Wind and Architecture

Design research about possibilities to integrate wind turbines into the building.

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Synopsis

"Wind and architecture" is the research project about possibilities to integrate wind turbines into buildings.

Master thesis "Wind and architecture" is divided in two main chapters.

First part, called design research, includes an introduction about the main topic contents such as external conditions, wind power and tall buildings. It gives detailed information and analyses about related design issues of wind turbines. Turbines are compared with different parameters in order to clear out design principles. These design guidelines will be used in the next semester design project.

Another key chapter called design project, where wind architecture will be proposed in the actual site. This section contains sketching, synthesis and presentation phases.

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Summary

Project “Wind and architecture” is research about possibility to integrate wind turbines into the building.

Energy consumption increases every year but resources getting less every day. Alternative energy resources might offer us necessary, however, seems attempts to use alternative energy resources stops at the solar panels. Wind energy has high potential but information, how to use it efficiently in urban context, is not really available.

Research examines several issues that is relevant in order to understand what problems should be solved during project proposal. It is concluded that collaboration between wind and architectural is sensitive and highly important, as such a issues as aerodynamics, turbine properties depends on each other and gives impact on architecture, and opposite.

Project site is chosen in Aalborg, next to Limfjord, as particular spot has very good wind conditions. However, it is crucial to understand, that project is as example, therefore site and function is secondary.

Chosen function is hotel, as context and municipality plan expecting development of particular site. Access to the site is possible from highway or with boat; therefore small yacht port is made next to the building.

Concept of building reflects on technical considerations about turbine operating processes. Chosen Darrieus turbine requires concentrate wind flow in order to prevent turbine stop. In order to provide continuous spinning, building is relatively shaped as

triangle, letting wind accelerate along W and S sides. These facades has turbine opening, what is carved hole, which gradually blends into the solid surface. Turbines are placed on each other and additionally fixed with traces in order to provide the best stability.

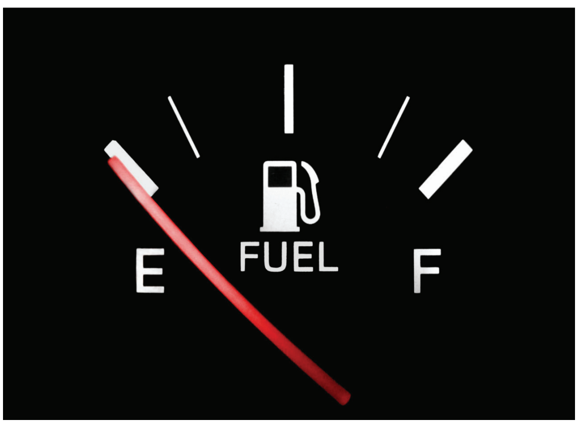
6 turbines in total are providing enough energy to cover energy demand for 2015.

Contrast between southern and northern facade makes building appear from different views in different way. Perforated layer that fills solid shield gives daylight to the hotel suites and public facilities. Northern side is open and has symbolic connection with landscape, slopping volume slightly.

Building plan created as open layout with three vertical blocks that serves as base point, letting rest of the functions float around. Basement is parking lot that has straight connection with highway exits. Ground floor serves for staff premises. 1st floor is main entrance to the hotel and contains double height restaurant, shopping facilities and administration room. Level above is continuing public functions – disco bar and conference hall. Three vertical connections serve as atriums; two of them extended as turbine openings to focus visitors' attention. Rest of 12 floors are hotel suits and is organized around tower middle core. Exception is top floor, where is placed view tower and cafeteria. The top floor is extended in several floors height, and dynamically reducing width of the volume.

Design research

Introduction



ill.001

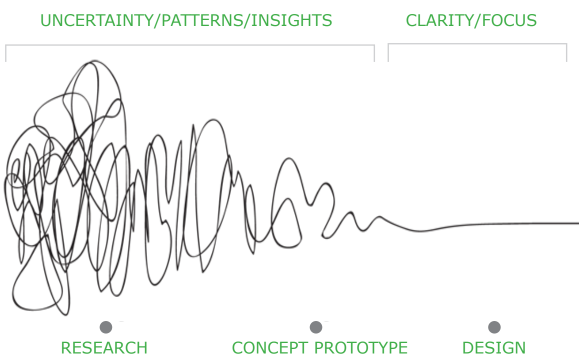
Nowadays economics, science and other facilities are based on energy use. Primary sources of energy consist of oil 36,0%, natural gas 23,0%, coal 27,4%, summing to an 86,4% in total for fossil fuels in primary energy consumption [1]. Non-fossil sources: nuclear 8,5%, hydroelectric 6,3%, and others (geothermal, solar, tide, wind, wood, waste) summing to 0,9 % [1].

As energy consumption increases every year for 2% [2], major fossil fuel crises may appear after few decades [3]. Growing population and technologies cost more and more energy consumption. Therefore, it is essential to begin to think about other energy possibilities.

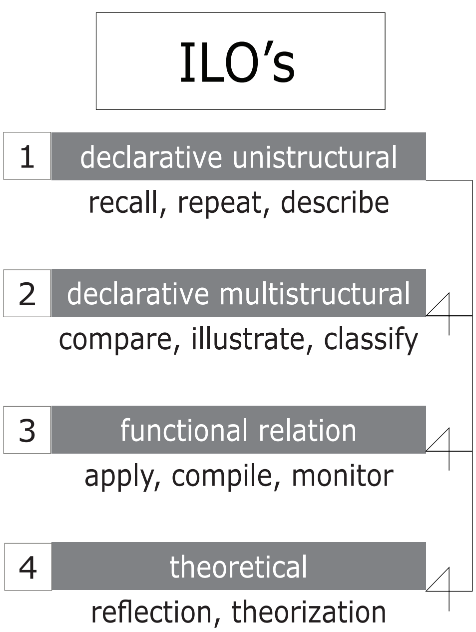
Wind power is one of efficient, renewable resources that have been harvested long time ago. But these tries stops at off-shore or on-shore wind farms what is difficult to integrate in an urban context. Of course, energy can be transferred from site to the site but, in this case, part of it becomes a transmission loss.

In last years, by developing technologies, few examples of integrated wind turbines are made. However, too little information and the assumption has been reached publicity to gain some analytic feedback about pros and cons of wind energy utilization.

Methodology



ill.002



ill.003

Research method

Research method is used to enlarge knowledge about chosen topic and make a qualitative information systematisation.

"Research is an organized and systematic way of finding answers to questions" [4].

Research is planned, limited scope activity that has some certain activities to get the most accurate results. Main focus is set on relevant, important questions, which are giving necessary answers. If there is no question, research is not functioning. Ill.002 shows principle about amount and clarity of information amount that is examined during research [4].

Intended Learning Outcomes

To have control over research process and whole design project, it is necessary to understand possible outcomes. ILO consists from four main parts that should be reached in different project phases (ill.003).

1st phase enlarges knowledge about basic info units. Outcome is possible issues that are worth to be studied deeper.

2nd phase compares and classifies information. Outcome of this phase must be clarified issues what could be used for next phase.

3rd applies collected info to the main object. Knowledge of previous phases helps monitor design.

4th sums up research and give conclusions or proposal [5].

Report organization

Report is divided in to parts as the task is solved during two semesters.

Report layout is made in order to help reader easy follow report context. Bookmarks on the top of a page make reader notice of his presence point into report. Report research consists from three main phases - research of topic, design issues and design principles, excluding introduction chapter.

Introduction chapter gives a brief insight into research part and methodology.

The topic chapter is made as an introduction about the main topic contents to gain deeper insight into relevant issues. External conditions chapter discusses question about climate and renewable resources in a global context and Denmark. Skyscraper chapter introduces the reader with building type and gives retrospection into history. Wind power chapter present different turbines and hurdles what could be crucial in case of interaction with inhabitants. Turbines are compared with relevant parameters in order to select few most efficient turbines. Integration potential will be analysed in the next research step. Aerodynamic chapter is telling main principles of form and details, in order to obtain an additional efficiency of buildings. Few case studies are analysed and developed into different aerodynamic proposal in order to understand the interaction between wind and building.

Second main chapter is design issues. It is continuing research about turbines and relevant parameters that will be used as primary points for design principles and criteria.

Wind chapter takes a look on wind pressure questions in connection with building construction. Productivity chapter calculates efficiency level for turbines, what was chosen in the previous chapter. Calculations are made according ZEB energy demands and wind power formula.

Integration chapter pays attention to turbines potential use in a different context, with different visual appearance and parameters that increase integration potential.

Last main chapter is design principles that serve as conclusion and basis for 4th semester design process.

4th semester report consist from 4 parts: program, where context and relevant design tools is discussed. Sketching phase consists from three subchapters, explaining process until final project proposal approaching. Detailing phase focuses on specific project parts that is relevant to understand in detail.

Presentation chapter visualy closes reader journey throught the research.

As additional information, appendix contains several calculations that might be usefull to read for deeper project understanding.

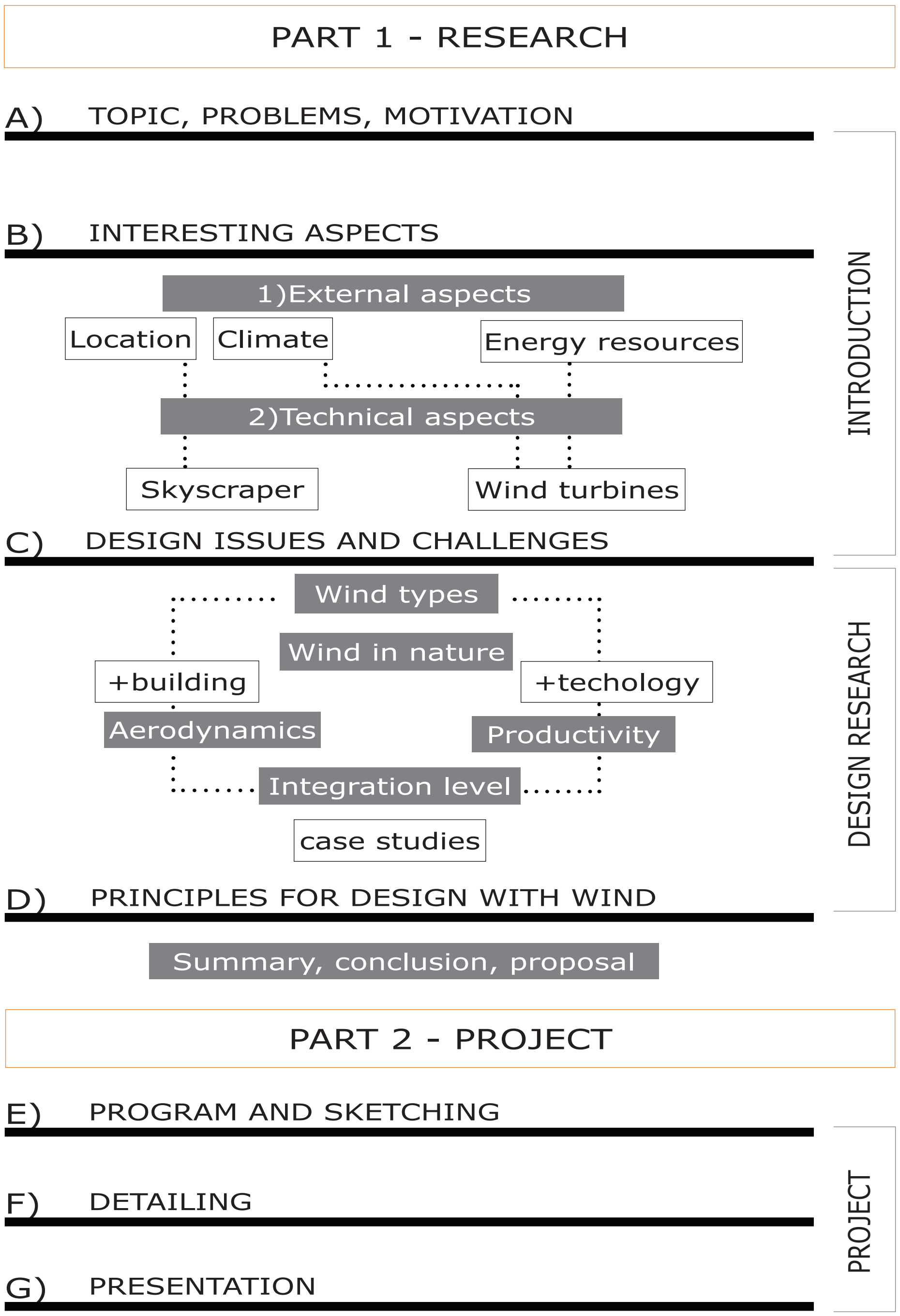
Conceptual organisation

9th semester is made using research method. Intriguing aspects that are worth to be studied is found after considering topic and problems.

Design issues and challenges require a closer look to different relevant topics that are necessary to understand before define final project proposal.

As an outcome are design principles, for design with the wind that will be as a guideline for design proposal in 10th semester.

10th semester is based on 9th semester research and chosen design principles.


PART 1 - RESEARCH
A) TOPIC, PROBLEMS, MOTIVATION
B) INTERESTING ASPECTS
1)External aspects
Location
Climate
Energy resources
2)Technical aspects
Skyscraper
Wind turbines
C) DESIGN ISSUES AND CHALLENGES
Wind types
Wind in nature
+building
+techology
Aerodynamics
Productivity
Integration level
case studies
D) PRINCIPLES FOR DESIGN WITH WIND
Summary, conclusion, proposal
INTRODUCTION
DESIGN RESEARCH
PART 2 - PROJECT
E) PROGRAM AND SKETCHING
F) DETAILING
G) PRESENTATION
PROJECT

ill.004

Topic

External conditions

ill.005

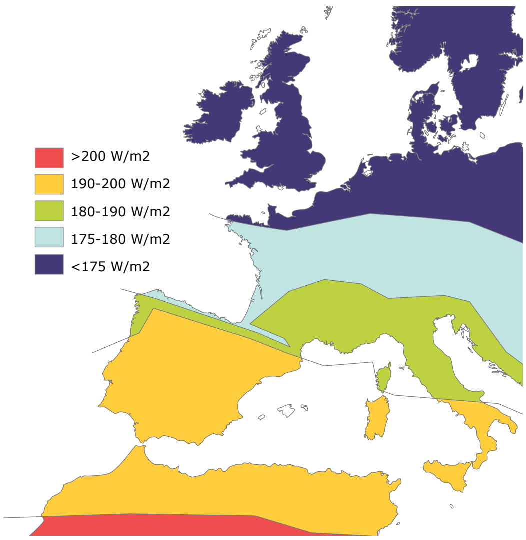
External conditions are essential in order to maintain effective energy harvesting. Different energy resources are suitable in different climate zones.

This topic gives overview about main energy resources and climate conditions in general and specified for Denmark, as the project will be situated in Denmark.

Solar, Biomass, Wind, Hydropower, Geothermal are renewable energy resources, but not all of them cost high efficiency also not all of them is possible to use in architectural purposes.

The most efficient energy resources are solar, wind power as it is supplied by atmospheric objects and is all over the year. However, also hydro power and geothermal energy can be used for other purposes and location.

Solar energy



ill006
Europe solar map

ill.007
Oppenheim - Marina and Beach Towers, UAE

Solar radiance: the most efficient solar altitude is between 15 and 45 degree, where Sun can be collected. Regions beyond 45° have worst conditions for the use of direct solar radiation, as almost half of solar radiation is scattered [6].

Geographically Denmark is situated at 54-57 degree N [7]; therefore, solar energy might be collected, but not in high efficiency class. Better solar conditions can be found at the Southern-East part of Denmark. Rest of country equally gets from 900-1000 Kwh/m2, what is just a third part comparing with effective solar zones [6].

Earth can receive 51% of the Sun's solar energy. The rest of it is absorbed by clouds and the atmosphere, then radiated back into space [8].

Solar cells are used to absorb solar energy. Solar Cells or photovoltaic cells convert sunlight directly into electricity. Collectors are installed to heat up water pipes to gain hot water supply, but concentrators mirror surface absorbs heat and generate electricity [8].

Advantages: free, all over the year, easy to integrate in design.

Disadvantages: Location, where sunlight is effective all over the year, expensive [8].

ill.008
Europe tectonic map

Geothermal energy

ill.009
Atkins - The Songjiang Hotel, China

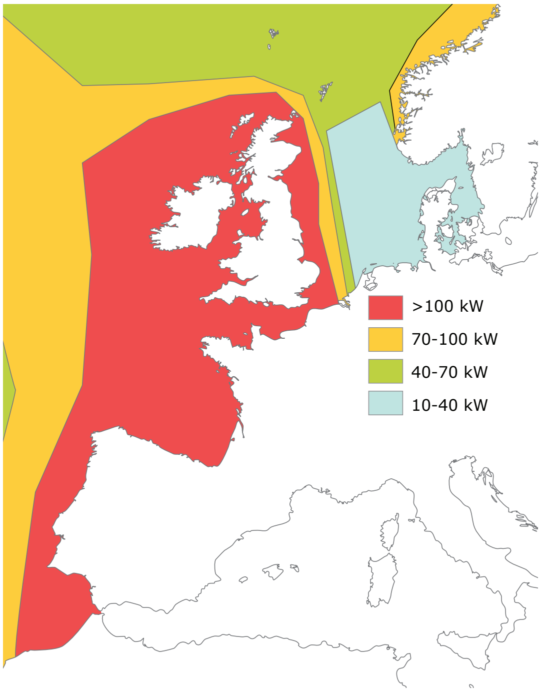
Geothermal energy: appear in tectonic active zones [9].

Denmark is located on a stabile tectonic Eurasian plate that is not seismic active.

Use the Earth heat for direct-use applications, geothermal heat pumps, and electrical power production [8].

Advantages: No need of fuel, no pollution, renewable [8].

Disadvantages: Location, close to geo active zones, not transportable, may contain gas [8].



ill.010
Europe tidal map

ill.011
New Oakville Hospital, USA

Hydro energy

Hydro energy: to convert water power to electricity it is necessary to have rivers with a strong flow and height level difference. Tidal energy requires high tidal wave potential.

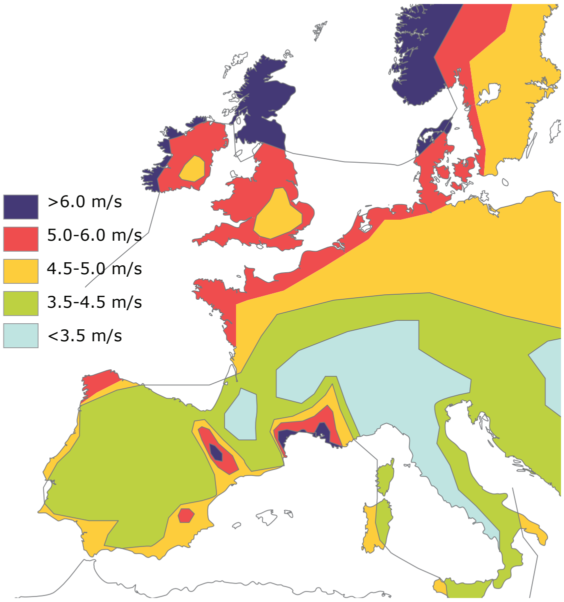
Denmark is situated in flat land, and it contains just a few rivers [10]. Country is bordered with inner bays and seas, so tidal wave energy potential is low. Therefore, use of hydro power is not effective.

Hydro power uses flowing water energy and converts it to electricity power. Another form is tidal energy that uses wave power [11] [8].

Advantages: clean, renewable, very efficient, no need have fuel [8].

Disadvantages: disturbs natural flow of rivers, change fish migration, catastrophic failure, tidal energy technologies often suffer from salted water erosion [8].

Wind energy:



ill.012
Europe wind speed map

ill.013
Atkins - Bahrain WTC, Bahrain

Wind speed: Wind speed is distributed uneven. High wind speeds are located on coast lines and at flat areas. It is regulated by atmospheric air changes. The minimum wind speed at which the wind turbine will produce usable power is typically between 7 and 10 mph [12].

Denmark is located in high wind speed zone, especially west coast line, which is faced to North Sea. Average wind speed is more than 14 mph. This wind speed level provides advantageous conditions for using wind power as the main energy resource [13].

Wind energy systems generate electrical power by harvesting power. Wind using machines are called wind turbine [8].

Advantages: free, no waste, compact, good use in less sun shined areas and it is plentiful [8].

Disadvantages: Location, might interfere with radio, TV signal, noisiness, threat to birds [8].

Summary

	Solar	Geothermal	Hydro	Wind
Products	Solar cells, collectors, concentrators	geo pumps, pipes.	hydro pumps, pipes.	wind turbines, generators
Integration potential	high	medium	medium	high
Accessibility	15-45 altitude degree	seismic zones	fast flow rivers, waterfalls, open sea areas	various places, flat zones
Architectural aspects	It could be use roof surface, design elements or facade. Panels aesthetic appearance is modern and functional.	Changing building structure and layout. Building visual appearance is not presenting idea behind so much as wind or solar architectures.	Water power could be used as architectural design - waterfall, ocean visibility.	Symbol of sustainability and green life style. Attracts attention of society and investments. Problems with noise and daylight.
Technical aspects	Problems with panel adjustment into the Sun diretion, what gives best efficiency.	Easy usage and combinations with inner instalation.	Specific location creates suitable construction conditions to use hydro energy. Big problems might cost catastrophic failures.	Accessibility maximum. Problems may cost turbulence created by building volume Static instability.

ill.014

Tall buildings

Tall buildings are not outcome of modern industrialized world. Human desire to build high is old as civilisation by itself [Bungale, 2011].

First high rises was erected in antique worlds such as Egypt, Inca, Mayan, and Indian Imperia.

They were trying to reach sky as important role in their world took religion.

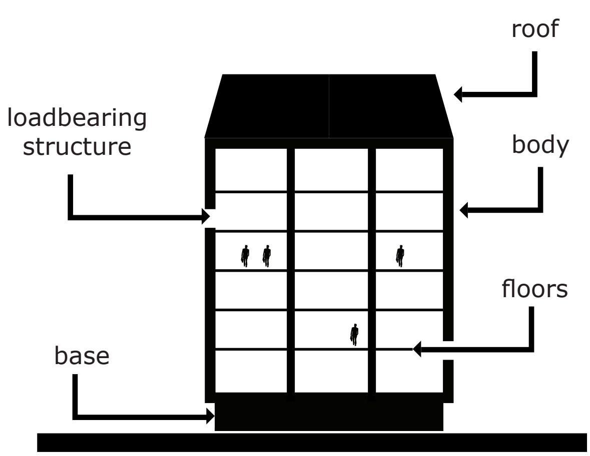
At medieval age, high buildings were symbol of power, religion, but it also served functionally; for defence, light and many different purposes.

High rise population increases during development of structural systems and material availability.

Skyscrapers developed just in last century as population was increasing, and there was need for more living spaces [Bungale, 2011].

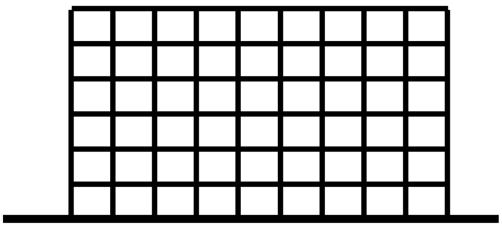
Skyscraper is unique of its structure. It breaks Aristotelian principle (ill.015) that every building must consist from 3 parts – foundation (base), middle (body) and top (cover) [huxtable, 1984].

The skyscraper structural scheme contains middle core that serves as loadbearing element, storey partitions for dividing body and envelop that creates aesthetical appearance.

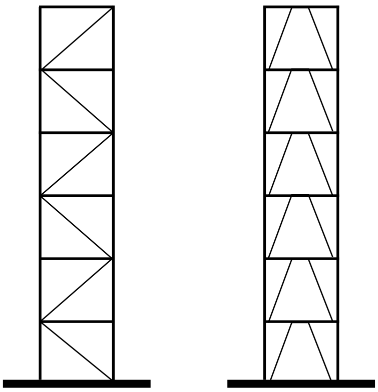


ill.015
Aristotelian building principle

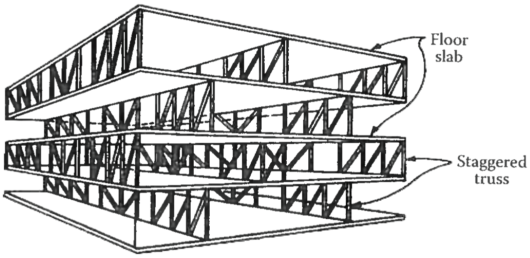
Structural classification



ill.016
Rigid frames



ill.017
Braced frames and eccentric bracing



ill.018
Staggered truss

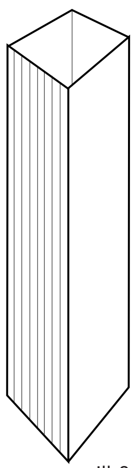
High rises can be divided into several groups. Those groups reflect on structural principles that regulate the height of building.

Rigid frames – not exceeding 25 storeys:
Rigid frame is a moment frame that is supported vertically. It is constructed with beam and column elements. This system developed in late 1800s and it was using iron and reinforcement concrete.

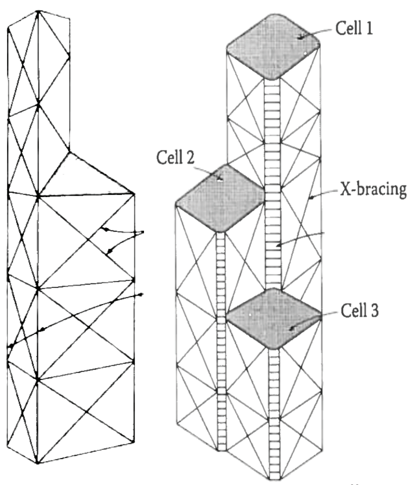
Braced frames – 25-30 storeys:
This system improves rigid frames by adding diagonal braces. It minimizes horizontal shear forces and bending of beams and columns.

Eccentric bracing – 25-30 storeys:
The eccentric beams are designed to limit large forces from entering braces. System remains stability under inelastic deformations.

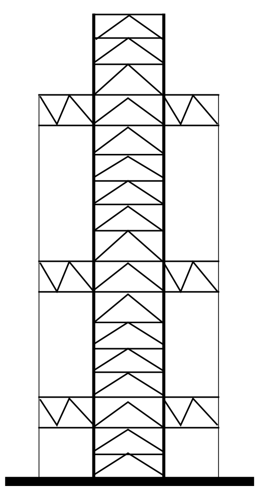
Staggered truss - not exceeding 25 storeys:
This system was made for particular building volumes that have the same width. Trusses are arranged between columns and provide good static resistance.



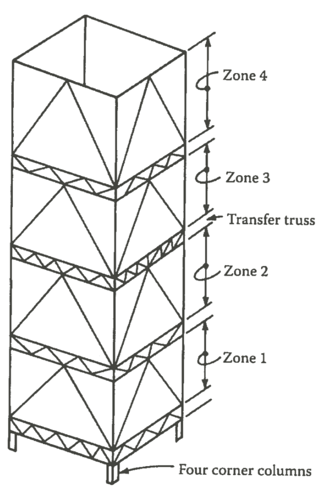
ill.019
Framed tube



ill.020
Trussed and bundled tube



ill.021
Outrigger and core system



ill.022
High efficiency system

Framed tube – 50-60 storeys:

System can be defined as three-dimensional system that works by perimeter in order to receive and neutralize unwanted forces and stresses, by building going upwards.

Trussed tube – 60-70 storeys:

System has impact on facade appearance, as inner tube gains an extra strength from diagonal beams.

Bundled tube – 80-100 storeys:

System consists from different cells that vary in height and are independent. However, cells support each other. This is reason of building ability to go high.

Outrigger and core system – 40-50 storeys:

This system is used in skyscrapers and it developed along elevator. Core by itself is not so stabile than adding extra outriggers. They balance forces and shared moments.

High efficiency system for ultra-tall buildings - 100-150 storeys:

System is based on three main principles: transfer as much loads as possible in columns that resist lateral loads; distribute these columns as far as possible from each other and building geometric centre; interconnect these columns with truss system.

History

ill.023
Home insurance building, Chicago

ill.024
Wainwright building

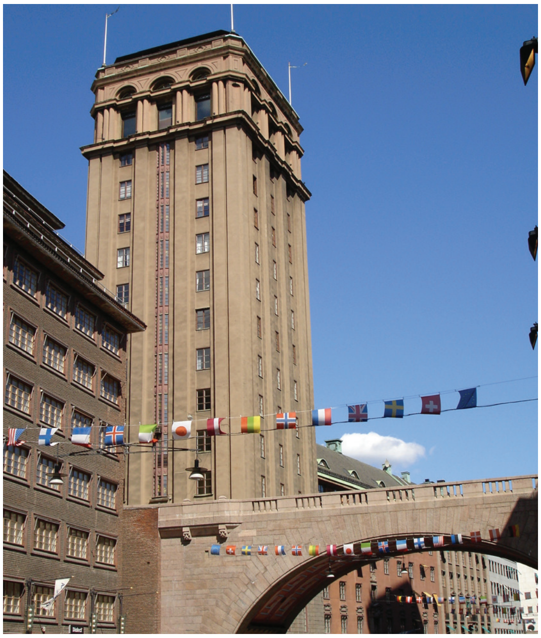
Development of tall buildings began with free-standing iron skeleton adjustments at England in the first half of 19th century. In 1889 G.Eiffel invented 300 m tall iron tower construction. This innovation gave inspiration kick for American engineers. After 1853, when Otis invented first mechanical elevator, tall building was possible to use for tenants [lepik,2004].

The 1st stage - functional phase stimulated building by economic reasons. These buildings had clarity, strength and expressive, aesthetic approach. Main design issues were structure and efficiency; therefore, construction speed, economy, size was leading priorities [huxtable, 1984].

The first tall building was founded in Chicago in 1885. Ten storey building served as Home insurance building (ill.023), but few years later, in 1892, 22-storey building was erected in the same city [lepik,2004].

The second phase was called eclectic that started to produce monumental highrises, as architects were not satisfied with existing building appearance. It was Gothic Greek temple and neo Italian style covers brought real beauty into 20th century city. Buildings varied form banal to brilliant; it was a second born for academic power, as previous phase left architectural considerations far away [huxtable, 1984].

To solve a problem about architectural qualities, L.Sullivan started to formulate



ill.025
Kungstornen, Stockholm

ill.026
Telefónica in Madrid

proportional rules to integrate building in the city environment. In 1891 Wainwright building (ill.024) had vertical columns in its facade to emphasize height [lepik,2004].

Few next passed as continue the fight about tallest building records.

The modernist skyscraper was creative challenge and original response to technological and cultural change that presented elegance. However, the style developed in two directions – modern and modernistic. The modern skyscraper was austere and delicate, but the modernistic one presented mode seductive building approaches with decorative arts [huxtable,1984].

Meanwhile in Europe, architects such as L.Mies van der Rohe, A.Gaudi, tried to compete with Americans and offer proposals for different towers in America while Europe was recovering after WW1.

Highest buildings were Kungstornen in Stockholm (ill.025) and Edificio Telefónica in Madrid (ill.026).

In 1930 Chrysler building (ill.027) overtakes Eifel tower and becomes the tallest building in the world. Very soon in 1931, Empire State building hits new record. These buildings stayed on the top of list until 1970s as construction for higher buildings were cost inefficiently [lepik,2004].

After modern "less is more" period, postmodernists changed skyline once again. All things that modernists wanted to bury are taken up once again – history, culture and décor art [huxtable,1984].

ill.027
Chrysler building, New York

ill.028
Petronas towers, Kuala Lumpur

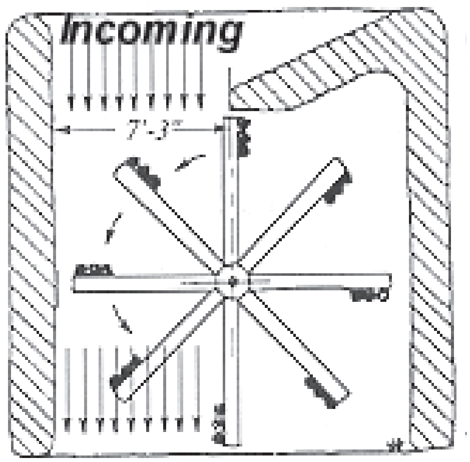
ill.029
Burj Khalifa tower, Dubai

In 1969 with technological development new phase of skyscraper evolution was starting. New record gets WTC in New York City – 415m. Previous half century North America was a leader in a tall building process, but new approaches reached also Asia - Singapore, Japan. In the end, of 20th century Petronas towers (ill.028) with 452m hit the highest peak. Petronas towers are supported by mega cylindrical frame system with high strength concrete. This is new construction turn [lepik, 2004].

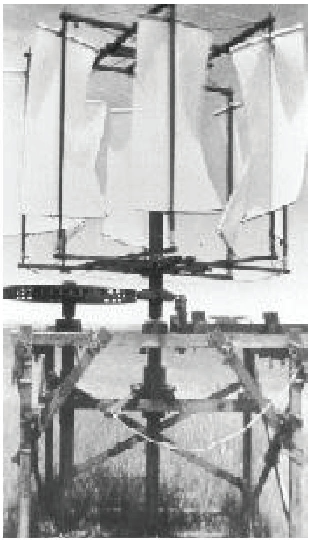
In the end of 20th century, Europe and Middle East joins high rise fashion; London, Frankfurt am Main, Dubai, Riyadh and many more cities.

Today's tallest building is Burj Khalifa tower (ill.029) in Dubai, and it is 828m [lepik, 2004].

Wind power



ill.030



ill.031

ill.032

History

The earliest invention, in order to use wind power, was sailing the boat.

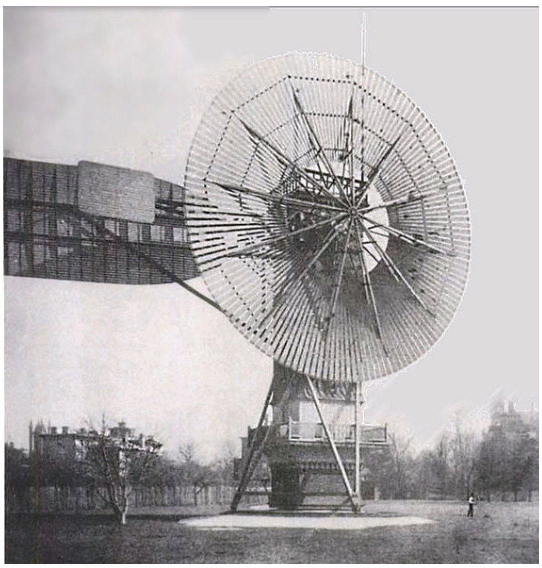
First windmills were developed in Persia (ill.030) about 500-900 A.D as water pumping and grain grinding technic. It was vertical axes system. More advanced and developed vertical windmill was invented at China (ill.031) in 1219 [14].

The first windmills in the western world were in the end of 13th century as horizontal axes system (ill.032). This radical change from Persian vertical axes system was explained as coping technology from water mills. This system was much more efficient that other one.

One century later, Dutch redesigned tower mills by ordering functions in different storeys and optimizing rotor speed limit.

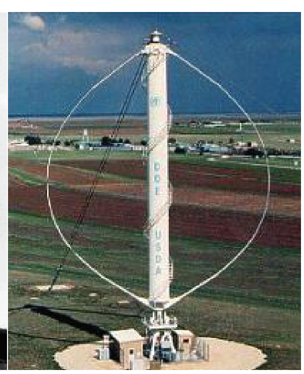
Improvements of mills continue next 500 years by developing wings to blades and combining water pumping system with irrigation. These windmills were using renewable energy resources in pre-industrialised Europe [14].

America was developing windmill system using steel blades that increased productivity. Between 1850 and 1970, six million, mostly small wind machines, were installed in the U.S. In the end of 19th century American blade system was one of first ones that change energy production from pumping and grinding to electricity supply.



ill.033

ill.034



ill.035

The first system was built in Cleveland, Ohio, in 1888 by Charles F. Brush in order to use large windmill for electricity. The Brush tool (ill.033) was a mill on post with a multiple-bladed rotor 17m. A large tail was hinged to turn the rotor out of the wind. However, this windmill was not as efficient as smaller aggregates, comparing with its expenses. In a while, cheap fossil fuel resources beat wind power generators.

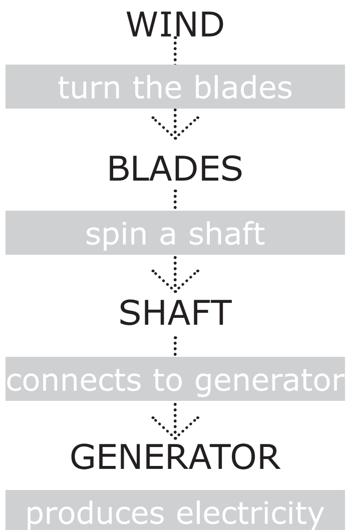
In 1920 small wind generators was serving agriculture and housing needs. But by the growing demand for electricity US extended electrical grid appliances, therefore, wind generators were stopped use as they were unable to follow electricity power needs [14].

Russia was the first country where in 1931 has been started large wind generator building next to Caspian Sea. In 1960s Denmark tried to minimise blades weight and during first energy crises. Wind power takes back trust.

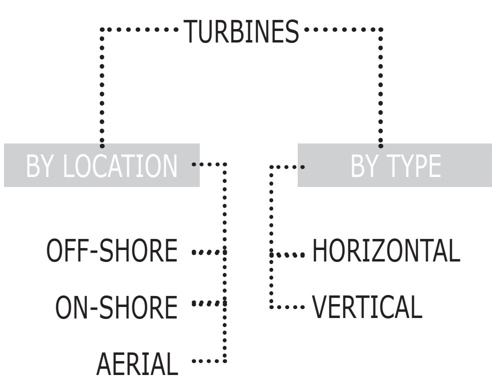
After 1973 Arabic oil crises, US involved wind energy development team to improve wind engineering conditions. Two blade wind generators (ill.034) were not so effective, so at 1981 in Colorado were established several farms with 3 bladed turbines. These wind turbines were bought from Danish firms that captured 50% of US market.

From 1990s, wind farms and independent turbines was distributed more and more along coastlines in US and Nordic – Western Europe [14].

Turbines



ill.036 Turbine working scheme



ill.037. Turbine classification

The dominant turbines in the market now are horizontal axes turbines, but vertical turbines are more integrated into building design [greenpaper, 2009].

