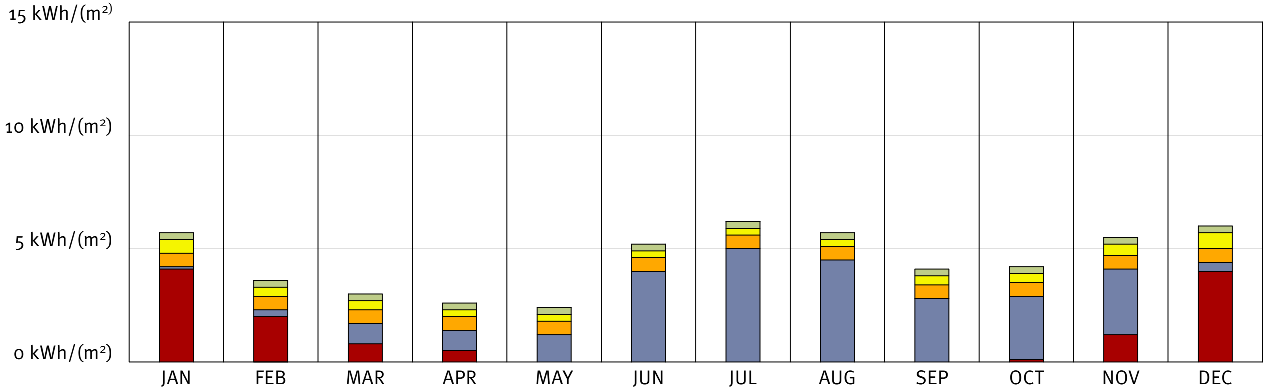
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER MONTH



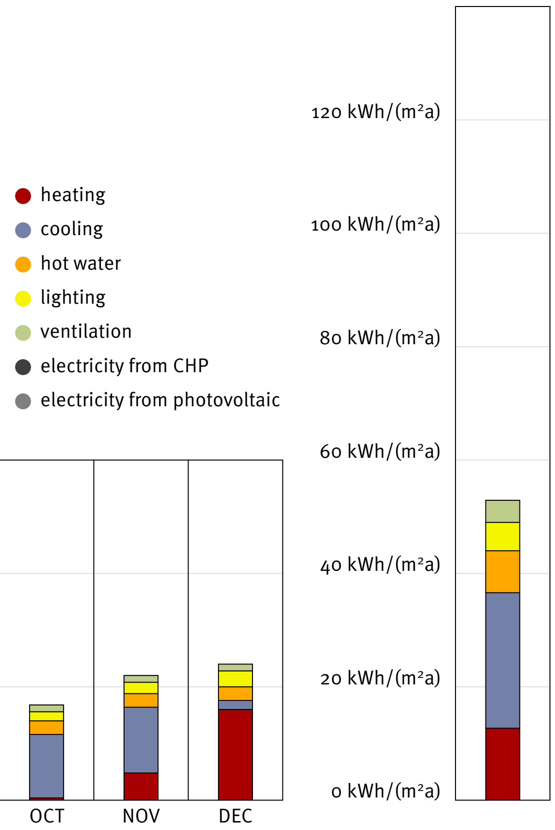
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER YEAR



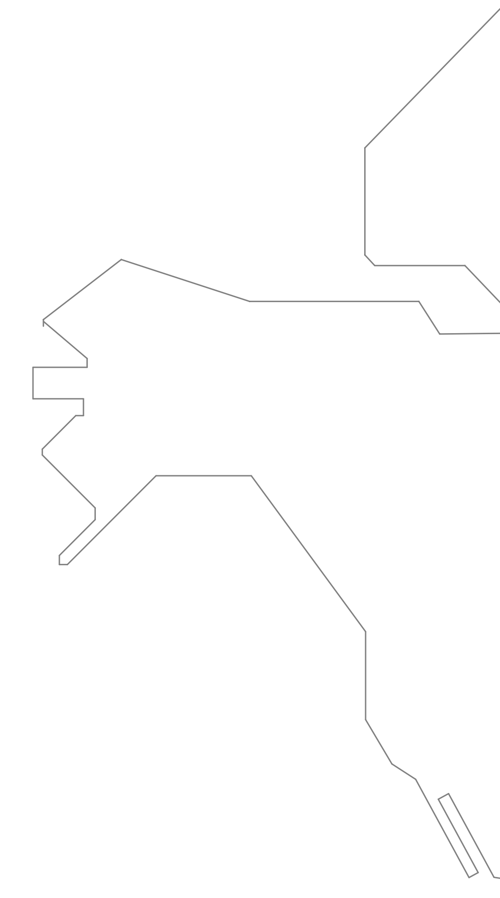
HEATING ENERGY BALANCE



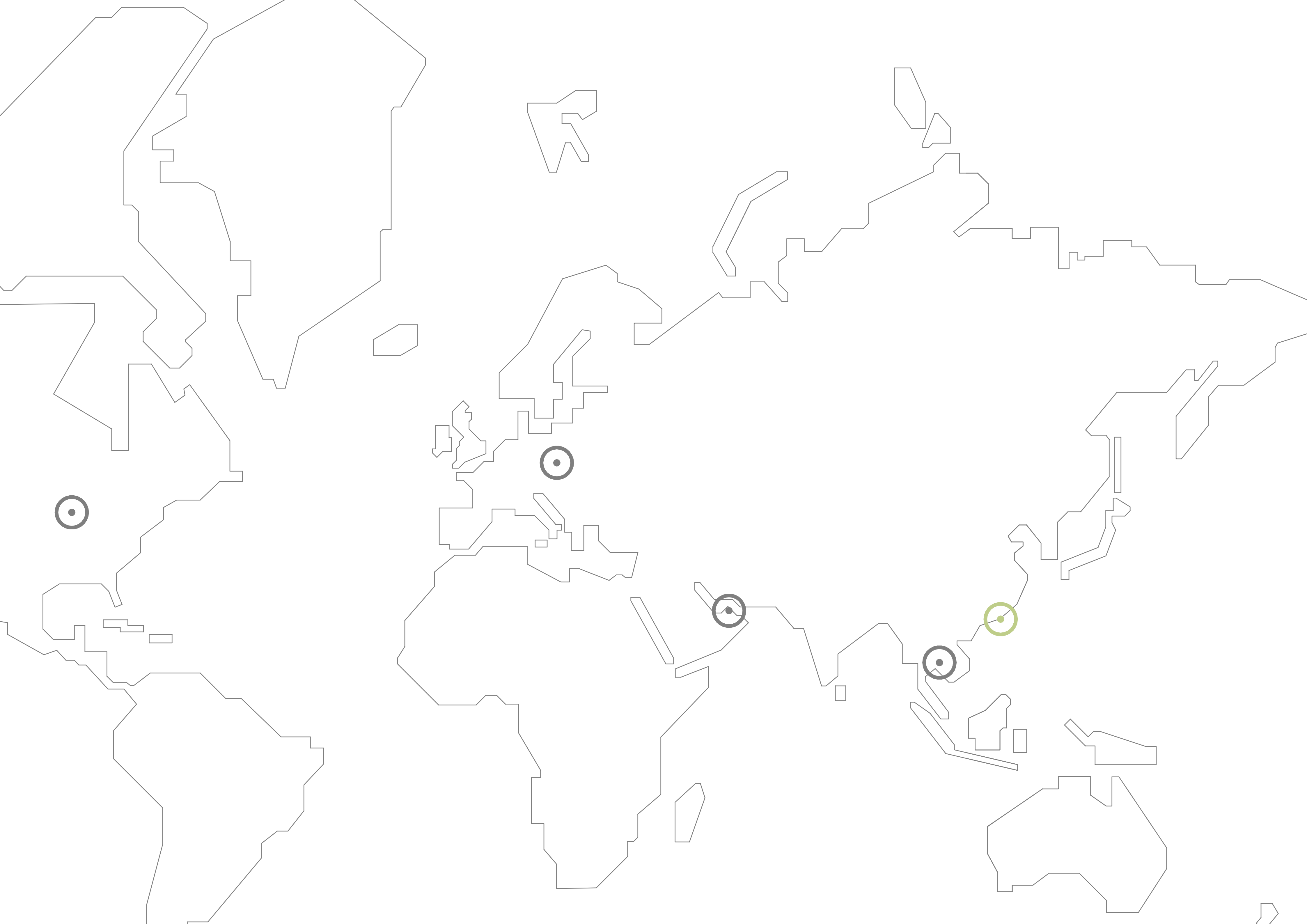
EFFECTVE ENERGY PER MONTH



EFFECTVE ENERGY PER YEAR



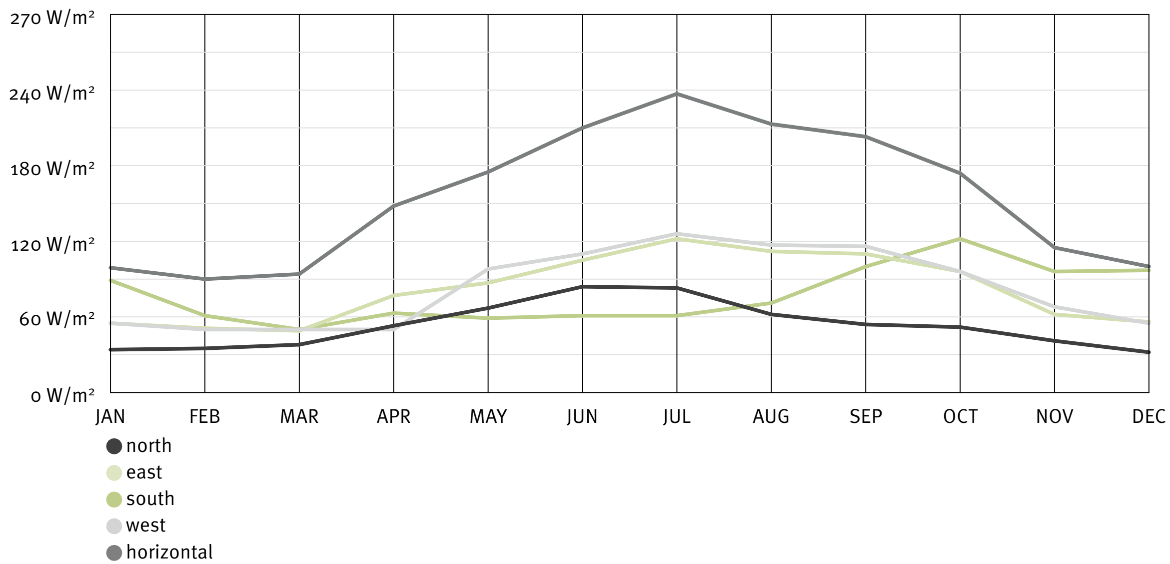
hanoi



5.1. BUILDING | HANOI

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	TEMPERATURE	°C	14,4	15,3	19,1	22,8	26,5	27,8	28,3	27,6	26,1	23,2	18,8	15,5
SOLAR RADIATION	HORIZONTAL	W/m²	99	90	94	148	175	210	237	213	203	174	115	100
	SOUTH	W/m²	89	61	50	63	59	61	61	71	100	122	96	97
	SOUTH-EAST	W/m²	75	58	51	73	77	84	97	99	112	115	80	81
	SOUTH-WEST	W/m²	76	56	52	76	83	87	99	103	118	114	87	79
	EAST	W/m²	55	51	49	77	87	105	122	112	110	96	62	56
	WEST	W/m²	55	49	50	80	98	110	126	117	116	96	68	55
	NORTH-WEST	W/m²	36	39	43	69	90	105	115	97	84	64	46	35
	NORTH-EAST	W/m²	36	39	43	66	81	100	112	93	81	65	45	35
	NORTH	W/m²	34	35	38	53	67	84	83	62	54	52	41	32

Ill. 148 | SOLAR RADIATION OF HANOI



DATA OF THE BUILDING. The building for Hanoi is a tower with 29 regular floors and 3 floors in the canted roof area. The floor's height is with 3.30 meters the same as in Vienna and Chicago. A regular floor has a gross floor area of about 750 m². The total gross floor area of the building is 23,000 m² and the building volume accounts for 73,800 m³. The glazing percentage is 70 % to the South, 60 % to the West and East and 50 % to the North. The building's core is at the Northern side of the building and it sticks out of the building.