Horizontal axes turbines (HAWT) have a rotor and a generator that is mounted on the top of a tower. It should be pointed into the wind in order to harvest energy. Small turbines catches wind by letting vanes adjust to face wind; large ones have a sensor, and it provides turning to obtain acceptable wind stream conditions.

Turbine's blades should be produced form stiff material to prevent them pushed into the tower. The blades are coloured light grey to blend in with the clouds. Typically they rotate between 10-22 revolutions per minute. The tubular steel towers range from about 60 to 90 meters high. This lifts the rotor to a height, where wind speed can achieve decent speed for energy production [15].

Vertical axes turbines have vertical rotor; therefore, there is no need to point blades into wind direction. Vertical turbines are more attractive for an integrated building design, as turbines solve the problem with turbulence and highly variable wind direction. Wind turbines can operate with low and high wind speed, so power can be harvested more hour average in a year. Many models are safer for birds, not so loud, and a gearbox is easier accessible for maintenance. In spite of all this advantages, vertical turbines are less efficient that horizontal ones [greenpaper, 2009].

Hurdles

ill.038

ill.039

ill.040

Hurdles can be divided in four main groups: [BIWT,2005]

1) Environmental - wind regime - high turbulence levels and veering and swirling winds;

a) High turbulence levels in the urban environment cost reduce productivity and induce unwanted stresses for building. It increases noise levels.

Solutions: VAWT systems are more resistant than HAWT but less productive, though. Investment could be alternative methods for HAWT systems, such as blade design and testing of turbulence conditions, web design and wind tunnel tests.

b) Implications of veering and swirling winds cost by blades vibration, and yaw deflection is coming from intended course.

Solutions: Integration in building design as wind tunnel effect. Building shape and turbine design can fix blades even in strong winds.

2) Noise and vibration issues – airborne sound, structurally transmitted vibrations.

a)Structurally transmitted vibrations depend from building and wind turbine’s size. Vibrations are created by spinning blades that transmitting them to structure and may cost discomfort for inhabitants. In long terms structure takes constant vibration amount that can damages it, especially using light and modern building structures.

Solutions: Design early stage should analyse connections and material resistance. Usage of insulations and flexible materials can solve vibration.

b) Noise reduction (Broad band, low frequency) is a serious issue to provide suitable conditions for using turbines in noise sensitive areas. Low frequency noise may cause more vibration than statically transmitted. It influent sensitive receivers, and it cost high and rapid discomfort feeling.

Solutions: Careful building and turbine design can prevent noisy structures. Establish testing laboratory to investigate possible solutions. Use turbines in regions with less sensitive environment. To use VAWT that creates min low frequency and noise levels.

3) Turbines design – blade design, safety issues for falling parts, easy access for maintenance

a) Turbine’s blades are not enough robust. The wind might break them down, and it may cost a lot of victims and damages.

Solutions: new designs should include safety margins and automatic shut downs in order of failure. Swish type blade – that makes less turbulence and movement. Wood laminate blade can be solid material for smaller blades.

B) Safety processes for falling rotors and parts are a critical issue. It should be evaluated with high importance level as it may cost catastrophic failure.

Solutions: Careful design and decision on mechanism location. Safety cage design. Testing turbines in a strong wind to improve design.

c) Omni directionality is high issue to harvest wind power that varies directions.

Solutions: VAWT has implemented rotating potential. HAWT should be considered further and improve its design with lacking issues. Usage of wind screens shadows.

4) Costs - installation, maintenance, transporting.

a) Production and mounting costs are high.

Solutions: since wind turbines are still a bit exclusive power supply, costs are comparably high. The Cost will drop by increasing productivity and demands.

b) Access for maintenance parts is necessary for any not fixed product.

Solutions: Design and location of the shaft should be easily accessible. Thus, design should increase quality of parts. So there is less need for maintenance.

Noise pollution

Noise is unwanted sound that disturbs and creates irritation. Noise level is measured in dB. Human hearing range differs from 0dB (threshold of hearing) until 140 dB (pain and immediate hearing loss) [16].

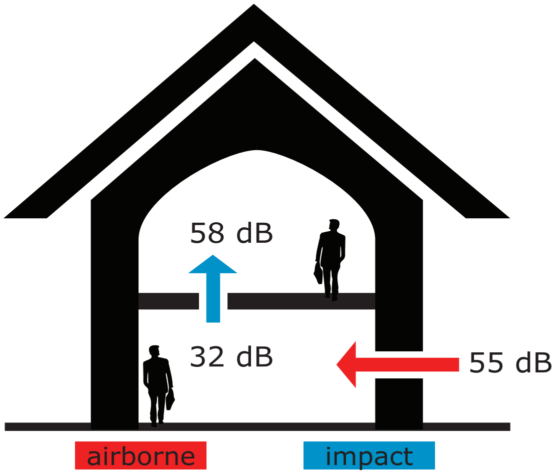
Sound is classified as acoustic, electronic, vibration and visual noise.

Acoustic sound is audible and could be heard, made by humans, devices or nature [17].

Electronic sound describes signal that is produced by electronic devices [17].

Vibrations sound could be found in construction or natural energy sources – waves, earth plate's movement etc. [17].

Visual noise is projected on pictures by using black and white image prototype [17].



ill.041 Sound demands

Noise in residential environment

Sound insolation in buildings should be made to provide a decent living conditions. Sound in building classifies into two groups – airborne sound and impact sound. Airborne sound is noise that is travelling in the air and transmits through openings and materials. Impact sound is noise that transmits as vibration noise through structure [SBI 172].

Max noise level (ill.041) in residential buildings is 58 dB impact sound and 32 dB airborne sound [BR10].

Noise levels from different sources

Place	Noise source	dB
Quiet	Threshold of hearing	0
Quiet	Breathing	11
HAWT	350m inside	25-35
Quiet	Quiet Room	28-33
Home	Computer	37-45
VAWT	6 m outside	38
HAWT	350m outside	35-40
Home	Typical Living Room	40
Home	Quiet Library	40-43
Home	Refrigerator	50-75
Home	Air Conditioner	55-59
Speech	Conversation	66-75
Home	Phone	70
Home	Doorbell	80
Public	Noisy Restaurant	85
Travel	Heavy Traffic	90
Speech	Loud Conversation	90
Tool	Tractor	95
Home	Max Stereo output	110
Public	Disco	110-120
Public	Rock Concert	120
Travel	Ambulance Siren	120
Military	Air Raid	130
Travel	Airplane Taking Off	140

ill.042 Different sources nosiness

List (ill.042) of different noise sources is given to increase general knowledge about sound level [18].

Wind turbine's produced noise comes from the gearbox and wind turning blades [18].

HAWT makes more noise that VAWT as it is more efficient and blades are bigger. VAWT is spinning with smaller movement and more delicate construction.

Noise level from 45 m HAWT is 90-100db. 350 m away it is 35-45 dB. Inside a house with demanded sound insulation 25-35 dB.

Noise level from 50 kW VAWT 3m away is 38dB [19]. Therefore, it is lower than 32dB inside house.

These results show that audible sound not disturbs inhabitant living close to windmills. However, off-shore wind turbines can create more vibrations that on-shore. These turbines are not meant to be implemented in the building or on-site areas.

VAWT is even more suitable for living conditions and creates almost no sound.

Impact on human health

A lot of discussion has been made to see if wind turbines created noise and vibration leaves some negative impact on human health. Meanwhile, there are organisations trying to ban utilization of wind farms, as they got opinions from people living close to farms. Especially in Australia [20].

However, scientists and local activists have been tried to investigate problematic situation, as wind power is essential for future energy independence.

Results came up negative. They picked several wind farms and questionnaire inhabitants in 10km radius, what is mentioned as dangerous zone. Among 10-12 thousand people, there was several who complaining about high blood pressure, head aches and sleep disturbance, but the most fascinating part that these symptoms was spreading along anti-wind turbines move. Therefore, the most disturbances get people who don't see any benefit from farms. By questioning tenants who have wind farms on their own land, results surprised. They haven't gotten any disturbance that could affect their health even if they live real close to them [20].

The audible sound created by a wind turbine, measured at 350 meters, is around 35-45 dB. To compare, rural night-time background noise is just 20-40 dB. Wind on its own produces levels up to 35 dB.

Greenpeace, in the Sept. 2006 report Global Wind Energy Outlook, suggest that noise from wind turbine is lower than trains road, traffic, industrial noise and construction activities [pdf_health, 2008].

Researchers conclude that this level is too low to do harmful effect on human health, by investigating infra sound levels [pdf_health, 2008].

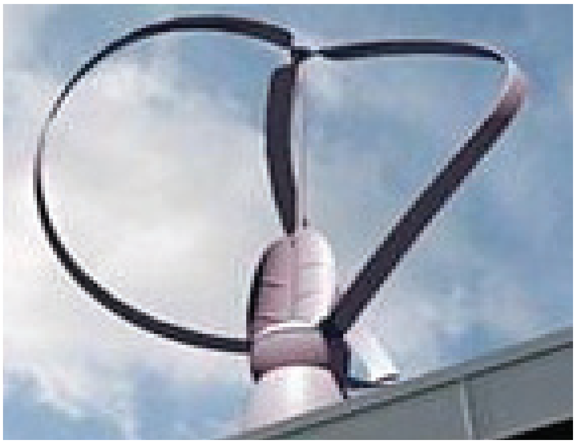
Infra sound level

Infra sound is low frequency sound waves for 0.01 Hz-20Hz what is on an edge of human hearing [44].

Natural sources that provide infra sound form 0.01-2 Hz are wind, waves, earthquakes, avalanches etc. Human made devices that spread infra sound are different soil and air machinery. High level of infra sound may cost stresses and pressure differences in the human body that is unwanted [44].

Wind turbines design has been developed during centuries. Earlier models had infra sound vibration problems, as they were using downwind motors. New models have upwind system and it minimise noise. All sound levels are lost 100 m away from turbine. Difference between both systems is that wind reaching upwind turbines do not passes by blades as it is in downwind case. This air motion creates unwanted turbulence and high level of infra sound [44].

Turbines specification



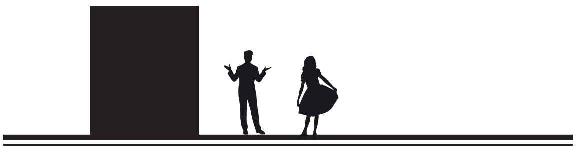
ill.043

Ecofy's Neoga

Vertical axes turbine is designed as Darrieus and Savonius type combination. It is an excellent product for locations with changing wind direction [BIWT, 2005].

Turbine as roof installation works in turbulent and dense environment. Ideal for one family residence.

Scale



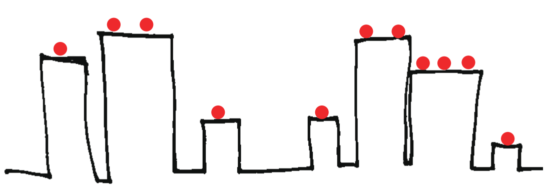
Type	VAWT
Productivity	3 kW/h
Size	rotor 2,8 m
1 turbine can supply	429 m^2

Solar panels compared with 1 turbine

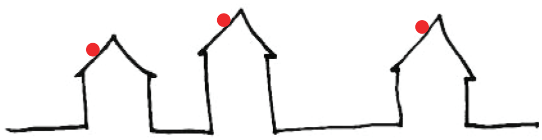
Urb	17 m^2
Sub	13 m^2

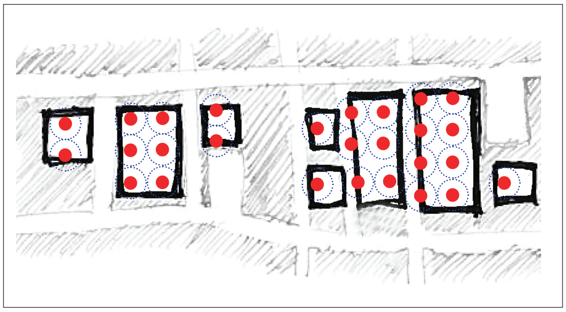
Turbines density potential

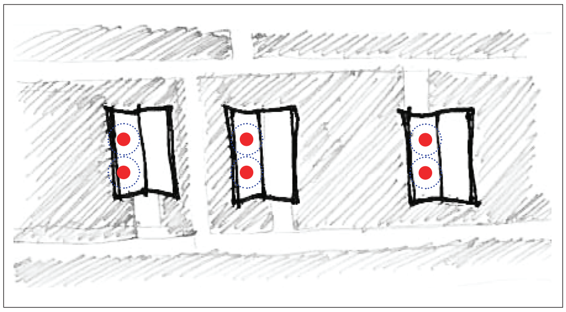
Urban



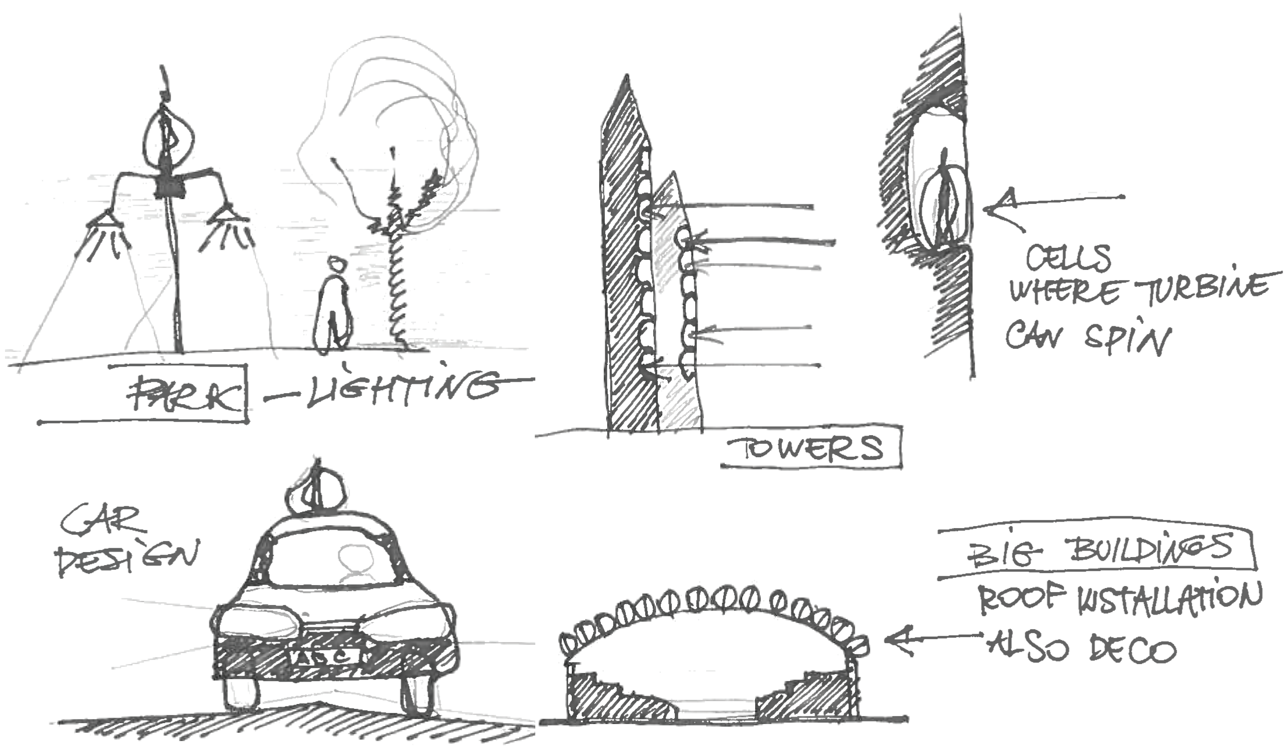
Suburban







References and integration proposals



ill.044

Ropatec

Ropatec's signature is noiseless, aerodynamic efficiency, smoothness of motion and aesthetically appealing design [21]. Roof installation, it works in turbulent and dense environment. Product is available in different scales.

Scale

Type	VAWT
Productivity	20 kW/h
Size	rotor 3,4 m

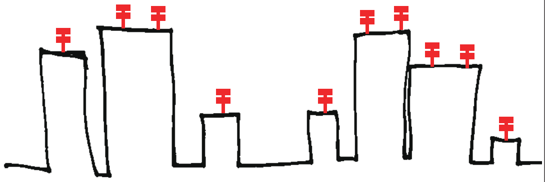
1 turbine can supply 2857m^2

Solar panels compared with 1 turbine

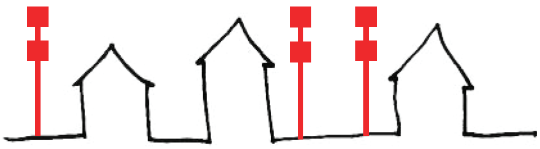
Urb	111 m^2
Sub	83 m^2

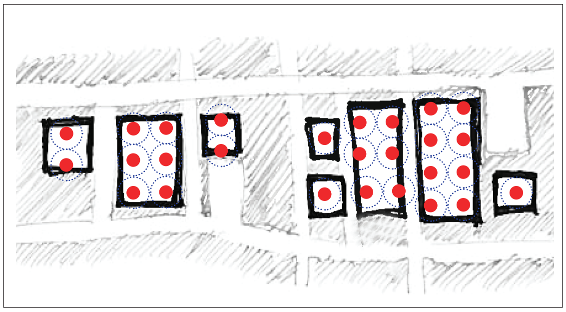
Turbines density potential

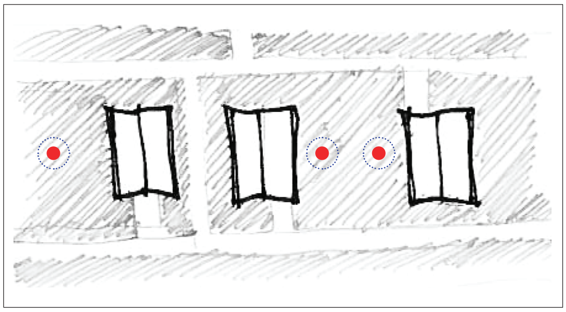
Urban



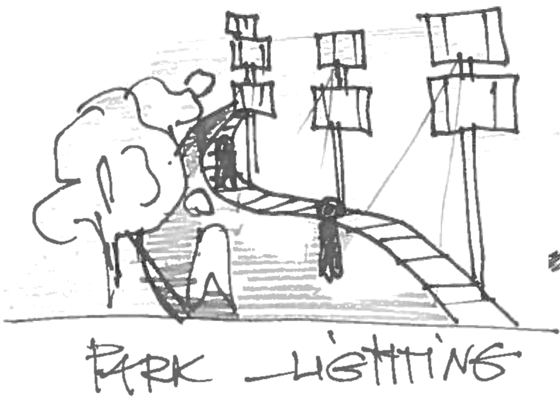
Suburban

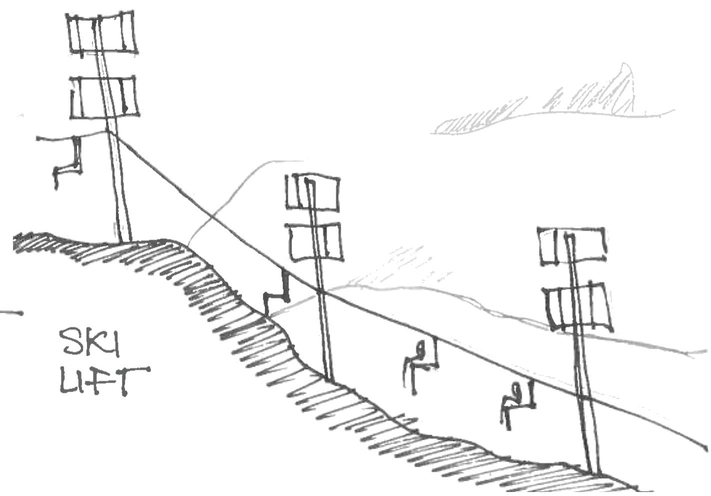






References and integration proposals





ill.045
Sydney

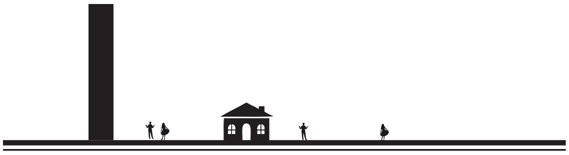
Hungarian windmill

ill.046

VAWT is working in both slow and strong wind. Structure is trapping wind and makes turbine work more efficiently than other. 5.5m wide and 29 m high turbine can produce 210 kW. Turbine can alter its size from 10-20m in diameter and 30-120m high [barikad,2011].

Turbine is made of 2 layers. Outer layer consists from openings that inlet air to the inner layer - Darrieus type mechanism. Opening cells reduce turbulence, speed up flow. It can use variable and steady wind.

Scale



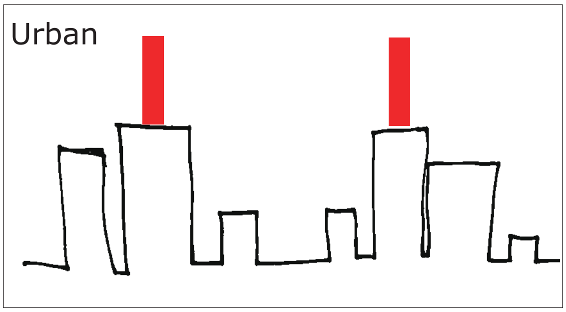
Type	VAWT
Productivity	210 kW/h
Size	foot 5,5 m x29m
1 turbine can supply	30000 m^2

Solar panels compared with 1 turbine

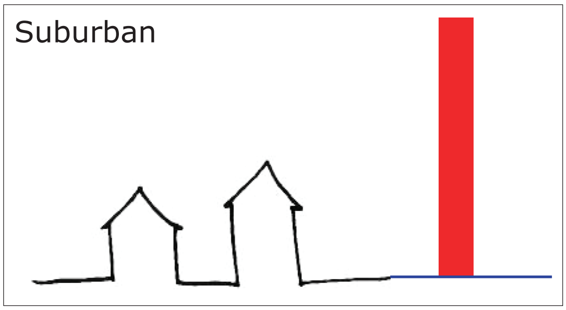
Urb	1167 m^2
Sub	875 m^2

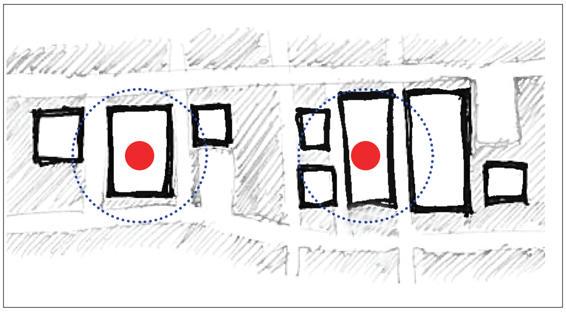
Turbines density potential

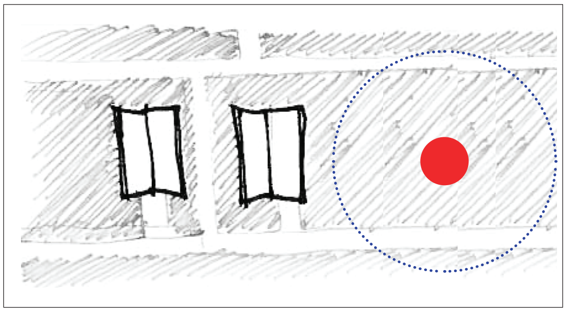
Urban



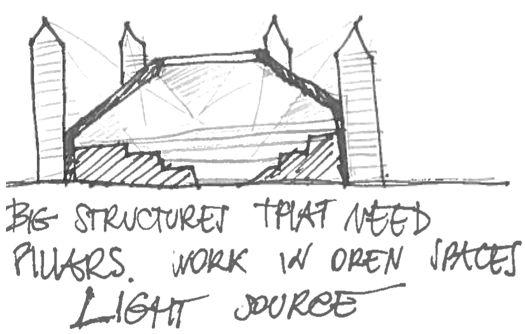
Suburban

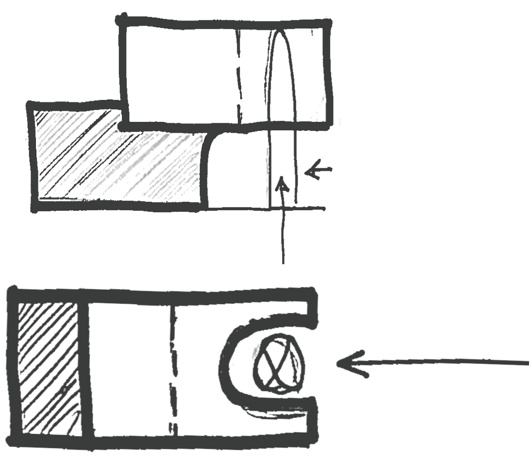


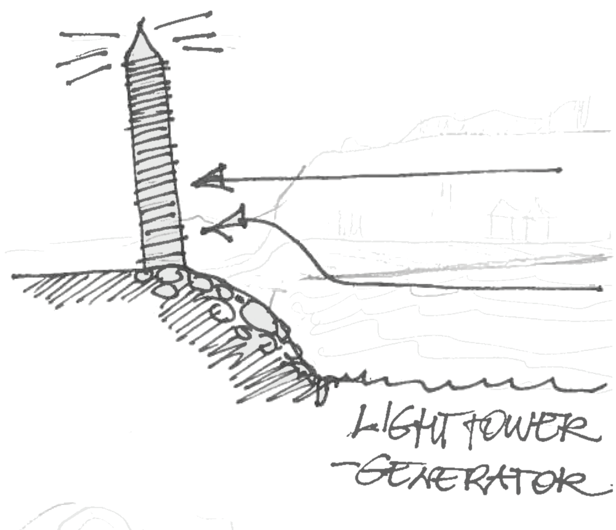




References and integration proposals








ill.047

Aerotecture

Aerial turbine is horizontal or vertical axes turbine, which is specially made for BIWT and is fixed to building structure. Mechanism and gearbox is preserved the same as for free standing turbines [W. Brosius, 2009]. However, it need laminar wind and requires space around for fresh air inlet. Roof installations blocks can be attached in a row. Turbine can be used also vertically.

Type	HAWT
Productivity	1,5 kW/h
Size	3x1,5 m
1 turbine can supply	214 m²

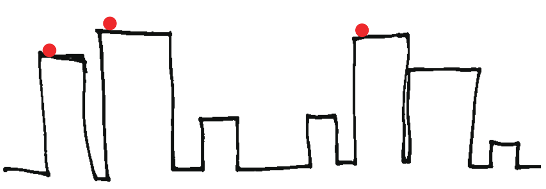
Solar panels compared with 1 turbine

Urb	8 m²
Sub	6 m²

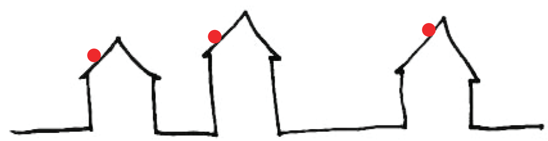
Scale

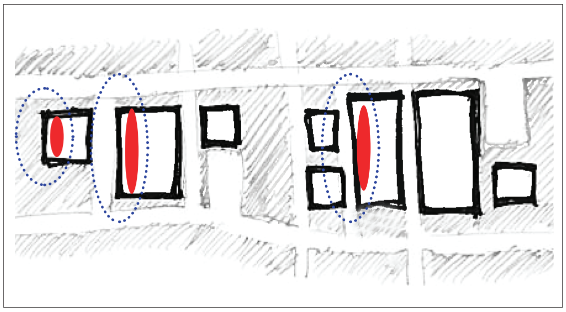
Turbines density potential

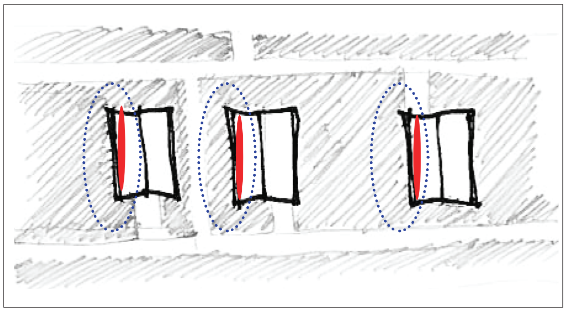
Urban



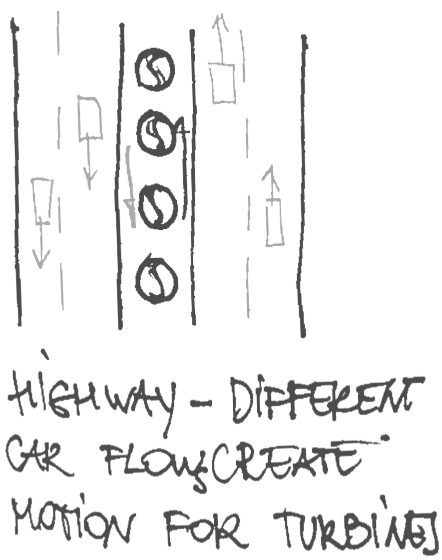
Suburban





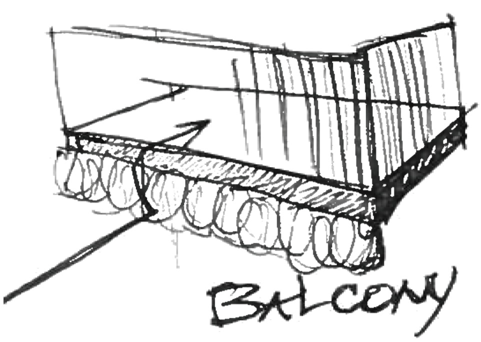


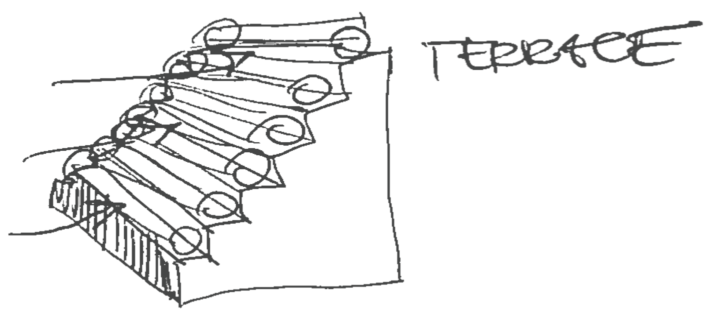
References and integration proposals




ill.048


ill.049





ill.050

Scale

Edge flow

HAWT is designed to collect wind energy in dense cities. Turbine is situated on the top corner. In order to be high efficient and immune from turbulence, HAWT is turned 90 degrees. Turbine is 36m long and 2,2 m in diameter [22].

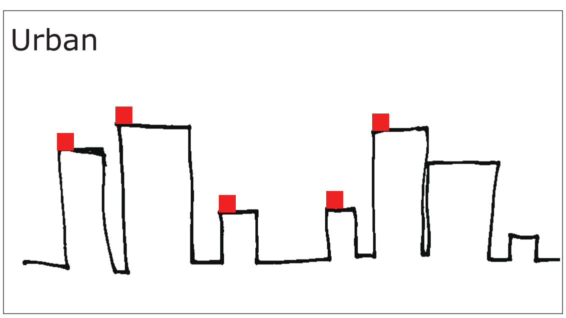
Turbines can be attached to each other. Existing size is too large for personal use. It is optimally updated to implement in industrial areas where building arrangement is even and has a place for the wind to accelerate.

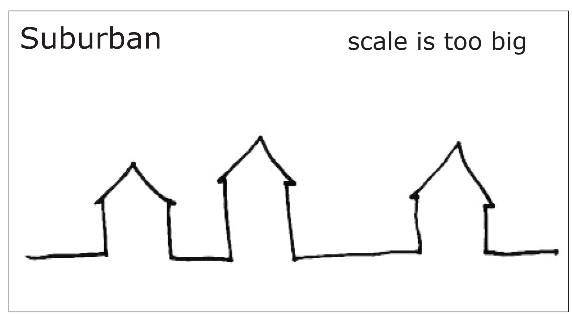
Type	other
Productivity	7,5 kW/h
Size	2,236 m
1 turbine can supply	1071 m^2

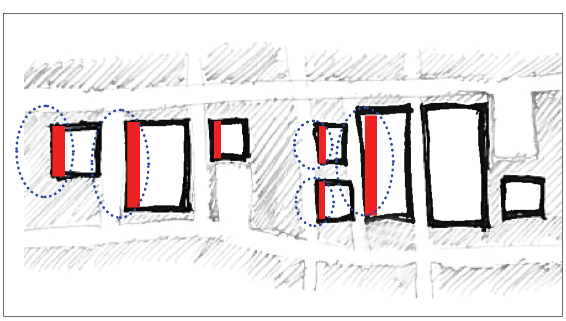
Solar panels compared with 1 turbine

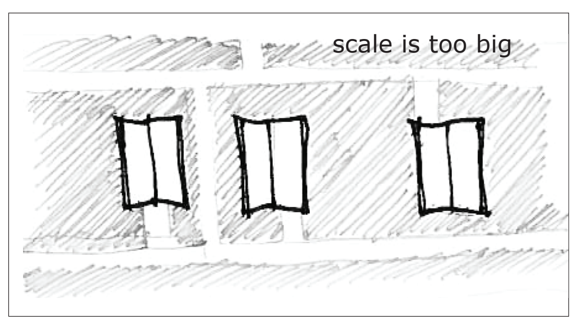
Urb	42 m^2
Sub	31 m^2

Turbines density potential

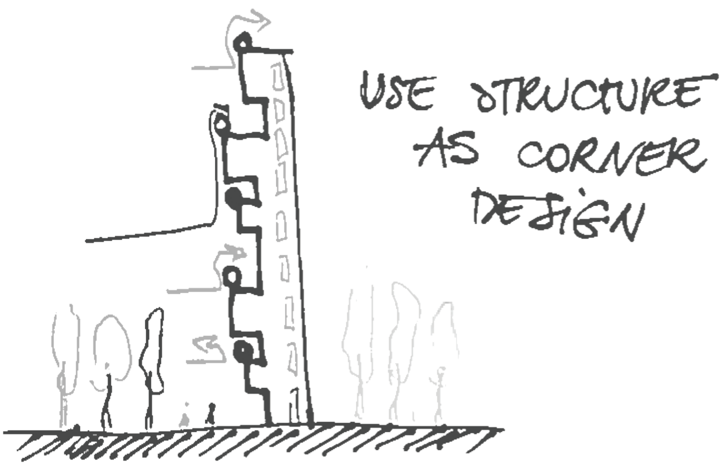




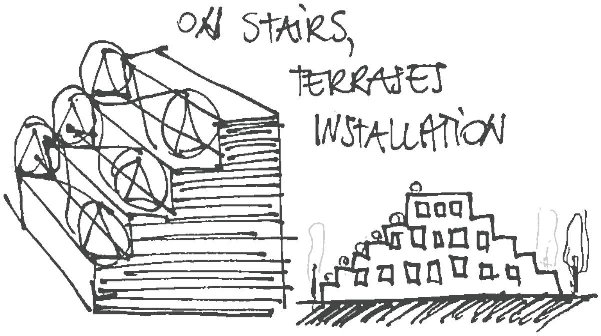




References and integration proposals




ill.051



Windside

ill.052

The Windside has an aesthetic quality. It has slow, graceful rotation of the double helix vane structure [23]. Roof and wall unit that differs in sizes can work with laminar but changeable wind. It can produce efficiently in dense context.

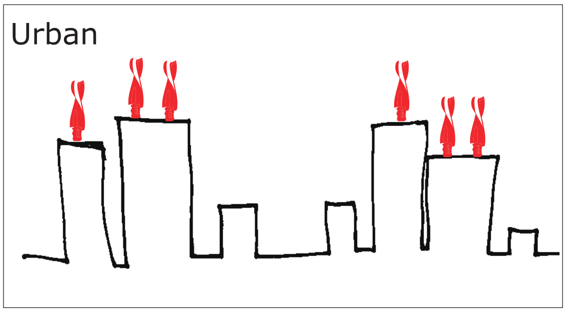
Scale

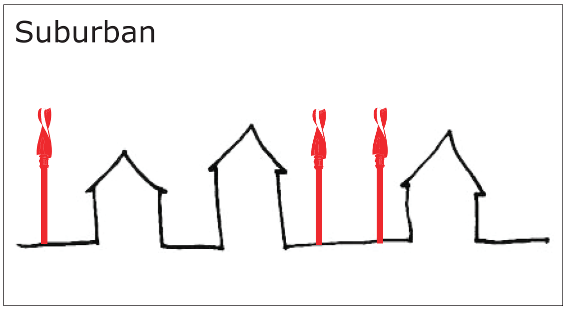
Type	VAWT
Productivity	5,5 kW/h
Size	rotor 3 m
	height 12m
1 turbine can supply	786 m^2

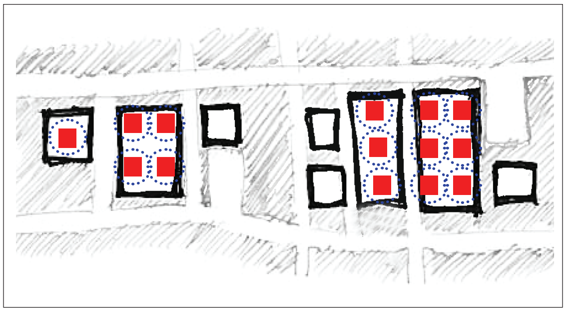
Solar panels compared with 1 turbine

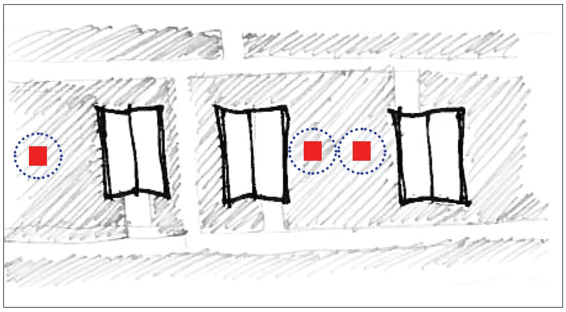
Urb	31 m^2
Sub	23 m^2

Turbines density potential







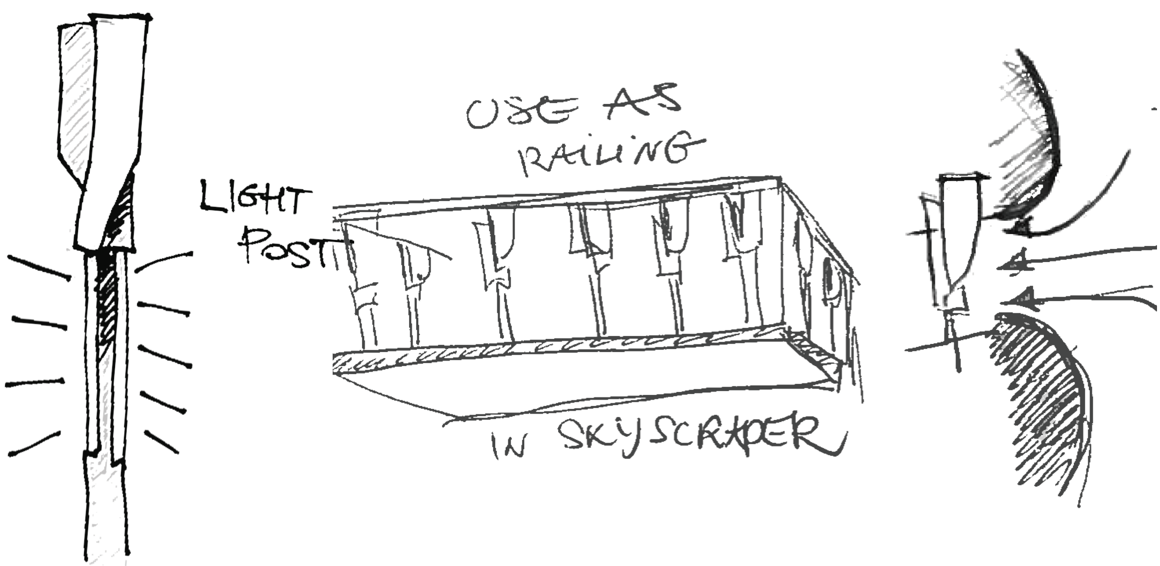


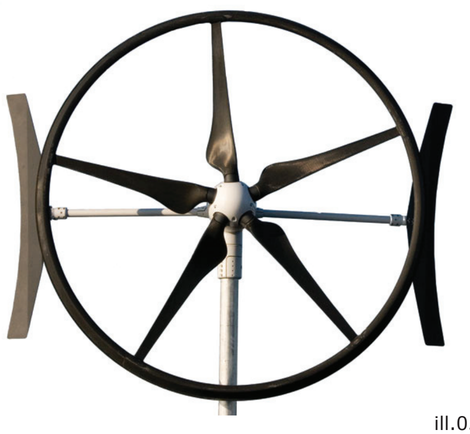
References and integration proposals

ill.053
Greenway Self Park, Chicago

ill.054

ill.055
Pearl River Tower, China





ill.056

Swift

Turbine is designed to be integrated into conventionally high rise building. Model consists from 90 degree angled duct with hidden rotor plane, and it takes inlet just from one side. Closed edges are joined with building massive.

Turbine can work with laminar wind and rotate according wind direction. It works as roof unit or integrated part in building.

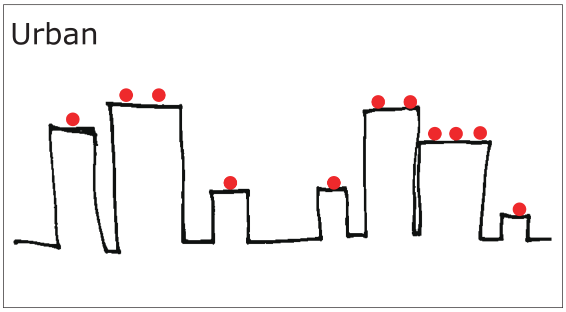
Type	HAWT
Productivity	1,5 kW/h
Size	rotor 2,1 m
1 turbine can supply	214 m^2

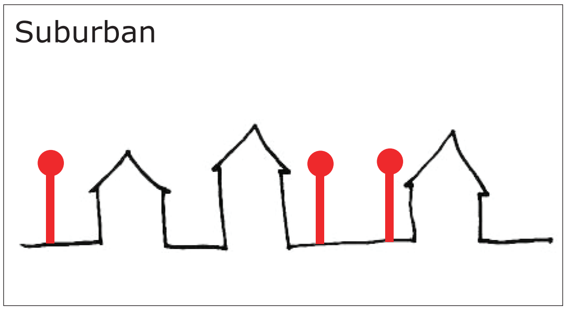
Solar panels compared with 1 turbine

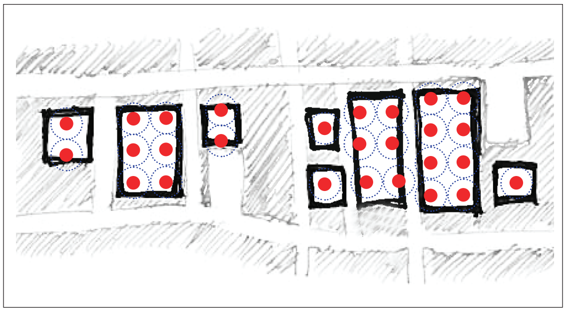
Urb	8 m^2
Sub	6 m^2

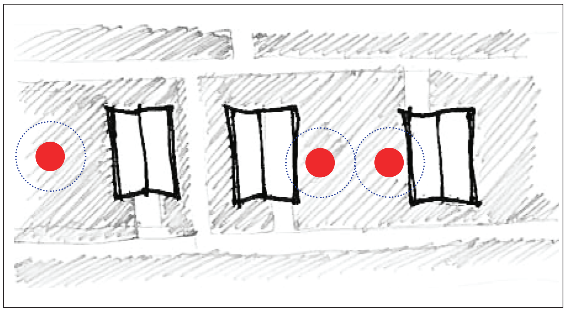
Scale

Turbines density potential



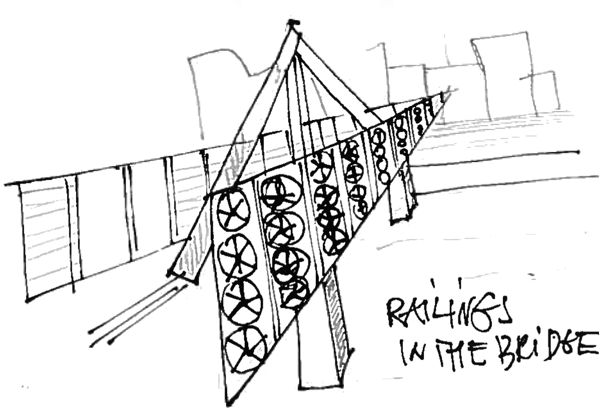


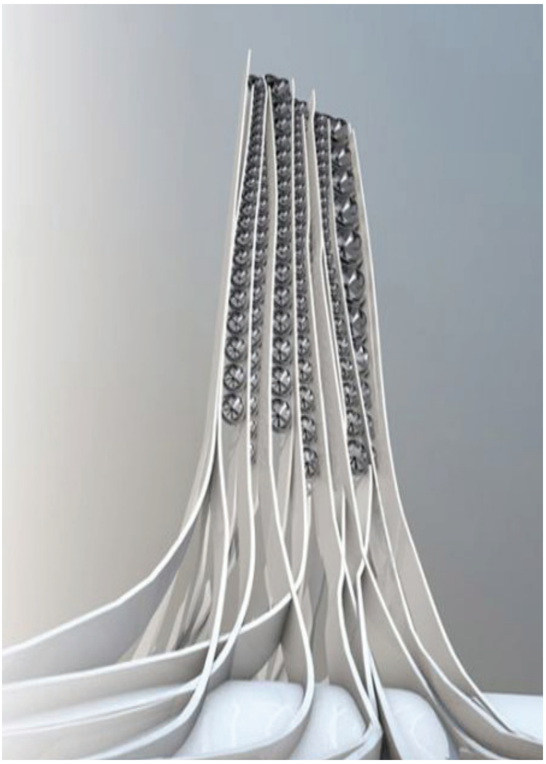




References and integration proposals

ill.057





ill.058
Gesterbine, Poland

AVX AeroVironment


ill.059

Turbine is spinning engines that generate energy from fluid energies such as water, steam, and gas. The sleek and modular units are also operating with less noise and vibration than conventional design [24]. Roof installation needs laminar wind flow. Works as wind wall and turbines can be attached in a row.

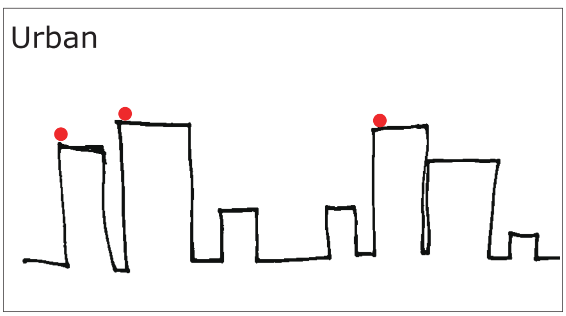
Type	HAWT
Productivity	1 kW/h
Size	height 3 m
1 turbine can supply	143 m^2

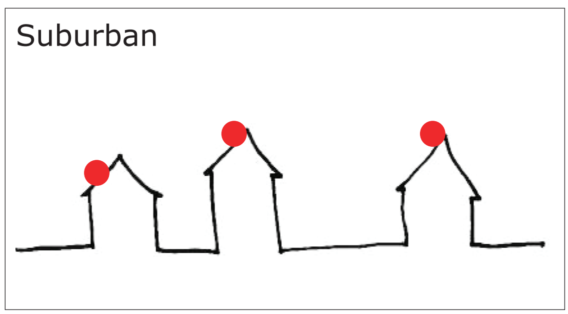
Solar panels compared with 1 turbine

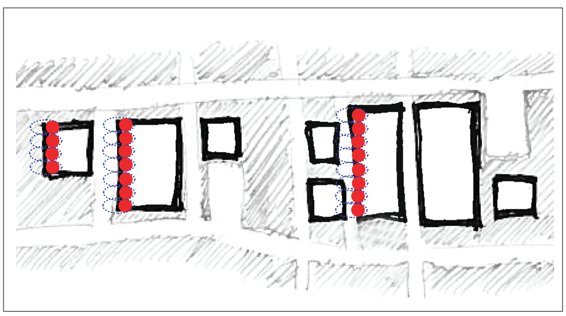
Urb	6 m^2
Sub	4 m^2

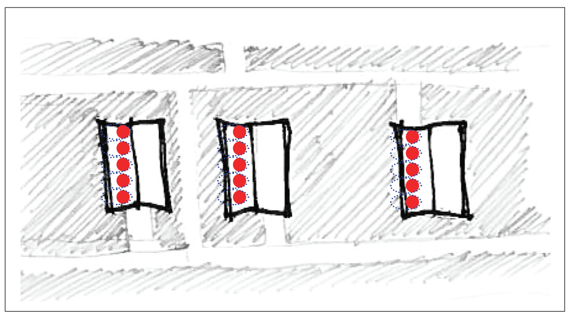
Scale

Turbines density potential





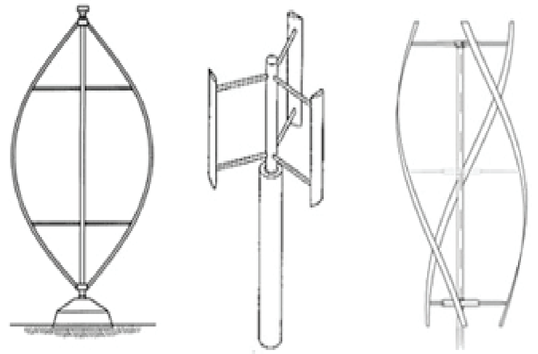




References and integration proposals

ill.060

Darrieus



Rotor Darrieus   Rotor Darrieus H   Rotor Hélicoïdale

ill.061

The Darrieus turbines operate by lift. The air foiled blades create a pressure differentially across the blades due to the Bernoulli Effect. Darrieus blades are accelerated as they move against the wind much like a sailboat going upwind. Because Darrieus turbines operate at higher speeds, they typically have higher power outputs and higher efficiencies [W. Brosius, 2009].

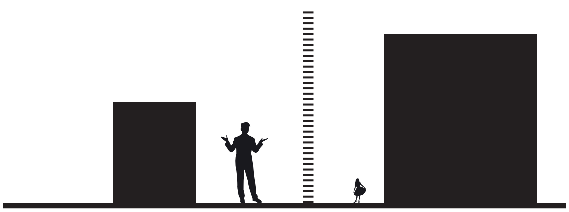
Turbines can take turbulence and variable winds and can be in different sizes and works in dense context.

Type	VAWT
Productivity	3 kW/h
Size	rotor 2 m
1 turbine can supply	429 m^2

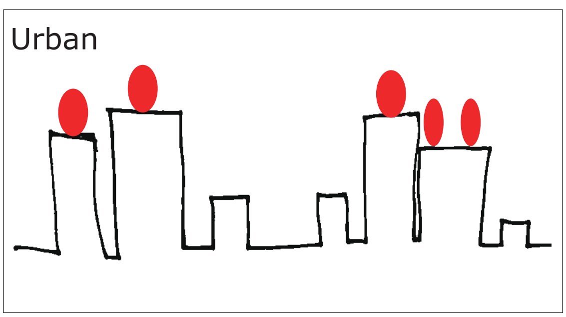
Solar panels compared with 1 turbine

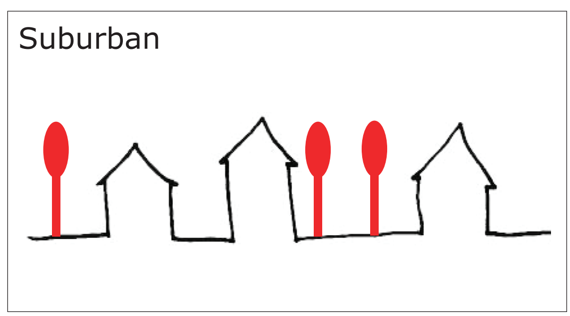
Urb	17 m^2
Sub	13 m^2

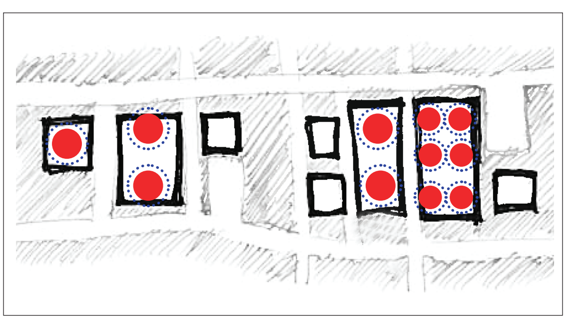
Scale

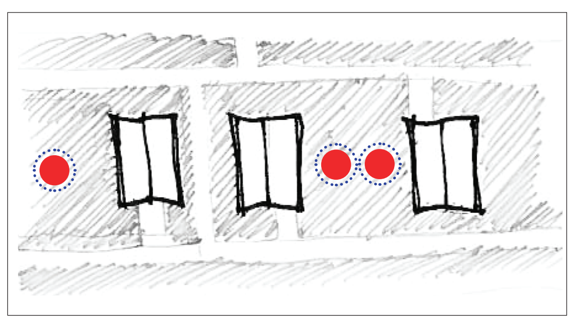


Turbines density potential





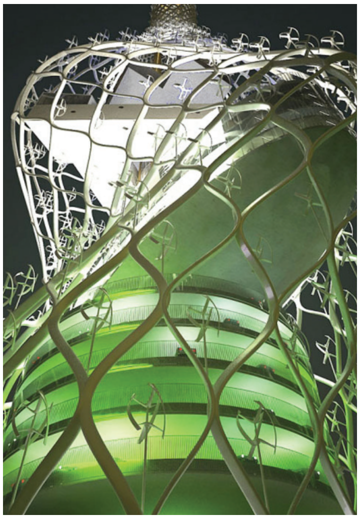


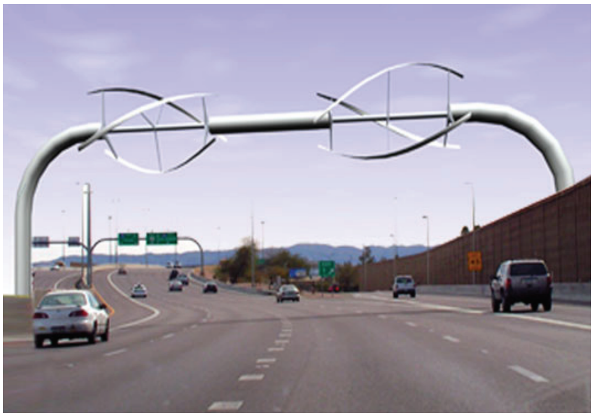


References and integration proposals

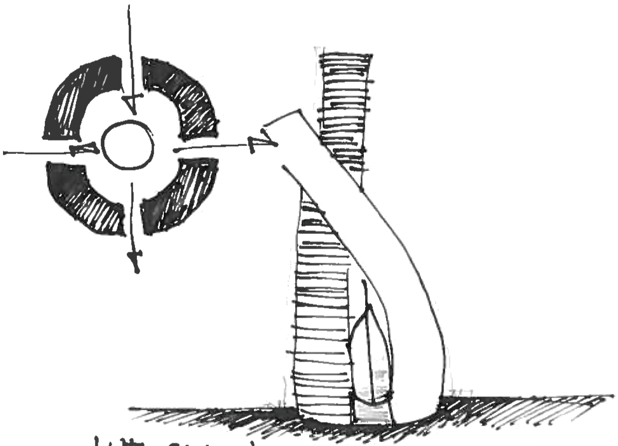

ill.062

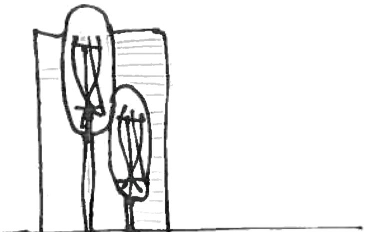
ill.063

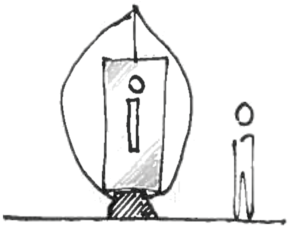

ill.064
Tower of Power Incorporate


ill.065


ill.066
Gullwing Twin Wind Towers , ARXX





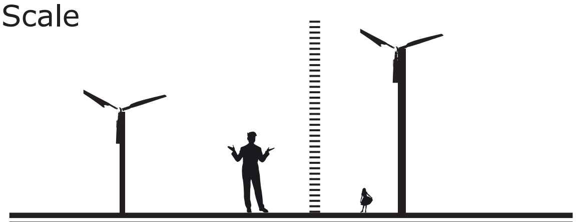


ill.067

Gazelle

Typical HAWT can be found in different sizes. The Gazelle provides power solution for a medium-sized users, such as small businesses, schools, water works and eco-centres. Rotor generates around 20kW of electricity [25]. Uses laminar wind and need space to accelerate wind speed. It can be used on post or integrated into the building.

Scale

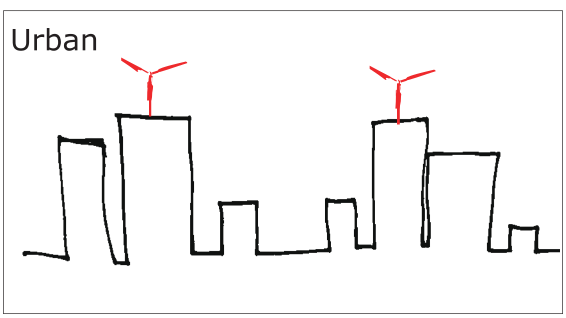


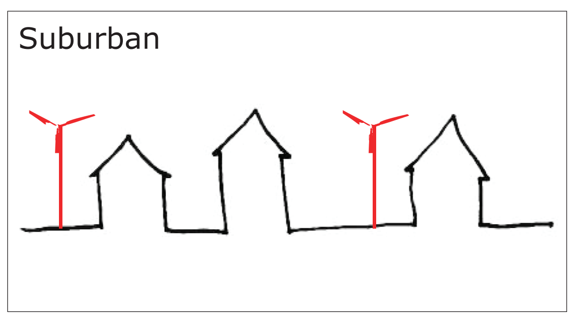
Type	HAWT
Productivity	20 kW/h
Size	rotor 11 m
1 turbine can supply	2857 m^2

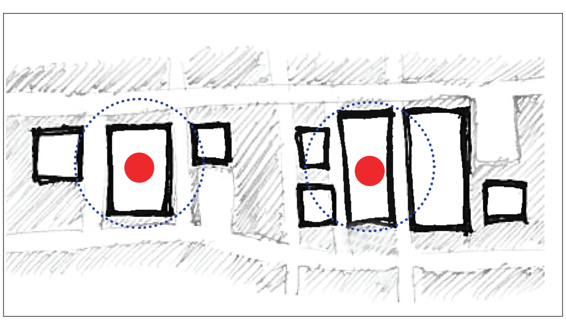
Solar panels compared with 1 turbine

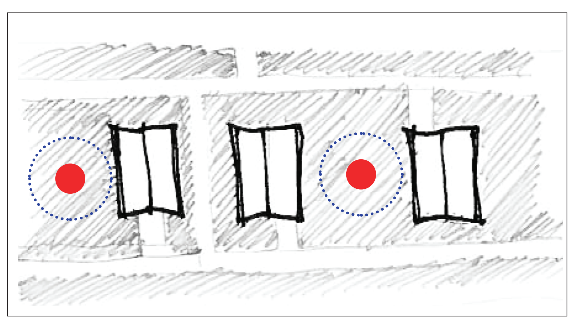
Urb	111 m^2
Sub	83 m^2

Turbines density potential

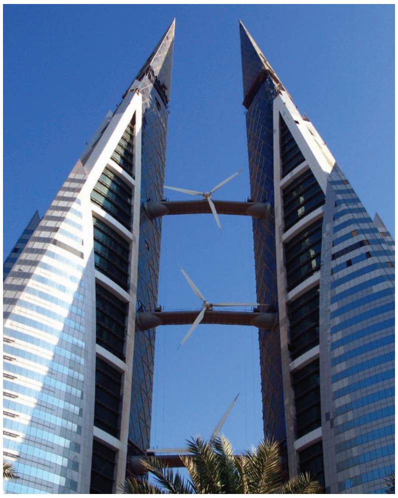








References and integration proposals

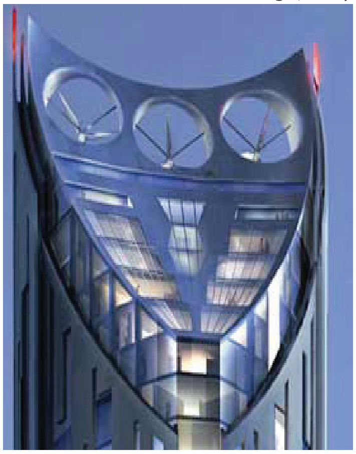

ill.068
Atkins, Bahrain WTC

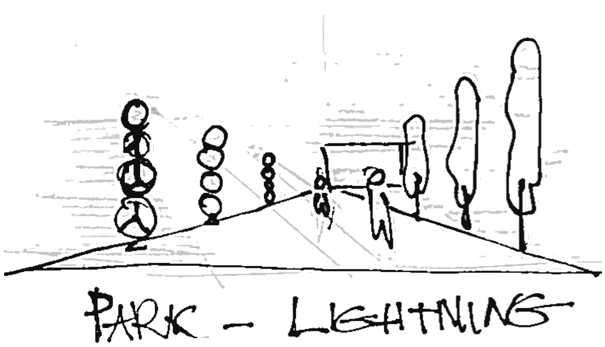

ill.069
Atkins, Anara tower , Dubai

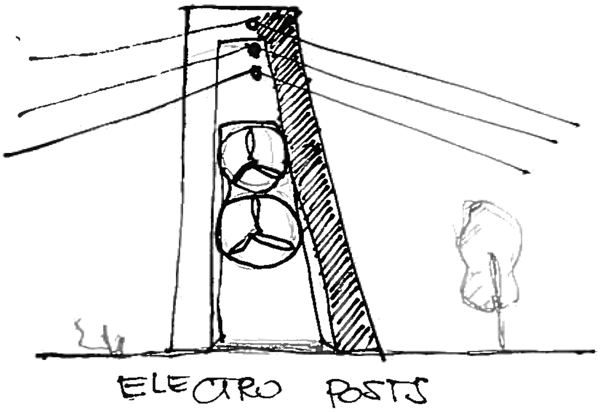

ill.070
Solar wind bridge, Italy


ill.071
Callebaut, Mexican Eco Tower


ill.072
Oppenheim, The COR Building, Miami


ill.073
BFLS, Strata Tower, London





ill.074

Winpods

Windpods wind turbines are harvesting technology for residential and commercial cases. The design of windpods is variable and can be adapted for different conditions.

The Windpods G1 is 0,45 m times 2,2 m. Windpods can work in combination with a solar PV or a stand-alone installation [26].

Scale

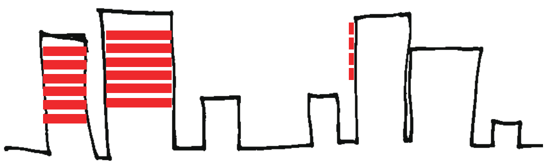
Type	other
Productivity	1 kW/h
Size	2,2 x 0.45 m
1 turbine can supply	143 m^2

Solar panels compared with 1 turbine

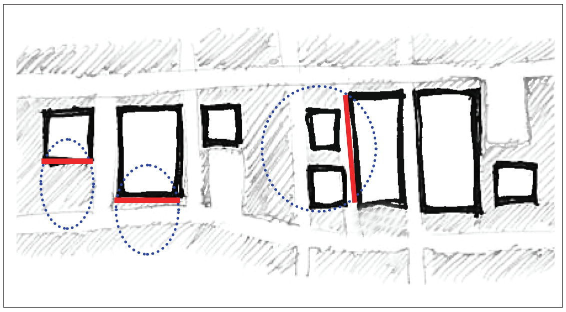
Urb	6 m^2
Sub	4 m^2

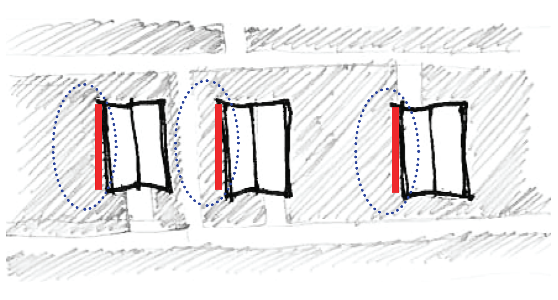
Turbines density potential

Urban

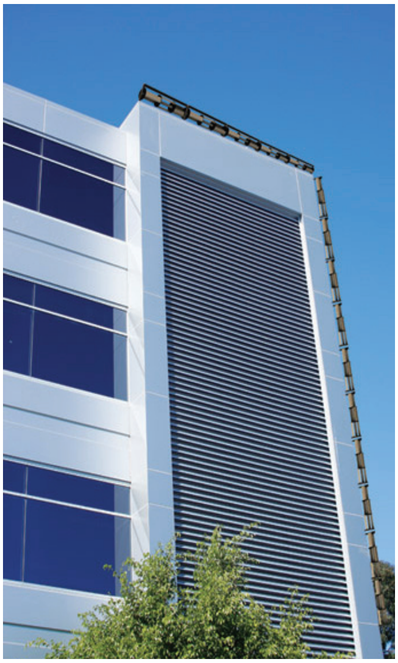


Suburban





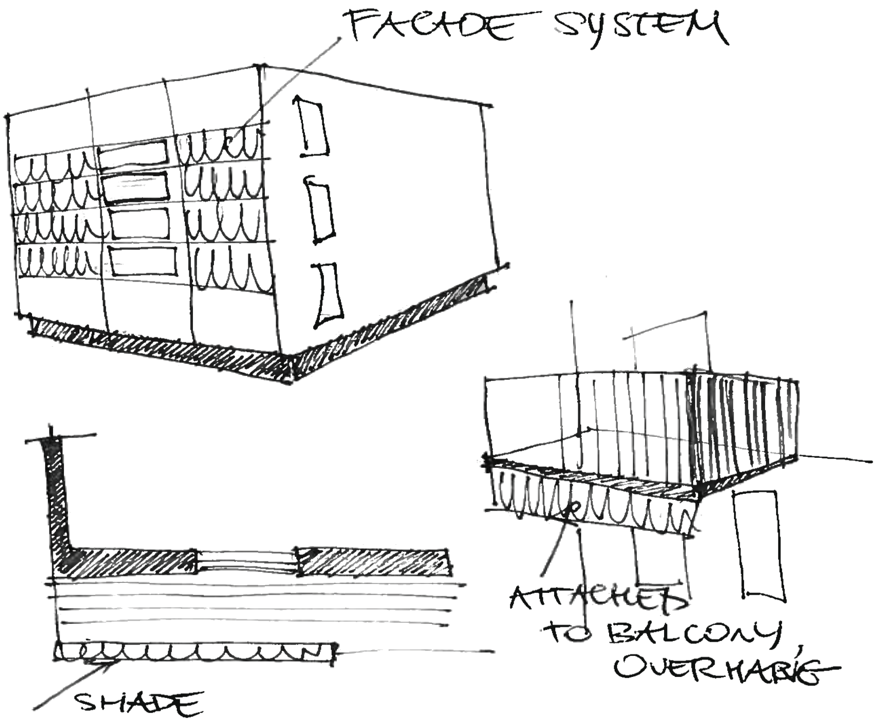
References and integration proposals



ill.075

ill.076

ill.077



Summary

Four wind turbines has been chosen to study in the next level: Ropatec, Hungarian, Darrieus and Gazelle (typical HAWT).

Ropatec wind turbine is VAWT with strong turbulence resistance and possibility to adapt to wind direction. It can be easily used in dense context; size can vary from large until small. Turbine has potential to produce efficiently.

Hungarian windmill achieve excellent efficiency, turbulence resistance, and it varies in size. However, it has difficulties with integration possibility and it needs a lot of open space around it in order to provide excellent wind intake.

Darrieus wind turbine has excellent resistance to turbulent winds; therefore, it can be used in dense context. Turbine has excellent integration possibilities, and it can work productively.

It can be fully integrated into the building. Turbine has problems to work in a turbulent environment. However, adjustments of building shape will stabilize wind flow and will increase wind speed.

Turbines have been compared by different characteristics in order to find technology that has potential to integrate in building design.

Laminar wind: describes straight wind flow. It is considered as negative characteristics, as urban context creates a lot of turbulent winds. However, by adjusting building design aerodynamically, it is possible to stabilize the wind stream.

Adjustment according wind directions: describes turbines possibility to rotate in wind direction in order to harvest more efficient.

Resistance to turbulence: is wind turbines ability produce effective in turbulent wind conditions.

Some wind turbines can work in a dense environment, and it can be placed close to each other.

Wind turbines are divided by the place where it could be integrated - roof installations or additional feature that is attached to the facade.

Integration level describes wind turbine potential to be installed in building design.

Size flexibility is a critical issue in order to optimize design solutions.

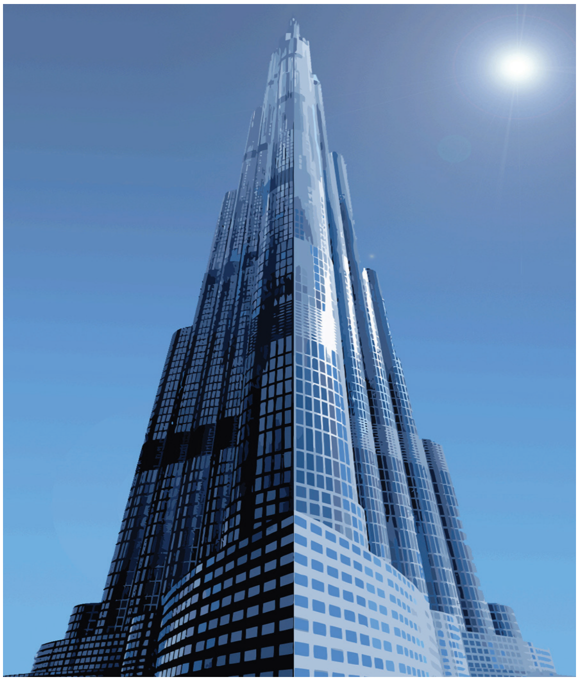
Efficiency is the main point, as wind turbine is going to be installed to produce energy.

			Windpods	Edge flow	Ropatec	Hungarian	Wind side	Darrieus	Gazelle	Ecofy's	AVX	Aerotecture	Swift
Data		Type	other	other	VAWT	VAWT	VAWT	VAWT	HAWT	VAWT	HAWT	HAWT	HAWT
		Produc. (kW/h)	1	7,5	20	210	5,5	3	20	3	1	1,5	1,5
		m2 one turbine can supply	143	1071	2857	30000	786	429	2857	429	143	214	214
Characters	Contact with wind	Laminar wind	x	x			x		xx		x	xx	x
		Adjust to wind direction			x								x
		Resist turbulent wind			xx	xx	x	xx		xx			x
	Integration	Dense	xx	x	xx		x	x		xx	xx	x	x
		Roof		xx	x		x				xx	xx	x
		Element	xx				x			x	xx		
		Integration potential	x	x	x		x	xx	xx				xx
	Size flexibility			x	xx	x	x	xx	xx				x
	Efficiency			x	xx	xx	x	xx	xx				

ill.078

Aerodynamics

ill.079



ill.080
Burj Khalifa tower, Dubai

“Aerodynamics is the study of forces and the resulting motion of objects through the air” [27].

Aerodynamics usually is applied to moving objects that break through air wall. In this project case, aerodynamics might be used in an opposite way - to increase wind flow and not block air flow that is necessary to provide appropriate wind conditions to wind turbine.

Building shape can be modified with minor or major methods [aerodyn, 2010].

Minor methods include compact design corrections that not changing main architectural and technical concepts, such as corner design (chamfering, fitting) or building rotation according main wind stream.

Adding fins in corners to a rectangular building, it significantly reduces the force of cross wind but increases along wind.

It is possible to reduce both of winds, by chamfering corners, but it will increase vortex.

The best strategy to reduce vortexes is to create rounded corners.

Major methods include sculpting volume body, openings in building massive, tapering and twisting options.

Volume gain more strength, and wind flow reduced in crosswind direction, by changing building density going upwards. Vortex forces can be reduced, by tapering volume (ill.080). However, tapered volume might show different re-

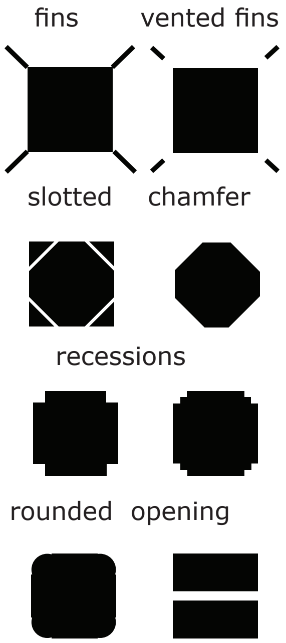
ill.081
D.Arnold, A.Ratzlaff, The Wind Tower

ill.082
AECOM, Kingdom Centre, Riyadh

sults according it size. Therefore, not always small vortex shedding is controlled, if it is at high volume.

Additional openings (ill.082) in building top floors decrease vortex-shedding, as wind flows through the opening and balances flow directions. Proportion of opening gives an impact on along wind and crosswind forces, as wind can penetrate the building.

Twisting building volume (ill.081) is another way to reduce vortex-shedding force. It is an effective method to manage and control wind flows [aerodyn, 2010].



ill.083 plan modification possibilities

Bahrein WTC

OBJECT: Bahrein world trade centre
LOCATION: Manama, Bahrein
ARCHITECT: Atkins Designs Studio
SIZE: 120,961m^2
COST: 9.6 milj. USA dollars

World's first building with 3 integrated 29 m blade's turbines is Bahrain's World Trade Centre in Manama [28].

Facilities - Office Towers offers 34-storey office space. Each tower provides accommodation with double height entrance lobby, balconies on every floor and high speed passenger lifts. Shopping centre will provide around 150 luxury brand outlets, restaurant and café areas and glass domed garden court for a relaxing [29].

First attempt to realize project as sustainable was to use solar energy but Bahrain overheat conditions encourage engineers move to more radical solution - integrated wind turbines [30].

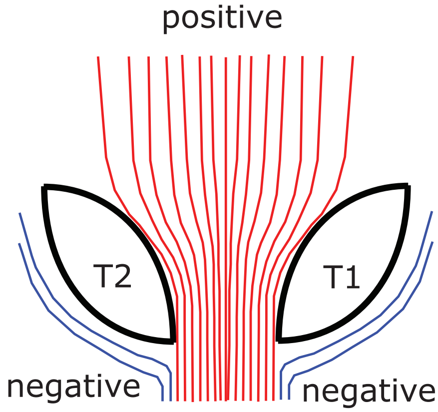
Tower's difference in their vertical shape will help reduce the stress differences between the bridges, which should provide an equal velocity amongst the turbines [31].

Certain places are covered with a deep gravel roofs in order to provide kinetic insulation, balconies and overhangs create shading. Dense, concrete core and floor slabs balance loads in building structure [32].

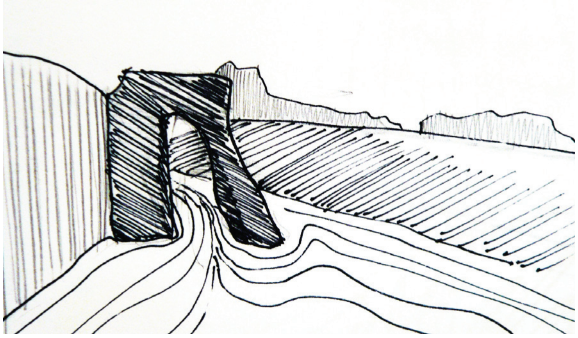
Aero turbines are supported by bridg-

ill.084

ill.085



ill.086 wind flow scheme



ill.087 nature reference - sea rocks

es (ill.085) spanning between the skyscraper complex's two towers. It can deliver approximately 11-15% of the energy needs of the building, or 1100 to 1300 MWh per year [45].

The projected energy yield from the turbines, taking into account wind and availability information, is estimated to be 225 MWh/year, total - 674 MWh [33].

The towers' elliptical forms and sail-like profiles act as air foils, funnelling the onshore winds between them and creating a negative pressure zone behind; meanwhile, accelerating wind velocity between two towers into the path of the turbines (ill.086) [30].

Energy policy is made that each resident has its own meter and can control energy consumption by his needs and economic situation [30].