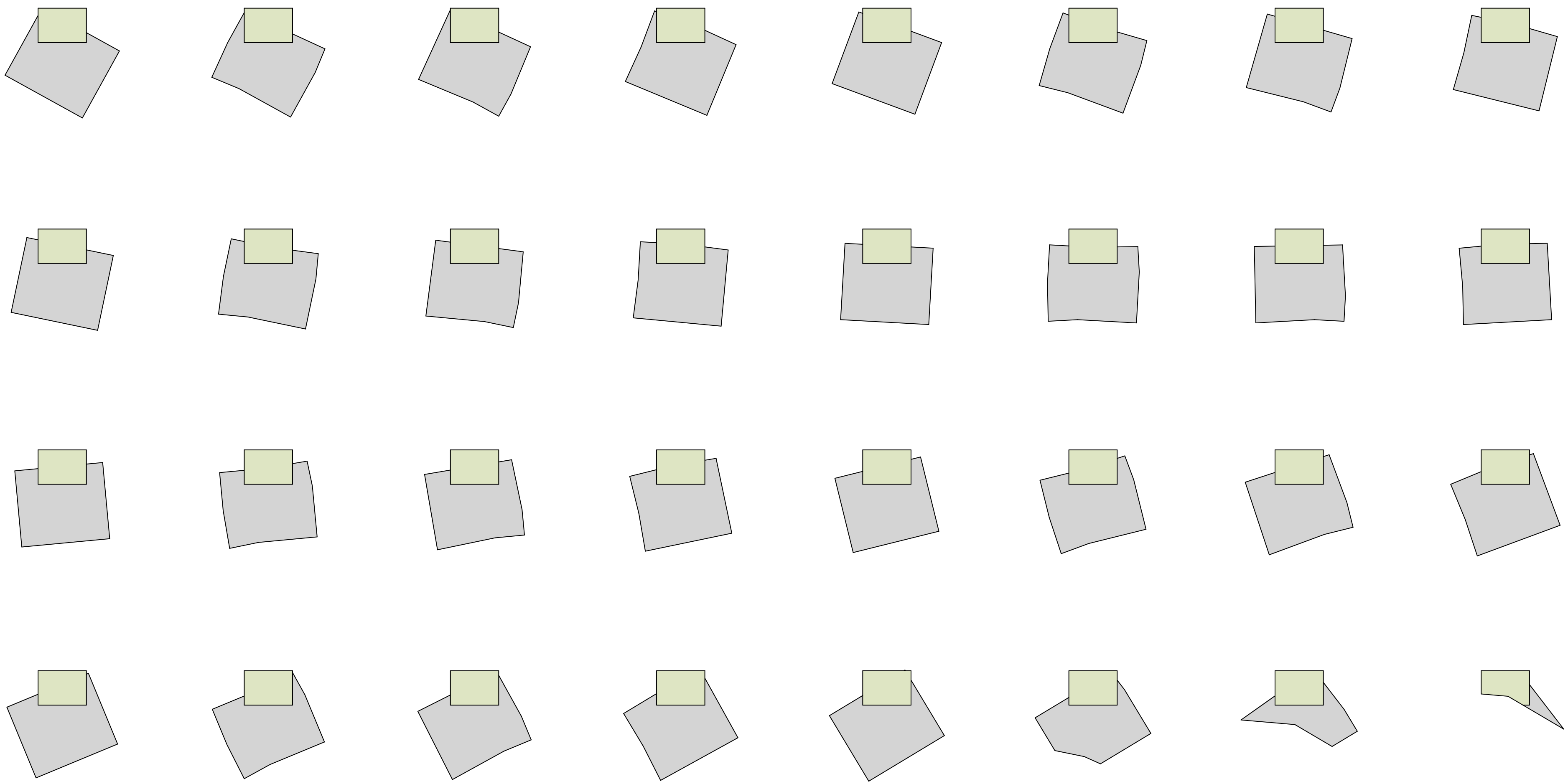
	DESIGN HANOI	DESIGN VIENNA
EFFECTIVE ENERGY DEMAND	**61.2 kWh/(m²a)**	**71.5 kWh/(m²a)**
HEATING	3.6 kWh/(m²a)	3.1 kWh/(m²a)
COOLING	39.7 kWh/(m²a)	50.8 kWh/(m²a)
HOT WATER	7.9 kWh/(m²a)	7.8 kWh/(m²a)
VENTILATION	4.3 kWh/(m²a)	4.1 kWh/(m²a)
LIGHTING	5.7 kWh/(m²a)	5.7 kWh/(m²a)

	DESIGN HANOI	DESIGN VIENNA
PRIMARY ENERGY DEMAND	44.4 kWh/(m²a)	48.4 kWh/(m²a)
HEATING	1.4 kWh/(m²a)	1.4 kWh/(m²a)
COOLING	16.6 kWh/(m²a)	20.9 kWh/(m²a)
HOT WATER	0.6 kWh/(m²a)	0.6 kWh/(m²a)
VENTILATION	11.1 kWh/(m²a)	10.8 kWh/(m²a)
LIGHTING	14.7 kWh/(m²a)	14.7 kWh/(m²a)
ENERGY PRODUCTION ON-SITE	-40.5 kgCO2/(m²a)	-38.6 kgCO2/(m²a)
TOTAL PRIMARY ENERGY DEMAND	**3.9 kgCO2/(m²a)**	**9.8 kgCO2/(m²a)**
CO2 EMISSIONS	10.8 kgCO2/(m²a)	11.8 kgCO2/(m²a)
CO2 EMISSIONS CREDIT	-9.9 kgCO2/(m²a)	-9.4 kgCO2/(m²a)
TOTAL CO2 EMISSIONS	**0.9 kgCO2/(m²a)**	**2.4 kgCO2/(m²a)**

ANALYSIS. Most of the energy in the subtropics goes into cooling and dehumidifying. The low demand for heating can be met by renewable heat sources such as ground source heat pumps. Solar collectors can also be used for heating as well as for providing hot water and cooling. Moreover, photovoltaic systems have high outputs in subtropical areas.

As the climate is very different from the one in Vienna, some meaningful changes have to be made to reach better values. Thermal insulation glass, for example, is not the right glazing for the subtropics. Sun protection glass with a U-value of 1.17 W/(m²K) is the better choice. Furthermore, suspended cooling ceilings should be integrated into the building instead of just using concrete core activation.
Unfortunately, the program does not allow CHP in combination with cooling. That is the reason for the high energy demand in cooling.

The design of the tower can reduce the effective energy demand remarkably by 10.3 kWh/(m²a).

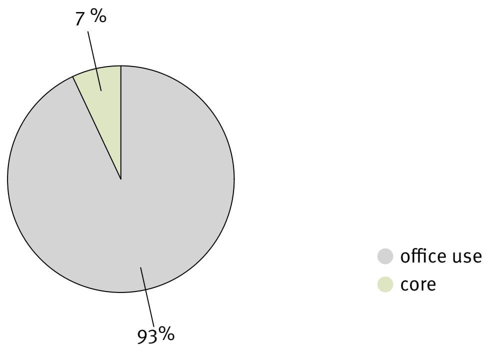


Ill. 149 | AREAS OF THE BUILDING

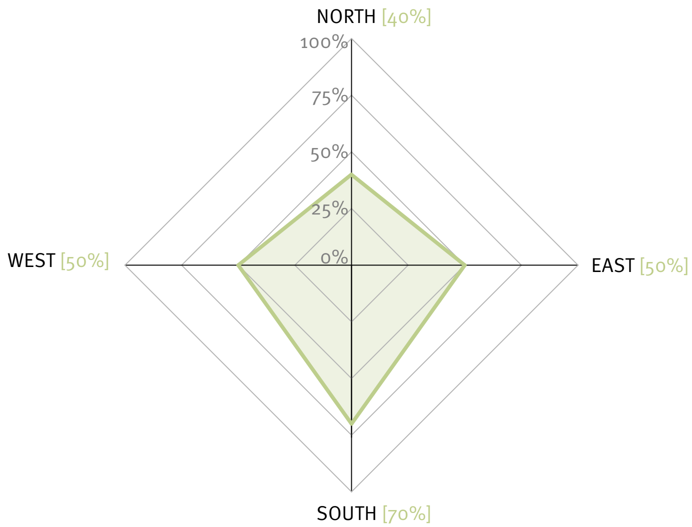
Showing each single floor with its zones.

		SOUTH	WEST	NORTH	EAST	HORIZ.
FACADE	m²	7,791.9	2,925.5	6,902.1	3,341.7	-
WINDOWS	m²	3,116.8	585.1	1,380.4	1,002.5	-
WALL	m²	4,675.2	2,340.4	5,521.7	2,339.2	-
BASE PLATE	m²					1,030.8
ROOF	m²					1,151.9
VOLUME	m³					71,211.0