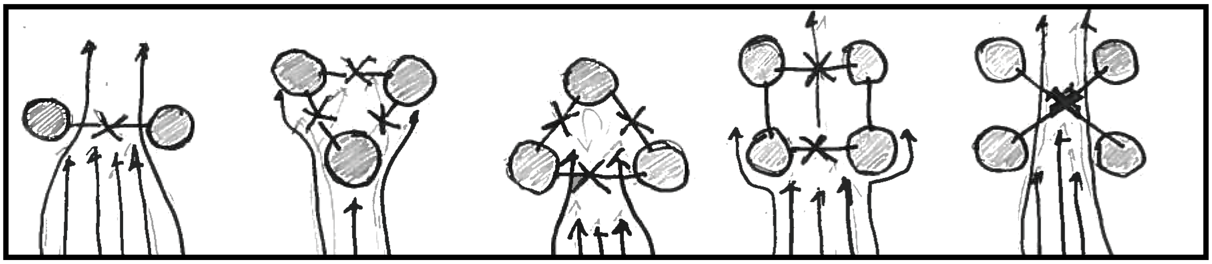
Complex is cooled by modern chilled water system that reduces energy consumption and overheating. Natural ventilation is provided by double-paned low-leakage windows that can be opened.

Sewage system is electronic to optimise water usage [32].

Building with advanced technologies and innovative solutions serves as iconic landmark and attracts sustainability admirers.

Aerodynamic approach and analyses

Volume distribution



1) increased wind speed;
2) representable facade;

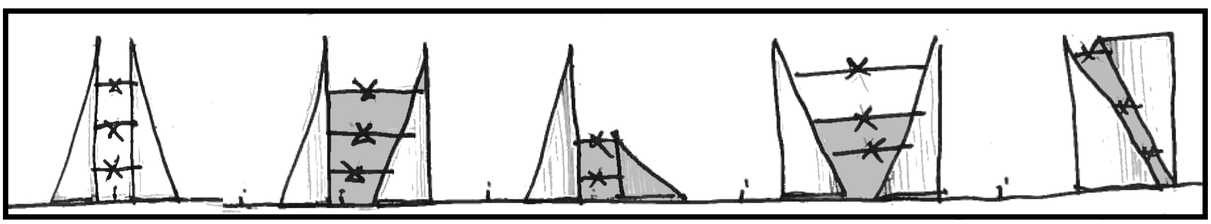
1) space between volumes;
2) first volume block wind stream for rest of turbines;

1) space between volumes;
2) first turbine gets all wind power and rest of them is less efficient

1) first turbine gets all wind power and second of them is less efficient;
2) good distribution for laminar wind

1) space between volumes;
2) reduced noise level;

Height relation



1) landmark;
2) statically stable;
3) top design reduce vortexes

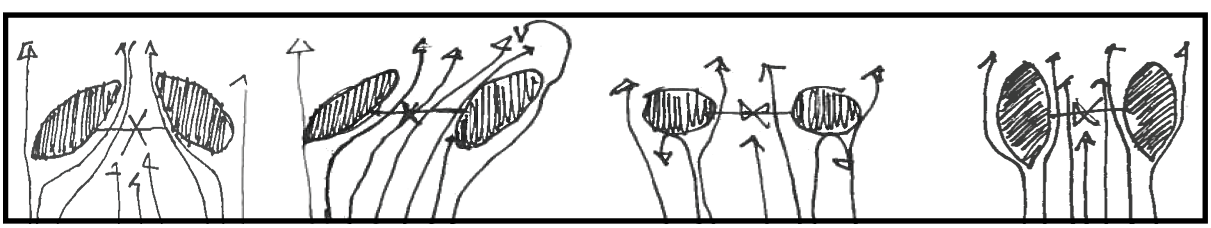
1) no tunnel effect;
2) visual instability;

1) taller volume is more suitable for living;

1) huge span;
2) bigger surface is exposed to noise zone

1) structural instability;
2) not enough space around turbines.

Plan adjustment efficiency



efficiency efficient
80%

efficiency efficient
70%
vortexes

efficiency efficient
40%
vortexes

efficiency ceficent
60%

Pearl tower

OBJECT: The Pearl River Tower,
LOCATION: Guangzhou, China
ARCHITECT: Skidmore, Owings & Merrill
SIZE: 214,100 m2
COST: 4 billion USA dollars

The 71 floor Pearl River Tower incorporates wind turbines, a double skin facade, radiant cooling, under floor air distribution, daylight harvesting, and solar photovoltaic. It is one of first sustainable tries of China, as its architecture usually is well known highly industrial and not eco-friendly output [34].

Super high skyscraper will be the greenest tower ever built so far, as it is using so many passive technologies [34].

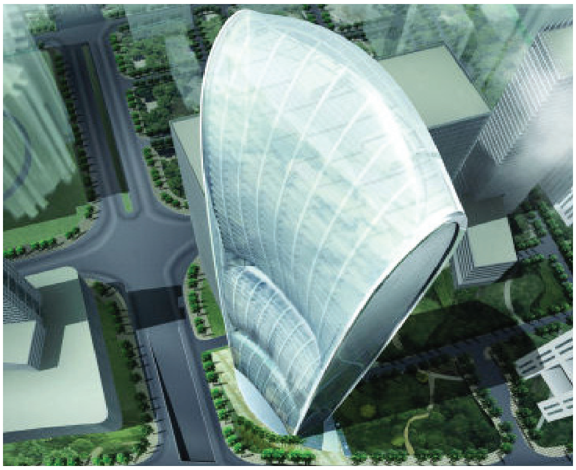
Office building goes under zero energy building class and will reduce its consumption for 58% than other recent skyscraper [35].

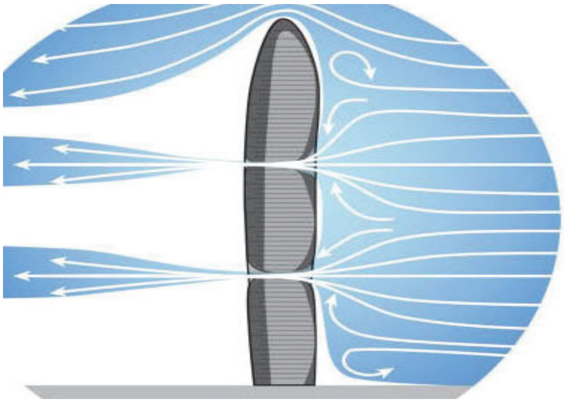
Wind power is combined with solar photovoltaic panels that are mounted in south façade, and can use solar gain to meet energy demands.

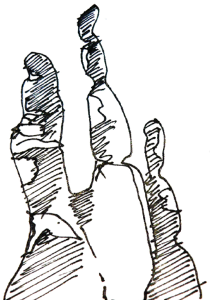
The 309-meter tower’s sculpted body directs wind to gaps at its technical floors, where winds are spinning turbines to produce power for building more than usual building volumes [36]. This channelled wind stream is speeding up and gives more energy.

The Pearl River tower has curtain facades at southern and northern sides. Windows is made of double-glazed glass; wall with motorized louvers hat rotate to


ill.088


ill.089


ill.090


ill.091 nature reference - termit mould

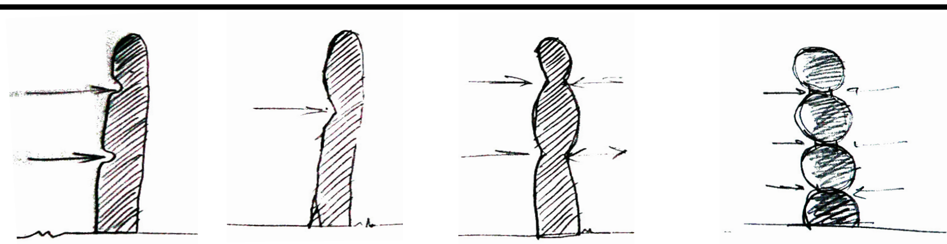
keep the building chill and provide fresh air ventilation [37]. Sensitive daylight control automatically adjusts light level indoors according daylight level outdoors. Special floor plate's design provides better cooling processes, as slab is comparably thin. It is implemented under air distribution [35]. Water reclamation is used from condensate on chilled tubes and used as water in flushes and plantings.

Vertically building is pitched in two places (ill.090) that balance stresses and curvature releases wind loads. VAWT is chosen Windside as these turbine work more sufficient (until 35%) than HAWT by using concrete building structure and volume curvature [35].

Skyscraper catches people attention with its high sustainability level; sadly there is the opinion that this will be just an exception on inefficient building background. However, designers and engineers promise that building will pay back in 5 years and make money starting from that.

Aerodynamic approach and analyses

Opening distribution

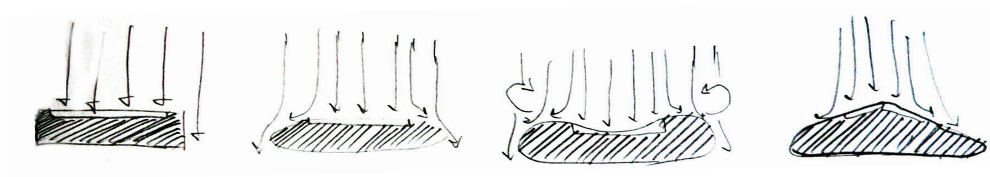


1) Openings control productivity level, by placing opening in effective height and respecting distance between them;

2) If openings are from two sides, tower can harvest wind from a different direction winds.

3) If openings are situated 360 degree, it can harvest wind all over the season and in any conditions.

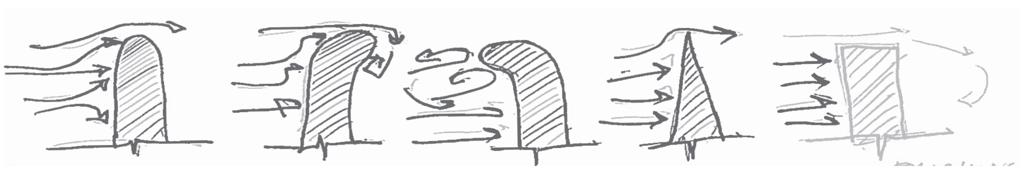
Plan aerodynamics



In order to lead wind upward and create good outdoor environment, it is necessary chose appropriate layout outline.

Straight surface is receiving the most of winds, but it creates corridor effect in street level. Curved surface reduce stress and leads wind towards. Concaved surface is the best for leading winds upwards, but it can create vortexes. Deflected surface dissolve winds and reducing productivity.

Peak design



In order to lead wind over building, it is necessary to design peak according aerodynamic principles. Peak shouldn’t block received wind, as it can cause unwanted vortexes. Big volume on the top of the building makes turbulence, therefore, narrowed upper part enhance productivity and static stability.

Strata

OBJECT: Strata Tower,
LOCATION: London, UK
ARCHITECT: BFLS London
SIZE: 36,600m2
COST:170.2 million USA dollars

Strata SE1 is the architectural icon 43 storeys high. It has 408 apartments, all with floor-to-ceiling windows and inspiring views of London [38].

Tower has three integrated 18kW 9m-diameter wind turbines. Even, if building fund just 8% of the building's energy needs, Strata tower represents sustainability and follows tries to improve energetic situation in UK [38].

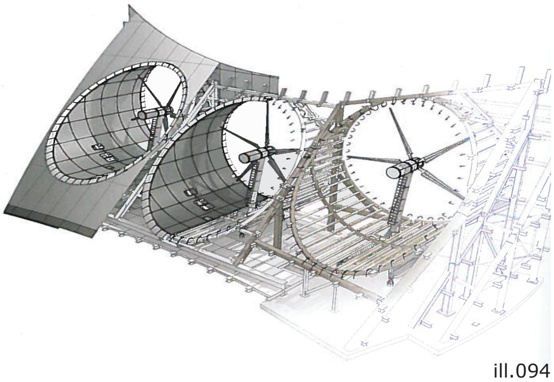
Turbines contain enclosures of a form Venturi around the plane of the blades; therefore, it improves overall efficiency and avoids wind noise or vibration [skynews, 2011]. 5-blade turbines are more quiet that 3-blades ones [46]. Building energy policy includes maximisation of using natural daylight and natural ventilation, high-performance glazing.

Aerodynamic form of a building improves wind condition and protects from adverse winds, and helps to generate more power, as the wind is leaded up [39].

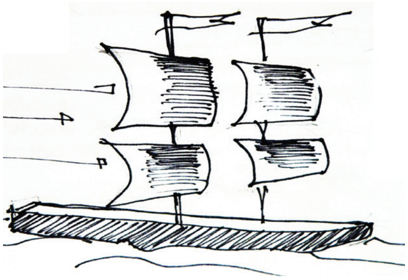
The structure, what is casted in-situ, use 200 mm-thick post-tensioned concrete for floor slabs. They are supported on an irregular arrangement of


ill.092

ill.093



ill.094



ill.095 nature reference - boat

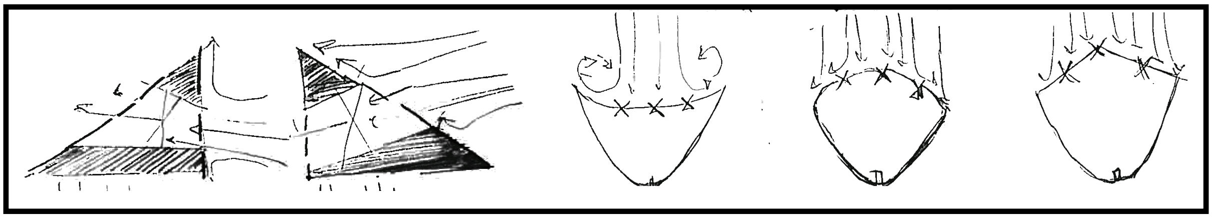
300mm-wide high-strength blade columns. It was fundamental to the design of the building to reduce concrete and CO2 usage in this restricted area [40].

However, this project receives a lot of attention. Some opinions describe this building as design ugliness. Inhabitants complain about noise and vibration disturbance, some of them claims they never have seen turbines working, and turbines are a just a symbolic badges [41]. It even got a nick name - electric razor as the shape sticks out from context. Company answer on this question is that wind turbines need additional electrical update, as the power went off for part of the city, when turbines started to work. Sadly, economic situation put on hold further case development.

Aerodynamic approach and analyses

Turbine into peak

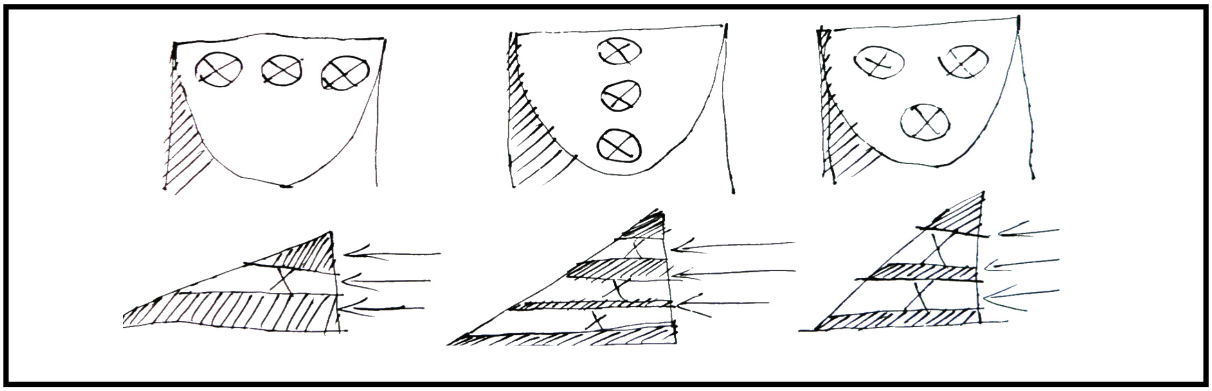
Plan aerodynamics



Max efficiency gains straight surface, and it leads wind through. If the surface is angled, part of winds passes by and it may cause vortexes.

Concaved surfaces are the best to lead wind upward, even if it creates vortexes. Therefore, it is necessary to get right proportion between concave and height.

Distribution of openings



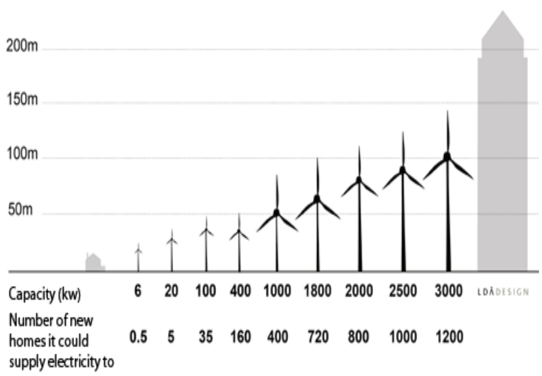
Openings, where are situated wind turbines, have an important role to provide acceptable noise conditions for living areas. If openings are placed in one line horizontally, sound is spreading in one level, if it is in a vertical line; more storeys have direct contact with noisy areas.

However, taking in consideration section, vertical distribution gives better efficiency, as turbines can be placed in tunnelling environment.

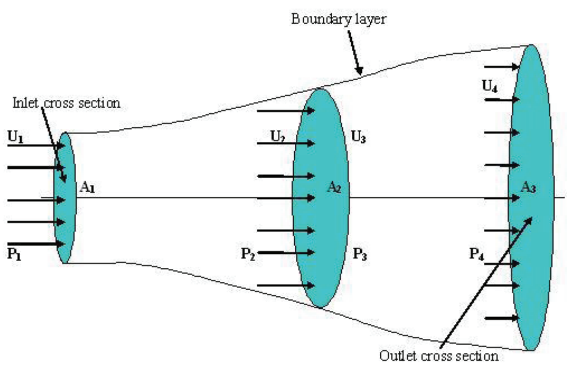
Design issues

Productivity

Wind energy is kinetic energy and could be harvested as air motion. [42]



ill.101 - mean wind speed of 6m/s.



ill.102

Suitable wind speed in urban areas is considered as lower than off-shore, although building high-rises wind level might increase. Bigger wind turbines can be mounted in higher peaks, but smaller ones can supply smaller housing units [BIWT, 2005].

It is not possible to harvest 100% as captured wind has to leave the turbine. Theoretically power could be achieved max 59,3% as it is set in Betz Law (ill.102). Betz coefficient is made according theory and research about air motion that makes turbine spinning. Betz coefficient is a point between max productivity and min speed what is needed for air movement.

However, this number is set by taking in consideration ideal conditions and no disturbance. Realistic wind harvesting gives less because mechanical appliances such as rotor blade friction and drag, gearbox, generator and converter, reduce the power delivered by a wind turbine. Therefore, max productivity is around 45%.

Wind resources are simply to integrate with solar energy; therefore, annual energy amount increases [BIWT, 2005].

Wind power calculation

1) $Pw=0{,}5*\rho*A*Vh^3$

Pw	*Power of wind (W)*
ρ	*Air density (kg/m3)*
A	*Swept area (m2)*
Vh	*Actual wind speed (m/s)*

2) $A=\pi r^2$ - HAWT

A	*Swept area (m2)*
π	*3,14*
r	*blade length (m)*

3) $A=Dt*lb$ - VAWT (H-type)

A	*Swept area (m2)*
Dt	*diameter of turbine (m)*
lb	*blade length (m)*

4) $A=Dt*lb*0.5$ - VAWT (egg beater)

A	*Swept area (m2)*
Dt	*diameter of turbine (m)*
lb	*blade length (m)*

5) $Pm=Pw*Cp$

Pm	*Actual power (W)*
Pw	*Power of wind (W)*
Cp	*Betz coefient*

6) $Vh=Vp*((h/Vg)^a$

Vh	*actual wind speed*
Vp	*teoritical wind speed*
h	*height*
Vg	*coefficient (place)*
a	*height (place)*

To get an idea about turbine productivity is not necessary to have complicated formulas [wind_calc, 2005].

Formula 1 is general wind power calculation. It is necessary to know swept area (A), what could be calculated by formula 2-4 according of turbine.

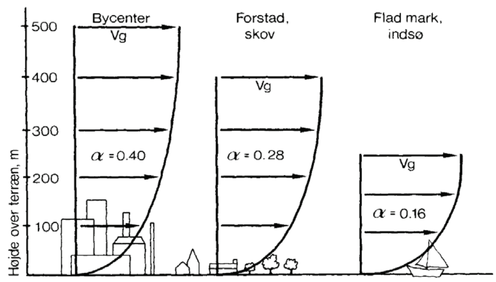
Air density is taken at standard temperature 1.924 kg/m3 (273 K, pressure =101,3 KPa).

Actual wind speed must be calculated according average wind speed (formula 6) in place, terrain coefficient (ill.104) and height above ground.

Results have to be multiplied with Betz coefficient (ill.103) in order to get actual wind power.

Wind turbines	%
Multibladed farm water pump	10-30
Sailwing water pump	10-25
Darrieus water pump	15-30
Savonius wind charger	10-20
Horizontal wind charger (to 10kW)	20-30
Horizontal wind charger (over 10kW)	30-45
Darrieus wind generator	15-35

ill.103



ill.104

Productivity of chosen turbines

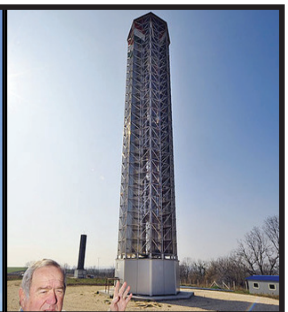

	Ropatec		Hungarian	
∅	h	kW/h	h	kW/h
1,0	1,3	0,5	5,2	2,1
5,0	6,5	13,2	26,0	52,8
10,0	13,0	52,8	52,0	211,3
15,0	19,5	118,9	78,0	475,4
20,0	26,0	211,3	104,0	845,2


	Darrieus		Gazelle	
∅	h	kW/h	A (m2)	kW/h
1,0	1,6	0,3	0,8	0,4
5,0	8,0	8,1	19,6	10,3
10,0	16,0	32,5	78,5	41,0
15,0	24,0	73,1	176,6	92,3
20,0	32,0	130,0	314,0	164,1

ill.105

The most productive turbine is Hungarian windmill because of it delicate construction. Ropatec turbine is the most successful one from efficiency and integration. However, Gazelle and Darrieus turbines can be implemented in more specific locations, and using right proportion between size and efficiency, these installations might become very successful solutions.

Calculations are done according [wind_calc, 2005] and weather conditions are taken for [petes, 2009], setting main location in Aalborg, Limfjord.



		Ropatec					Hungarian				
	Ødm	1	5	10	15	20	1	5	10	15	20
m2	kW/h	0,5	13	53	119	221	2,1	53	211	475	845
100	0,7	1,4	0,1	0	0	0	0,3	0	0	0	0
1000	7	14	0,5	0,1	0,1	0	3,3	0,1	0	0	0
5000	35	70	2,7	0,7	0,3	0,2	17	0,7	0,2	0,1	0

		Darrieus					Gazelle				
	Ødm	1	5	10	15	20	1	5	10	15	20
m2	kW/h	0,3	8,1	33	73	130	0	10	41	92	164
100	0,7	2,3	0,1	0	0	0	1,8	0,1	0	0	0
1000	7	23	0,9	0,2	0,1	0,1	18	0,7	0,2	0,1	0
5000	35	117	4,3	1,1	0,5	0,3	88	3,4	0,9	0,4	0,2

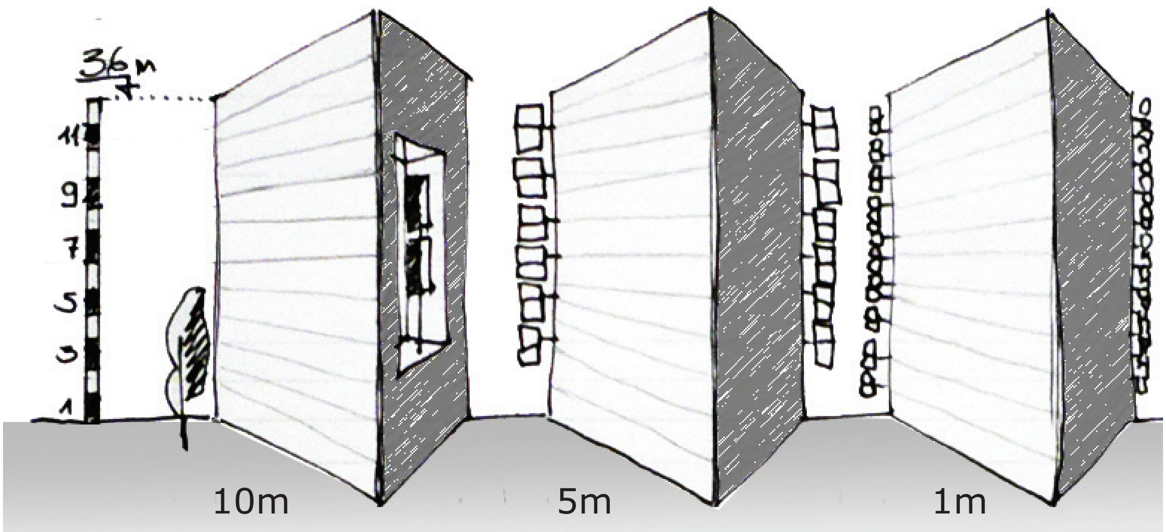
ill.106

In order to understand the scale and productivity proportion, sketching and calculation have been made. Energy consumption is taken form ZEB requirements for 2015 60 kW/h per year [BR10], including average electric consumption.

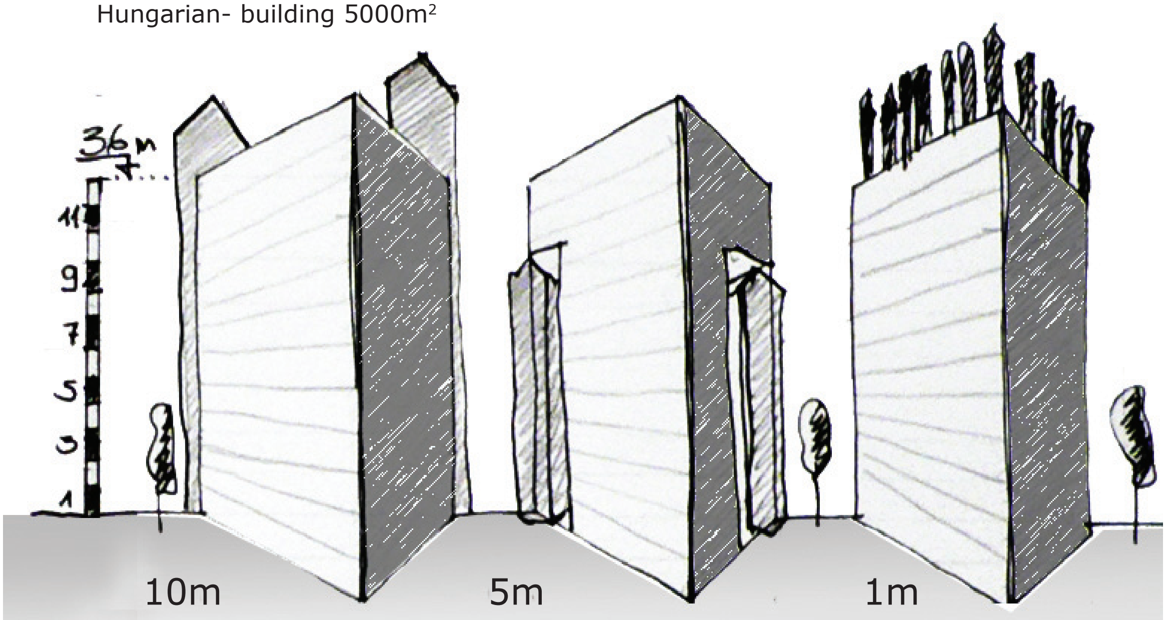
Sketches are made in a large scale building 5000 - as easier example to show different solutions and expressions.

It needs to have an opening through building in order to allow air motion, by integrating large scale turbine into building. Smaller ones can be placed on the top of roof or attached to building sides. Hungarian turbine is difficult to integrate, especially large one, as it works as freestanding volume.

Ropatec - building 5000m^2



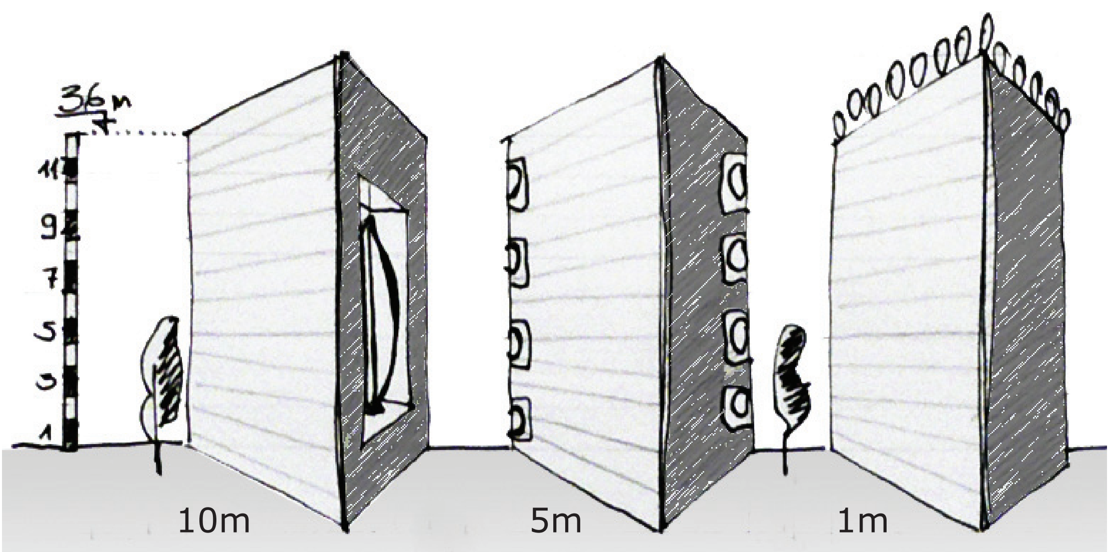
Hungarian- building 5000m^2



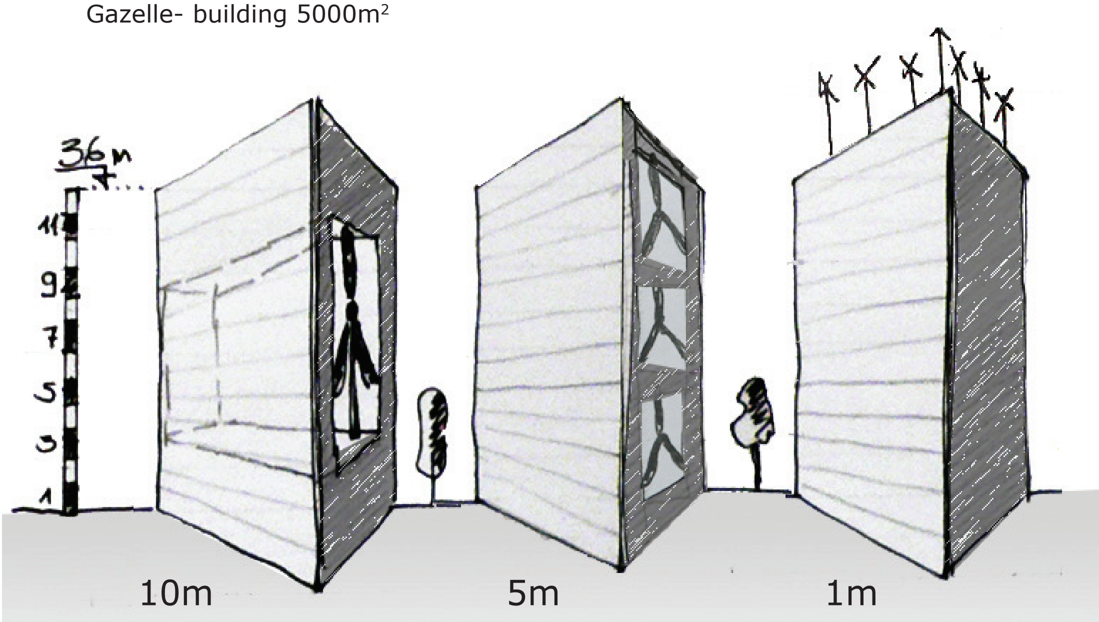
ill.107

Darrieus turbine works the same as Ropatec, but medium size can be installed in niches.
Horizontal turbine needs to have air movement through building, but in order to use small turbines, it has to be placed on the roof or between volume.

Darrieus- building 5000m^2



Gazelle- building 5000m^2



ill.108

Integration


ill.109
Atkins - Anara tower


ill.110
Agustin Otegui'- Nano Vent-Skin

Integration in this topic is meant as interaction level between two objects. Different parameters describe integration and gives answers to question about potentials in order to install turbine into building more efficiently.

Appereance

Wind turbines could be integrated in two different ways from aesthetic approach.

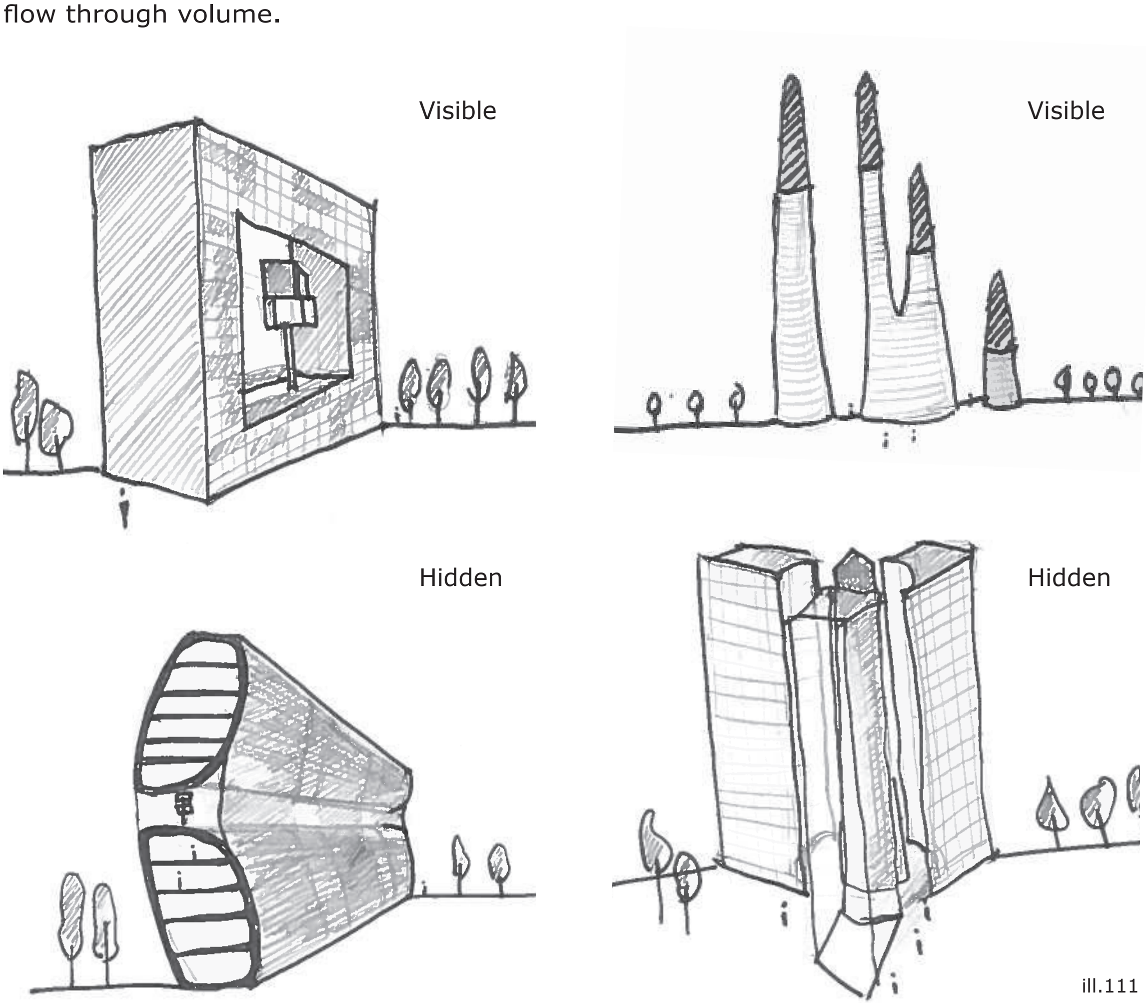
One of them is visible and representable design (ill.114). Attention is paid to sustainable view. It requires a lot of area waste, but meanwhile, it solves interaction problems between turbines and living-working space.

Another appearance is hidden (ill.115). Turbines are installed into buildings, and it is not visible or not takes the main attention from building design. It is more suitable for VAWT, as it works in dense conditions. This approach requires building shape modification, often according aerodynamics.

Visual appearance

Ropatec turbine can be exposed on post or without it, attached to surface then. Big size is more suitable for visible approach, but smaller turbines can be integrated deeper into building volume. As it is VAWT, turbine can spin even if surrounded by other volumes. However, wind flow should be not interrupted and flow through volume.

Hungarian turbine has a high percentage of efficiency. Problem is to integrate volume into a building, as turbine is not flexible and require free range. However, building shape can be adjusted to make reasonable design where turbines can be attached.

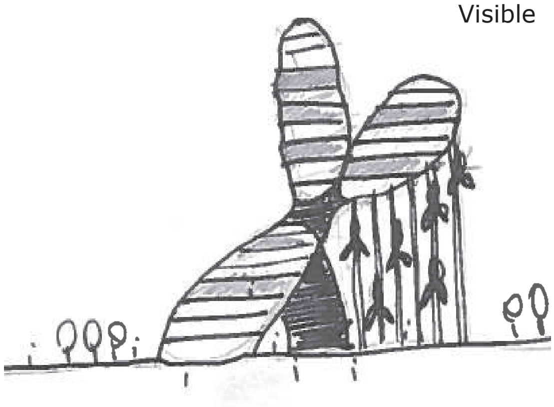


ill.111

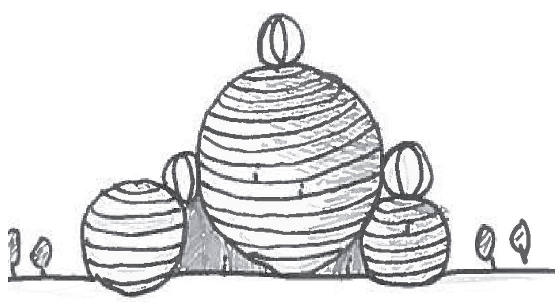
Horizontal axes wind turbine Gazelle can be free standing or attached unit. But as it need laminar wind flow and open distance, it is difficult to integrate it into building volume without making extensive opening. Turbines can be just attached to surface and function as additional elements.