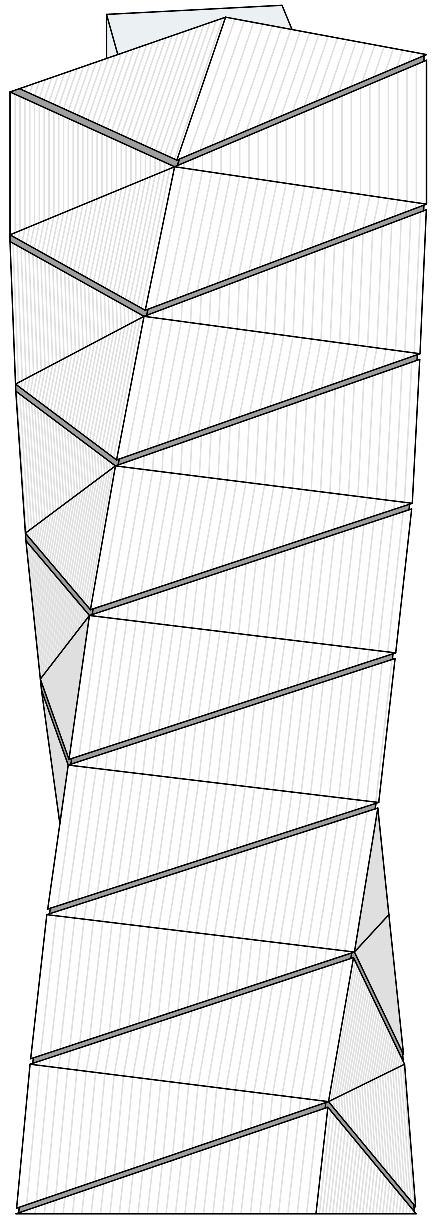
AREAS OF THE BUILDING



DISTRIBUTION OF ENERGY CONSUMING ZONES

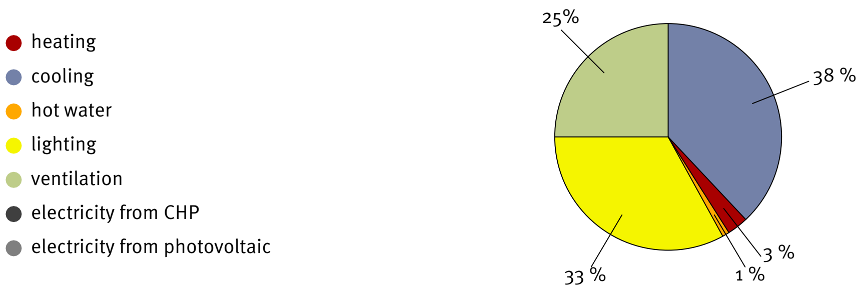


ORIENTATION OF THE WINDOWS

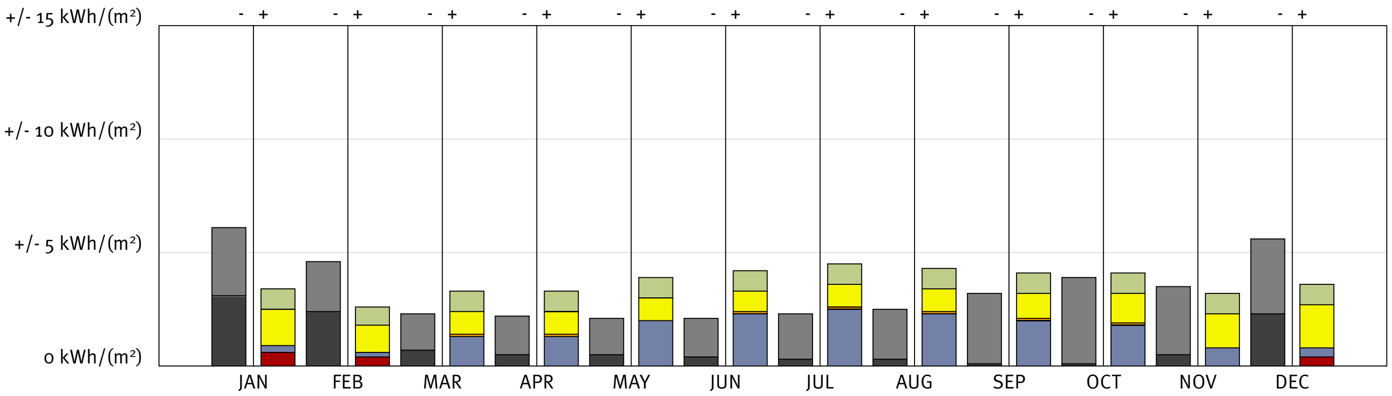


SOUTH ELEVATION OF THE BUILDING

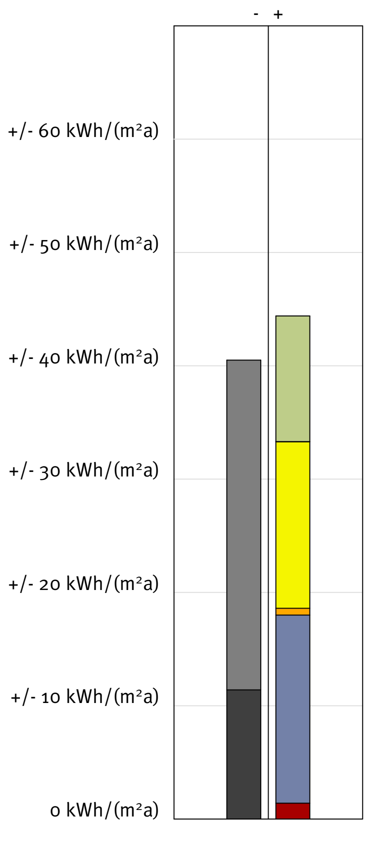
5.2. CHARTS | HANOI



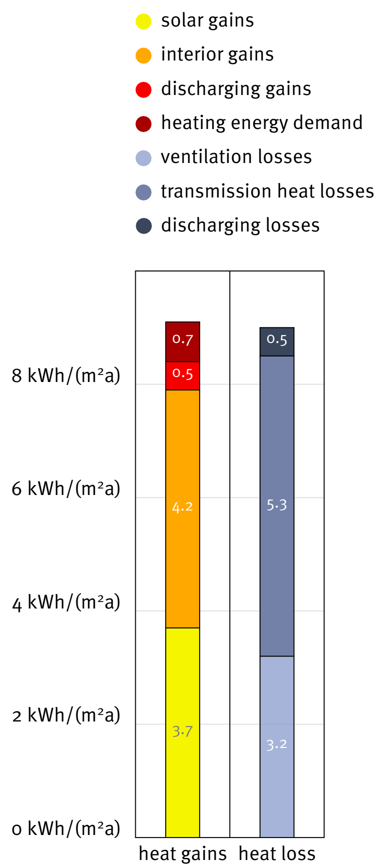
DISTRIBUTION OF PRIMARY ENERGY DEMAND



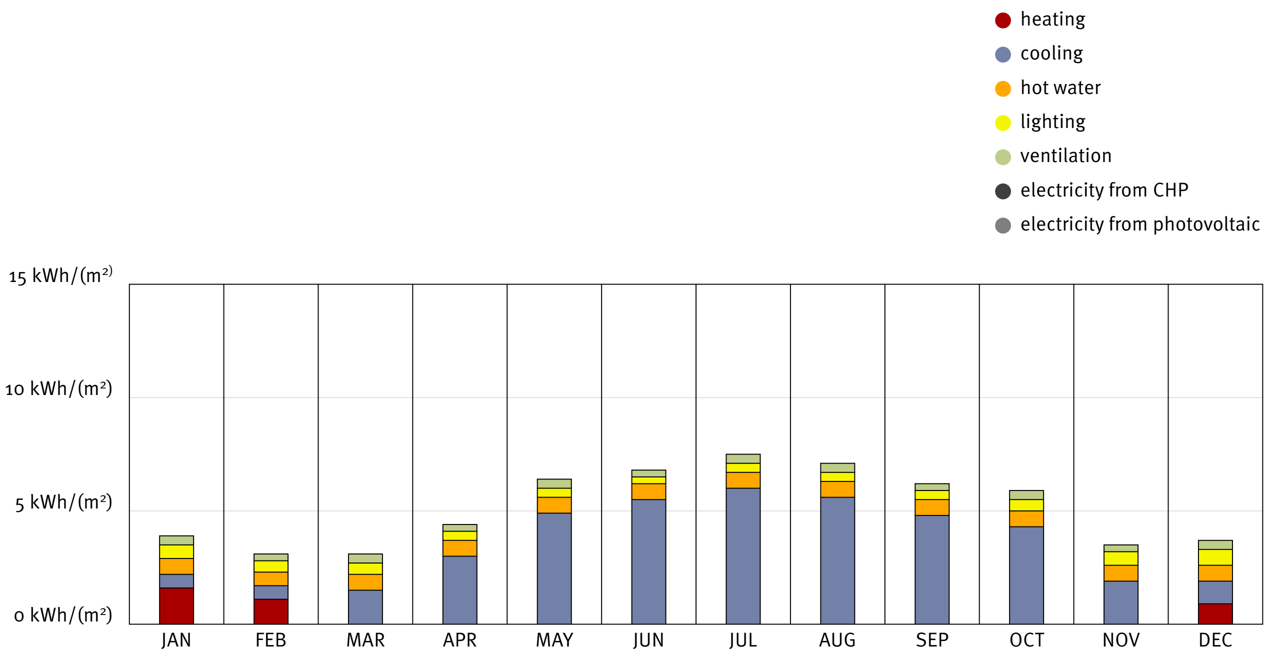
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER MONTH



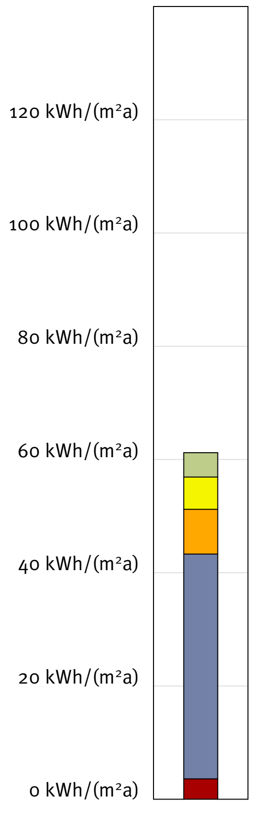
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER YEAR



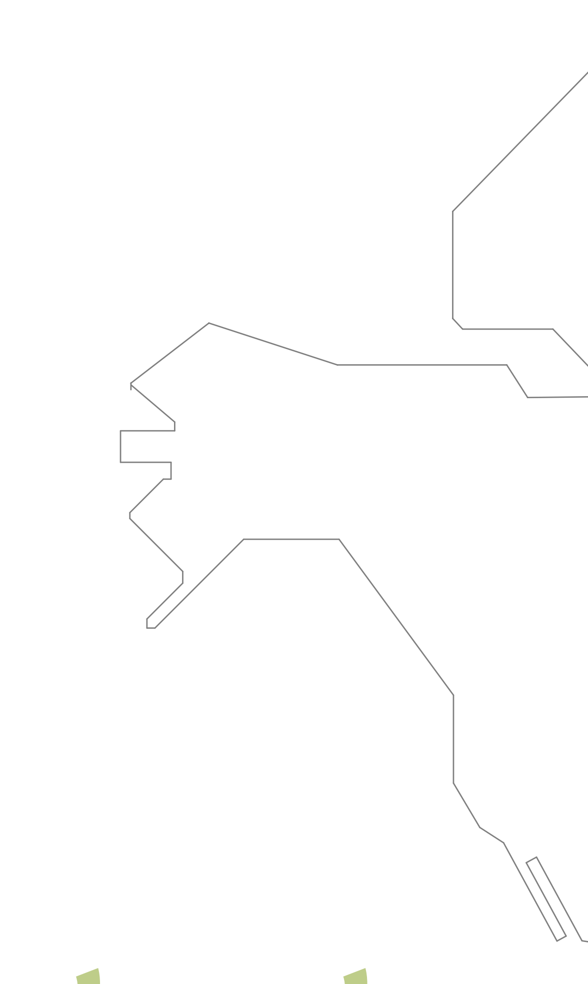
HEATING ENERGY BALANCE



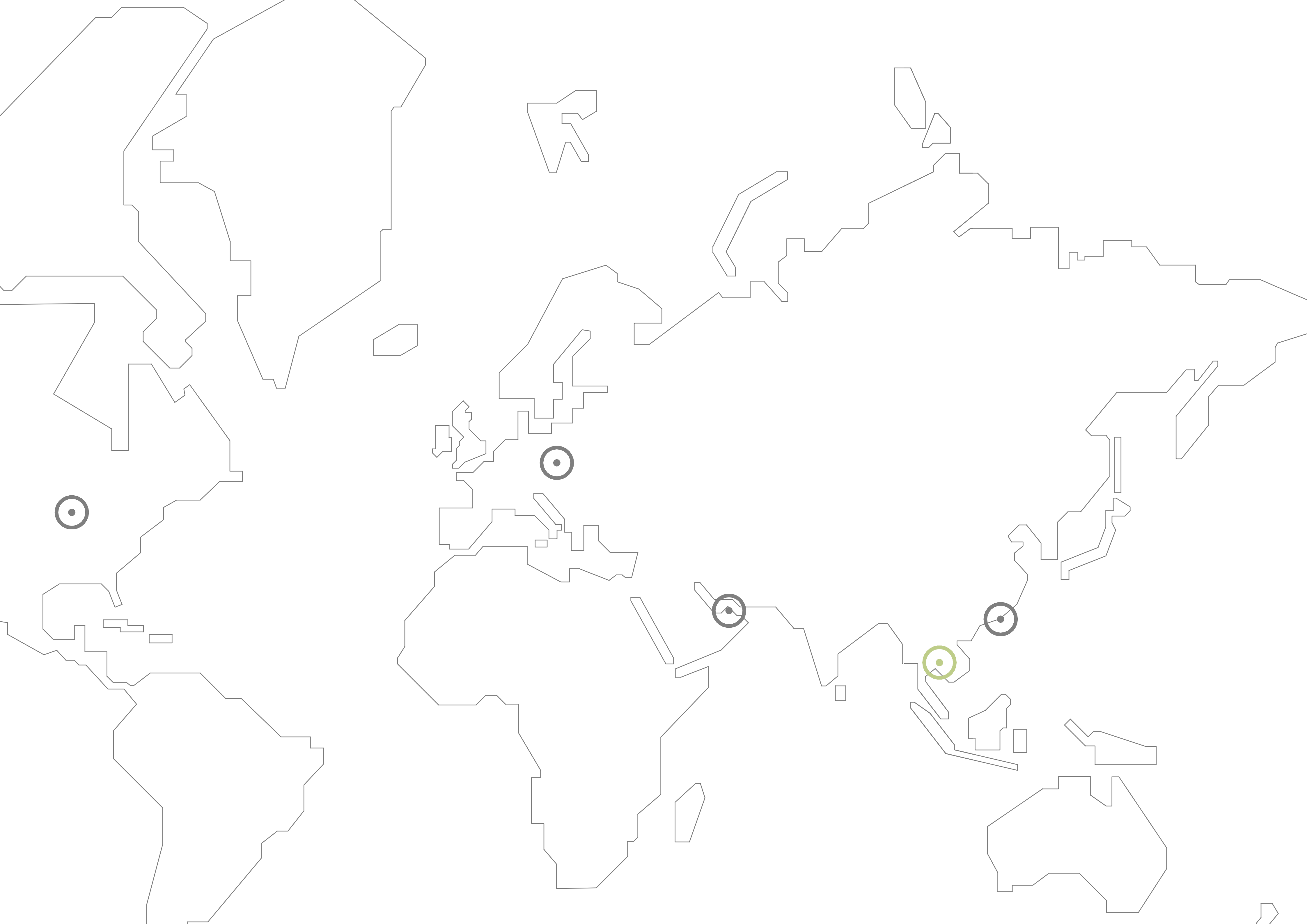
EFFECTVE ENERGY PER MONTH



EFFECTVE ENERGY PER YEAR



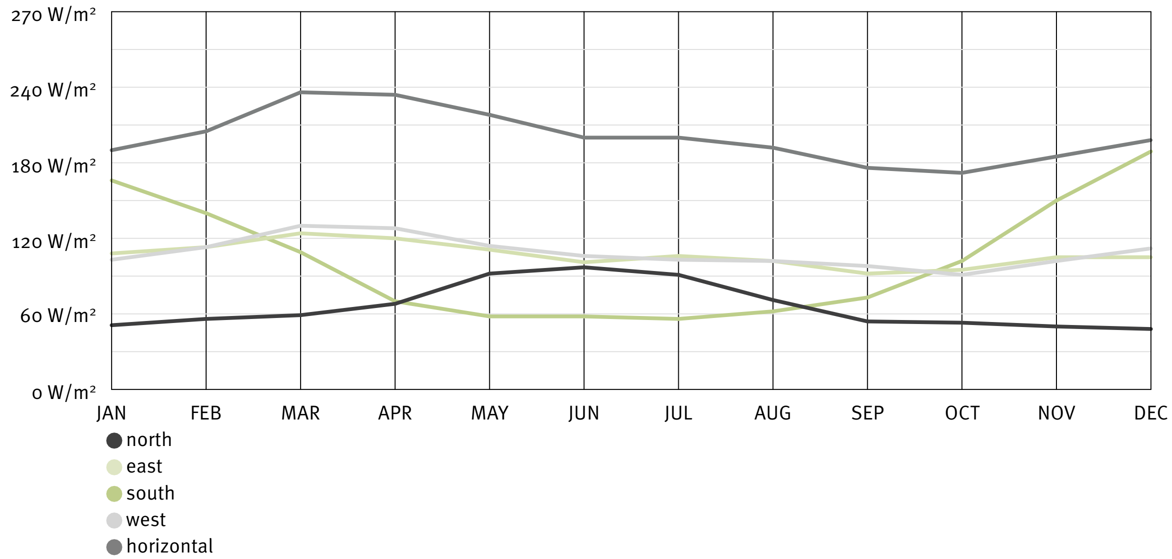
bangkok



6.1. BUILDING | BANGKOK

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	TEMPERATURE	°C	27,2	28,3	28,8	29,3	28,6	28,1	28,0	28,1	28,3	28,3	27,7	26,8
SOLAR RADIATION	HORIZONTAL	W/m²	190	205	236	234	218	200	200	192	176	172	185	198
	SOUTH	W/m²	166	140	109	70	58	58	56	62	73	102	150	189
	SOUTH-EAST	W/m²	144	132	125	104	84	76	79	86	88	105	134	152
	SOUTH-WEST	W/m²	139	133	130	110	86	78	78	86	92	100	131	161
	EAST	W/m²	108	113	124	120	111	101	106	102	92	95	105	105
	WEST	W/m²	103	113	130	128	114	106	103	102	98	91	102	112
	NORTH-WEST	W/m²	60	72	93	108	110	107	102	93	78	67	61	57
	NORTH-EAST	W/m²	62	73	90	102	108	102	104	93	75	69	62	56
	NORTH	W/m²	51	56	59	68	92	97	91	71	54	53	50	48

Ill. 160 | SOLAR RADIATION OF BANGKOK



DATA OF THE BUILDING. The building for Bangkok consists of three separate towers. The Northern and Southern tower are for office use and the one in the middle is the central core for the development of the building. It consists of 21 regular floors and 3 floors in the canted roof area. The floor's height amounts to 3.30 meters and a regular floor has a gross floor area of about 1,030 m². The total gross floor area of the building is 22,700 m² and the building's volume is 71,200 m³. The glazing percentage is limited to 40% in the South, 30 % to the East and 20% to the West and North.

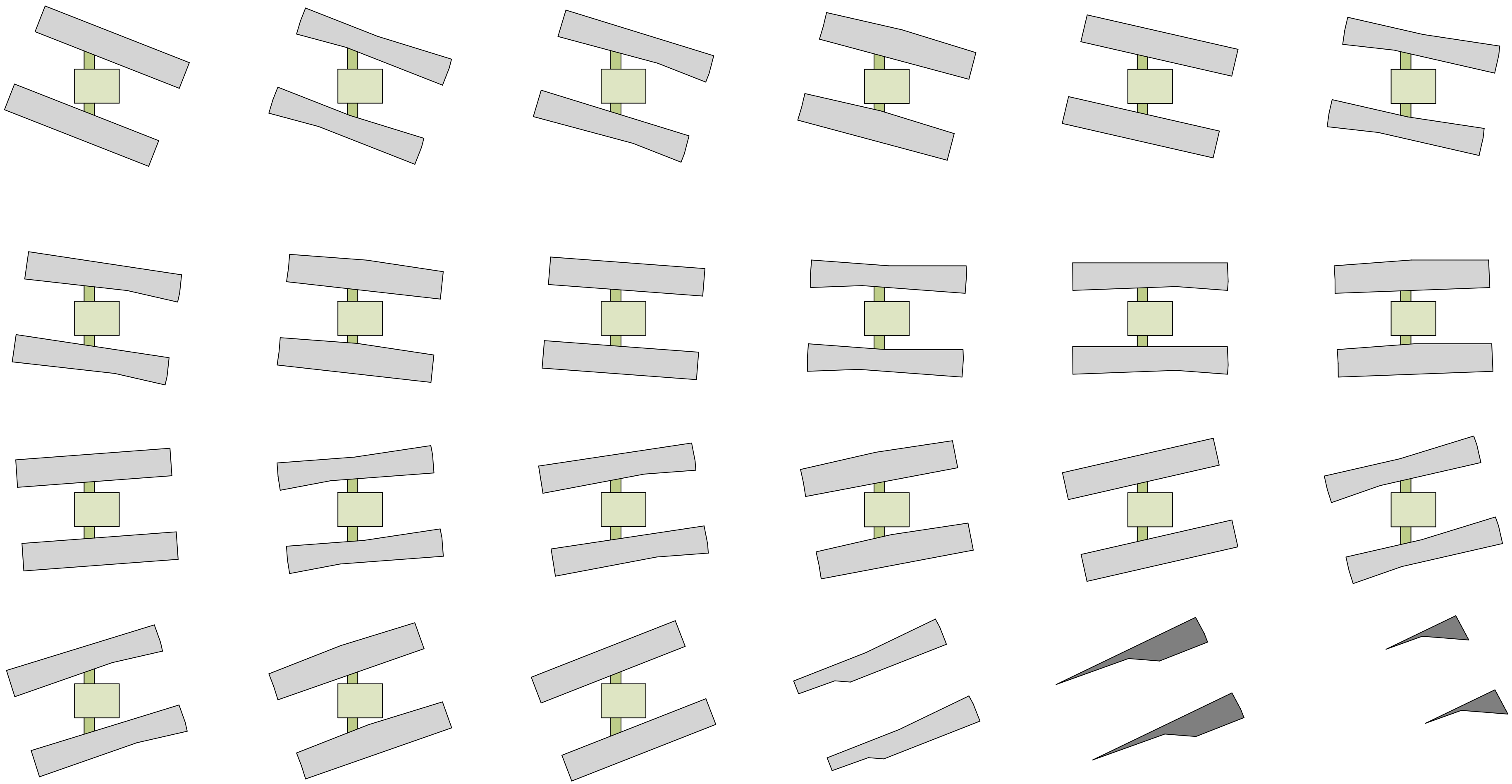
	DESIGN BANGKOK	DESIGN VIENNA
EFFECTIVE ENERGY DEMAND	**96.7 kWh/(m²a)**	**105.9 kWh/(m²a)**
HEATING	2.9 kWh/(m²a)	2.9 kWh/(m²a)
COOLING	75.4 kWh/(m²a)	85.4 kWh/(m²a)
HOT WATER	8.1 kWh/(m²a)	7.8 kWh/(m²a)
VENTILATION	4.4 kWh/(m²a)	4.1 kWh/(m²a)
LIGHTING	5.9 kWh/(m²a)	5.7 kWh/(m²a)

	DESIGN BANGKOK	DESIGN VIENNA
PRIMARY ENERGY DEMAND	58.8 kWh/(m²a)	61.2 kWh/(m²a)
HEATING	1.4 kWh/(m²a)	1.4 kWh/(m²a)
COOLING	29.8 kWh/(m²a)	33.6 kWh/(m²a)
HOT WATER	0.8 kWh/(m²a)	0.8 kWh/(m²a)
VENTILATION	11.4 kWh/(m²a)	10.8 kWh/(m²a)
LIGHTING	15.4 kWh/(m²a)	14.7 kWh/(m²a)
ENERGY PRODUCTION ON-SITE	-62.8 kgCO2/(m²a)	-60.1 kgCO2/(m²a)
TOTAL PRIMARY ENERGY DEMAND	**-4.0 kgCO2/(m²a)**	**1.1 kgCO2/(m²a)**
CO_2 EMISSIONS	14.3 kgCO2/(m²a)	14.9 kgCO2/(m²a)
CO_2 EMISSIONS CREDIT	-15.3 kgCO2/(m²a)	-14.6 kgCO2/(m²a)
TOTAL CO_2 EMISSIONS	**-1.0 kgCO2/(m²a)**	**0.3 kgCO2/(m²a)**

ANALYSIS. As there is no need for heating, the building's systems are focused on active cooling and dehumidifying in the tropics. Solar collectors can be used to heat water only. In the tropics, solar cooling or more precisely desiccant cooling systems are good solutions for cooling and dehumidifying. According to high solar radiation all over the year the use of photovoltaic elements can yield a good return.

That is why, I filled out the same building parameters and service systems as for Hanoi. The only difference is the glazing percentage, which is a lot lower for Bangkok in order to reduce heat gain. Unfortunately, the horizontal shading does not have the positive expected effects, because the program does not consider environmental illuminance and the degree of reflection from surrounding facades.
Moreover, there should be no heating energy demand at all, as the outdoor air temperature is constantly above 26 °C. It can only be explained in the program, as you have to choose a heating generation system and each system has its specific value for calculation.

The building design for Hanoi can lower the primary energy demand but as there is no atrium, the energy demand for lighting and ventilating is higher.



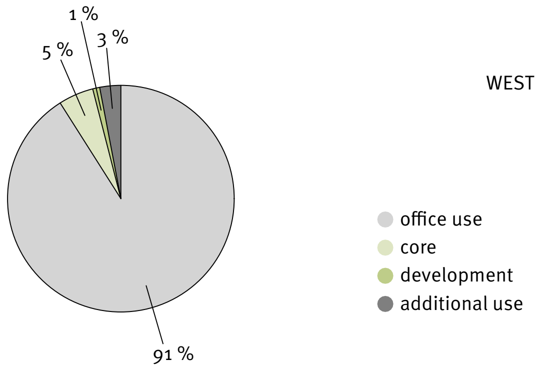
Ill. 161 | AREAS OF THE BUILDING

Showing each single floor with its zones.

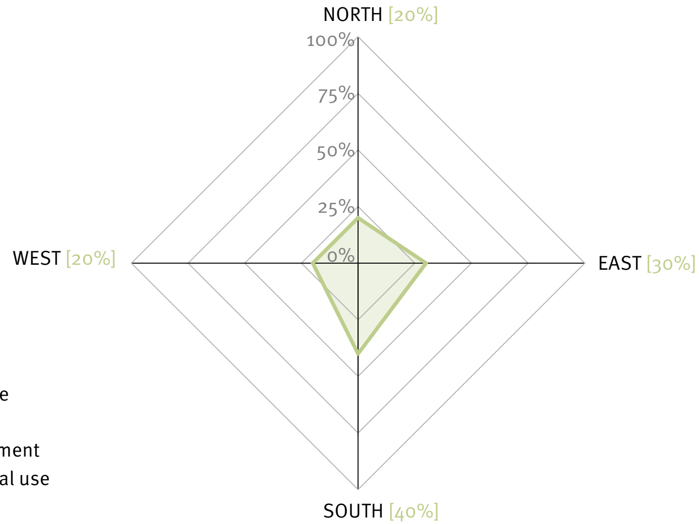
- office use
- core
- development
- additional use

		SOUTH	WEST	NORTH	EAST	HORIZ.
FACADE	m²	7,791.9	2,925.5	6,902.1	3,341.7	-
WINDOWS	m²	3,116.8	585.1	1,380.4	1,002.5	-
WALL	m²	4,675.2	2,340.4	5,521.7	2,339.2	-
BASE PLATE	m²					1,030.8
ROOF	m²					1,151.9
VOLUME	m³					71,211.0