Darrieus turbine is similar to Ropatec, as both of them are VAWT. However, Darrieus is more flexible and can be freestanding. It is easy to integrate large sizes into building volume or attached to surface. As it has resistance of turbulent wind, it can be placed on the ground.

Visible



Visible



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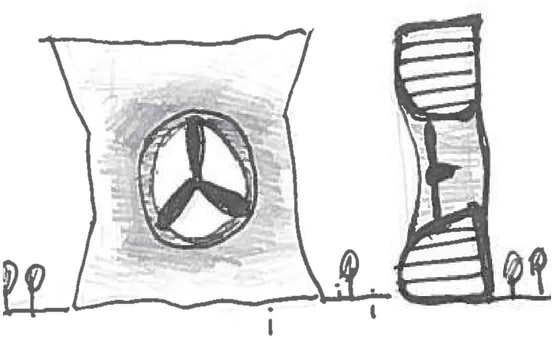

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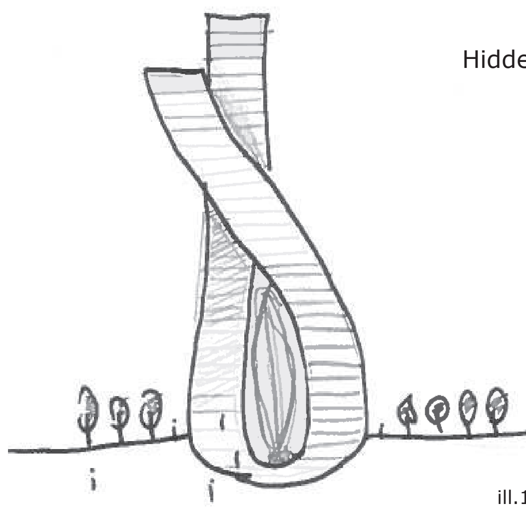


ill.112

Size flexibility

	Parameter	Ropatec	Hungarian	Darrieus	Gazelle
Flexibility	differs in height	x	x	x	
	differs in diameter	x	x	x	x
	can change in proportions	x		x	

ill.113

One of key parameters is the flexibility that increases design integration possibilities. All chosen turbines can differ in height or diameter, but just Ropatec and Darrieus can change their proportion what gives more design solutions.

Placement

	Parameter	Ropatec	Hungarian	Darrieus	Gazelle
Placement	roof	x	x	x	x
	facade element	x			x
	into building			x	
	ground level		x	x	
	deep into opening	x		x	
	attached to surface		x		x

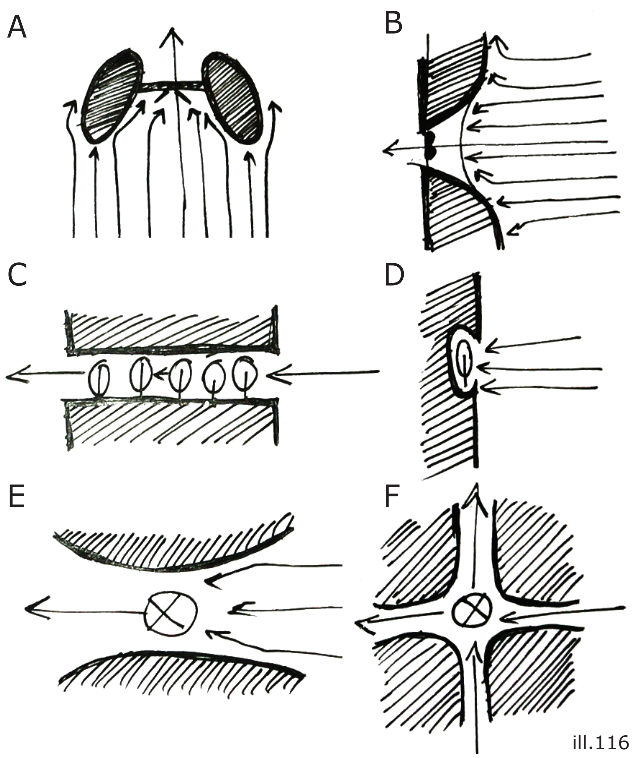
ill.114

Placement divides turbines into two groups. First one requires skyscraper, as turbine has to be placed above turbulent zone. Another group is more suitable for ground level; therefore, it could be implemented into lower skylines. Second grouping is based on turbines location on horizontal axes - deep into volume, or just as an attachment to the surface. All VAWT can be installed into volume, as they can work in dense context. HAWT need open space to be placed into building volume as it lowers productivity.

Aerodynamic principles

	Parameter	Ropatec	Hungarian	Darrieus	Gazelle
Aerodynamics	tunneling	x	x	x	x
	dense tunneling	x		x	
	opening in wall			x	
	fully surrounded by volume	x		x	
	partly surrounded by volume		x		

ill.115



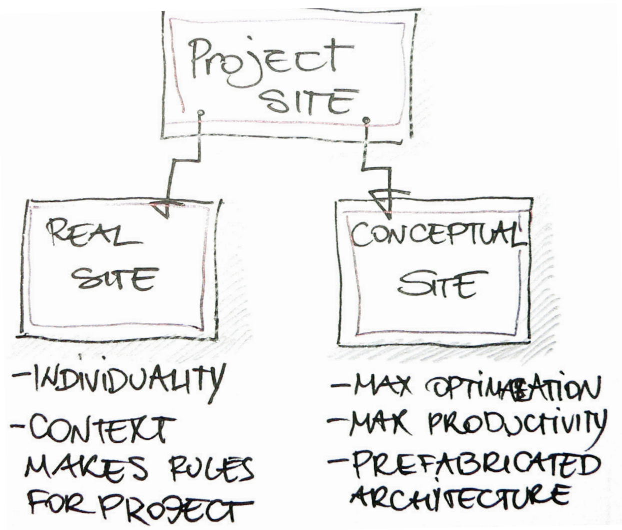
ill.116

Aerodynamic principle is based on tunnelling, as it increases wind speed. Tunnelling can be implemented either plan (ill.116) (A) or section (B). Plan tunnelling is effective for all turbines, but Hungarian one requires bigger opening, therefore, not always it can be integrated. However, by enlarging space (E), or placing between two volumes, Hungarian turbine works sufficiently.

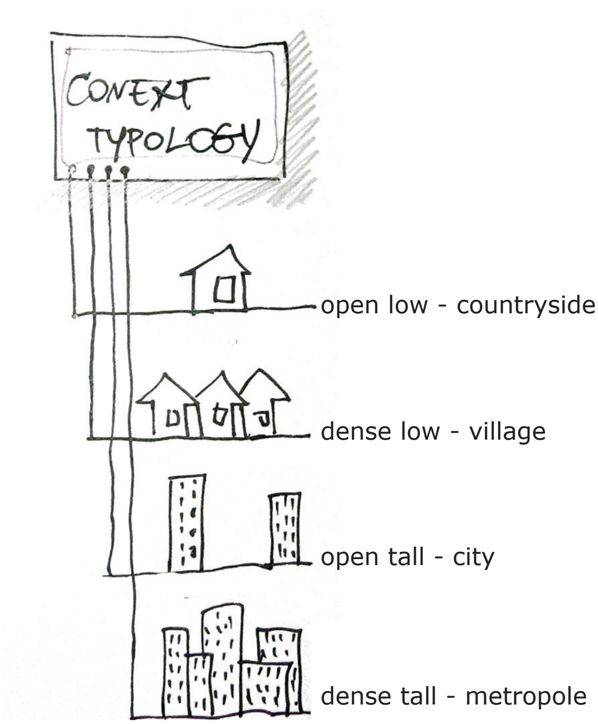
Tunnelling can be divided also by density. VAWT works in the dense environment; therefore, it is possible to place more of them into one line (C), while HAWT can be placed just one. Exception is Hungarian turbine that can't operate in dense, as into the tunnel it not receives enough wind.

Darrieus turbine is the most flexible one. It could be installed into niche (D), as it works well in the turbulent environment. Turbine can be surrounded by volumes (F), leaving wind channels for the wind to accelerate.

Project site



ill.117



ill.118

Context is soul and reason for every project.

Project site could be real or conceptual (ill.117). Conceptual site can give max optimization and productivity for design, but the problem is that there is no ideal site. So it may create prefabricated architecture that is no use.

In case of conceptual architecture, it is possible to reveal design principles and guidelines that could be used as part for an existing project.

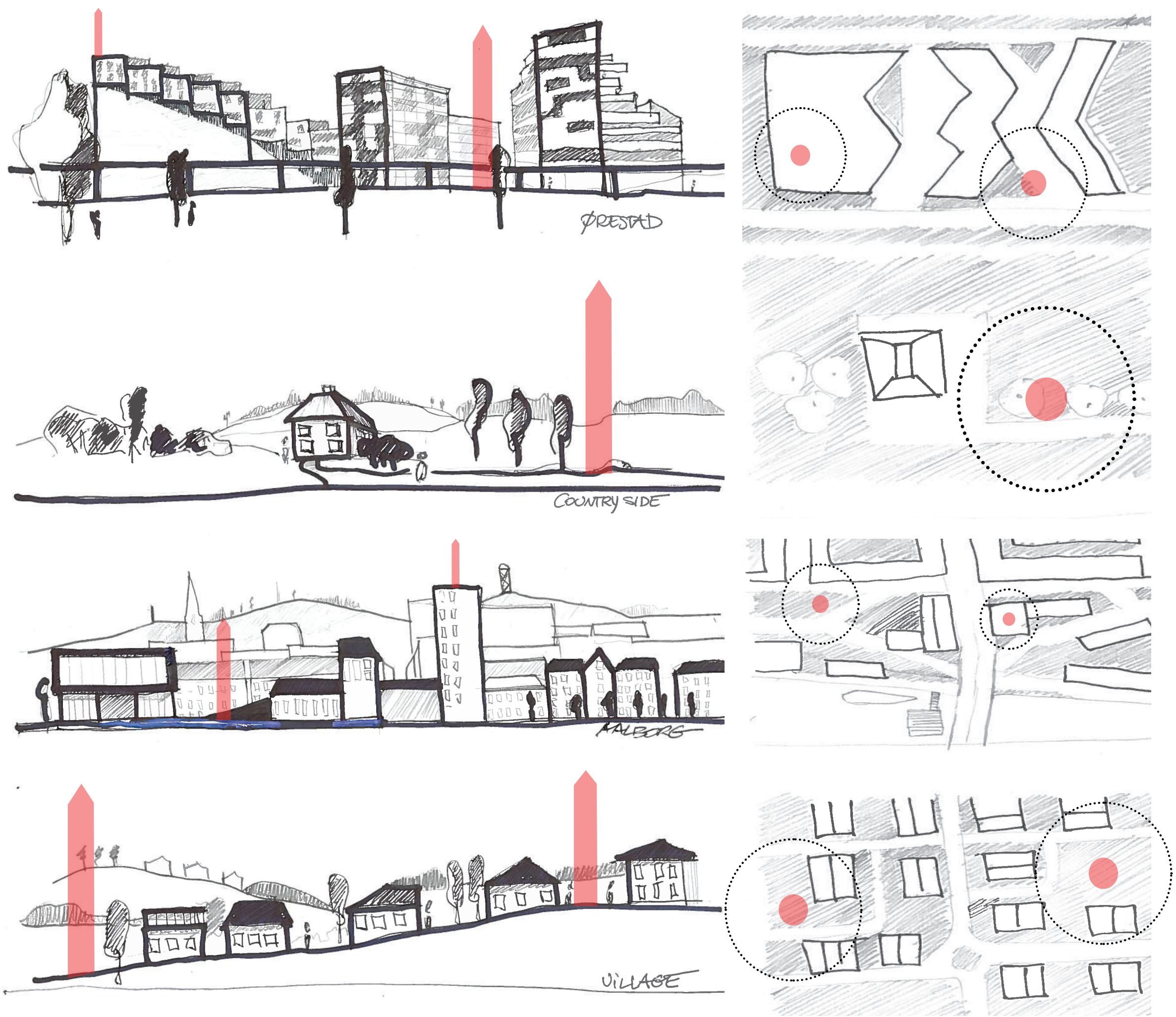
The project brief gets climate conditions and context, by choosing real site. In this case, every project has potential to achieve specific and unique design that is optimized for a particular place and interest group.

Context typology (ill.118) could be divided into four main groups. Open low describes countryside with few house volumes. Dense low is village organization where is dense but low building height environment. Open tall illustrates picture of the city with some tall elements and low dense layer. Skyscraper city goes under dense tall, what presents dense and tall volumes.

In order to find the place for chosen turbines, different context sketches have been made.

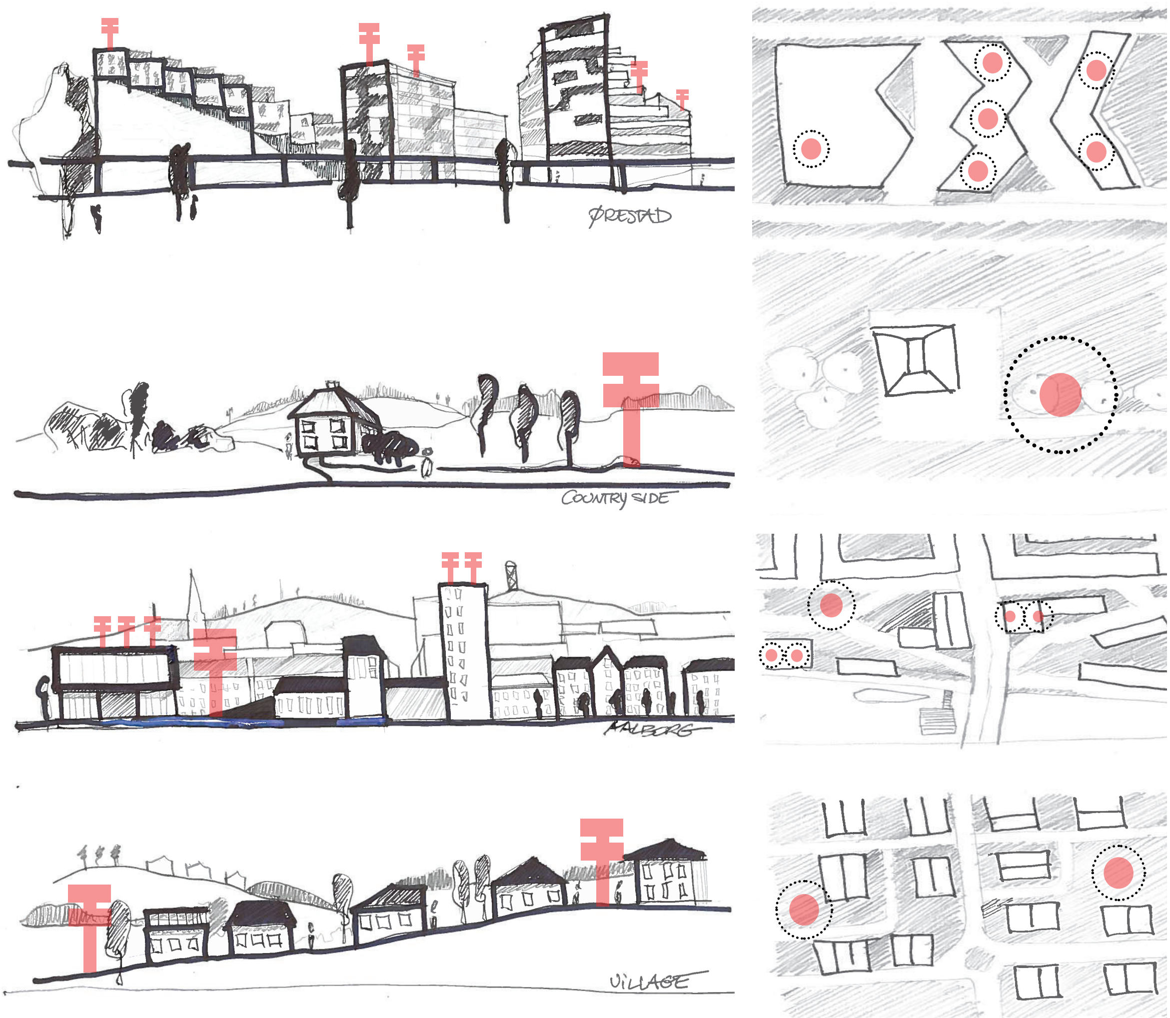
Turbine in context

The best efficiency Hungarian windmill can achieve in open low context - countryside, as it requires a lot of inlets. In the urban context, Hungarian turbine can be placed in public squares or on the top of roof or between low volumes.



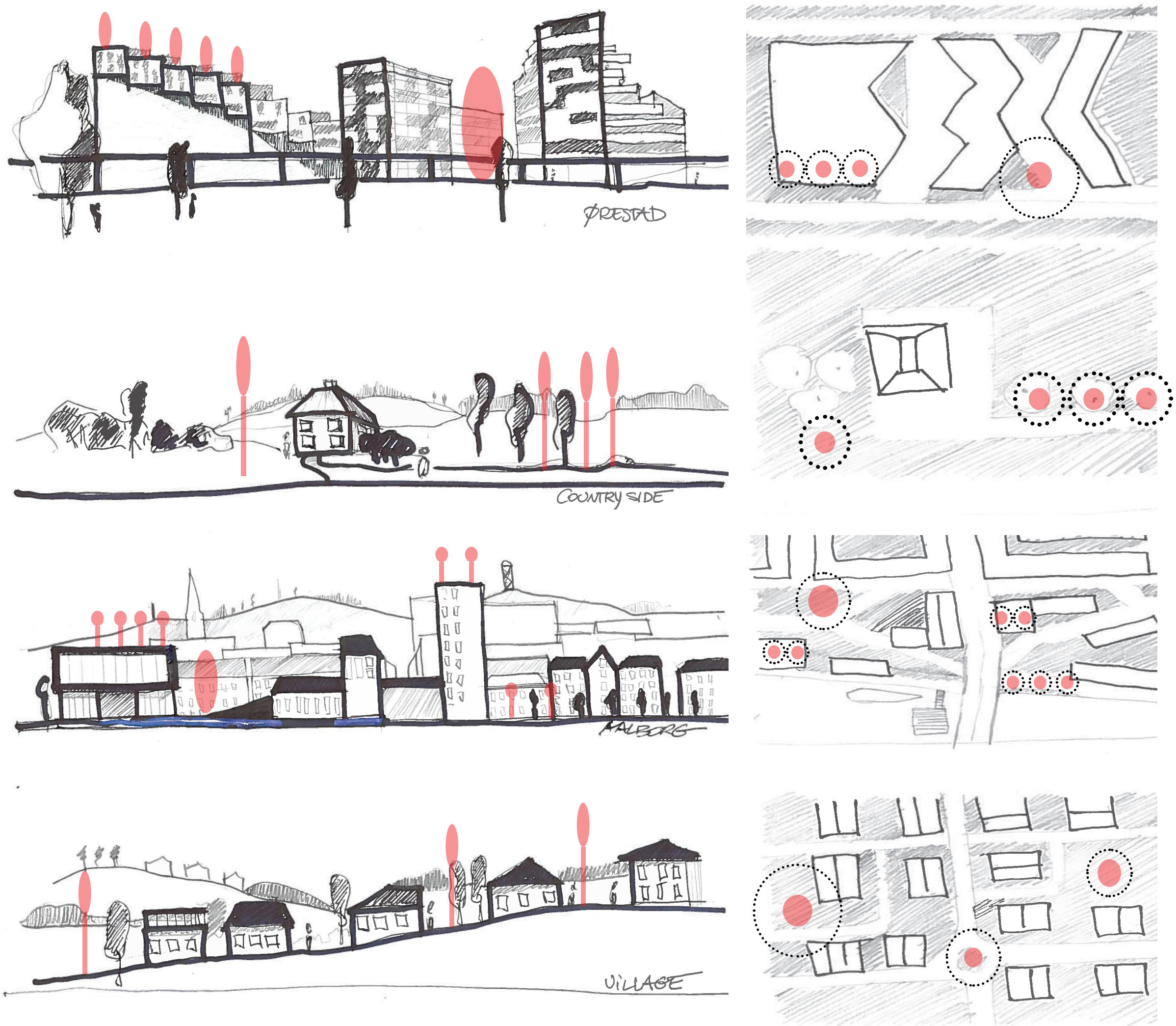
ill.119

Ropatec wind turbine shows the best performance on the top of the roof, as on the ground level are turbulent winds that it decreases productivity. The best integration potential Ropatec can achieve in dense tall or open tall context, where turbine can be installed into building, meanwhile capturing enough wind.



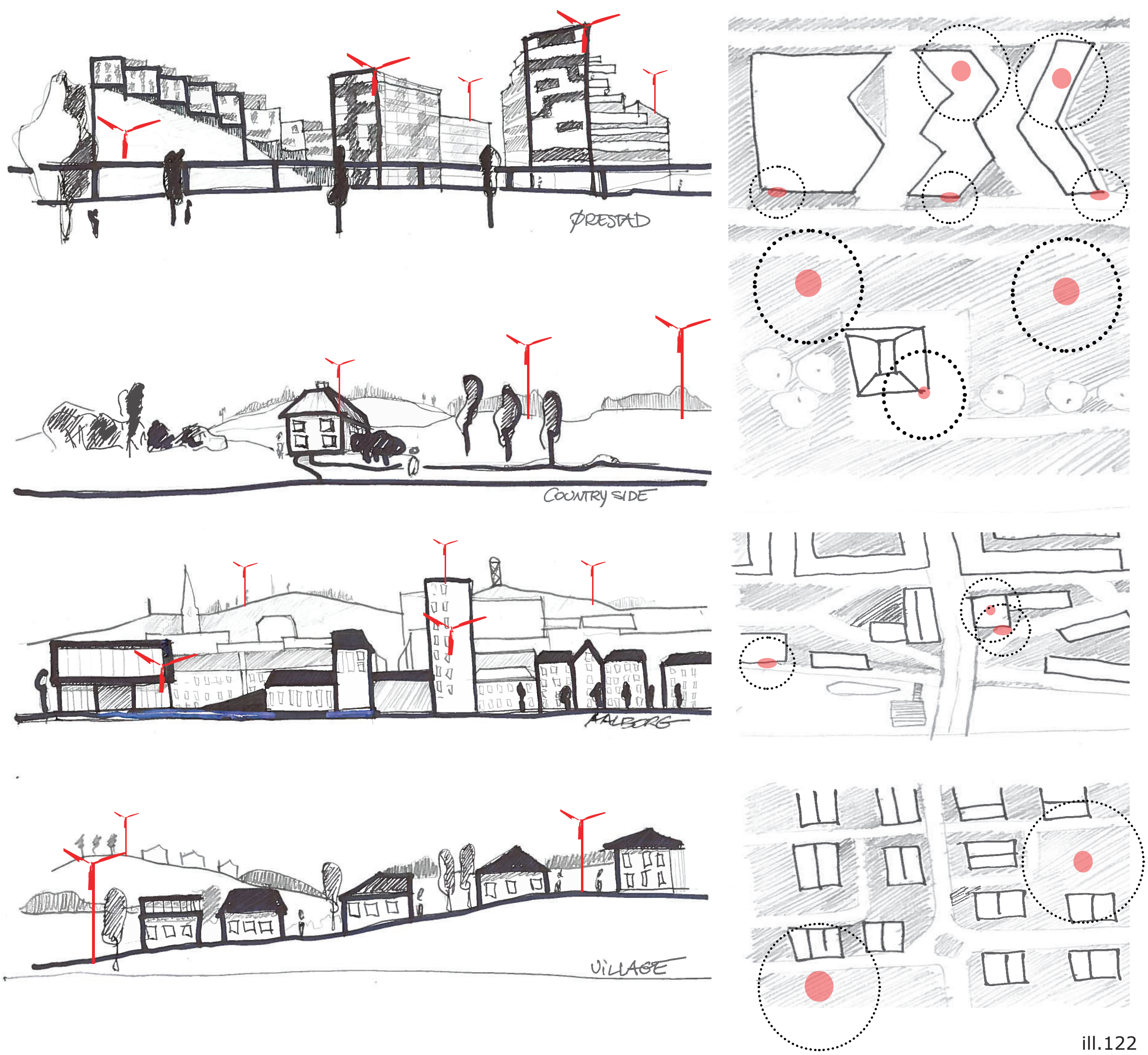
ill.120

Darrieus turbine is effective in all scales, as it is flexible in size and can be adjusted for the particular situation. Big scale can be implemented in tall context or placed in the public area. Smaller scale can be attached to building as additional elements or placed on top of the roof.



ill.121

HAWT is highly recommended off-shore or onshore open areas, where it could be placed high and with a large size rotor. However, as Gazelle can be detached from post, rotor can be placed into or between buildings. In this case, it is important to remember air circulation and necessary distance between turbines.



ill.122

Design principles

Design principles have been clear out in order to be used as a design guideline for next semester.

Aerodynamic approach (ill.123)

This point is responsible about wind flow correction, as laminar and powerful wind stream will increase production of turbines. It is also essential to lead wind flow over and between buildings in ground level to reduce turbulence levels and vortexes.

a. Plan aerodynamics are monitoring outdoor environment at ground level. Wind flow has to be lead around the building, and if it necessary, moved upwards to increase air circulation for turbines. Attention also must be paid to the corner design, as corner modifications can magnificently change wind move around the building.

b. Volume and section aerodynamics take control over layout arrangement and continuing lead wind upwards. Depending on building concept, section's aerodynamics provide air intake into sustainable openings or niches, where are situated turbines.

c. Peak design moves wind over the building and prevent further vortexes that might cause unstable conditions for turbines. In order to minimize vortexes possibility, openings or tapering is advised.

Integration considerations

This point tells about integration possibilities and potentials to install turbines into buildings or consider different parameters to adjust turbines to building design.

a. Visibility or invisibility of turbines depends on building and turbines size. Big turbines can be integrated just in massive scale buildings, and it will be demanding building design in order to produce efficiently. Smaller scale turbines can be integrated deeper into building volume, so they will be hidden or partially hidden.

b. Placement matters from turbine type. Choosing Hungarian wind turbine, it will be attached to the envelope. HAWT can be installed between two volumes, on the top of the building or will require opening behind mechanism to provide proper air movement. Attention has to be paid to interaction between noisy areas and living spaces. Connections have to be analysed from functional and aesthetical viewpoint in order to provide a decent living conditions.

c. Size flexibility potential for turbines is determined by turbine's technical requirements. The most flexible one is Darrieus, as it can change dimensions in all directions. Gazelle can vary in diameter, Ropatec – in 2d dimension, but Hungarian turbine has to be enlarged proportionally to keep efficiency.

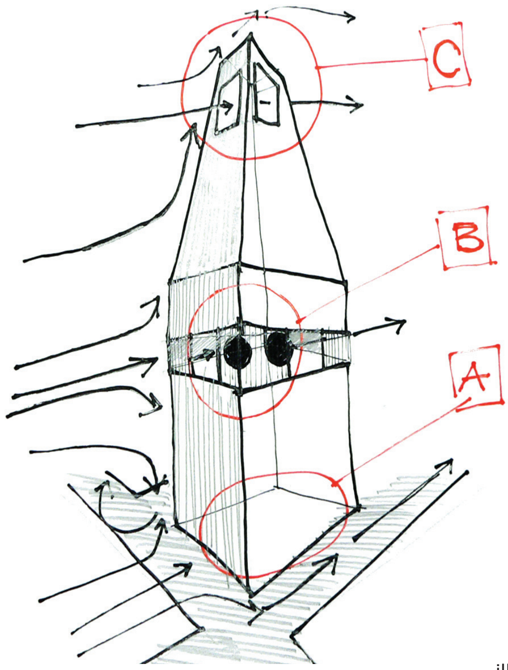
Productivity issues (ill.124

This issue is important in order to achieve the best efficiency result. It demands energy production amounts and interaction between building height and productivity level.

a. Turbine size depends from height and position, where is it situated. It is essential to find the right balance between these parameters to fit in context and still fulfil energy demands.

b. Building has to provide 60 kW/h/m2 in a year, as it goes under ZEB group.

c. Passive solutions can be used, in order to fulfil energy demands – solar cells, natural ventilation, double facade etc.



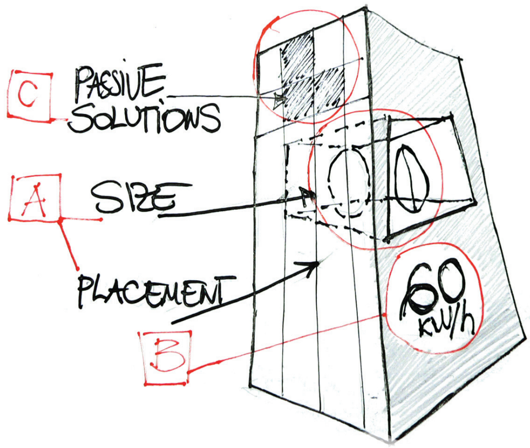
ill.123

Project site

Project site has to be chosen, according few important parameters.

a. Elevation flexibility has to consider in order of implementing tall building into landscape. In the case, if building volume is much higher than context, dispensation can be given, but it has to be well founded decision.

b. Wind access to the site is essential for project productivity. Meanwhile, sun and outdoor qualities has to consider, as it will be residential building.



ill.124

Design project

Program

Project brief

Ill.125

Ill.126

4th semester project focuses on the research about aerodynamics and wind harvesting principles, in order to proposed design for high-rise. Research deals with aesthetic, spatial, social, functional, urban issues, meanwhile solving technical problems. Interaction between wind harvesting and architecture possibilities is vital in the research process.

Context in this particular research is secondary, as project focuses on research about wind integration. Therefore, building will be placed in Denmark, North Jutland, as this region is having good wind flow. More specific, Aalborg city, as it is the biggest urban area in North Jutland. Site will be chosen according to the best wind conditions and possible contextual relevance.

Building will be high-rise in order to harvest wind efficiency, however, scale should be chosen sensitive to respect area. Building function is secondary.

Considerations must be made about wind conditions and possibility to use it in the building energetic program. Building has to fulfil energy demend for 2015, if it is possible Zero energy. Wind is primary energy resource. Building form has to be consider from aerodynamic point in order stabilize turbulent wind level.

Design principles need to be used as a guideline for design approach, as they are based on semester research.

Area around Aalborg, especially west part and around Egholm Island is very efficient. It has excellent wind conditions - strong and laminar wind as mainly wind blows form SW and west, over open space above fjord that helps flow to accelerate.

Aalborg has few high-rises that extend until 50-60m. Mostly all of them are situated close to the waterfront. This tendency will be guiding contextual decisions.

However, it is crucial to keep in mind, that this project is research or as an example. Building location is chosen to make project possible to solved and found an relevant function.

Project scope

Main focus in the project is to accelerate wind and provide sufficient wind conditions to the turbines. Turbines have to be integrated into the building volume.

Project is dealing not only with a sustainable approach but also with new experience possibilities to the visitors. Wind turbines can be used as design elements or main focus points.

Structural considerations about load bearing capacity and turbines installation will be technical consideration and main load bearing parts has to be dimensioned.

Design questions about volume appearance and connection with horizontal planning will be shown in three parts: ground floor, sleeping facilities and cafe on the top of the building, as these three points is main representative elements of the building. Consideration of material will helps to make appropriate expression of building facade and structure.

Sustainable elements will include considerations about indoor climate, such as natural ventilation. In order to meet energy requirements, calculation in BE10 will be made.

Project site

Aalborg development vision

Since beginning of the 20th century, skyline of Aalborg city is created by industrial buildings. Industry is playing big role at Aalborg development, however, Aalborg municipality is willing to change city's image by adding well designed high rises.

Proposed development regions are on either side of Limfjord: Østre Havnebassin, Lindholm Brygge, Hedegaards silolandskab, Toldbodgade and region close to airport. Old railway territory close to Arkaden can also be turned to high rise region but, as this site historically are covered with low building volumes, municipality left this question opened [48].

Aalborg municipality also has project "Growth axis" that focuses on particular region development. Zone includes central city around Limfjord Bridge, area next to the airport, far west and south of the city [47].

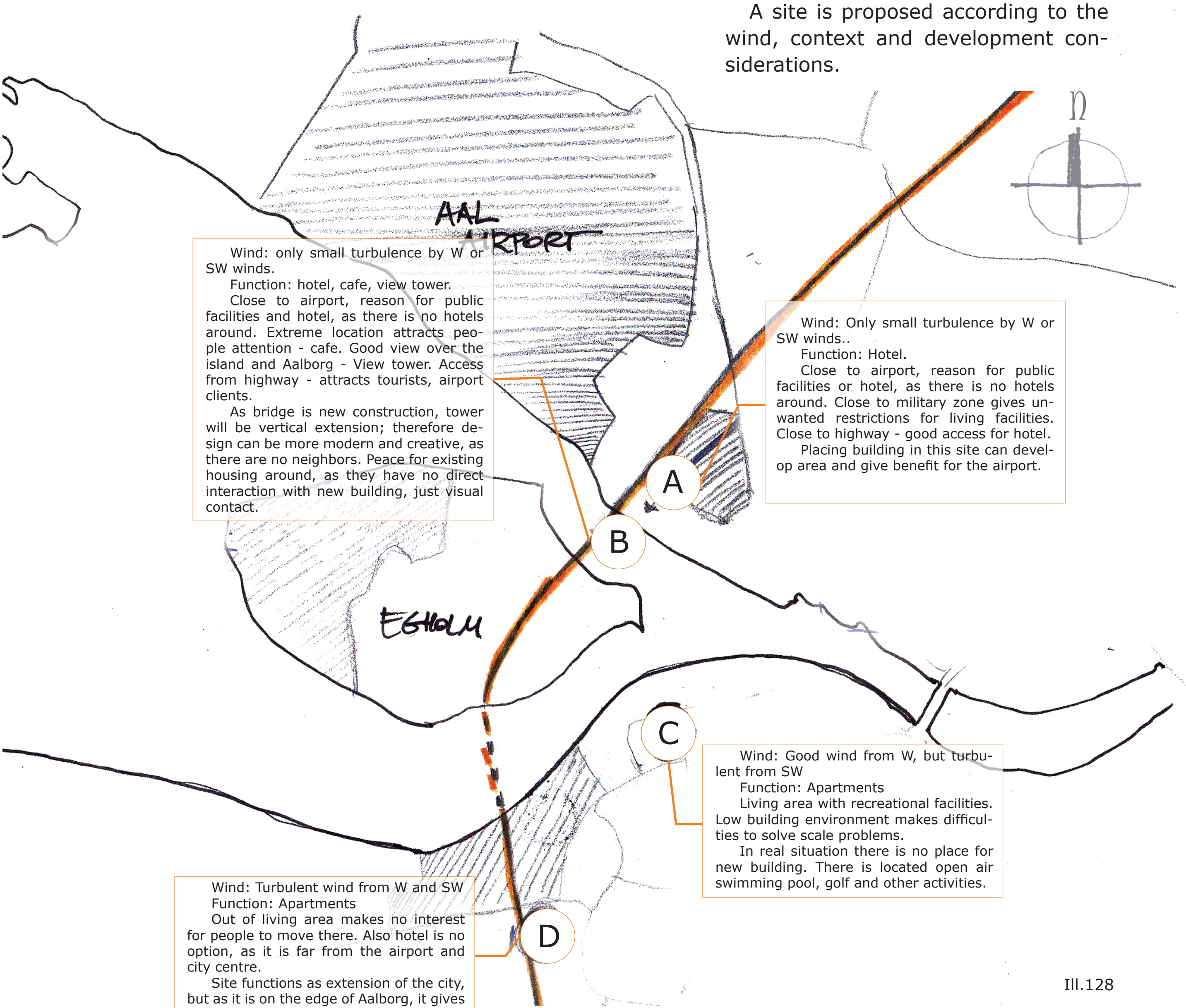
On other hand, municipality is strongly controlling high rise population. Building has to bring more than just place to live or work. It has to have high architectural ambitions that are incorporated into urban context. Sustainable solutions for the climate and traffic logistics, and it must be ensured that the project contributes development of the city and the surrounding space in a good way.

Considering verticals height, building has to exceed at least 35m or 11 storeys, as lower volumes will not be visible in urban context [48].

Ill.127- Growth Axis

Site proposals

A site is proposed according to the wind, context and development considerations.



A

Wind: Only small turbulence by W or SW winds..
Function: Hotel.
Close to airport, reason for public facilities or hotel, as there is no hotels around. Close to military zone gives unwanted restrictions for living facilities. Close to highway - good access for hotel.
Placing building in this site can develop area and give benefit for the airport.

B

Wind: only small turbulence by W or SW winds.
Function: hotel, cafe, view tower.
Close to airport, reason for public facilities and hotel, as there is no hotels around. Extreme location attracts people attention - cafe. Good view over the island and Aalborg - View tower. Access from highway - attracts tourists, airport clients.
As bridge is new construction, tower will be vertical extension; therefore design can be more modern and creative, as there are no neighbors. Peace for existing housing around, as they have no direct interaction with new building, just visual contact.

C

Wind: Good wind from W, but turbulent from SW
Function: Apartments
Living area with recreational facilities. Low building environment makes difficulties to solve scale problems.
In real situation there is no place for new building. There is located open air swimming pool, golf and other activities.

D

Wind: Turbulent wind from W and SW
Function: Apartments
Out of living area makes no interest for people to move there. Also hotel is no option, as it is far from the airport and city centre.
Site functions as extension of the city, but as it is on the edge of Aalborg, it gives no use for this moment.

Ill.128

Exploration of the site


Ill.129

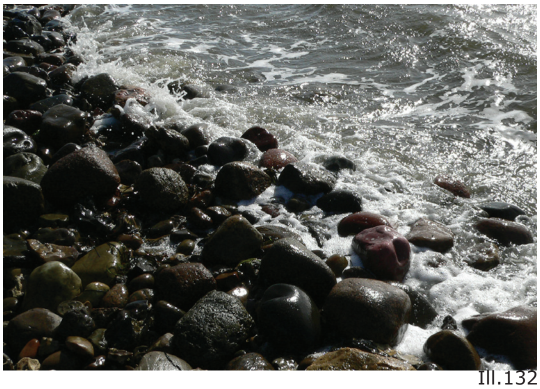

Ill.130


Ill.131

Project will be situated on north coast of the Limfjord. (ill.128 B or C) - Strait between Egholm and Lindholm or Lindholm coast as these sites are provided with a best wind conditions.

Wind: SW and W
Place has good wind conditions, as turbulence level is low. It comes from low woods; however, wind from SW crosses Egholm over agricultural land. This land is flat and without obstacles that might change wind direction.

Context: flat land
Site is covered with low vegetation and receives a lot of strong and rough winds. Nearness of water strengthens wind power. Site is surrounded with a grass fields, stoned coastline and isolated bushes.
Development vision (ill.127) of the Aalborg has been planned to improve urban life in area close to airport, as it will develop city and attracts more visitors.
There is no straight connection with any existing housing. This gives pros and cons in the same time. It is advantage to the design, as it not needs to follow existing architectural tendencies. However, flat land limits height of the building. This is issue that should be considered carefully. Nearest high-rise is Høje Brygge is 55m. Making several view analyses (ill.139-140) from Limfjord bridge, it is clear that building volume can go up to 70m.


Ill.132


Ill.133


Ill.134

Difference between the sites - building on the bridge or at the coastline - is major. If building will be situated on the bridge, it will give problems with accessibility. However, successful solution can give strong contextual link between project and surroundings.

Planned motorway will give easy access to the building.

Function: Hotel

Location on or near the bridge is not suitable for apartments as it is far from social activities. Moreover, highway nearness gives nosiness and problematic access for people without vehicle.

On the other hand, this place is proper site for a hotel or other public facility. It is close to the airport and there is no other hotel nearby.

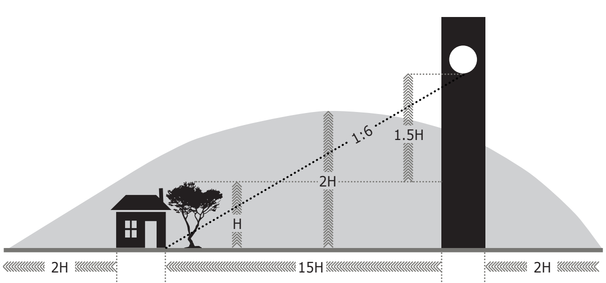
Extreme location will attract both Aalborg inhabitants and tourists. Therefore, a good idea might be locate view tower on the top of the building, in order to share fantastic view over Allborg city. That will be benefit to the Aalborg citizens.

Photo vision

Ill.135

Height consideration

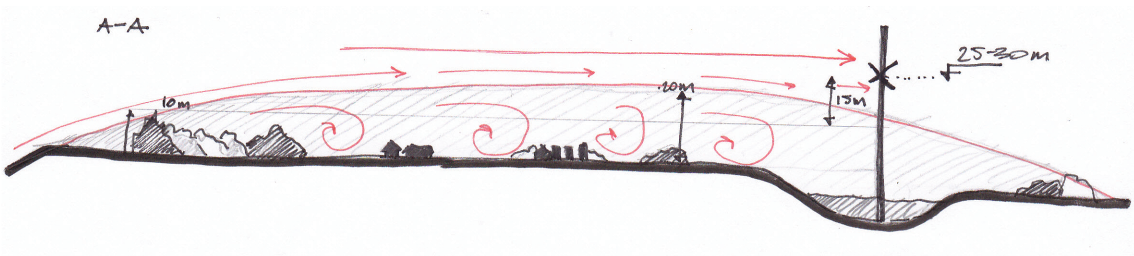
Ill.136- Highrises



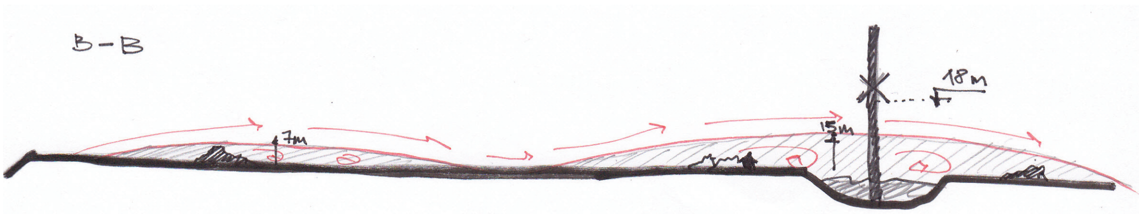
Ill.137
Turbulent zones

Most of high rises is situated close to waterfront. This makes city skyline more contrast, as main building height is around 5-6 storeys.

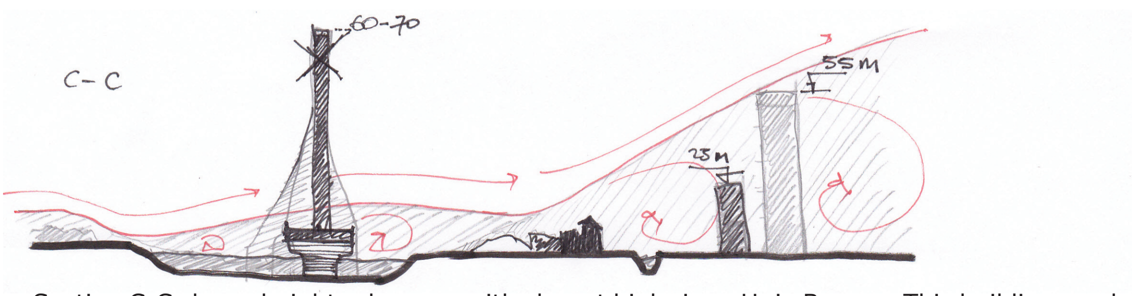
Air turbulent level on the ground level is 1,5 h above closest obstacle. This site has benefit of low volumes around it, therefore building height don't have to be as tall as it could be in the city. Wind turbine has to be placed so high that proportion between distance until closest obstacle and height is 1:6.



Wind from W brings the biggest turbulence, as it blows over woods and farms. From this section building should not have opening lower than 25-30 m from ground.



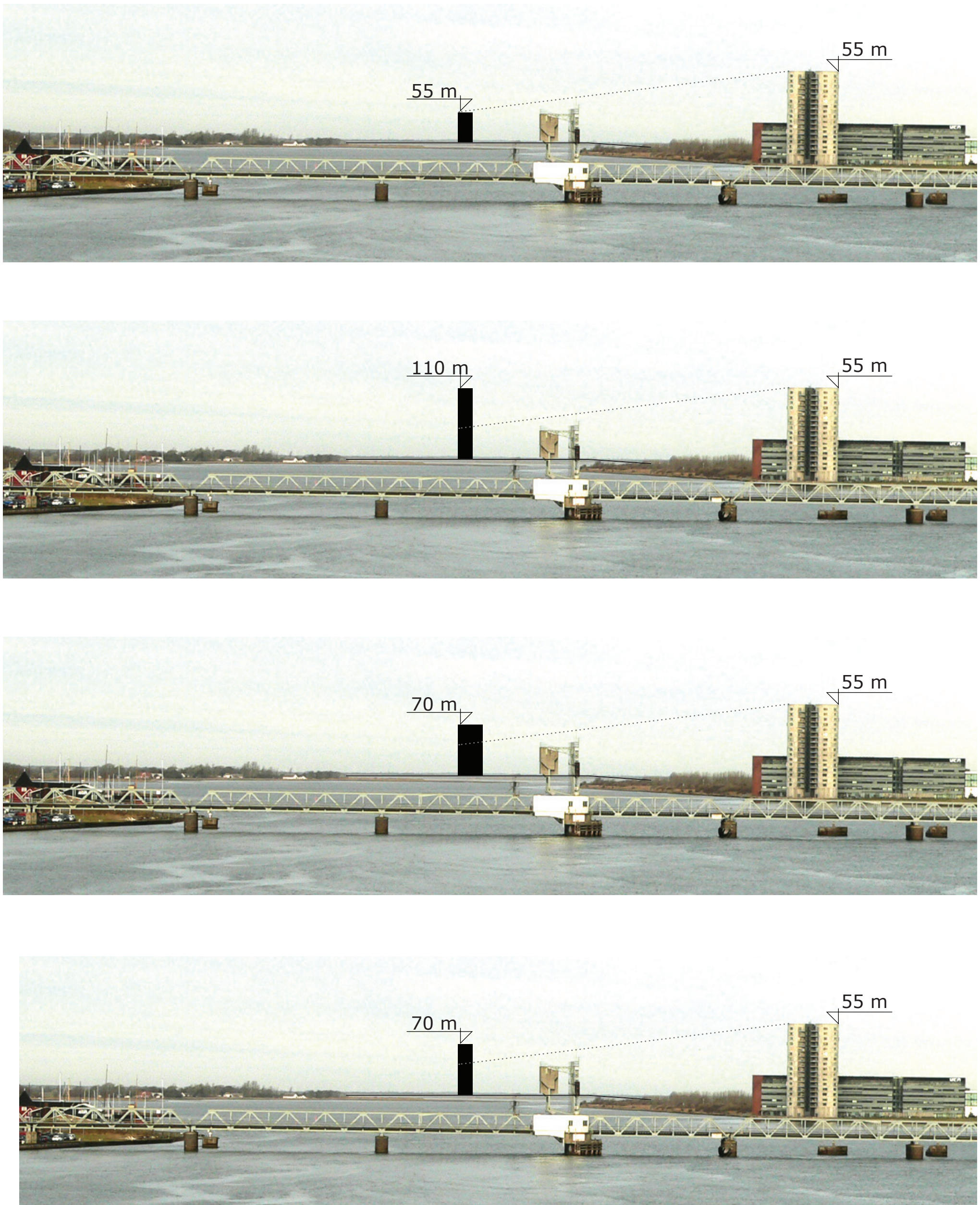
Wind from SW is much more laminar, as it has no real obstacles in its way. Agriculture land continuous laminar wind stream from fjord waters.



Section C-C shows height relevance with closest high rise - Høje Brygge. This building can be taken as reference, therefore proposed building height could be around 60-70m

Ill.138
Turbulence analyses

View analyses



ill.139

Limfjord bridge is the best spot form the city to observe verticality and blending with surrounding context.

Perspective line was made in order to get more accurate comparing system. As control point was taken building on the Egholm Island.

First four pictures analyse if building will be on the bridge.

The best impression was get when building is around 70m - a little bit higher than Høje Brygge and comparably slender. Volume stands out but not overacts with surroundings and low left coast. If building is higher than 70m, it creates huge contrast on Egholm background.

If volume is wide, it creates expression of too massive obstacle, but intentions are to create light structure.

If volume is the same height as Høje Brygge, it fits in context; however it is problem to implement wind turbines in so limited height.

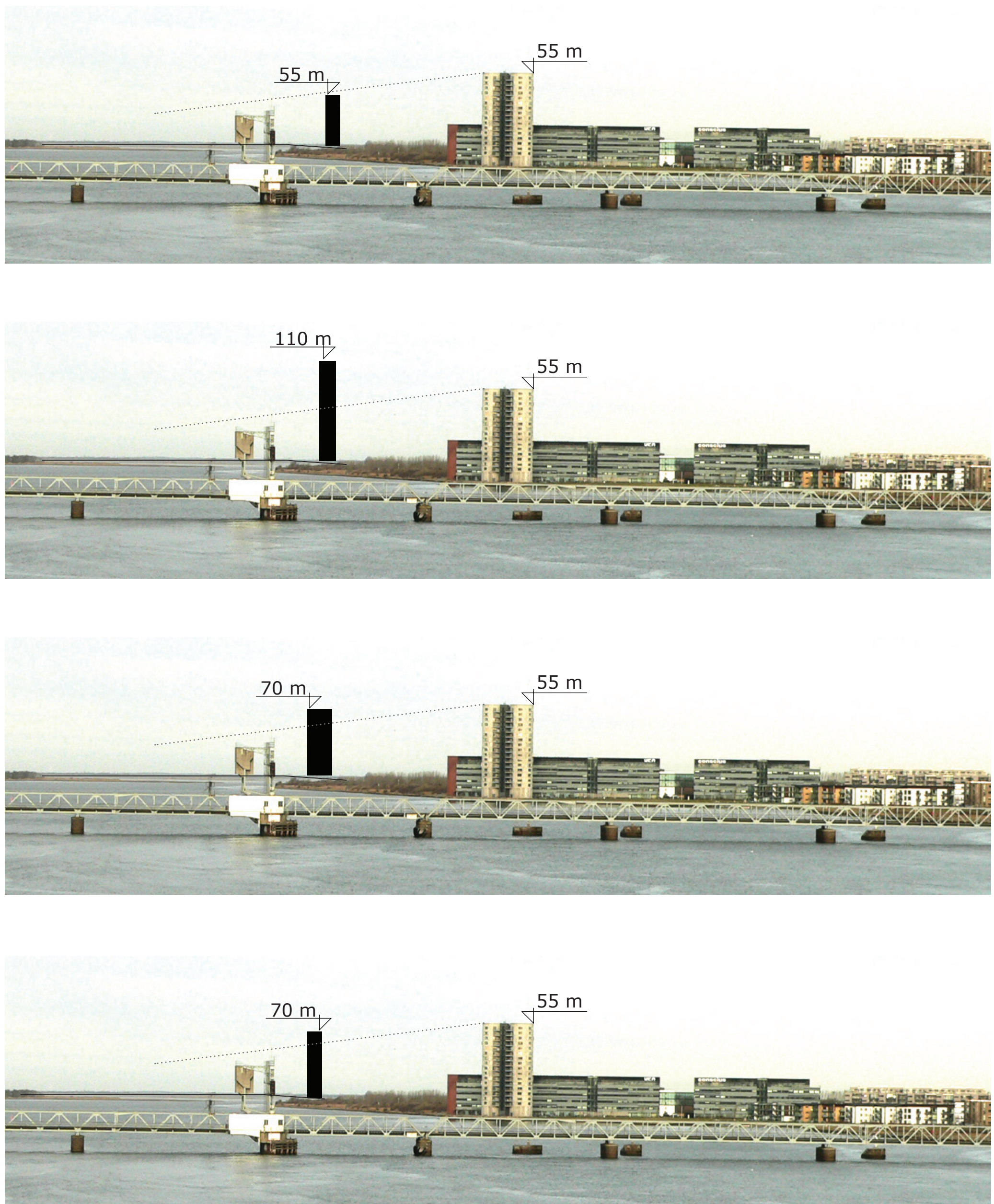
By exploring another site spot - on the Lindholm coast, extended possibilities are discovered.

Building volume fits much better in different heights and widths, as building context is more dense and urban.

If volume is higher than Høje Brygge, it still contrast to much with surroundings but it not leaves so big impact on Egholm flat lands.

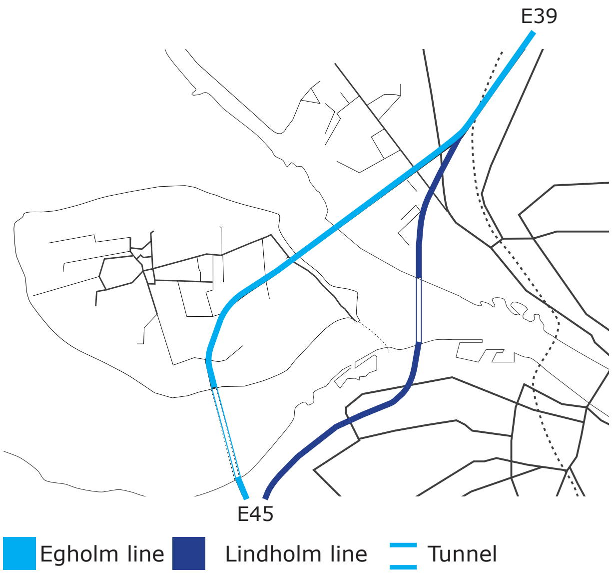
If the volume is around 70 m, building width is not playing so big difference as Høje Brygge is considered as reference on the right coast line.

In order to decide site and the best building appearance, different sketches will be made in the sketching phase, considering interaction with a bridge and without it.

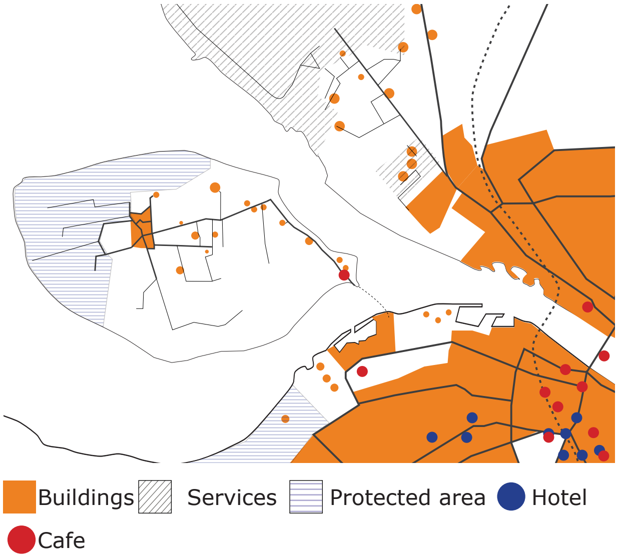


ill.140

Mapping



Ill.141
Infrastructure



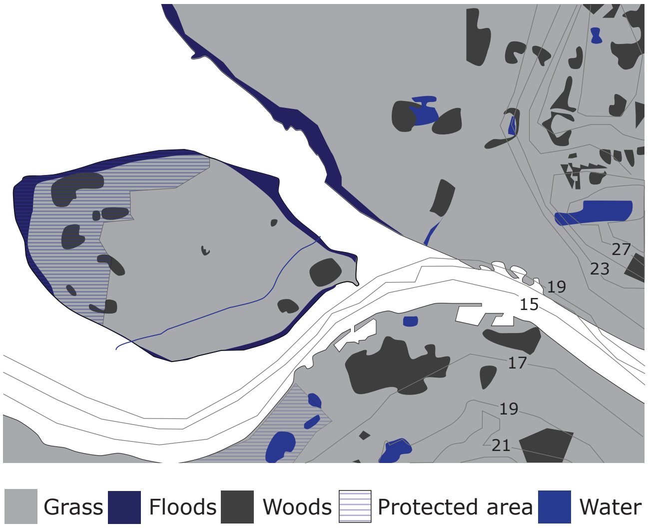
Ill.142
Functions

Local plan of Aalborg city is planning to establish new connection over Limfjord. There has been made three proposals - Egholm line, Lindholm line and parallel line to existing tunnel.

This project will be situated near Egholm; therefore this line is main base point for building location and contextual attachment.

New highway will be right branch of E45 and it will connect with E39 across Limfjord. Road goes nearby west Aalborg and highway continue under the Limfjord southern races (Hasseris Bay) in a 1,150 m long tunnel to Egholm, and a 600 m long bridge across the fjord's northern race between Egholm and Lindholm [49].

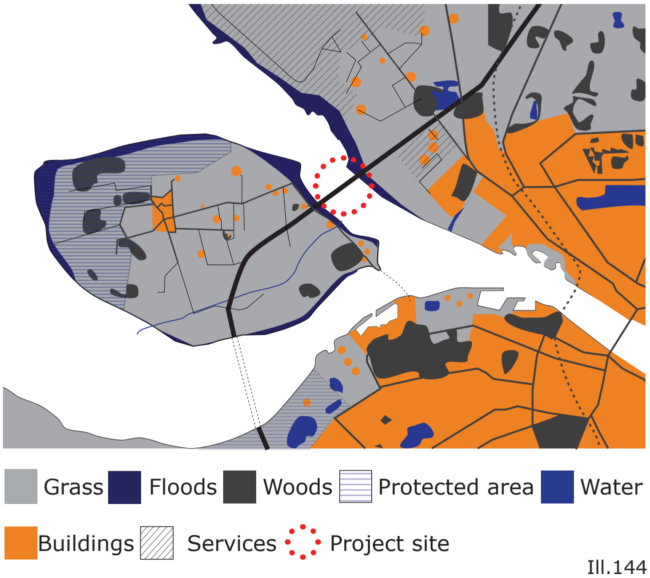
Main building region is both sides of Limfjorden Bridge, therefore all cafes and hotels are located in the centre of Aalborg and Norresundby. Protected areas, where building processes is forbidden, are on Egholm W side and area, where new highway enters land in Aalborg side. Land to the West of Lindholm is used by Aalborg airport and military services.



Ill.143
Nature

Egholm and West-North side if flat land, therefore wind can free blow across land. However, few woods an be found that gives shelter and protection for wind erosion. Because of flat land, part of coast line gets under the water during heavy rains and flood season.

As Egholm and lands around it is a haunt for birds' population, part of the island is protected zone [50].



Ill.144
Project site

Project site is chosen between Egholm and Lindholm as a vertical extension of the bridge.

Planned highway encourages project appear in exact place and nearness of Aalborg airport and lack of hotels makes this location useful in right moment.

Microclimate

Wind

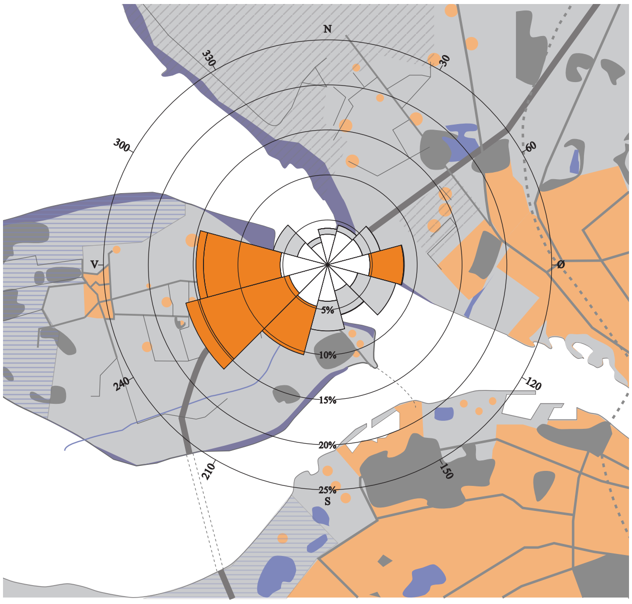
Microclimate has a big impact as it is main concept for design; therefore investigation of the local conditions has been made.

Wind conditions on the site have a big inpact on the design of the building complex regarding outdoor spaces, the building shape and the most importantly wind turbines.

The wind rose (ill.145) show the strength of the different wind directions from different times of the year. The dominant wind direction seen over the whole year is coming from west and SW. The best wind direction is from west, as near water resources provide laminar wind and unwelcome turbulence is prevented.

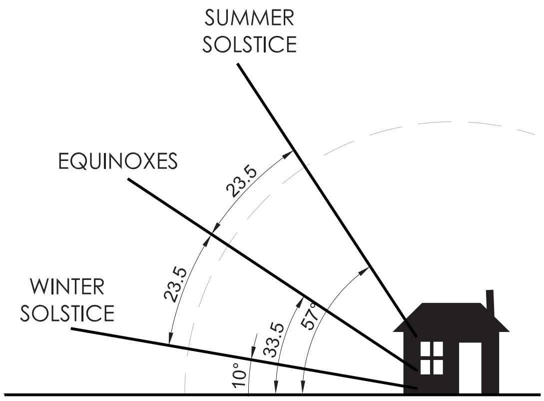
Wind conditions on the site depend on global wind streams. When west wind blows, it is the strongest one, as it has no disturbance until it reaches the island. Wind from north and south has min impact, as it is reduced by landscape massive. Wind from east can also be strong, as it tunnelling on water in the Limfjord, but it is more turbulent because of bridges and vertical building massives.

In conclusion, to provide a wind stream to wind turbines, it is important to focus on SW side design.



Ill.145
Wind map

Sun



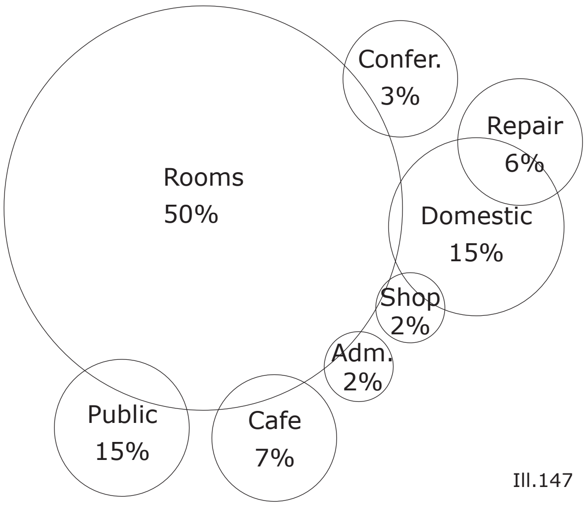
Ill.146
Solar angles

In order to provide good indoor climate, prevent overheating and use passive solar in the winter, Sun angle analyses was made. As project building will be high rise, overheating is common problem among similar buildings. Methods to control solar inlet are many: usage of proper materials, shapes and construction elements.

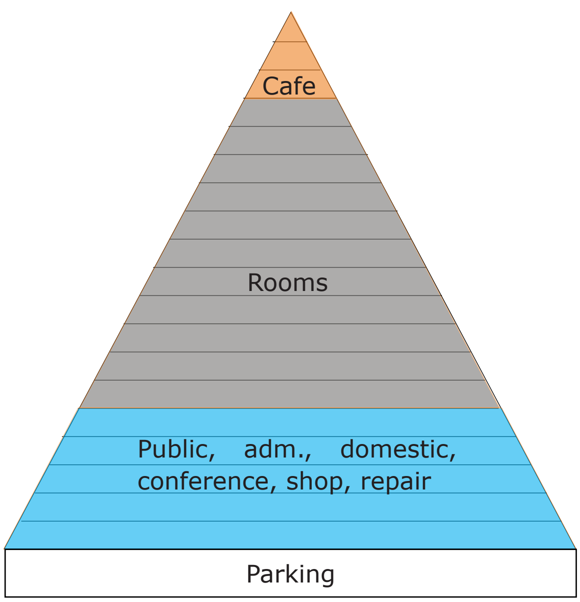
The winter solstice condition is the most critical one as the latitude of Sun at Aalborg's location is just 10,5° and it causes long shading among buildings and pellucidity in apartments. The Sun rises in SE and sets SW, therefore sunlight only reach a narrow southern sector. At Equinoxes and summer solstice Sun makes larger circle form E and NE to W and NW, thus it gives more sunlight in the evenings. [Petes2, 2011].

As building site and area around it has just few low building volumes, there is no shading and focus will be on overheating issues.

Hotel program



Ill.147



Ill.148

In order to calculate initial hotel size, height, perceptual relation was made, by taking reference from Neufert guidline [neufert, 2002].

Main part 50% makes accommodation facilities, including wc, bathrooms, hallways. Rest of 50% is left for all other services and personal space.

Public facilities, as reception, lounges, guest room's gives 15%, but domestic part together with repair service 21%. This zone serves as kitchen, laundry rooms and other spaces that deal with maintenance. Cafe or restaurant, shops or small kiosks and conference rooms gives 11% as entertainment possibilities for customers. Administration takes just 2% and is situated close to reception.

Placing functions into building level diagram, highest 3 floors will take cafe and view tower, as valuable view over city will attracts any people. In next 12 floors will be situated accommodation facilities, as they are over noisy area and give beautiful view for apartments. First floors will be used for social functions - conferences, guest rooms, lounges, shops and kiosks, domestic part and administration.

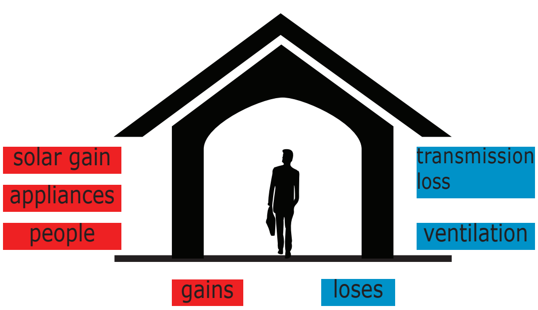
Ground floors will be used for parking, as this noisy area is not suitable for accommodation or public facilities.

Energy demands

	BR 2015	ZNE princ.
Heating (temperature)	20 °C	22 °C
District Heating Water	250 l/m^2	375 l/m^2
Ventilation	0,3 $l/s/m^2$	0,38 $l/s/m^2$
Appliances	1725 kWh/apart. (lighting included	
Energy consumption	30 kWh/m^2	20 kWh/m^2
Max U-value for structures	Ext.wall - 0.1 W/m^2K; Floor - 0.08 W/m^2K; Roof - 0.07 W/m^2K; Window - 0.9 W/m^2K	

ill.149

Energy balance principle is based on gains and losses equality In case with cooling and heating, aim is to reduce cooling, therefore maintaining indoor climate with low energy consumption.



ill.150
Energy balance principle

To establish a energy building it is necessary to:

1. Focus on this from the beginning of the project phase and follow it all the way through the design process;
2. Cut down the energy consumption drastically;
3. Invest in on-site power generation;

For zero energy buildings, the aim has been set around 20 kWh/m^2 in order to renewable energy cover the energy consumption. The purpose of zero energy buildings is to reduce energy consumption because of resource shortage and environmental purposes.

The principles for ZEB [43]

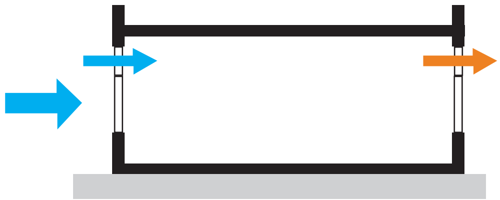
- Low energy consumption (A+ energy standard appliance)
- Consumes and generates energy from renewable resources
- Annual balance between consumption and production

For low energy buildings BR2015, energy consumption is 30 kWh/m^2, also it changes several parameter, such as DHW, ventilation rate and indoor temperature.

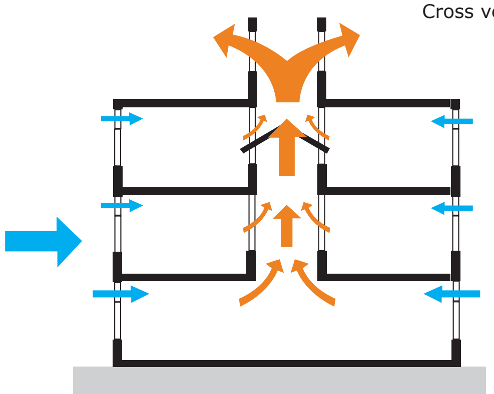
Building energy frame will be calculated as BR2015, with intention to reach zero energy requierments.

Indoor climate

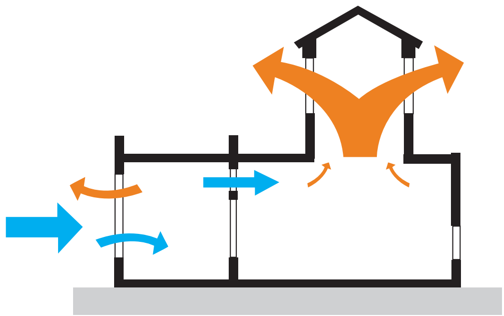
Ill151
Single sided ventilation



Ill.152
Cross ventilation



Ill.153
Stack ventilation



Ill.154
Combined cross and stack ventilation

Natural ventilation

Fresh air is necessary in buildings to provide oxygen and CO2 circulation in order to have thermal comfort.

The use of natural ventilation has advantages like no energy consumption, improved indoor climate in summertime and natural ventilation can be used together with other passive energy saving technologies. However, it may lead to discomforts like slow air movement that can result in high indoor temperatures, poor air quality and noise from the outdoor [51].

A few conditions that is essential in order to have natural ventilation:

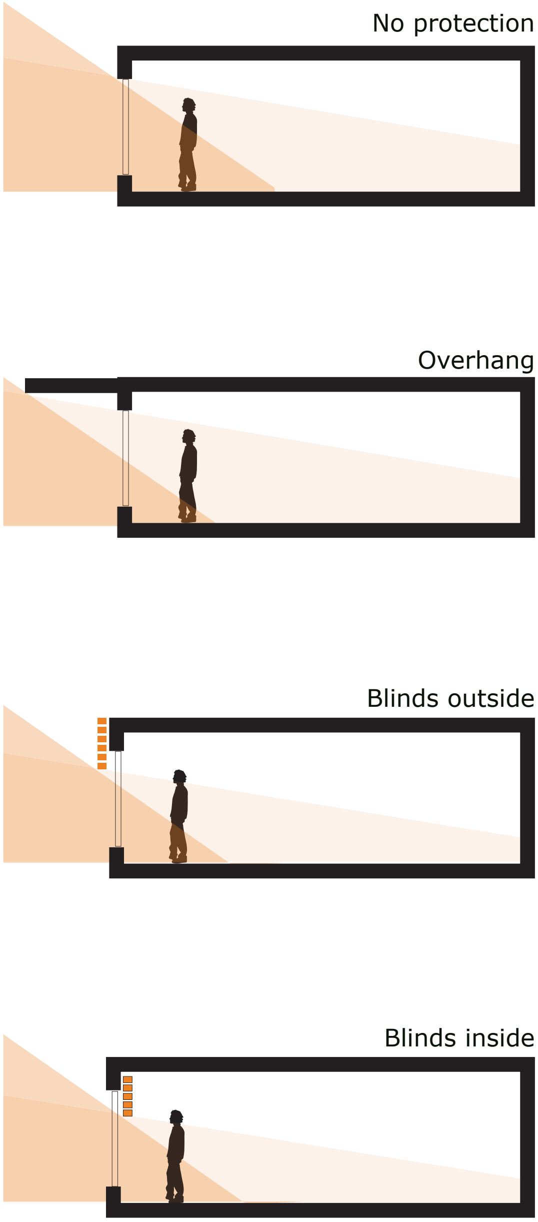
Room dimensions - relation between room height and depth shouldn't exceed 5 units in cross ventilation case.

Building layout - open layout diffuses air slower than closed one.

Type of ventilation

Cross ventilation means openings in two or more walls or roof. This could also be joined together with single sided ventilation.

Stack ventilation is used in buildings with light well or atrium to exhaust air through it. The air could be let out through a chimney. The stack ventilation strategy functions vertically and horizontally. The inlet is taken through the windows in the facade, while roof openings are used for outlet. In case of overheat, outlet openings and narrow bands above the windows open automatically to decrease temperature. Other windows are controlled manually because of security.



Ill.155
Shading possibilities

Overheating prevention

Modern facades with large glazing areas and high rises often has problem with overheating, as they are exposed to Sun. Therefore it is important to consider possibilities, how to design building in order to receive best thermal conditions.

Diagrams show different solutions:

No protection.
Sunlight enters room without any disturbance. It may create very hot climate in spring and autumn when sun is strong.

Overhang.
It slightly decrease amount of straight sunlight. Depending on layout, it is possible to control solar gain in necessary amount. Change facade appearance.

Blinds outside.
Decrease amount of sunlight but cover part of view. Changes in facade, adding extra elements.

Blinds inside.
Decrease amount of sunlight and no changes on facade. However building design is not though over and user have to improve it.

Despite these constructive solutions, usage of glass, different facade materials and facade cooling systems, might be effective as well

Materials


Ill.156


Ill.157


Ill.158

High rise building requires a special material that has good tension and compression properties. Concrete is good for compression but steel has great tension qualities. These materials often is used together in order to get best results. However, weight of concrete by itself cost some issues. Therefore more popular become to use only steel constructions. Towers can become taller and better bear the loads.

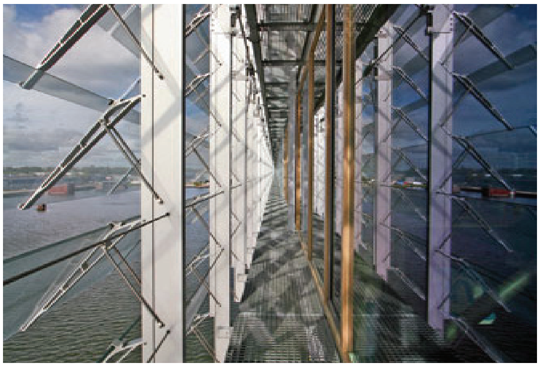
Glass and other polymer materials have good weight and strength proportion, therefore, often these materials is used as building cladding. Glass serves as excellent light transporter, in order to provide daylight into indoor spaces. However, glass is bad insulation by itself. In this case special windows block is made with an insulation layer that provides good thermal conditions and keeps warm into the building during winter time. Polymer materials can have the same appearance as glass form outside, but it can be extended with insulation layer. Combination of both materials can give good aesthetical view and height insulation qualities.

In order to achieve the best indoor environment, it is necessary to consider materials from acoustic perspective, as concrete, glass and steel reflect the noise and make reverberation and echo effect. In this case absorption wall, ceiling materials is suggested, that has porous surface and prevent sound bouncing.

Design details


Ill.159


Ill.160


Ill.161

In many building cases solutions to provide acoustic or thermal comfort is design failures, however, there is many design possibilities, how to implement functional elements into interior design.

Absorption panels can be place on the wall and their structure is hiding absorbing plate behind them. There is much variation of the panels to find the most suitable for every interior.

Surface under stair landing can have special patterned plaster what is place on the top of concrete element and absorbing material.

In case of doubled glazing, outer layer can serve as ventilation layer in summer and as warm layer in the winter. Moreover, space between them can be used as solar gain collector, in order to transmit warm air into living space during the night.

Ill.162

Ill.163

Ill.164

Installing the turbine

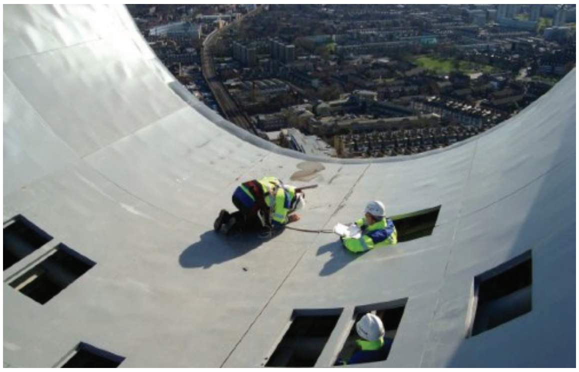
Turbine weights a lot as it is big and made from steel. This obstacle makes very crucial consideration about structural issues.

There are just few companies that have experience to install wind turbines into building or urban environment - Windside, Norwin. Therefore, information is limited.

VAWT can be placed on stand, HAWT on stand or let nacelle (engine box of turbine) lay on surface. Standing turbine can be place in many different places that not requires much more than solid base and proper load transmission. Laying turbine need to have special rack or support elements that not block wind flow.

At Bahrein WTC turbines are placed on the bridge that joins two buildings. In this case an extra attention has to be paid to bending moments in the bridge. If there will be failure in the top turbine and it fill fall down, another two will go down too.

Starta tower has standing HAWT that is placed into separate openings. Tunnelling accelerates wind speed but separate opening ensure bigger safety than in Bahrain WTC case. Key point for this installation is stable base for stand and secured other surface that will have min damage in case of failure.