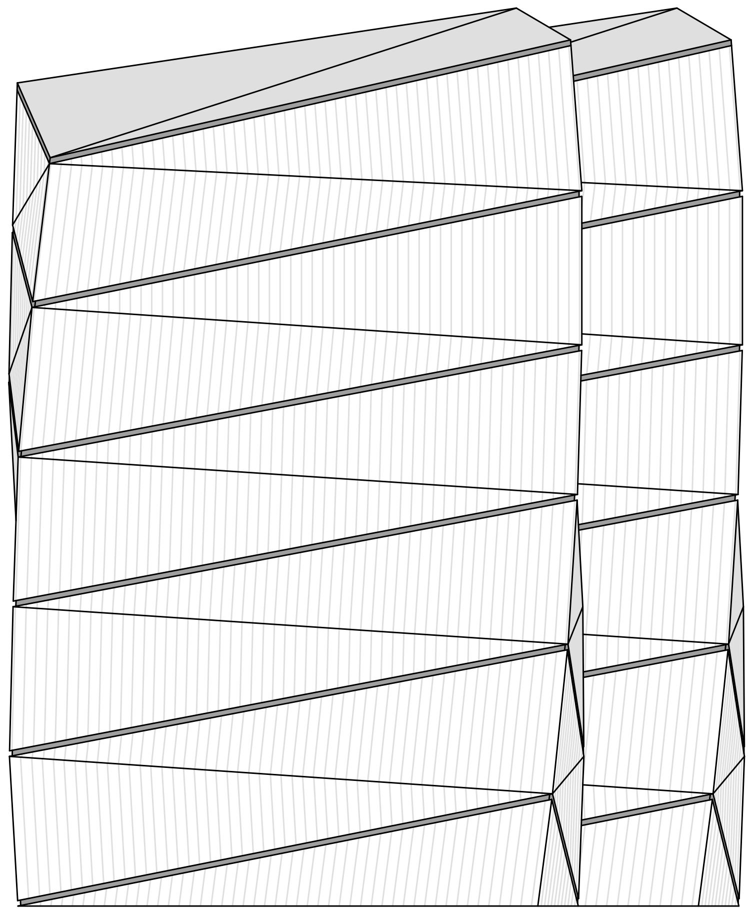
AREAS OF THE BUILDING



DISTRIBUTION OF ENERGY CONSUMING ZONES

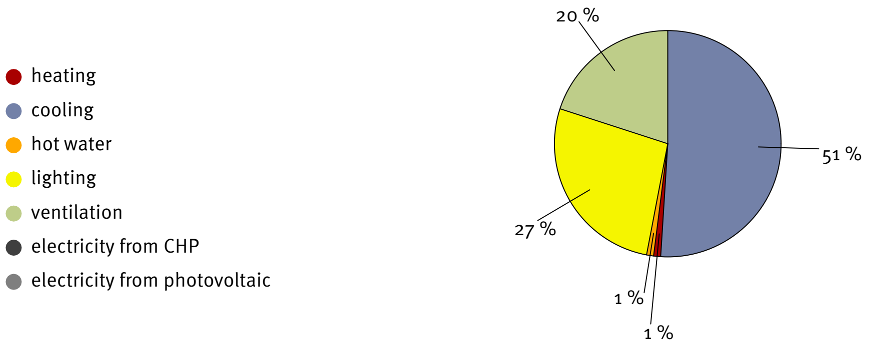


ORIENTATION OF THE WINDOWS

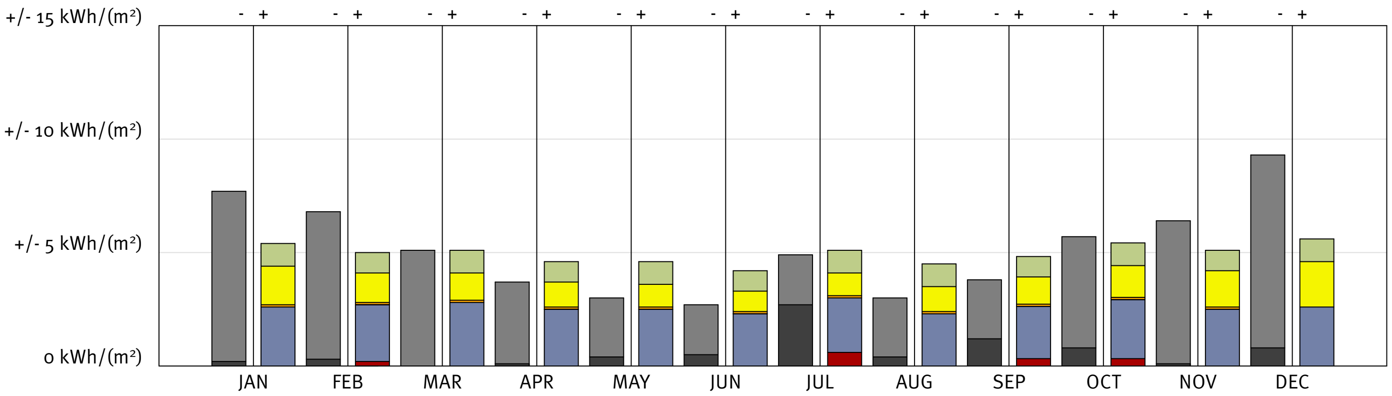


SOUTH ELEVATION OF THE BUILDING

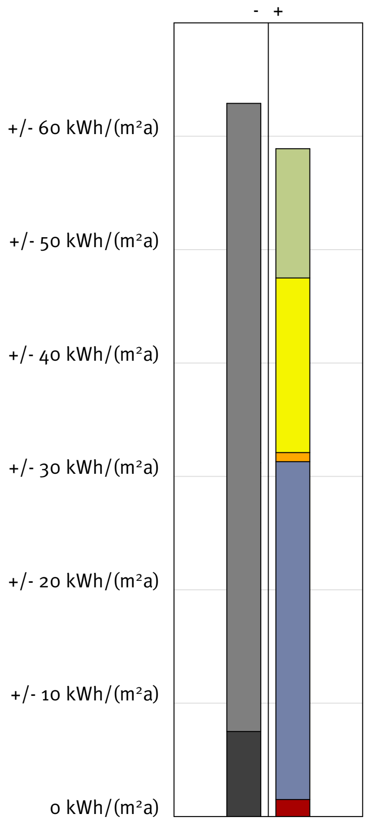
6.2. CHARTS | BANGKOK



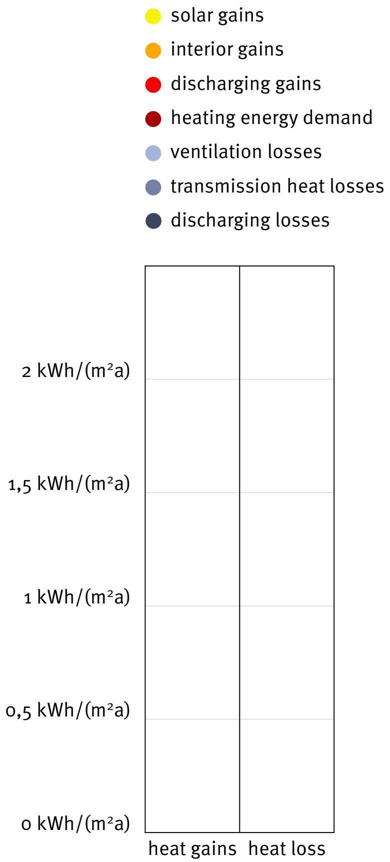
DISTRIBUTION OF PRIMARY ENERGY DEMAND



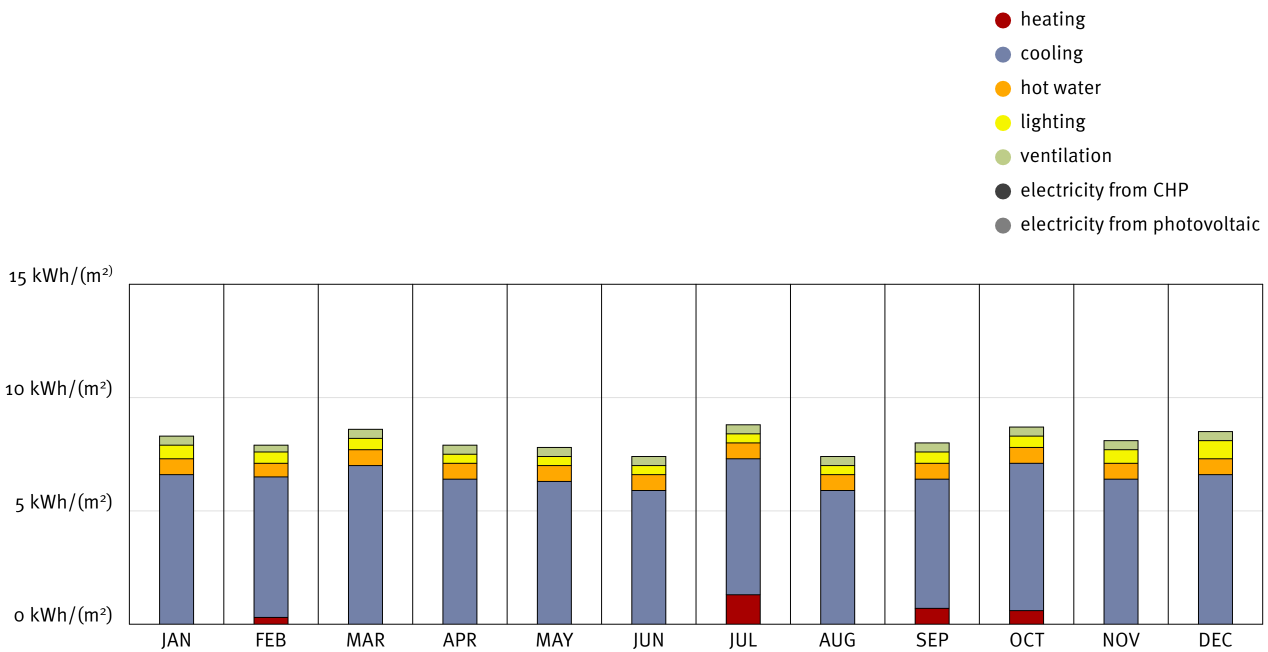
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER MONTH



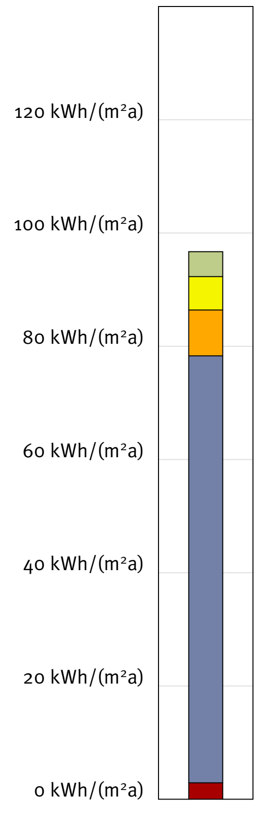
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER YEAR



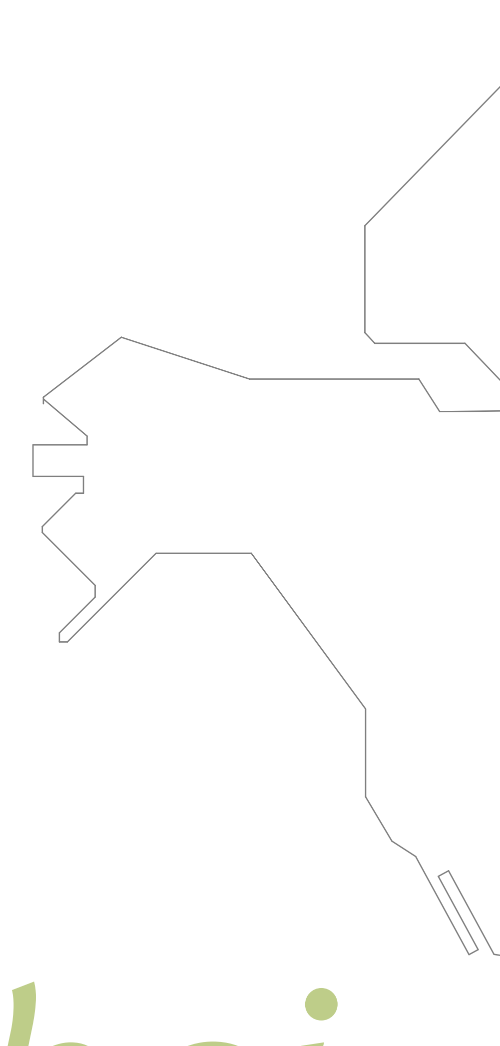
HEATING ENERGY BALANCE



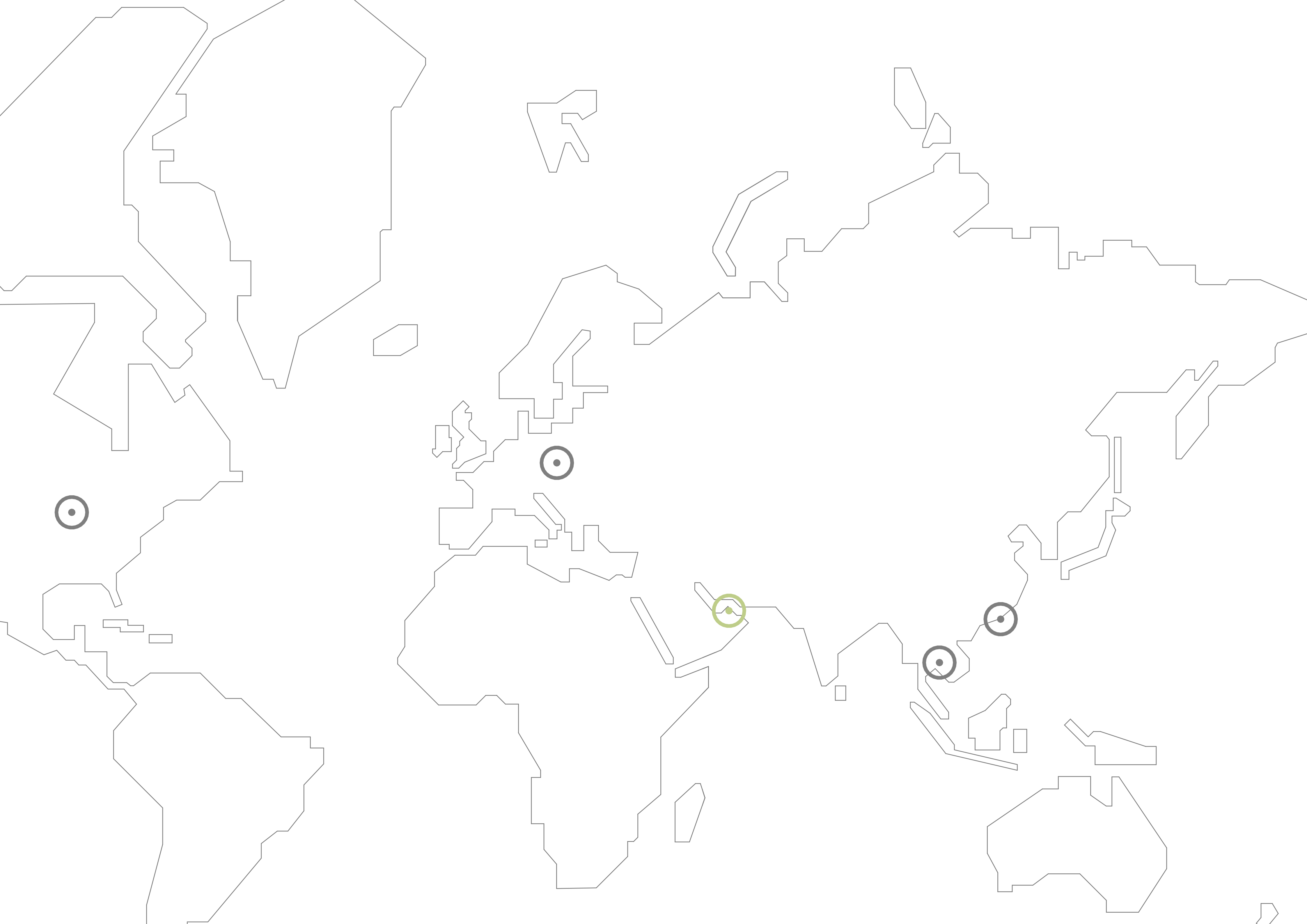
EFFECTVE ENERGY PER MONTH



EFFECTVE ENERGY PER YEAR



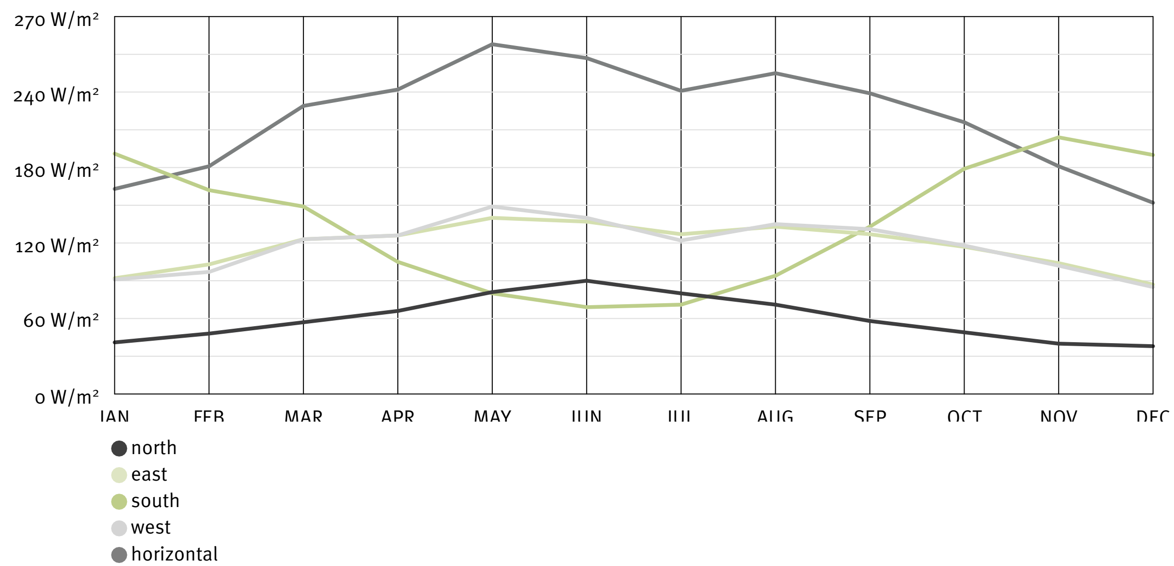
dubai



7.1. BUILDING | DUBAI

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	TEMPERATURE	°C	19,9	20,1	22,3	25,6	29,2	31,5	34,0	34,3	32,5	29,3	25,0	21,7
SOLAR RADIATION	HORIZONTAL	W/m²	163	181	229	242	278	267	241	255	239	216	181	152
	SOUTH	W/m²	191	162	149	105	80	69	71	94	133	179	204	190
	SOUTH-EAST	W/m²	153	142	144	124	119	109	105	123	139	157	165	150
	SOUTH-WEST	W/m²	151	135	145	125	125	111	103	125	143	158	163	148
	EAST	W/m²	92	103	123	126	140	137	127	133	127	117	104	87
	WEST	W/m²	91	97	123	126	149	140	122	135	131	118	102	85
	NORTH-WEST	W/m²	46	57	80	97	126	126	109	109	88	66	47	42
	NORTH-EAST	W/m²	46	59	80	97	119	124	112	107	87	65	48	42
	NORTH	W/m²	41	48	57	66	81	90	80	71	58	49	40	38

Ill. 172 | SOLAR RADIATION OF DUBAI



DATA OF THE BUILDING. The building for Dubai is very similar to the one for Bangkok but it has 2 additional towers. Thus, to reach a similar gross floor area, it only has 17 regular floors and 3 floors in the canted roof area. The floor's height is with 3.30 meters the same as in the other climate zones. A regular floor has a gross floor area of about 1,350 m² and in total it has 24,500 m². The building's volume is 78,600 m³. The glazing percentage is limited to 40% in the South, 30 % to the East and West and 20 % to the North.