Ill.165

Ill.166

Ill.167

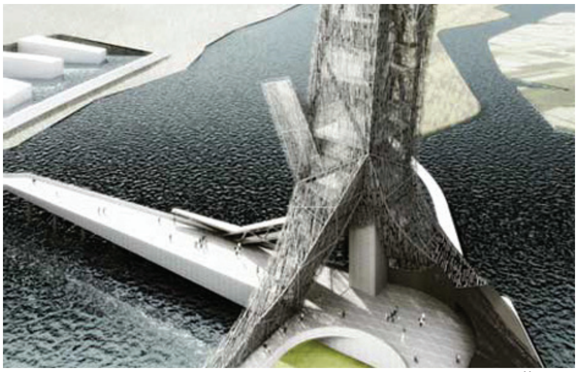
If design proposal deals with many small turbines, efforts for safety are not so crucial. Turbines can be located in cage and in case of falling it will not destroy building construction. However, frame can disturb wind flow and create turbulence. Moreover, productivity range is much lower than having one big turbine.

Until now there are just 3 buildings with realized fully integrated turbine projects: The Bahrain WTC, The Strata Tower and Their Pearl River tower.


skeleton key sb. hoved-
skeptic sb., skeptical adj.
(am.) = sceptic, sceptical
skerry ['skeri] sb. (skotsk)
klippe.
sketch ¹ [sketʃ] sb. 1. skitse
rids; 2. (teat.) sketch.
researcher

Sketching

01 Phase


ill.168
Miyi tower


ill.169
Endeavor skyskraper bridge, UK


ill.170
Anzac Bridge, Austraia

Inspiring references

In order to find relative references, inspirational ideas have been divided into few groups that help to organise and observe necessary fields.

Bridge

If building will be situated on the bridge, it is necessary to observe some technical and design issues.

Building can function as bridge, supporting bridge span with cables. Volume (bridge supporting element) can be closed or opened, but it has in balance.

Building can be joined together with highway; therefore it is as extruded element.

Ill.168 shows how to create space in the middle of bridge. From usual walking path it turns to public space. In this project case the highway requires straight connection and no disturbance. However, public space can be created among one of the exits.

Ill.169 presents support element that is organised in two directions without straight connection. It gives design and creative quality to the project.

Ill.170 visualizes more casual cable bridge, however, the peak express public space possibility, what was one of the intentions in this project.

ill.171
Naijing tower

ill.172
Rīga, Latvia

ill.173
Marina tower, UAE

Expression

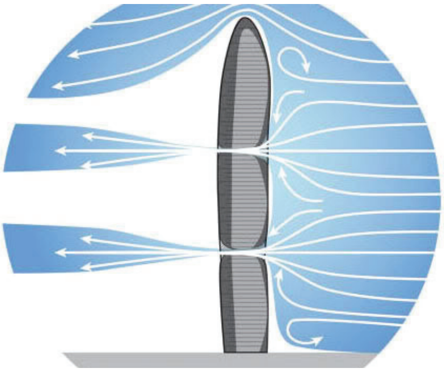
To make project visually atractive, an expression has to be clear and focused on main issues. It is not mean that building have to be absolutely innovative, but it need to contain some wondering moments in order to make observer explore building more closer.

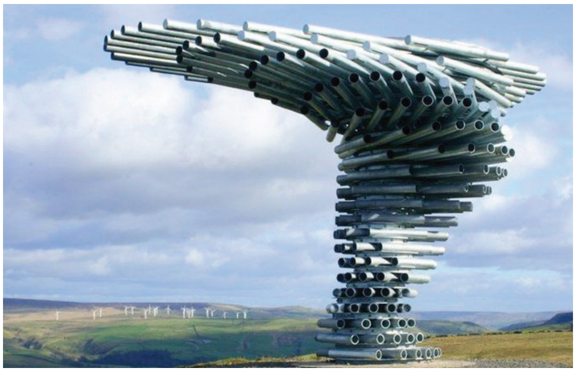
Ill.171 is landscaped and in the same time vertical project. It attracts people with opening and possibility to walk on the building, letting visitors explore building shape details.

Ill.172 presents diversity of shape. From different viewpoints you still can read number 800. This concept excellently functions in the crossings. Similar idea, when building changes is in Italy near Milano, where people that driving on the highway can observe play between two building volumes. Both of them are inclined but from different viewpoints they look either straight or inclined.

Ill.173 Marina hotel consist from two volumes that creates space between them. Volume invites people into the gap between building parts. Moreover, building layout is contextual and integrates into city planning.


ill.062
Darrieus


ill.090
The Pearl River Tower


ill.174
Wind Chime building, Tonkin Liu, UK

Wind

Wind is main tool, modifier and aim in this project. Building is going harvest wind, therefore few design elements will be subjected to changes because of wind.

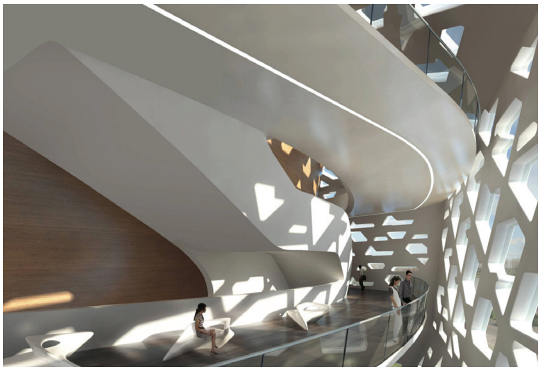
As this project is research to understand possibility to integrate turbines into building, architecture part might suffer to get the best result. However, it doesn't mean that architecture is not important. Moreover, this will be challenge to satisfy both fields.

Ill.062 is using wind turbine in very elegant and sufficient way. It is exposed to society and works like tectonic concept, where structure is design.

Ill.090 is building with fully integrated turbines into the volume. Openings divide and modify building volume. It is simple but not less genius way, how to find interaction between two main issues - architecture and wind.

Ill.174 presents aerodynamic shape. Not just concept about turbines modifies building. Wind by itself erodes massive and polishes it until perfect and solid shape. This quality might give to the building design elegance, pureness and simplicity, meanwhile working with modern shapes and newest technology.


ill.175
Neil Barrett Flagship Store, Japan


ill.176
Beethoven concert hall, Germany


ill.177
City life Milano, Italy

Inner spaces

Building outer expression is first that attracts people attention, however, inner spaces is these ones that give to the building functionality and point of being there. Impression about inner spaces is next step after first contact. It can inspire visitor even more or the very opposite - disappoint him.

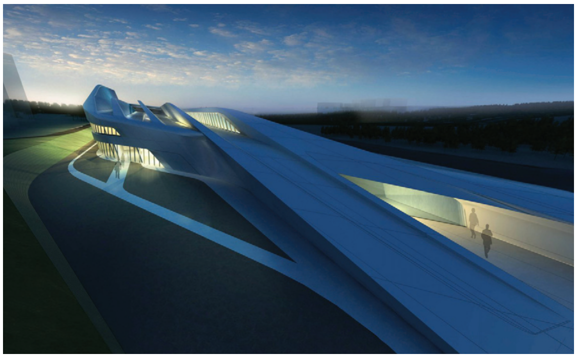
Zaha Hadid is leader in creation of modern and overwhelming inner spaces. The way how she is dealing with surfaces and elements makes people wondering. It is just design detail; however, it gives huge impression to the view. Detailing helps reveal intentions.

Ill.175 shows contrast between solid and organic and the way how it is possible to make attractive space.

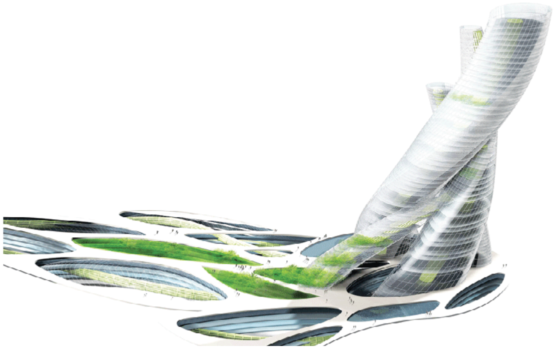
Ill.176 is an example how inner design elements (stairs, platforms) can divide big atrium and make it habitable. Meanwhile shapes are playing with light and shadows, creating more lively space. Solidity and pureness of materials gives clean impression.

Ill.177 is functional concept in order to join furniture with main structure. Architect again is playing with pureness. Pure lines leads visitor and rounded corners make space cozy.

Ill.178



Ill.179
EOEN energy research center, Germany



Ill.180
Three root house

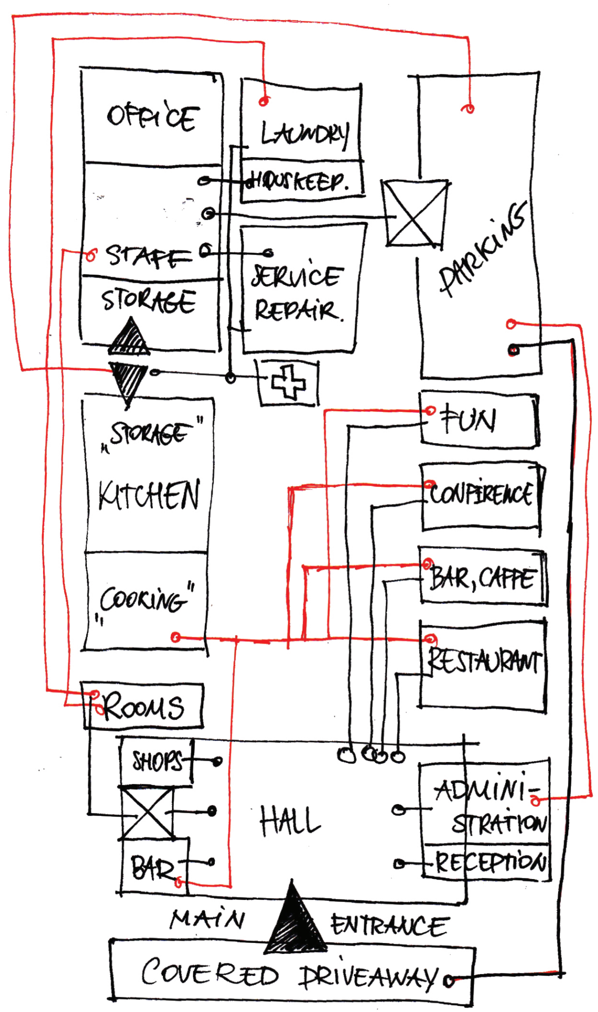
In connection with flat lands

It is important issue, how to experience transmission from flat lands to the high-rise in this sensitive context. High-rise is vital for wind harvesting but connection with landscape will turn this research more individual and specified in low building areas.

Ill.178 is design example where horizontal object is lifted with rational impression.

Ill.179 is Energy centre by Zaha Hadid in Germany. Architect varies access layers and heights'; therefore building is fully integrated with surroundings. This division is also functional and visually entertaining, as observatory need to explore possible paths from different view angles.

Ill.180 is representing functional separation between public-opened and private -denser. Base volume is filled with green openings and bridges that are considered as natural references and are situated close to the ground. Dense volume twists out and blends with ground volume with intimate and sensitive touch.



Ill.181

Connection map

Connection between rooms and spaces is the same crucial as outer infrastructure. Building layout have to be easy understandable and accessible for every hotel visitor.

Neufert is offering typical interrelationships scheme between ground floor spaces. This scheme will be taken as reference to the layout.

In addition for main entrance, two more separate entrances have to be created for staff and delivery services.

Entering main entrance, reception desk should be place as main focus point. From here visitor will have guide to move further. However, it should not block movement, as people that are intended to visit cafe or view platform should not disturb hotel activities.

Main hall or lounge has to have connection to the entertainment facilities (bar, restaurant, waiting lounge etc.).

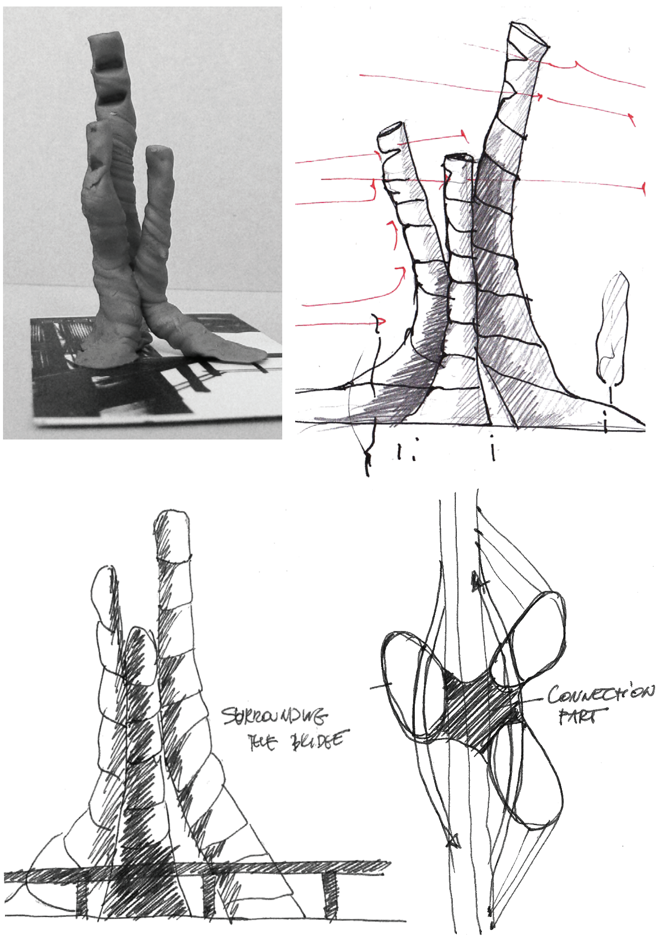
Vertical connections have to be reached easily. There should be two separate elevators that will serve for visitors and staff. Staff elevator need connection with service areas: eating, housekeeping and repair facilities.

Parking will be placed as first level above water, therefore connection between exits and parking lot entrance need to be visible at arriving moment. Exception case is, if hotel provide parking services.

02 Phase

Initial concepts

Several initial concepts have been made according aerodynamic approach. It is important to create basic shell that will be modified later. In the same time, architectural intentions is taken in consideration, the same as interaction between volume and its situation in the bridge.



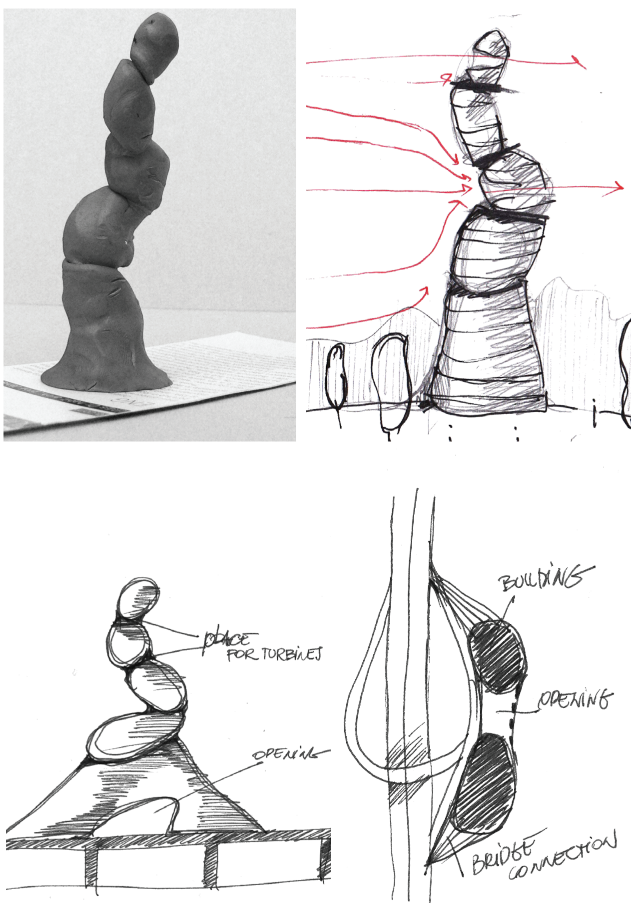
Ill.182
Twisting towers

Twisting towers.

Attention is paid, how to lead wind upwards in order to make more intense wind flow to the turbines. In the same time expression on outer shell is erosion. Volumes are creating space between them, but as building is on the bridge, it is hard to maintain it.

In connection with bridge volumes can be places around the highway, however, organisation is a bit clumsy.

Possibility to integrate turbine is possible into opening and on the top of the building, as logical continuing.



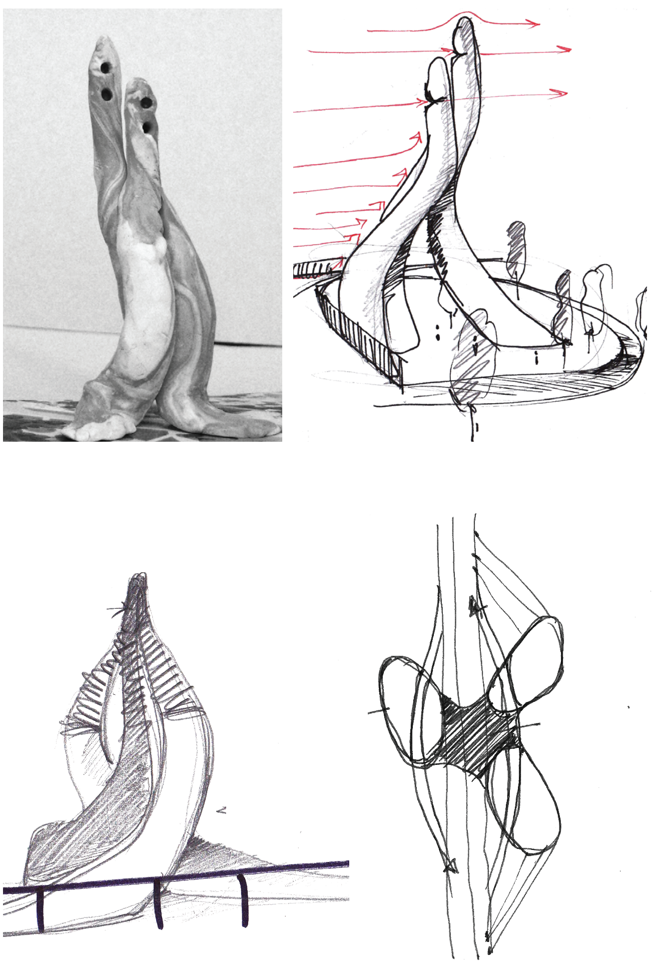
Ill.183
Divided towers

Divided tower.

Wind flow is deforming tower parts by sliding them forward and backward. However, this arrangement help accelerate wind just from one directions, therefore max wind speed can be achieved partly.

In connection with bridge volume is not working as free standing massive. Shape has been modified in the foot and turned into triangle base with opening to make mass lighter. Therefore building can be placed in the middle of the road or on site along one of the exits.

Turbines are placed between pieces, where it seems as logical place to open a volume.



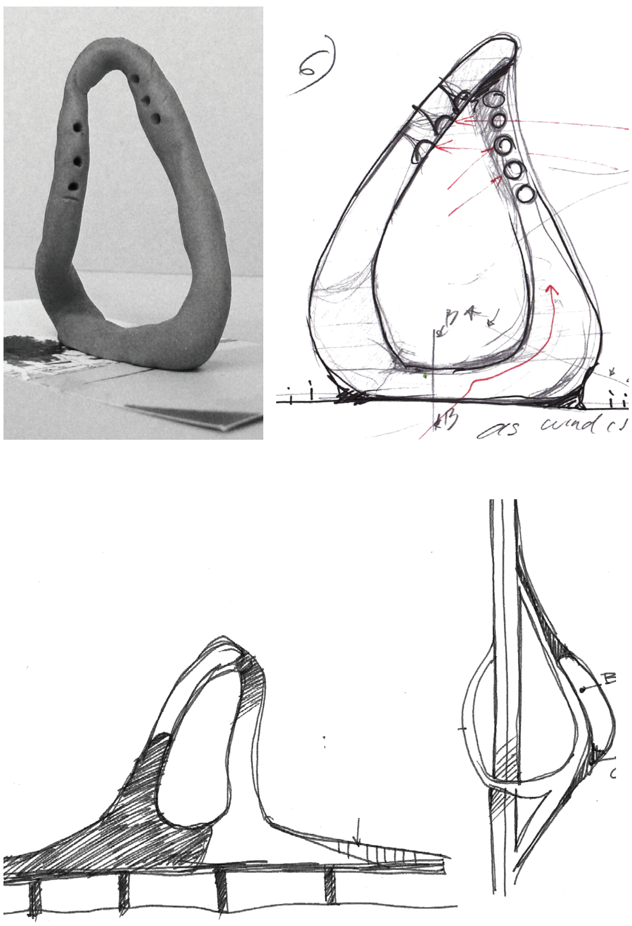
Ill.184
Supporting volumes

Supporting volumes.

Volumes twist around each other, supporting each orthe ans creating interesting spaces between.

When appear bridge concept, volumes was changed to make them more landscaping and possible to situated around bridge, remaining concept about leading wind upwards and twisting towers so they support each other.

Turbines are placed on the top of building, what gives max efficiency as wind is not blocked.



The Ring.

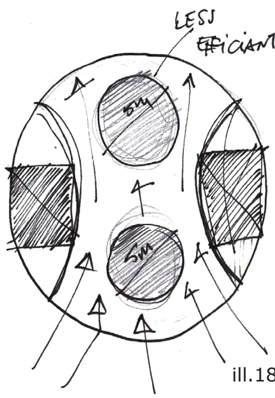
Opposite of all rest of concepts, this consist just from one volume, what makes it more pure and clear. Ring is twisted in order to harvest winds from west and southwest sides. As the volume is twisted and inclined, it changes shape from different viewpoints.

In the connection with bridge it can be situated along one of the exits, therefore building doesn't get so big traffic noise.

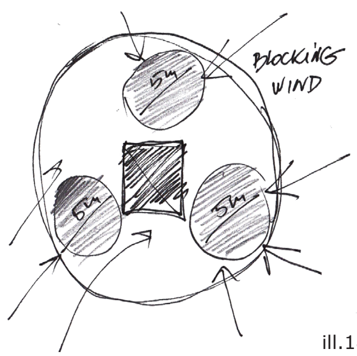
Turbines will be situated on the top of the building, before both ring sides connect.

Ill.185
The ring

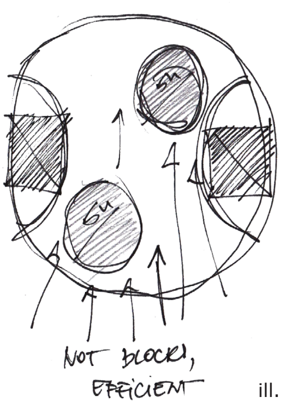
Detailing



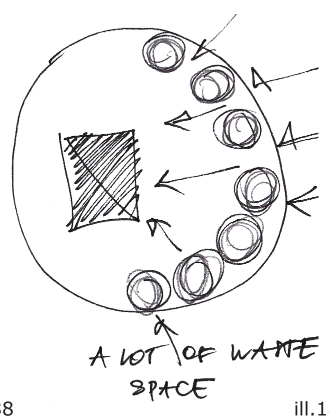
ill.186

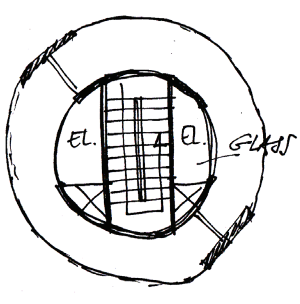


ill.187

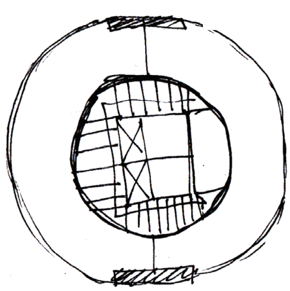


ill.188


ill.189



ill.190

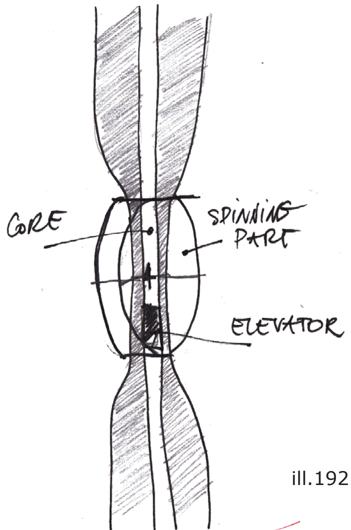

ill.191

Apart from architectural and aerodynamic approach, should be developed possibilities of turbine placement. Variations depend on chosen concept, however, few effective solutions is the ones that is good for several concepts.

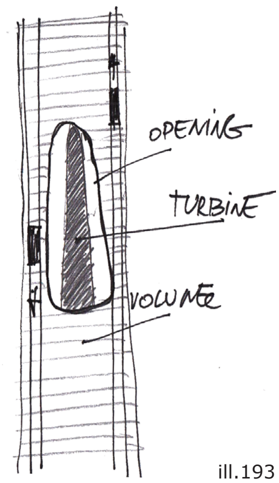
Vertical turbines inside of building.

Decision of amount of turbines is highly related to the design and place, where it will be situated.

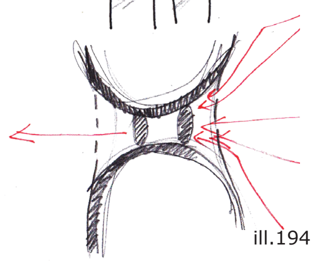
Using one (ill.190-ill.191) turbine, it is big, can be integrated into the function, example together with elevator or staircase that is situated in the middle core. Another possibility is to place it on the top of volume (ill.196). In this case it will get the best efficiency, but might be too visible. Less visible is turbine that placed into the volume (ill.193), in this case it will be smaller and might be placed more of them. Two turbines can be placed one behind another (ill.186), but it this case one behind will be blocked to harvest efficiently. Turbines can be push aside (ill.188), then it gets more wind. By situating three turbines (ill.189), all of them are block with the middle element (ill.197), as building need to maintain some vertical connection and access to higher levels. The same situation appears, if row of turbines is place around building element (ill.189). In the section all of smaller vertical turbines work well, if tunneling effect (194) in the opening is established.



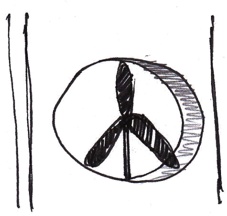
ill.192



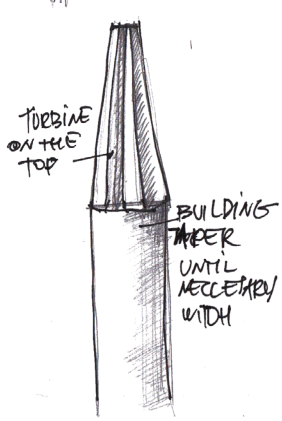
ill.193



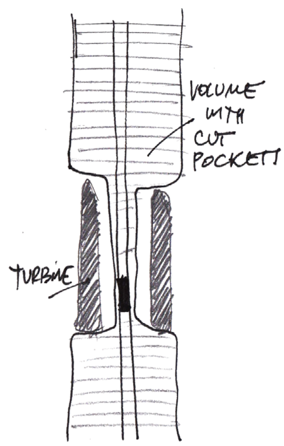
ill.194



ill.195



ill.196



ill.197

Horizontal turbine (ill.195) is the most inefficient to implement into the building. It can be faced just to the one direction and it needs a lot of free distance around blades. But in building site wind is changing and there is two main wind directions.

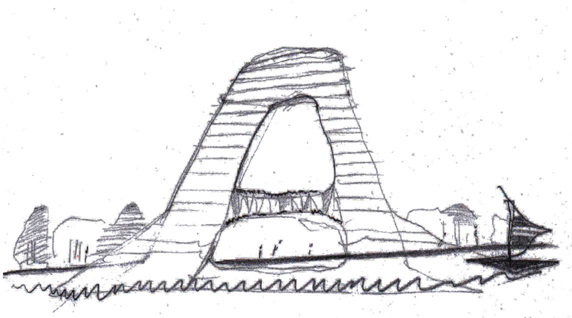
Hungarian one is the most efficient and the best place to locate is on the top of the building (ill.196). Tries to implement it into the building requires a lot of wasted space and it is hard to integrate with other building elements.

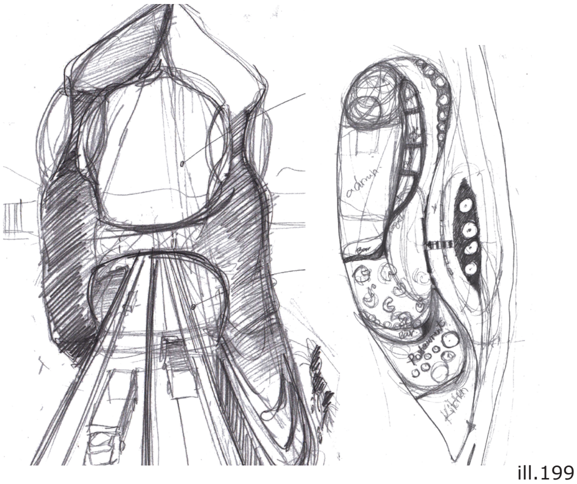
Darrieus turbine is the best for integrations as some building element, as core size can be adjusted and use for multi purposes. However, this turbine is the less efficient.

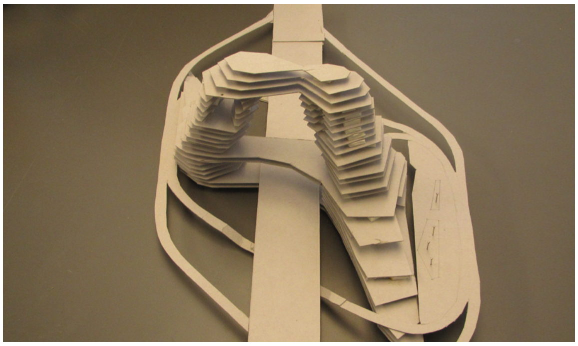
Ropatec turbine has some problems with integration because of its shape. It takes to much area to use it core.

Therefore this project will focus on one of the vertical turbines - Hungarian or Darrieus. It could be possibility to use both of them in order to increase productivity.

Interaction between technical and architectural concepts


ill.198


ill.199

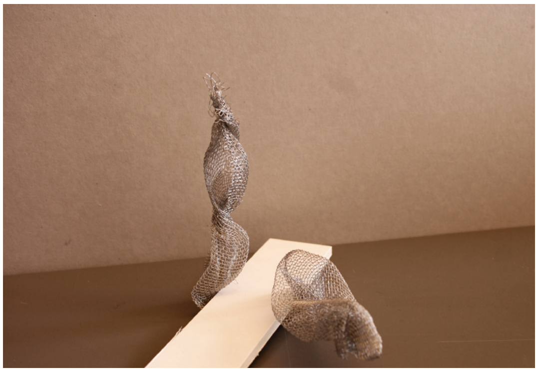

ill.200

The most of the architectural intentions achieved ring concept, as it represented pureness and clarity. However, situation of the turbines and existence of big opening not creates clarification. This concept was taken for more detailed resolving and, in combination with other expressions from other concepts and bridge, first iteration was made.

Iteration 01

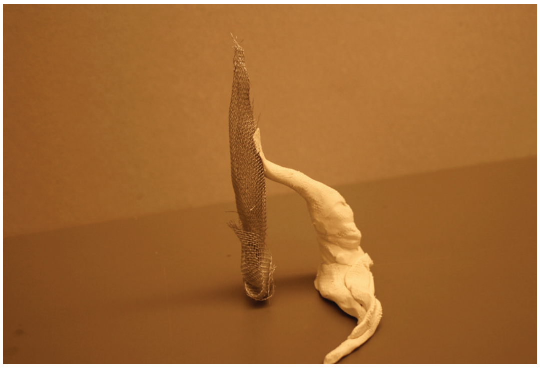
Architectural explanation for opening in the middle of volume is to make lighter volume and give the light for more building surfaces. It lacks functional quality; therefore building was turned 90 degree, so the highway is going through the opening. Visually hole invites and makes building arrangement more logical. Turning of building, made problems with connections, as both building sides will be used as hotel. Because of that, connection under bridge was deleted and new one established few floors above the highway. Volume from ring becomes "snake" that flaps over the highway, still remaining simplicity of the volume.

By creating connection above highway, building opening was divided in two parts. Therefore question about necessity of the hole is still discussable, as it creates several functional problems.



ill.201

ill.202



ill.203

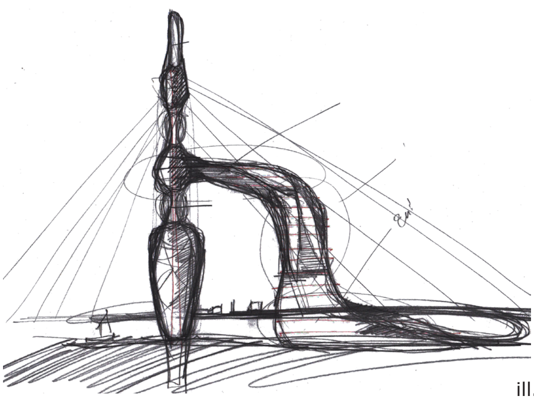
Concepts were taken for further development in order to solve architectural and productivity connection. Next models differ by emphasizing the tower, instead of horizontal connection on the top of the buildings.

Ill.201 express proposal without connection, however this separates two volumes, and it still maintain problem about functional organisation. Horizontal communication might be made under the bridge, where it is not visible but it creates flow even more complicate, as to move from one tower to another, people need to move until ground level. Another question about two volume necessities appears.

Ill.202 plays with connection into the middle of tower. Contrast between materials presents contrast between function, as solid surface is hotel but frame is supporting construction. In this case, functions are situated in the one side and it orders the flow. There is no real necessity to have a supporting structure, as it doesn't serve functionally.

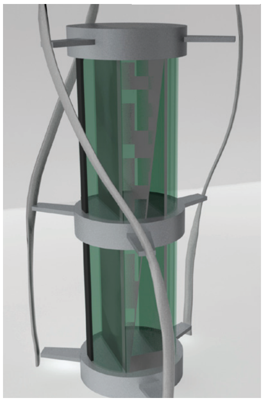
In the ill.203 volumes are switched and structural tower supports solid volume. Turbines can be situated on the top or between structural towers. Horizontal connection serves as bridge to the public cafe that is situated in cross point.

This approach was taken for detailed resolving, as functional and structural concepts interact with each other.

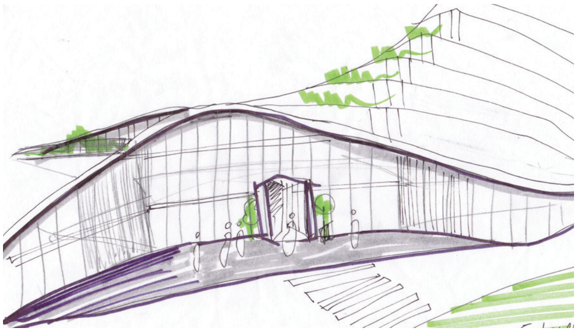


ill.204

ill.205



ill.206



ill.207

Iteration 02

Important thing about this concept is that both volumes, the same as architectural and technical issues, improve each other.

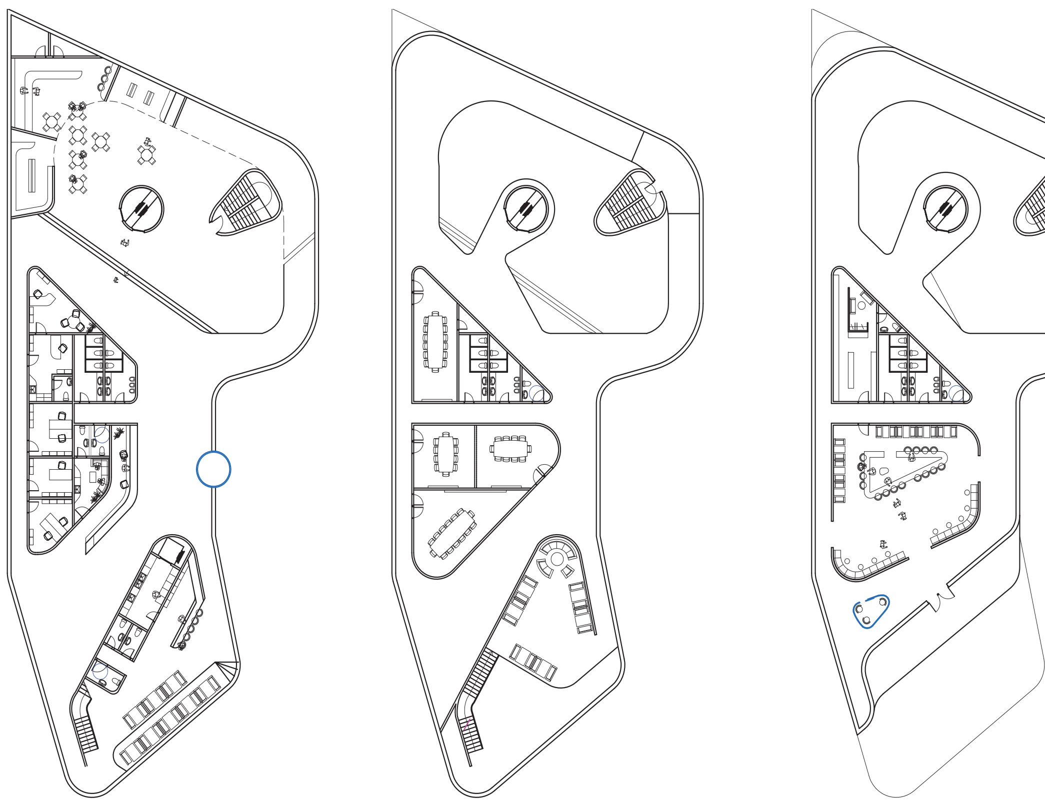
Wind is approaching the tower from SW without any disturbance, as the tower is placed in the middle of bridge and faced to the W. However, turbines can spin in any wind conditions. Tapered shape helps lead wind upwards.

Structural tower supports bridge, hotel and turbines and is considered as productive building part. Solid volume gives a great weight to the building with its function, facade and architectural impression. To link both volumes, horizontal bridge is made, that serves as path to the cafe and visually turns in structural volume to the solid surface. Cafe is places in the cross point, therefore there is necessity to use structural tower for access.