	DESIGN DUBAI	DESIGN VIENNA
EFFECTIVE ENERGY DEMAND	**92.1 kWh/(m^2a)**	**106.2 kWh/(m^2a)**
HEATING	2.9 kWh/(m^2a)	2.9 kWh/(m^2a)
COOLING	72.3 kWh/(m^2a)	85.7 kWh/(m^2a)
HOT WATER	7.6 kWh/(m^2a)	7.8 kWh/(m^2a)
VENTILATION	4.0 kWh/(m^2a)	4.1 kWh/(m^2a)
LIGHTING	5.3 kWh/(m^2a)	5.7 kWh/(m^2a)

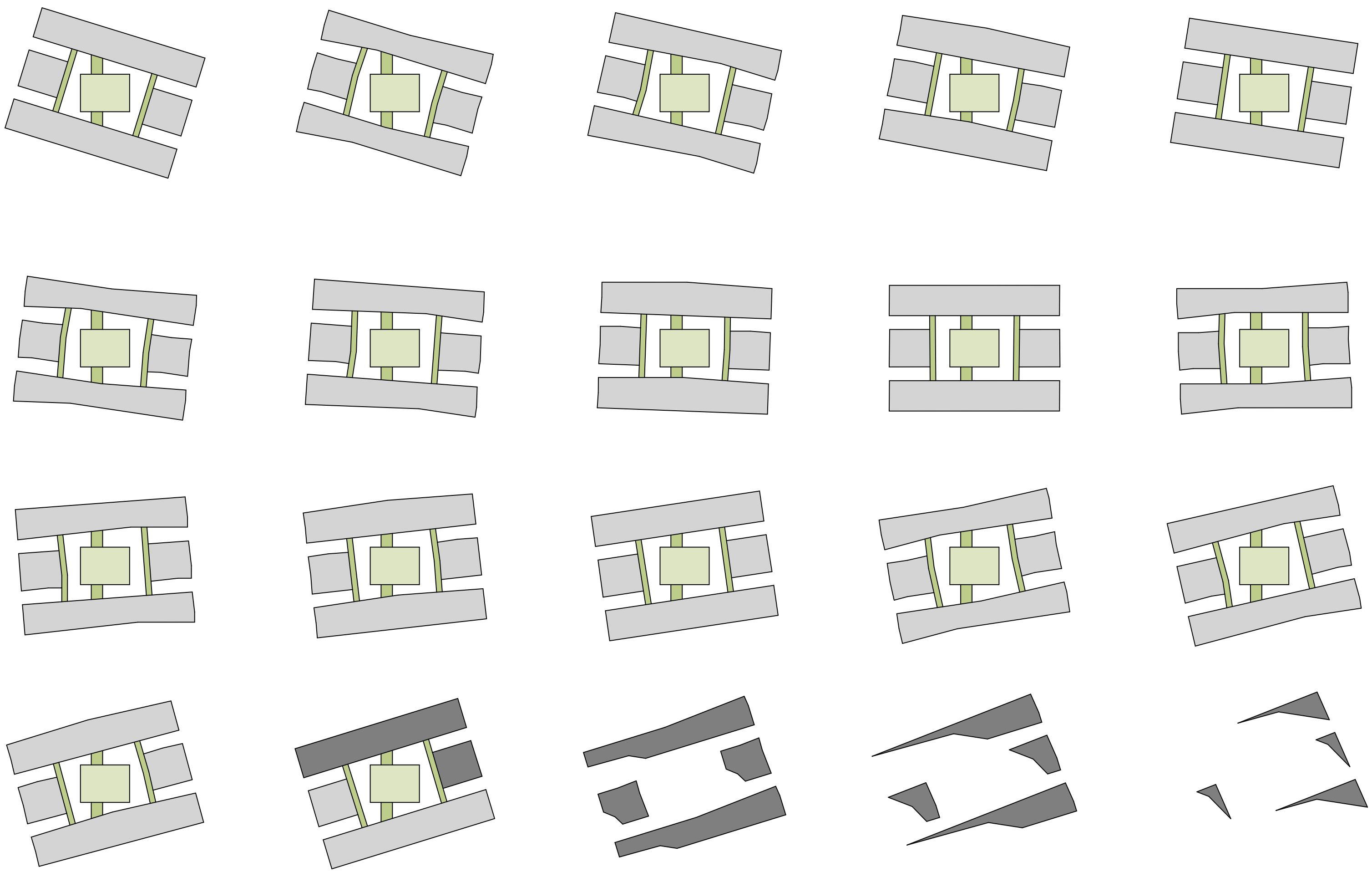
	DESIGN DUBAI	DESIGN VIENNA
PRIMARY ENERGY DEMAND	55.3 kWh/(m^2a)	61.4 kWh/(m^2a)
HEATING	1.4 kWh/(m^2a)	1.3 kWh/(m^2a)
COOLING	28.7 kWh/(m^2a)	33.7 kWh/(m^2a)
HOT WATER	0.8 kWh/(m^2a)	0.8 kWh/(m^2a)
VENTILATION	10.5 kWh/(m^2a)	10.8 kWh/(m^2a)
LIGHTING	13.9 kWh/(m^2a)	14.7 kWh/(m^2a)
ENERGY PRODUCTION ON-SITE	-64.3 kgCO_2/(m^2a)	-66.1 kgCO_2/(m^2a)
TOTAL PRIMARY ENERGY DEMAND	**-9.0 kgCO_2/(m^2a)**	**-4.7 kgCO_2/(m^2a)**
CO_2 EMISSIONS	13.5 kgCO_2/(m^2a)	14.9 kgCO_2/(m^2a)
CO_2 EMISSIONS CREDIT	-15.7 kgCO_2/(m^2a)	-16.1 kgCO_2/(m^2a)
TOTAL CO_2 EMISSIONS	**-2.2 kgCO_2/(m^2a)**	**-1.2 kgCO_2/(m^2a)**

ANALYSIS. In desert areas a lot of cooling is necessary. The soil can be used as a source unless the average temperature of a year is lower than 20 °C, which is the case in the winter period. Options for cooling can be solar cooling or desiccant cooling as well as cooling ceilings.

For that reason, the building's parameters and service systems are the same as for Hanoi and Bangkok. That is why the result is very similar to the one for Bangkok. It is slightly better, as the building's envelope is bigger and the buildings smaller.

If you compare the design of Vienna with the one of Dubai the primary energy demand for cooling can be lowered. Also the energy demand for ventilation and lighting could be decreased a little bit.

At this point, I also have to mention, that the horizontal shading could not be considered in the way it should, because the program only has the data but not the appearance behind it. It does not calculate, what the building looks like.



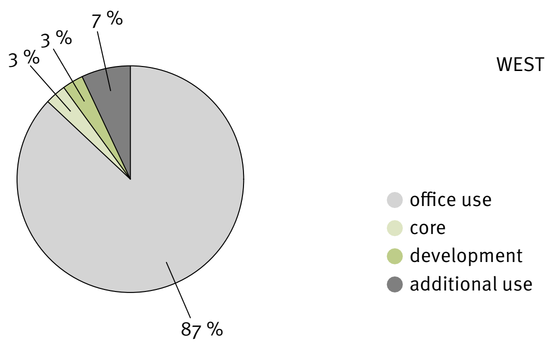
Ill. 173 | AREAS OF THE BUILDING

Showing each single floor with its zones.

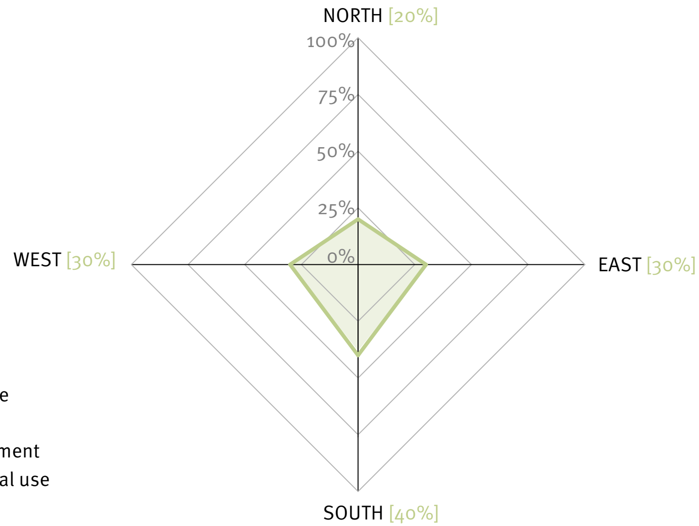
- office use
- core
- development
- additional use

		SOUTH	WEST	NORTH	EAST	HORIZ.
FACADE	m²	7,960.7	3,655.6	7,366.1	3,677.1	-
WINDOWS	m²	3,184.3	1,096.7	1,473.2	1,103.1	-
WALL	m²	4,776.4	2,558.9	5,892.9	2,574.0	-
BASE PLATE	m²					1,288.1
ROOF	m²					1,488.1
VOLUME	m³					78,611.0

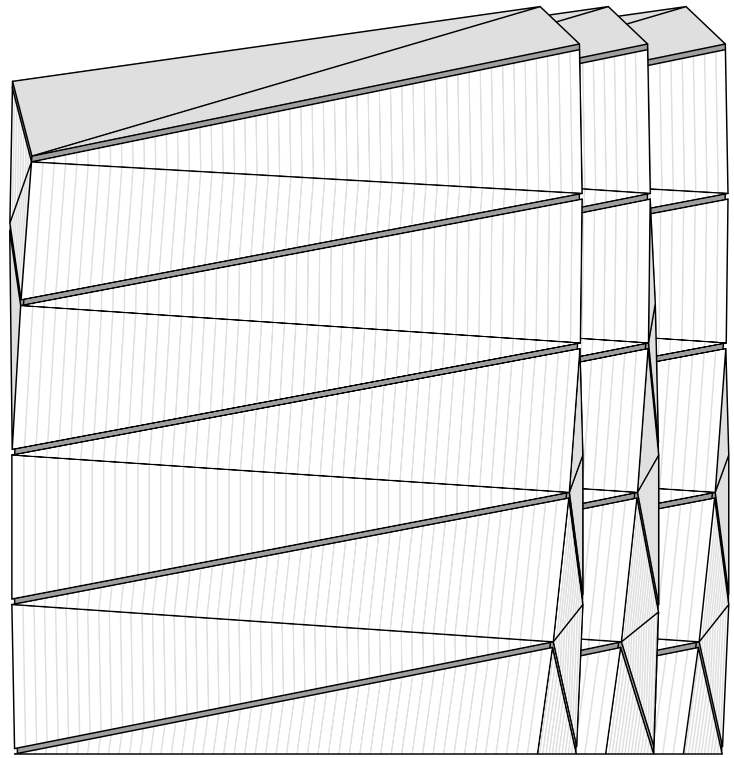
AREAS OF THE BUILDING



DISTRIBUTION OF ENERGY CONSUMING ZONES

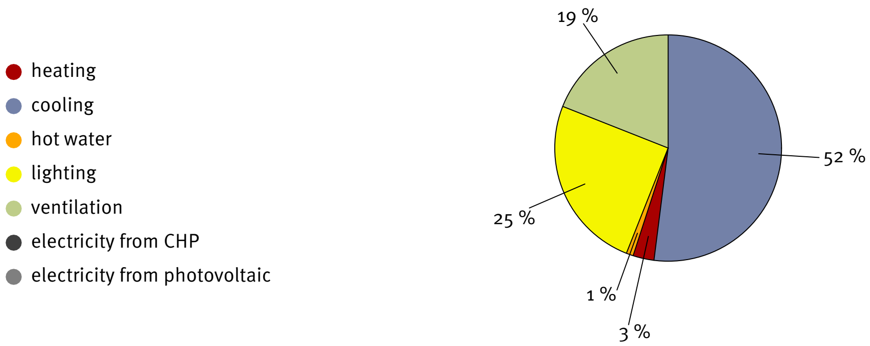


ORIENTATION OF THE WINDOWS

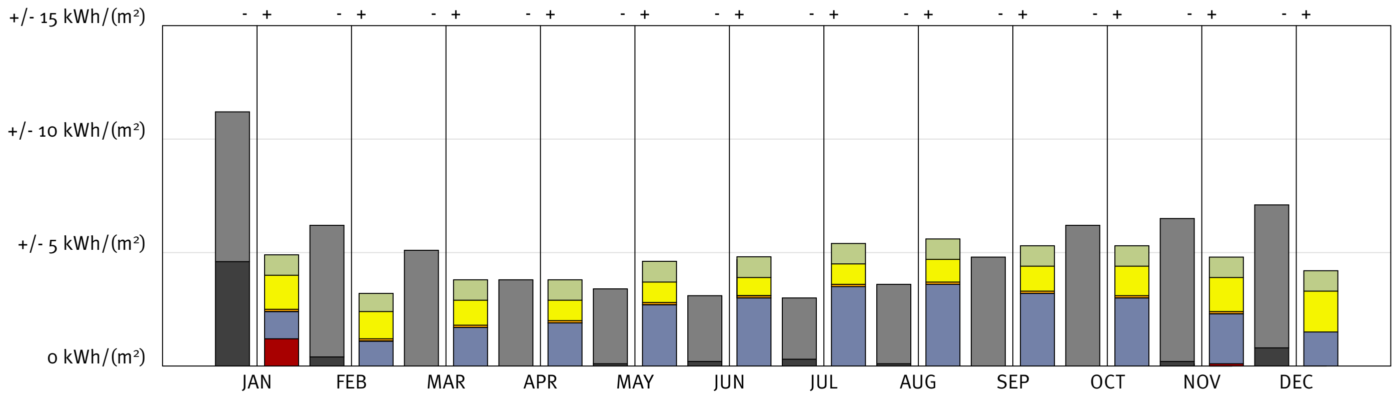


SOUTH ELEVATION OF THE BUILDING

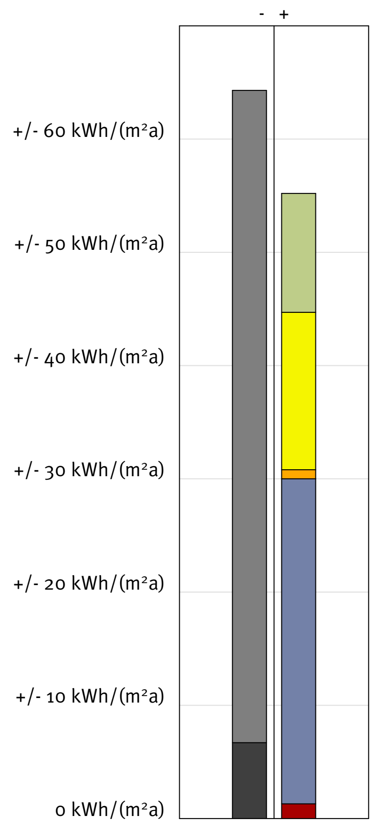
7.2. CHARTS | DUBAI



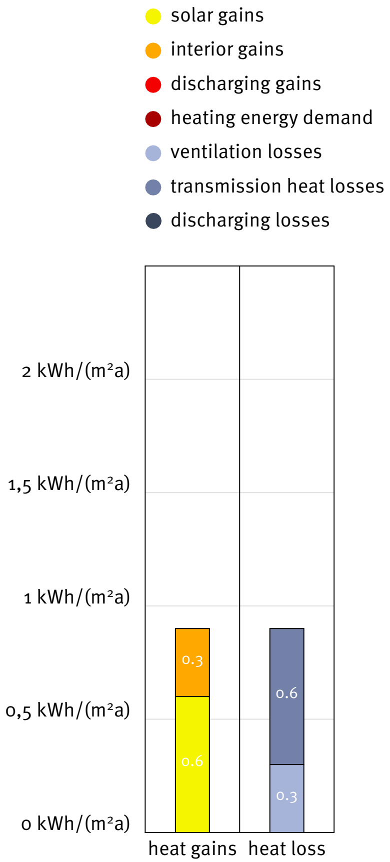
DISTRIBUTION OF PRIMARY ENERGY DEMAND



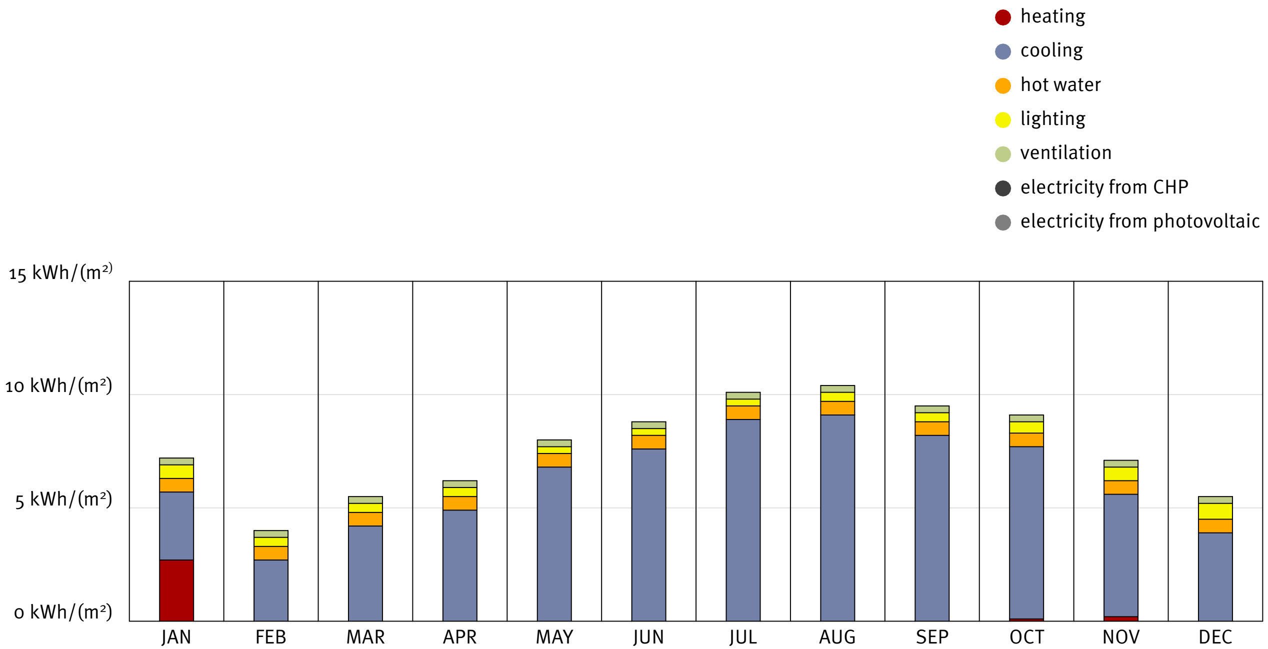
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER MONTH



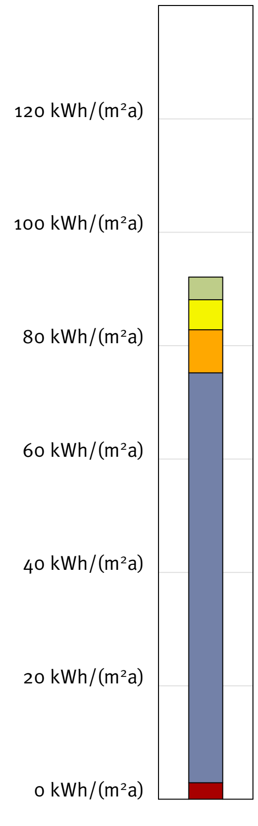
ENERGY PRODUCTION ON-SITE AND CONSUMPTION PER YEAR



HEATING ENERGY BALANCE



EFFECTVE ENERGY PER MONTH



EFFECTVE ENERGY PER YEAR

8. CONCLUSION

EnerCalC is definitely a good program for a simple calculation and it was, for sure, the best choice for my comparison. It was very easy to understand and to handle. Nevertheless, it did not consider all the aspects, which I paid attention to in my designing period. Some influencing parameters such as the environmental illuminance and the degree of reflection from surrounding facades could not be filled out in the program. That is why I could not shade the buildings as they would be in reality. It was also annoying to discover that the CHP only considers heating and hot water but not cooling. It would have been interesting, how much effect that might have caused. Anyway, the results speak for themselves and are really good. The results could show, that the design, the construction and building's service systems have huge influences on the energy efficiency and ecology.

A design of a building cannot be the same for each place, location, and local climates have to be taken into account. Some minor changes can have very positive effects on the primary energy demand.

CHAPTER VI
CONCLUSION

At the end of my thesis, I want to give a personal final statement.

In March 2012, I started thinking about the topic of my thesis. As I got the opportunity to write it in San Luis Obispo / California, and as my passion is travelling around the world, I wanted to find something in a global context. So I came up with the idea to design a building in Austria and transfer it to other places spread all over the world. What is more, I never designed a really huge and complex building during my study. That is why I chose the office building as my main function. In the end I had found my topic **“GREEN GLOBAL OFFICE BUILDING”** - a corporate design in different climate zones.

I asked Arch. DI Heimo Staller for supporting me with my challenge and began reading lots of books and doing some research. In March 2013 I began with the theoretical part of my thesis. So far, everything went flawlessly. But as I started to work on my design, I realized, how complicated and complex my topic actually was. At first it is a huge challenge to design an office building in an energy efficient way. But I cannot tell you how frustrating it was, to find a design, that can be transformed to other climate zones. So I had to work on a strong and individual design with high recognition value to create an overarching corporate identity. One to two months of frustration, sketches and unsuccessful attemps passed, as I finally found the answer to all my questions.

Now, my design is not only a compromise between architecture and functionality as well as energy efficiency - NO, it is all together. There are five designs that speak for themselves. They are plus-energy buildings and have a unique corporate architecture, that could represent one huge company worldwide.

CHAPTER VII

ADDENDUM

1. DICTIONARY

A	
access control system	Zugangskontrollsystem
adjustability	Einstellbarkeit
air flow	Zuluft
air humidity	Luftfeuchte
air stream	Luftstrom
air temperature	Lufttemperatur
air-conditioning plant	Klimaanlage
airtightness	Luftdichtheit
altitude	Höhenlage
angle of radiation incidence	Einstrahlwinkel
anti-glare shield	Blendschutz
anthropogenic	vom Menschen verursacht
attenuation	Dämpfung
autoclaved aerated concrete blocks	Porenbetonsteine
B	
biomass	Biomasse
blind	Rollladen
blower convector	Gebläsekonvektor
bracing structure	Aussteifung
building envelope	Gebäudehülle
C	
canted roof	abgeschrägtes Dach
cantilever	freitragend
characteristic length	charakteristische Länge
circuit logic	Schaltkreislogik
CO_2 emission	CO_2 Emissionen
cogeneration	Kraft-Wärme-Kopplung
column	Stütze
combined heat and power plan	Kraft-Wärme-Kopplung
composite construction	Verbundbau
compressive force	Druckkraft
concrete core activation	Betonkernaktivierung
condensate drainage	Kondensatablass
conservatory	Wintergarten
continentality	Kontinentalität
convector	Konvektor
cooling system	Kühlsystem

corporate architecture — Firmenarchitektur
corporate identity — Firmenidentität

D

daylight provision — Tageslichtversorgung
degree of surface sealing — Versiegelungsgrad
dehumidify — entfeuchten
density — Dichte
development — Erschließung
distribution of land and sea — Land-Meer Verteilung

E

earth duct — Erdkanal
east/west orientation — amerik. Nord/Süd Orientierung
effective energy demand — Nutzenergiebedarf
embodied-energy — Grauenergie
employee — Arbeitnehmer
end energy demand — Endenergiebedarf
environmental performance — Umweltleistung
evaporation — Verdunstung

F

ferroconcrete — Stahlbeton
fluctuation — Schwankungen

G

geothermal energy — Erdwärme
glare-shield — Blendschutz
glazing percentage — Fensterflächenanteil
global radiation — Globalstrahlung
gross floor area — Bruttogrundfläche

H

heat loss — Wärmeverlust
heat protection — Wärmeschutz
heat pump — Wärmepumpe
heating energy demand — Heizwärmebedarf
humidify — befeuchten

I

Illumination — Beleuchtung
insulation — Dämmung
irradiated energy — eingestrahlte Energie

J

jet-effect	Düseneffekt
jutty	Vorsprung

K

L

latitude	Breitengrad
lever arm	Hebelarm
life-cycle-costs	Lebenszykluskosten
light distribution	Lichtverteilung
loop	Kreislauf
lush rainforest	üppiger Regenwald

M

market capitalization	Börsenwert
mission statement	Leitbild
moisture	Feuchtigkeit
multinational corporation	Weltkonzern

N

natural ventilation	natürliche Lüftung
net floor space (NFS)	Nettogrundfläche

O

Oriel	Erker
outdoor air temperature	Außenlufttemperatur
outflow of moisture	Feuchteabfuhr

P

photovoltaic systems	Photovoltaiksystem
pollutant	Schadstoff
precipitation	Niederschlag
pressure	Druck
primary energy demand	Primärenergiebedarf
proximity to the ocean	Meeresnähe

Q

R

radiator	Heizkörper
refrigeration unit	Kühlgerät
rigid	starr
room climate	Raumklima

S

skylight	Oberlicht

socket outlet	Steckdose
soil	Erde
solar collector	Solarkollektor
solar cooling	solare Kühlung
solar heat gain	solarer Wärmegewinn
solar radiation	Solarstrahlung
spatial structure	Raumstruktur
specific heat capacity	spezifische Wärmekapazität
split-unit	Splitanlage
subsidiary	Tochtergesellschaft
suction	Sog
sun protection	Sonnenschutz
surface sealing	Oberflächenversiegelung
surface-to-volume ratio	A/V-Verhältnis
suspended ceiling	abgehängte Decke
sustainability	Nachhaltigkeit
T	
tensile load	Zuglast
thermal bridge	Wärmebrücke
thermal buoyancy	thermischer Auftrieb
thermal conductivity	Wärmeleitfähigkeit
thermal mass	Speichermasse
traction	Zugkraft
transmission factor (g)	Energiedurchlassgrad, g-Wert
transmission heat loss	Transmissionswärmeverlust
transmitting medium	Übertragungsmedium
twisting	Drehung
U	
U-value, Thermal transmittance	Wärmedurchgangskoeffizient
V	
ventilation system	Lüftungssystem
vertical coring bricks	Hochlochziegel
W	
window lintel	Fenstersturz
windward	Luv
X	
Y	
Z	

2. BOOKS

Ábalos, Iñaki / Herreros, Juan: Tower and office. from modernist theory to contemporary practice. (Cambridge: Massachusetts Institute of Technology Press, 2003)

Eisele, Johann / Staniek Bettina: BürobauAtlas. Grundlagen; Planung; Technologie; Arbeitsplatzqualitäten. (München: Callwey, 2005)

Gaiddon, Bruno / Kaan Henk / Munro, Donna: Photovoltaics in the Urban Environment. Lessons Learnt from Lage-Scale Projects. (London / Sterling: Earthscan, 2009)

Grech, Chris / Walters, David: Future Office. Design, Practice and Applied Research. (London / New York: Routledge, 2008)

Gonçalves, Joana Carla Soares / Umakoshi, Érica Mitie: The Environmental Performane of Tall Buildings. (London: Earthscan, 2010)

Hagner, Alexander: Büro Raum Planung. Allgemeine Grundlagen. (Neudörfl: Neudörfler, 2004)

Hascher, Rainer / Arnold, Thomas: Entwurfsatlas Bürobau. (Basel: Birkhäuser, 2002)

Hausladen, Gerhard / De Saldanha, Michael / Liegl, Petra / Sager, Christina: Climate Design. Solutions for Buildings that Can Do More with Less Technology. (Munich / Saint Tropez / Porto Corallo: Birkhäuser, 2004)

Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012)

Myerson, Jeremy / Ross, Philip: Das kreative Büro. (Stuttgart: Deutsche Verlags-Anstalt, 1999)
Roberts, Simon / Guariento, Nicolò: Building integrated photovoltaics. A handbook. (Basel / Boston / Berlin: Birkhäuser, 2009)

Schulze, Siegfried / Krause, Carl: Bürobauten. (Stuttgart / Bern: Karl Krämer Verlag, 1967)

Voss, Karsten: Bürogebäude mit Zukunft. Konzepte, Analysen, Erfahrungen. (Stuttgart: Fraunhofer, 2010)

Yeang, Ken: The Green Skyscrapers. The Basis for Designing Sustainable Intensive Buildings. (Munich / London / New York: Prestel, 1999)

Yeang, Ken: the skyscraper. bioclimatically considered. (London: Academy Editions, 1996)

3. PDF

Bratschi, Urs: Architektur als Marketinginstrument. Mehrwerte für Unternehmen durch Corporate Architecture in KMU-Magazine, No. 10 (12/2007 - 01/2008) Viewed on 04/29/2013 under http://www.marketingarchitektur.ch/downloads/KMU-Magazin_1007.pdf

N.Ed.: Hoch gedämmte Häuser brauchen Speichermassen. Vorteile im Sommer und im Winter in Aktuell Bauen mit Mauerwerk + Beton, No. 10 (10/2006) Viewed on 07/22/2013 under http://www.gfg24.de/download/Human-Healthy-Speichermasse.pdf

Oehlinger, Christine / Egger, Christiane / Stieger, Johann / Dell, Gerhard: Strom sparen Schritt für Schritt im Büro. Wie Sie Ihren Stromverbrauch ohne große Investitionen um 10% senken können. (Linz: O.Ö. Energiesparverband, 2010) Viewed on 07/23/2013 under http://www.stromsparenjetzt.at/fileadmin/redakteure/ESV/Info_und_Service/Publikationen/Strom_sparen_Buero_2010.pdf

Österreichische Post AG: 1030 Wien Rasumofskygasse- Büro- und Geschäftsgebäude. EU-weiter offener zweistufiger anonymer Generalplanerwettbewerb (Realisierungswettbewerb). Auslobungsunterlagen 1. Fassung. Teil D Funktionale Gebäudequalität. [Unpublished paper.]

Sahner, Georg / Drittenpreis Julia: Bauherreninformation für das Baugebiet Kornburg Nord. (Nürnberg: Umweltamt und Stadtplanungsamt der Stadt Nürnberg, 2008) Viewed on 03/19/2013 under http://www.nuernberg.de/imperia/md/baureferat/dokumente/planen/bauherreninformation_kornburgnord.pdf

Universität Karlsruhe: Effiziente Energienutzung in Bürogebäuden. Planungsleitfaden. (Augsburg: Bayrisches Landesamt für Umwelt, 2008) Viewed on 07/21/2013 under http://www.hannover.ihk.de/fileadmin/pdf/ihk/themen/umwelt_energie/energieeffizienzbuerogebaeude.pdf

Staller, Heimo: Energetik im Entwurf WS 2011. [Unpublished paper.]

4. INTERNET

ARCHDAILY (2011): Cilento, Karen: EEA + Tax Office / UNStudio. Viewed on 05/17/2013 under www.archdaily.com/130671/eea-tax-office-unstudio/

ARCHDAILY (2012): Furuto, Alison: Wuhan Marine Science and Research Tower Proposal / ACID + AaL + Studio méta-. Viewed on 08/03/2013 under www.archdaily.com/306256/wuhan-marine-science-and-research-tower-proposal-acid-aal-studio-meta/

AXXIO (n.y.): Konstruktionsweisen für den Hochhausbau. Viewed on 07/19/2013 under www.axxio.net/highrise/Tragwerk/tragwerke.htm

BAUNETZWISSEN - NACHHALTIGES BAUEN (n.y.): Atrien. Viewed on 07/22/2013 under www.baunetzwissen.de/glossarbegriffe/Nachhaltig-Bauen-Atrien_664128.html?bid=577089&index=A

BAUNETZ WISSEN - NACHHALTIG BAUEN (n.y.): Gebäudeform. Viewed on 07/22/2013 under http://www.baunetzwissen.de/standardartikel/Nachhaltig-Bauen_Gebaeudeform_662875.html

BAUNETZ WISSEN - NACHHALTIGES BAUEN (n.y.): Gebäudeorientierung und Zonierung. Viewed on 07/22/2013 under www.baunetzwissen.de/standardartikel/Nachhaltig-Bauen_Orientierung-und-Zonierung_662877.html

BAUNETZWISSEN - HEIZUNG (n.y.): Bauteilaktivierung. Viewed on 03/21/2013 under www.baunetzwissen.de/glossarbegriffe/Heizung-Bauteilaktivierung_675251.html?bid=584747&index=B

BAUNETZWISSEN - TAGESLICHT (n.y.): Atrien und Lichthöfe. Viewed on 07/22/2013 under www.baunetzwissen.de/standardartikel/Tageslicht_Atrien-und-Lichthoefe_167206.html

BAUNETZ WISSEN - TAGESLICHT (n.y.): Verglasungs- und Fensterflächenanteil. Viewed on 07/22/2013 under www.baunetzwissen.de/standardartikel/Tageslicht_Verglasungs-und-Fensterflaechenanteil_167222.html

BUSINESS DICTIONARY (2013): Hot Desking. Viewed on 06/20/2013 under www.businessdictionary.com/definition/hot-desking.html

BÜROWISSEN (2012): Innovative Bürokonzepte. Viewed on 07/19/2013 under www.buerowissen.ch/Zukunftsvisionen/Innovative-Burokonzepte-/#!prettyPhoto

BAULINKS (n.y.): Wohlfühltemperatur / Humidex im RLT Magazin. Viewed on 07/23/2013 under http://www.baulinks.de/raumlufttechnik/wohlfuehltemperatur.php

BG BAU (n.y.): 7.4.2. Beleuchtung. Viewed on 07/23/2013 under www.bgbau-medien.de/zh/z418/7_4_2.htm

BUSINESS INSIDER (2013): Collins, Ben: "Hot Desking" Is A Big Trend -- Here's Why A Lot Of People Hate It. Viewed on 06/20/2013 under au.businessinsider.com/hot-desking-is-a-big-trend-heres-why-a-lot-of-people-hate-it-2013-4

CLIMATE CHARTS (n.y.): Bangkok, Thailand. Viewed on 04/29/2013 under www.climate-charts.com/Locations/t/TH48455.php

CLIMATE CHARTS (n.y.): Dubai, United Arab Emirates. Viewed on 04/28/2013 under www.climate-charts.com/Locations/u/UE41194.php
CLIMATE ZONE (n.y.): Chicago. Viewed on 04/15/2013 under www.climate-zone.com/climate/united-states/illinois/chicago/

CURRENT RESULTS (n.y.): Annual Average Relative Humidity in US Cities. Viewed on 04/15/2013 under www.currentresults.com/Weather/US/humidity-city-annual.php

DEZEEN (2012): Frearson, Amy: V on Shenton By UNStudio. Viewed on 07/29/2013 under www.dezeen.com/2012/08/01/v-on-shenton-by-unstudio/

ENERGIE SPARHAUS (n.y.): A/V-Verhältnis, Kompaktheit von Gebäuden. Viewed on 07/22/2013 under www.energiesparhaus.at/fachbegriffe/azuv.htm

ENOB (n.y.): EnerCalC 2013 – Vereinfachte Energiebilanzen nach DIN V 18599. Viewed on 04/26/2013 under www.enob.info/de/software-und-tools/projekt/details/enercalc-vereinfachte-energiebilanzen-nach-din-v-18599/

EOS WEB (n.y.): Viewed on 04/28/2013 under eosweb.larc.nasa.gov

IMMONET (n.y.): Die Pflanze als lebender Saubermacher für das Office. Viewed on 07/19/2013 under www.immonet.at/pflanzen.htm

GREENSOURCE (2011): Dumiak, Michael: Education Executive Agency and Tax Offices. Viewed on 05/15/2013 under greensource.construction.com/green_building_projects/2011/1109_Education_Executive.asp

INHABITAT (2011): Meinhold, Bridgette: Spain's Largest Vertical Garden Cleans Air Inside Office Building. Viewed on 07/19/2013 under inhabitat.com/spains-largest-vertical-garden-cleans-air-inside-office-building/

JOSRE (n.y.): Pearl Ricer Case Study China. Viewed on 07/29/2013 under www.josre.org/wp-content/uploads/2012/09/Pearl-River-Case-Study-China.pdf

MERRIAM-WEBSTER (2013): Office. Viewed on 03/06/2013 under www.merriam-webster.com/dictionary/office

MY FORECAST (n.y.): Bangkok, Thailand. Viewed on 04/29/2013 under www.myforecast.com/bin/climate.m?city=75672&metric=true

SHELL (n.y.): The Shell global homepage. Viewed on 04/30/2013 under www.shell.com

STADTKLIMA (1983): Hanoi. Viewed on 04/15/2013 under www.stadtklima.de/cities/asia/vn/hanoi/hanoi.htm

TAGESANZEIGER (2010): Google in Zürich: "Hier hätte sich auch Michael Jackson wohl gefühlt". Viewed on 07/19/2013 under www.tagesanzeiger.ch/digital/internet/Google-in-Zuerich-Hier-haette-sich-auch-Michael-Jackson-wohl-gefuehlt/story/31962316

T.R. Hamzah & Yeang (n.y.): Editt Tower. Viewed on 05/26/2013 under www.trhamzahyeang.com/project/skyscrapers/edit-tower01.html

URBARAMA (2009): Cucinella, Mario: Centre for Sustainable Energy Technologies, CSET Ningbo. Viewed on 07/29/2013 under en.urbarama.com/project/centre-for-sustainable-energy-technologies-cset-ningbo

US CLIMATE DATA (n.y.): Climate - Chicago - Illinois. Viewed on 04/15/2013 under www.usclimatedata.com/climate.php?location=USIL0225

WEATHER ONLINE (n.y.): Hanoi. Viewed on 04/28/2013 under www.weatheronline.co.uk/Vietnam/Hanoi.htm

WIKIPEDIA (2013): Bangkok. Viewed on 04/29/2013 under en.wikipedia.org/wiki/Bangkok

WIKIPEDIA (2013): Bioenergy. Viewed on 04/26/2013 under de.wikipedia.org/wiki/Bioenergie

WIKIPEDIA (2013): Climate of Dubai. Viewed on 04/28/2013 under en.wikipedia.org/wiki/Climate_of_Dubai

WIKIPEDIA (2013): Hanoi. Viewed on 07/29/2013 under en.wikipedia.org/wiki/Hanoi

WIKIPEDIA (2013): Kühldecke. Viewed on 03/21/2013 under de.wikipedia.org/wiki/Kühldecke

WIKIPEDIA (2013): Multinationales Unternehmen. Viewed on 04/30/2013 under de.wikipedia.org/wiki/Multinationales_Unternehmen

WIKIPEDIA (2013): List of corporations by market capitalization. Viewed on 05/01/2013 under en.wikipedia.org/wiki/List_of_corporations_by_market_capitalization

WIKIPEDIA (2013): Office. Viewed on 03/06/2013 under en.wikipedia.org/wiki/Office

WINDFINDER (n.y.): Wind- & Wetterstatistiken Bangkok Pilot. Viewed on 0429/2013 under www.windfinder.com/windstats/windstatistic_BANGKOK.htm

ZAMG (n.y.): Klimadaten von Österreich 1971-2000. Viewed on 03/16/2013 under www.zamg.ac.at/fix/klima/oe71-00/klima2000/klimadaten_oesterreich_1971_frame1.htm

5. ILLUSTRATIONS

pearl-river-tower-2.jpg. Viewed on 05/26/2013
Ill. 23: PEARL RIVER TOWER | www.bryanchristiedesign.com/uploadfiles/5760128_pearl_river.jpg. Viewed on 05/26/2013
Ill. 24: PEARL RIVER TOWER | archstorage.com/pics/70/5d/Pearl-River-Tower-design-Exterior-2_e76fd.jpg. Viewed on 05/26/2013
Ill. 25: BUILDING CONCEPTS | static.urbarama.com/photos/medium/10967.jpg. Viewed on 07/09/2013
Ill. 26: BUILDING CONCEPTS | worldhouse.ca/wp-content/uploads/2012/09/mario2.gif, 29.07.2013
Ill. 27: CSET IN NINGBO | static.urbarama.com/photos/original/10951.jpg. Viewed on 07/29/2013
Ill. 28: THE FACADE | static.dezeen.com/uploads/2012/08/dezeen_V-on-Shenton-by-UNStudio_5.jpg. Viewed on 07/29/2013
Ill. 29: V ON SHENTON IN SINGAPORE | www.detail.de/uploads/pics/v-on-shenton_15_rendering_skyline_02.jpg. Viewed on 07/29/2013
Ill. 30: ALTITUDE OF THE SUN | Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 15
Ill. 31: CLIMATE ZONES | own illustration
Ill. 32: POWER CONSUMPTION | Cf. Oehlinger, Christine | Egger, Christiane | Stieger, Johann / Dell, Gerhard: Strom sparen Schritt für Schritt im Büro. Wie Sie Ihren Stromverbrauch ohne große Investitionen um 10% senken können. (Linz: O.Ö. Energiesparverband, 2010) p. 13
Ill. 33: POWER CONSUMPTION | Cf. Ibid
Ill. 34: SHAPE OF BUILDINGS | Cf. www.energiesparhaus.at/fachbegriffe/azuv.htm. Viewed on 07/22/2013
Ill. 35: DIFFERENT BUILDING SIZES | www.baunetzwissen.de/standardartikel/Nachhaltig-Bauen_Gebaeudeform_662875.html. Viewed on 07/22/2013
Ill. 36: DIFFERENT WINDOWS AND POSITIONS | www.baunetzwissen.de/standardartikel/Tageslicht_Verglasungs-und-Fensterflaechenanteil_167222.html. Viewed on 07/22/2013
Ill. 37: ORIENTATION OF THE BUILDING | own illustration
Ill. 38: SUN PROTECTION | Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate. A Handbook. (Basel: Birkhäuser, 2012) p. 132
Ill. 39: AN ATRIUM | ad009cdnb.archdaily.net/wp-content/uploads/2010/11/1289830020-omk-171314-lr-528x237.jpg. Viewed on 07/22/2013
Ill. 40: ROOM CONDITIONING SYSTEMS | Cf. Hausladen, Gerhard / Liedl, Petra / De Saldanha, Mike: Building to Suit the Climate.

ACKNOWLEDGEMENTS

This project would not have been possible without the support of many people. This is why I would like to express my gratitude to:

Arch. DI Heimo Staller for his feedback, supervision and mentoring throughout the entire project.

FH Joanneum GmbH for educating me in architecture, construction, design and sustainability.

Marshall Plan and **California Polytechnic State University** for giving me the opportunity to write this thesis in San Luis Obispo / California.

Mama and **Papa** for caring for me, encouraging me and listening to me each and every time.

My three older brothers **Hannes**, **Walter** and **Thomas** for inspiring, challenging and supporting me for 24 years by now.

Christopher for accompanying me every single day in the last 6 years and making me become the person, that I am.

My friends **Blake** and **Michi** to be willing to proof read my thesis.

My friend **Markus** for checking my project according to the bearing structure.

All of **my friends** for detracting me from doing my work from time to time, to make life worth living.

ggdb