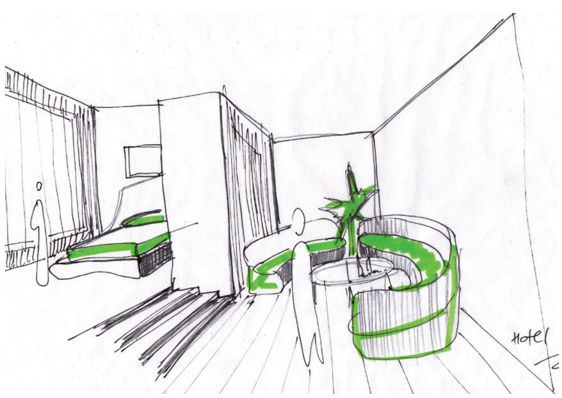
Turbines can be combined with an elevator. This decision leads to use Darrieus turbine, as its core can be variable and adjusted to different proportions.

Layouts are made as open, organic planning, in order to recall external shape. Big atrium functions as building soul and centre, distributing functions around it.

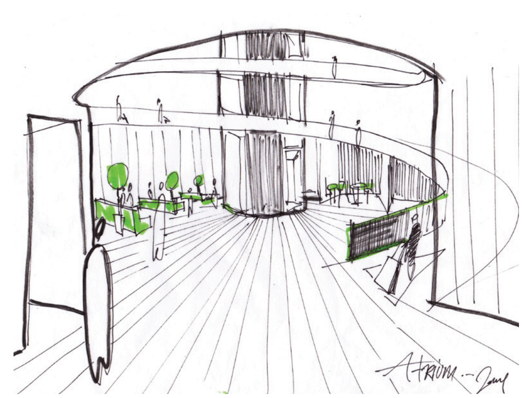
However, bridge existence complicates flow organization and visual appearance of tower not meets architectural intentions. It comes out more sculptural than proportionaly easthetic.



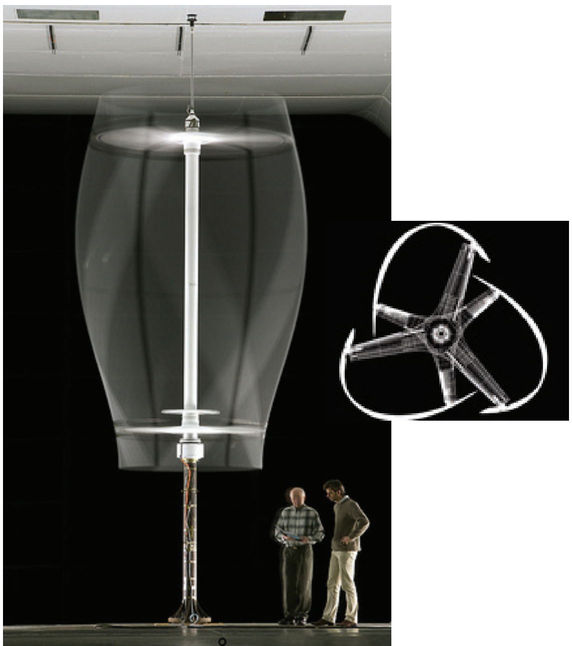
ill.208



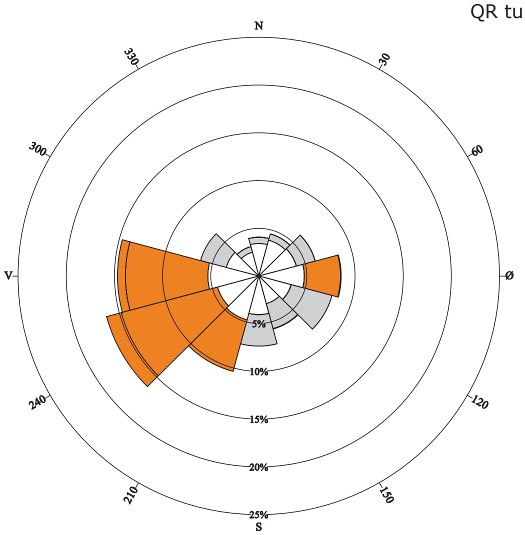
ill.209



ill.210



ill.211
QR turbine



ill.212

After first two iterations building concepts was not successful. It had a lack of argumentation and it pushes aside main issue - wind and productivity. Therefore, decision is rather to choose one turbine and develop building according to it, than try to adjust different turbines to the building concept.

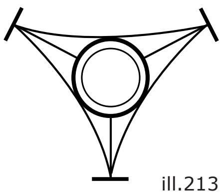
Choise of turbine

Darrieus turbine prototype is chosen because of it flexibility in the size, placement and installation options. However, productivity indices are not the highest ones. Therefore, more than 1-2 turbines will be placed in the building.

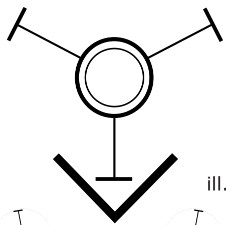
Darrieus turbines works very quiet comparing with a Ropatec or horizontal ones that is big advantage for integration purposes. Middle core can be used as part of other part (elevator, structural pillar), that makes turbines be not just sustainable unit but also be part of some other functional purpose.

Second issue is to focus on the main wind orientation, as to create perfect building is not the research assignment. Main wind blows from SW-W; therefore building design will be adjust to particular orientation.

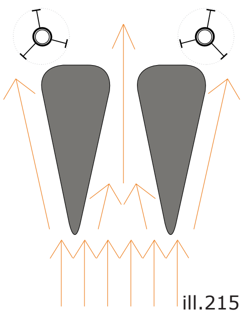
Average yearly wind speed is 16 m/s that is very suitable for chosen turbine, as it can operates from 5-26m/s.



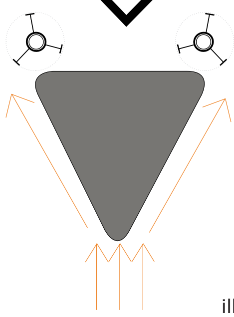
ill.213



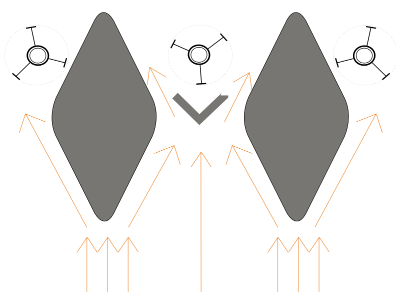
ill.214



ill.215



ill.216



ill.217

ill.218
QR installation

Technical concept

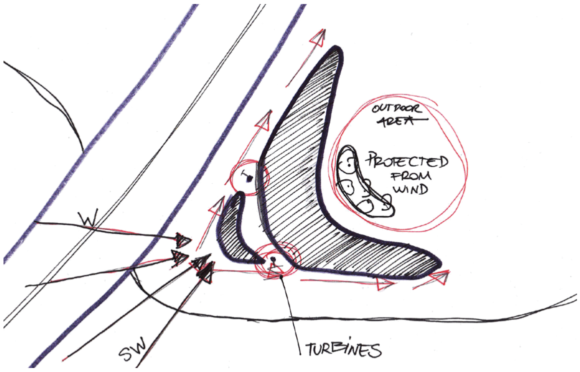
Darrieus turbines have some problematic issues. One of them appears, if wind meets two of blades in the same time. In this case, turbine needs manual start-up. Therefore, technical concept was made, how to prevent this mistake. One of solutions is to add extra plates (ill.213) that divided wind at the meeting moment. Another is to put some obstacle (ill.214) in the front of the first blade, so wind stream separates and hits a back blade.

If turbine is placed in connection with a building, building shape have to divide and lead wind until the blade (ill.215). Volume might have also an opening (ill.216).

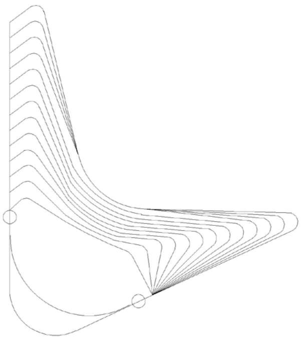
These two concepts can be combined (ill.217), where can be situated already 3 turbines.

Turbines can be situated also on the top of each other; this allows produce more energy using min of area. To prevent turbulence, traces are installed in connection with a loadbearing structure (ill.218).

Ill.219



Ill.220
Site proposal



Ill.221
Top view

Decision have been made for the site. In order to prevent all organisational problems on the bridge, building will be placed on the coast at Lindholm side. It will allow easy access from highway, more outdoor areas and possibility to access building as pedestrian.

Iteration 03

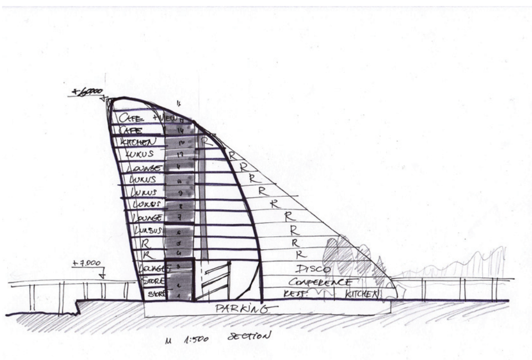
Building shape is triangular, therefore it leads and divides wind, accelerates it and turbines makes best performance.

Turbines are situated in the gap that divides building volume in two parts. Turbines is arranged in vertical line and supported by one column.

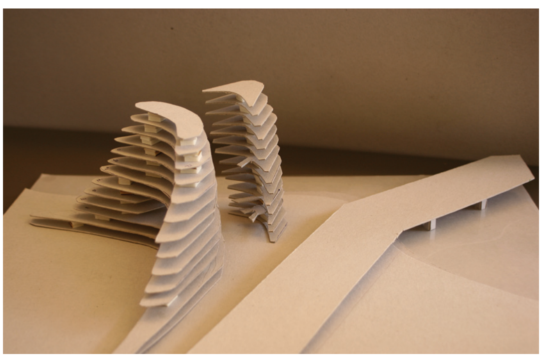
Building volume is decreasing area gradually going upwards, but maintaining opening size. Ground floors are longer and connect with a landscape.

To join functions in both buildings, several bridges are made across gap. Bridges will form the open space. However, gap creates few questions: how turbines columns will be connected to the building, do gap should be covered and turn into indoor atrium, solar accessibility.

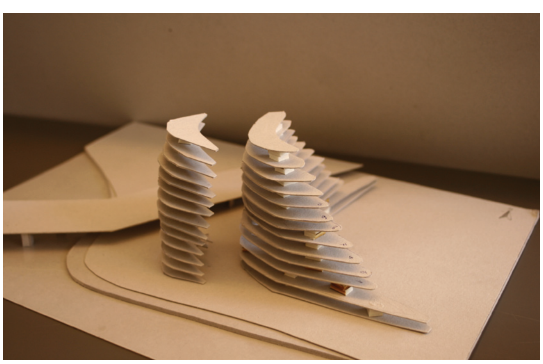
In the midterm seminar was suggested several options, such as closing the gap and make just curved carvings into the facade, therefore building will be just one volume and functions will be distributed more efficiently. According to the roof and turbine column connection, volume can grow gradually upon column, converting column as loadbearing element.



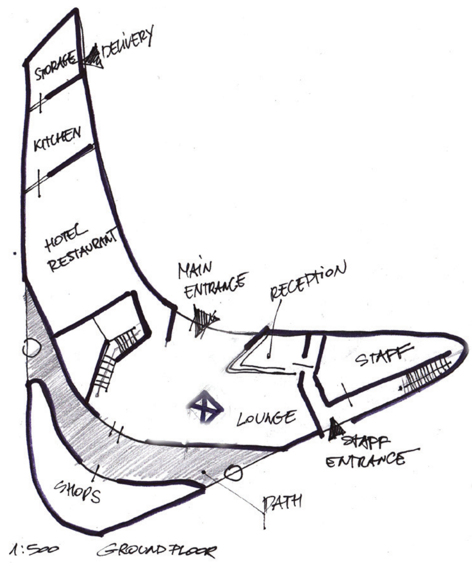
Ill.222
Section



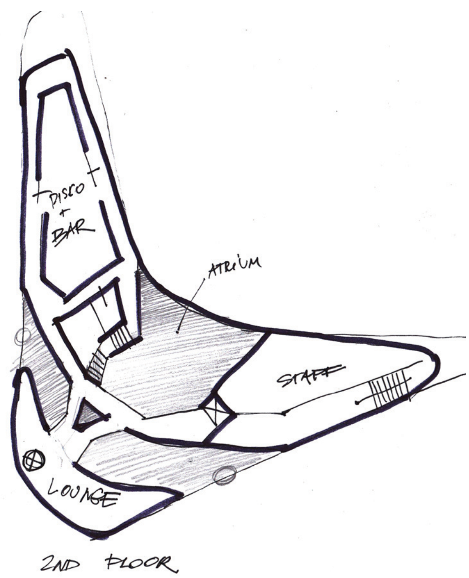
Ill.223



Ill.224

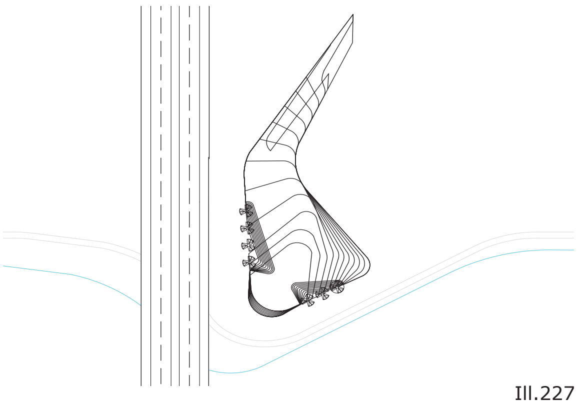


Ill.225
Entrance floor

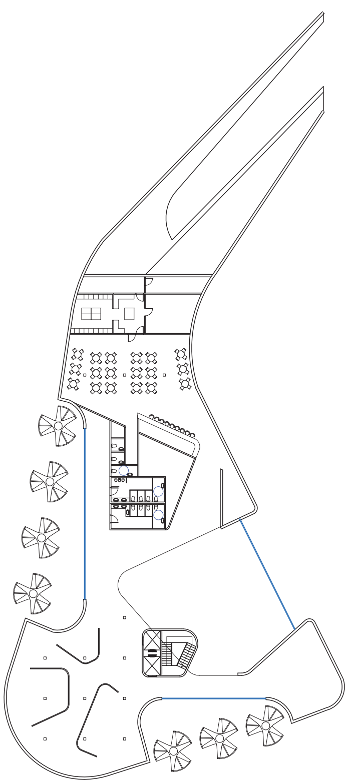


Ill.226
2nd floor

03 Phase



Ill.227
Site plan



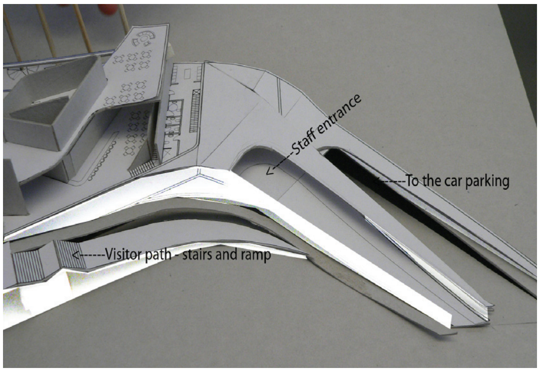
Ill.228
Entrance level

Volume maintain triangular peak, in order to lead the wind to the turbines. Shape is union, therefore instead of gap; volume has carved openings that grow over the turbines. Layout is stretched more to the highway direction, creating more irregular but more proportional shape.

Ground floor is organized in three levels that divides flow and helps building meet landscape (Pic.xx). First path leads cars into underground parking, next is used by staff, whose facilities is situated on the ground floor. Last two paths - ramp and stairs line - lead visitors of the hotel to the main entrance. Entrance level is situated at 1st floor to get lighter and interaction with turbines is more visible.

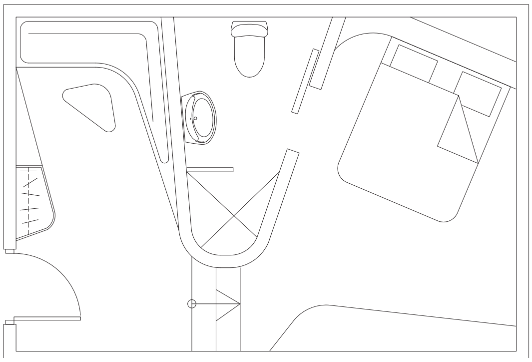
Entrance level contains from administration facilities, restaurant and its premises, main lounge and shopping possibilities. To drag more light into the building volume, atrium is connected with an entrance. Irregular layout allows playing with shapes, therefore vertical blocks (restroom facilities and vertical communications) is located as separate objects with design quality.

Main lounge has straight visual connection with turbine openings, so visitor can observe its working process through the glass wall. Openings are oriented to south and west, and are faced to the Limfjord, therefore, hotel main lounge can experience in different ambiences. To emphasize vertical blocks and to break straight vertical walls, inner walls are inclined, extending it location in con-



Ill.229


Ill.230


Ill.231
Hotel suite plan

nection with ceiling.

Next level is continuing public functions. There are situated conference rooms, exhibition room, and disco-bar facilities. Atrium divides functions to the each corner, letting transfer zone be located close to turbines, so they receives main visitor attention.

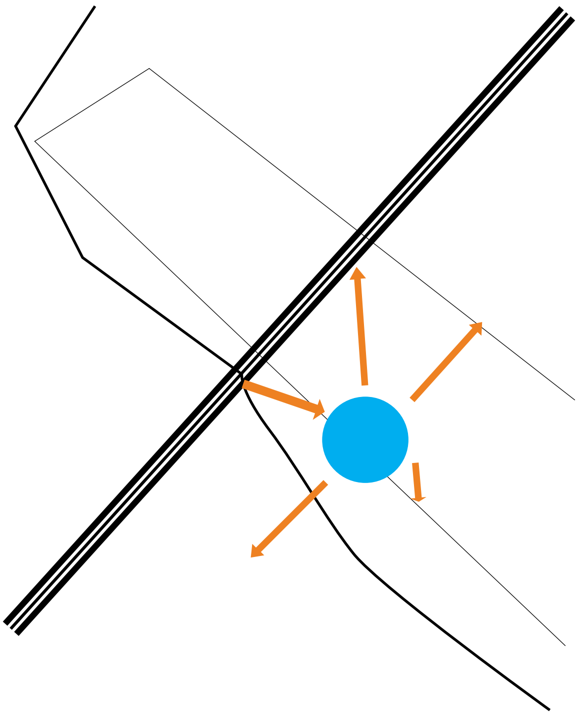
Next floors contain hotel rooms. Room (ill.231) is around 25m2, and has opened layout that consists from sleeping area, small lounge and bathroom facilities. Apartments will be situated along external wall, making area around turbines openings as transfer zone.

Problem appears with the peak design, as vertical connection has to be maintained through the all building. Tower lacks slenderness but the width of the tower depends also on turbines location. To cover 10000 m2 it is necessary to have 9 turbines. Solution can be found by using fewer turbines and therefore, area of tower will be less and it could become slender. These changes will strengthen contrast between public and private building parts; therefore building can express its function more understandable. Problems of hotel room distribution cause atrium and width of building, as every room needs daylight, but inner core is left free. Therefore, there is a lot of waste space.

These changes, however, are sensitive and the best average proportion between productivity and architecture have to be found.

Detailing

Master plan



Ill.232
Site connection plan

Ill.233
Sailing in Limfjord

This chapter will explain and develop master plan in order to get final proposal.

Vision for the site is to make attraction point containing urban and suburban qualities, as the function of building and infrastructure presents urban context but context is very sensitive and suburban. Detailed site analyses have been discussed in the program chapter.

Building is situated close to the water and surroundings not require special planning, as the site is flat grass land. Therefore, connection with existing plan is only few.

Highway.

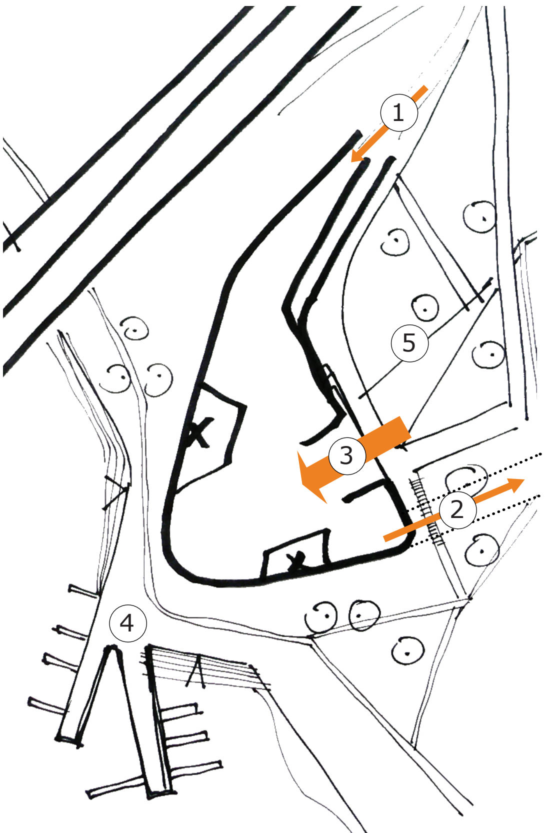
Planned highway is only road connection with Aalborg and Lindholm. In order to establish functional and easy access, four exits have to be provided. Two of exits will have straight access to the project area.

Walking path.

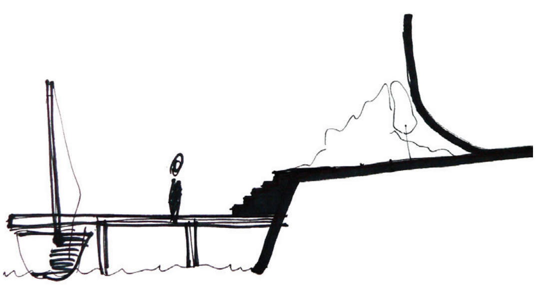
There is walking path in existing plan that is used for waterfront observing. By placing building on planned spot, walking flow is cut, therefore, new path is created, that continues existing path and let it integrate with new infrastructure.

Waterfront.

Alternative way to get until hotel is by boat. There are a lot of private yachts that sail through the Limfjord at good sailing weather. By establishing connection with waterfront, new port point is created and more potential clients can approach the building.



Ill.234
Master plan



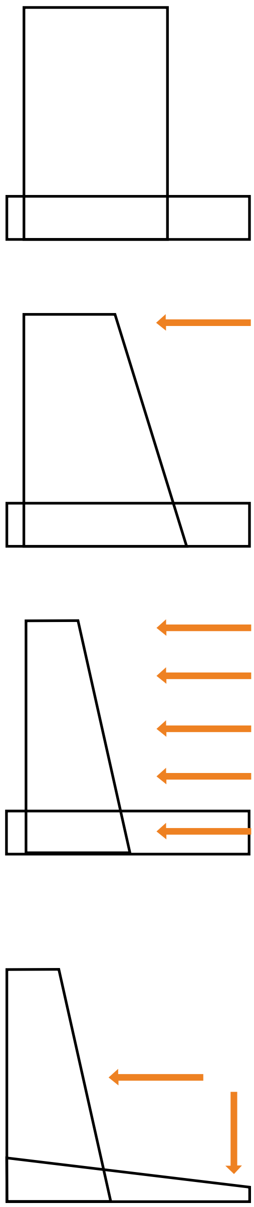
Ill.235

Arrival with car can be happened just from highway, as there are no other roads in the area. Exit has straight connection with parking area, where it enters the building at "buildings tail" (ill.234, nr1). Another opening is leading cars out, as underground passage (ill.234, nr2) and then it joins with road back to the highway. For transport that is just delivering or picking up visitors, brunch road is dividing before "tail", and connects with exit road back to the highway. Main entrance to the building is (ill.234, nr3) only one and all flow is happening through this point.

Arrival with boat can be happened to small port (ill.234, nr4). This area has connection with walking path and water can be accessed climbing downstairs. Level difference between (ill.235) wooden pier and walking path is less than meter, but created expression with level difference organize site and lets visitor explore surroundings. People, who pass by, can enjoy the port as qualitative outdoor space.

Hotel front has small stair platform that is covered with overhang to protect people from rain, who is waiting transport. Space across the driveway is designed for recreation and connection between existing walking path, main hotel entrance and staff entrance. In the centre is situated green area with benches and as this side is blocked from wind, it can be qualitative outdoor space.

Volume

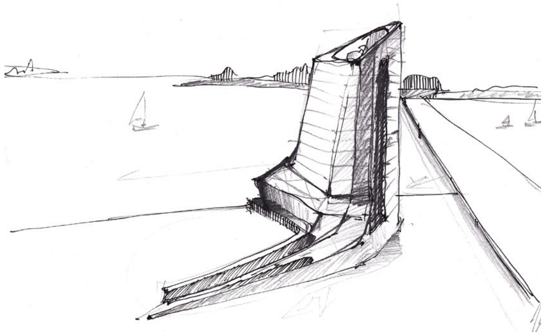


Ill.236
Volume development schemes

Main volume concept is to include two parts (ill.236) that intersects with each other. Volumes have different function, horizontal is public but vertical is private. To improve wind conditions, rectangular shape is tapered upwards. It also decreases area of the building and makes possible to install appropriate amount of wind turbines.
However, from architectural view, tower seems to wide comparing with public part and doesn't have impression of tower. Therefore, volume is squeezed more. It does make changes in layout and turbine installation possibilities, as vertical connection in the tower limits organized flow and dimensions of turbine opening is limited by function and outer shell.
Only solution is to find the best proportion between height, width, productivity and function.

Building height is limited by context, and it should not exceed 70m.
Width depends from turbine opening depth and logical circulation flow around vertical communication block and load-bearing elements.
Turbine amount is set by the total size of area. Dimensions of turbine opening depend on turbine amount.
Functional flow is flexible; therefore, to fulfil above mentioned issues, functional flow will be the modifying tool.

Ill.237
Heydar Aliyev Centre, Baku

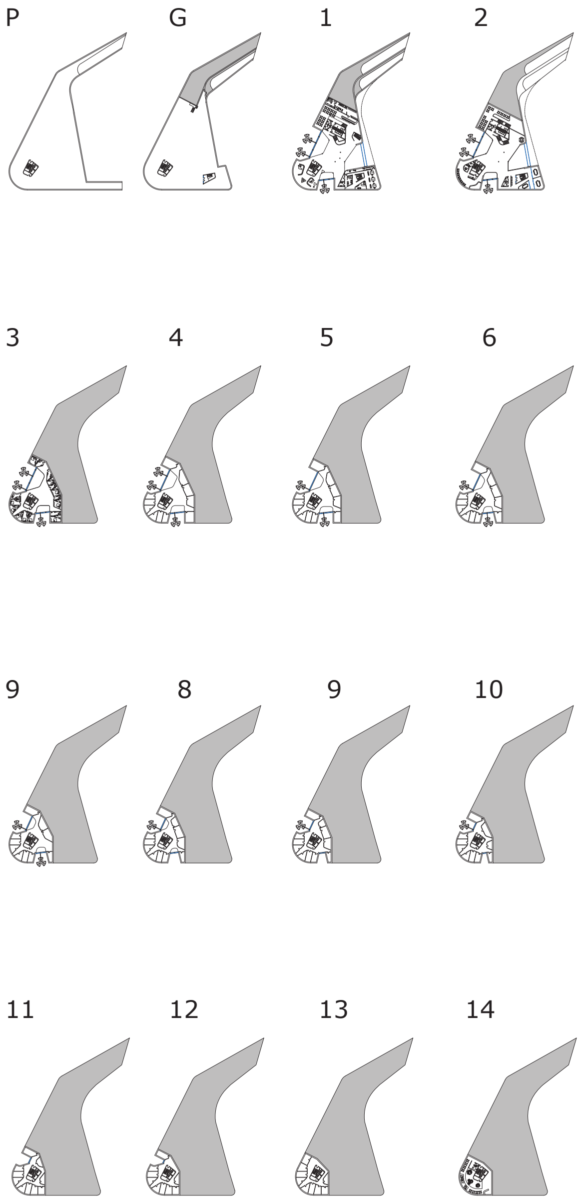


Ill.238

Ill.239

In order to understand possibilities of tower width, loadbearing principle is considered.
External wall is tapering upwards, so it is difficult to make it loadbearing, as load-bearing elements is sitting on top of each other. If external wall is not loadbearing, there should be situated many pillars in the middle of building. However, this solution will destroy intention of open and clear layout.
Solution and compromise is found to use bended profiles (ill.237) that is load-bearing and need just base points in one place. Columns on ground floor will be base points for space creating.
To understand, how much building can taper, attention to the peak design is paid. One of possibilities is to make it as cut (ill.238) with subtracted volume that could be used for wind protected garden. However, cut makes volume look wider than it is. Also weather conditions are not very suitable for such a openings and during rain it will be unusable.
Another possibility is to continue volume upwards and close it. Peak can be used as view tower in more floor height. This approach makes building look proportionally slender.
To connect roof over public floors with building "tail", roof smoothly even up level difference between 3rd and ground floor.

Layout



Ill.240

Overall layout

Building consists from 16 floors, of which parking is situated underground.
Parking place is 1500 m2 that provides parking place for every apartment and staff members (see area calculation, apex nr1). Parking area has two entrances - one in, another out, in order to provide easy traffic organisation.
In ground floor are situated staff facilities. It consists from domestic and repair departments (laundries, storages, maintenance rooms, technical rooms, first aid, and kitchen premises and staff flats). Floor has three vertical connections with upper floors to fulfil fire demands.
1st floor is main entrance level. To provide easy access from outside, hotel front is made in several levels. First floor consists from administration, shopping, and double height hotel restaurant.
On 2nd floor are situated conference rooms and disco hall. This floor has visual connection with entrance floor through the atriums. Two of them focus view to the turbines; the third one extends entrance opening.
In the 3rd -13th floor are placed hotel suites. There is two types of suites - standard and luxury. A floor area is reduced with each floor.
Top floor is view tower with small cafeteria. This space is opened in more floors, creating qualitative indoor place.

Layout development

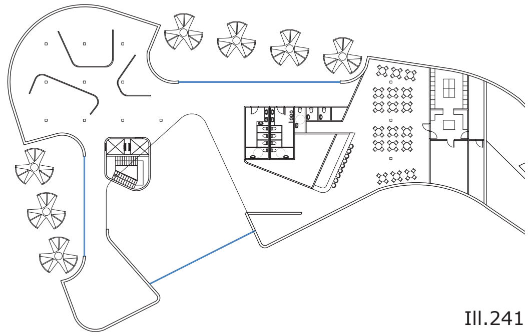
During project development, several layout changes have been made in order to fulfil all architectural and technical intentions.

First proposal (ill.241) included just one atrium, facing to the entrance; however, in this case, main focus was not on turbines. This was the reason to invert atrium, creating two atriums instead and facing them to the turbines (ill.242). Changes also solved problem about max efficient layout planning for hotel suits, as all of the rooms need daylight.

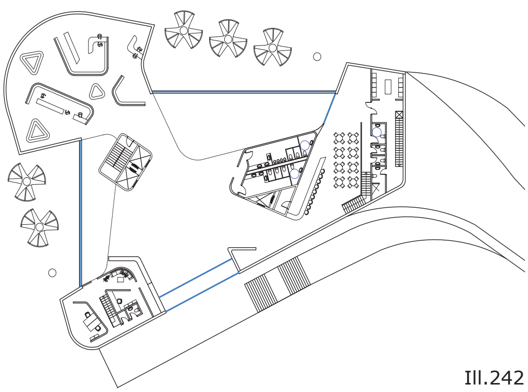
In the second proposal appeared difficulties with vertical connections, as one of them was blocking view to the turbines, another - main hotel core, had problems to organize space around it, as turbine hole and external wall was tapering upwards. Also space for administration was limited.

In third, existing proposal (ill.243), main vertical block, together with turbine openings, is moved more to the corner, letting tower be more slender. Organisation around staircases is improved and fulfil fire regulation about corridor width of 1300 mm. Administration space increased twice its area and it could fulfil all necessities.

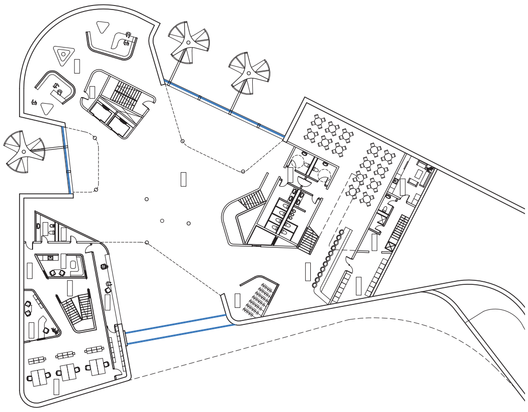
Total area of layout is less, therefore building need less amount of turbines.



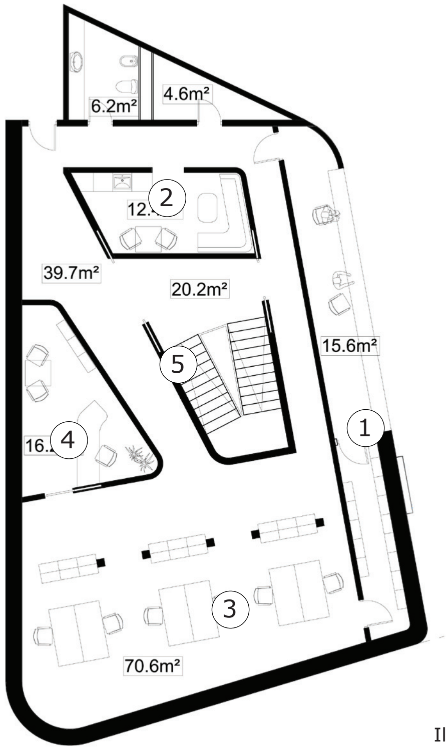
Ill.241



Ill.242



Ill.243



Ill.244

Ill.245

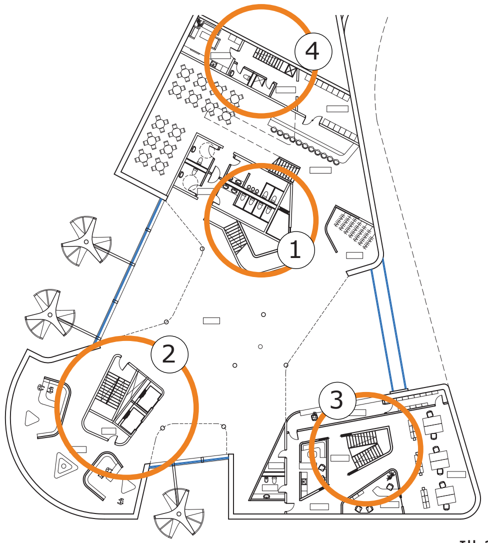
Administration

Administration consists from public and private part. Public part is reception (ill.244, nr1). It has straight connection with private staff zone.

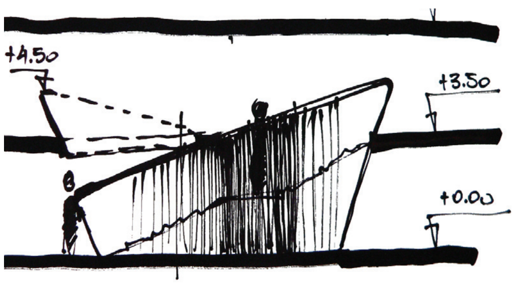
Close to the entrance of private zone is situated practical premises (ill.244, nr2) restrooms and lunch room.

Open workspace (ill.244, nr3) is situated at south east corner in order to get daylight. Manager office (ill.244, nr4) room is isolated, getting direct daylight from south side.

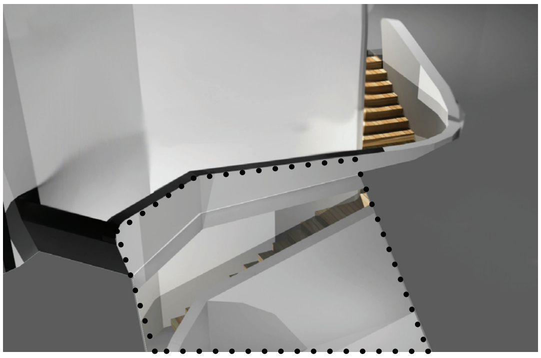
In the middle of administration rooms staircase is situated (ill.244, nr5) that functions as fire division and connection with conference room hall, as these rooms can be used for official meetings.



Ill.246



Ill.247



Ill.248

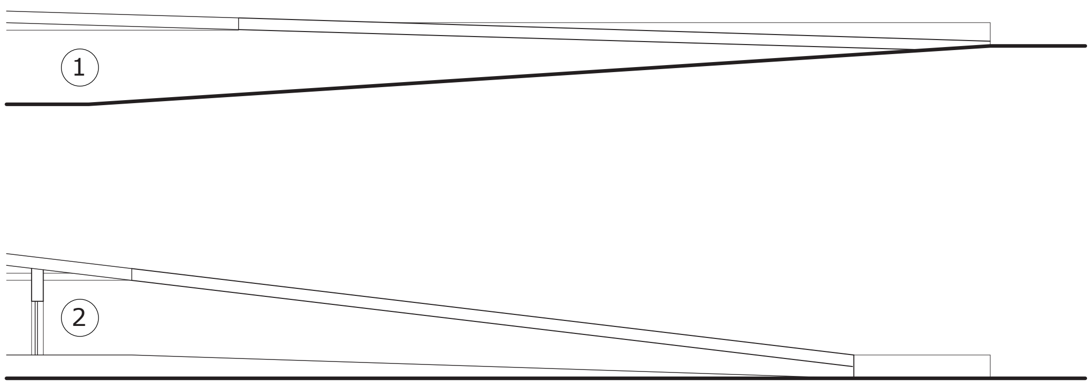
Vertical connection

Central staircase (ill.246, nr1) is designed to connect both public floors. As it is central object, idea is to make it more opened and organic, in order to serve as design object. Railing is integrated into staircase walls, therefore it has monolith expression.

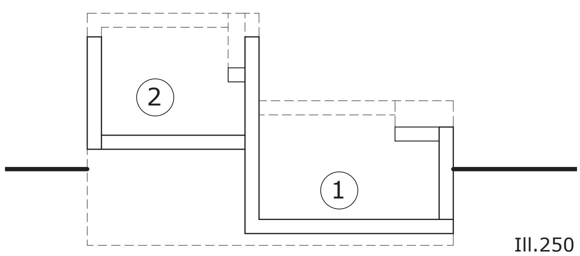
Another staircase (ill.246, nr2) that is main tower core contains from installation block (fire staircase, duct shaft, elevators and one room for staff use). Block is slightly tapering on bottom part, given inclined wall expression.

Extra elevators is place in the middle of building (ill.246, nr1) that serves for public floors, staff floor and parking lot, and the one (ill.246, nr4) for staff needs at kitchen part.

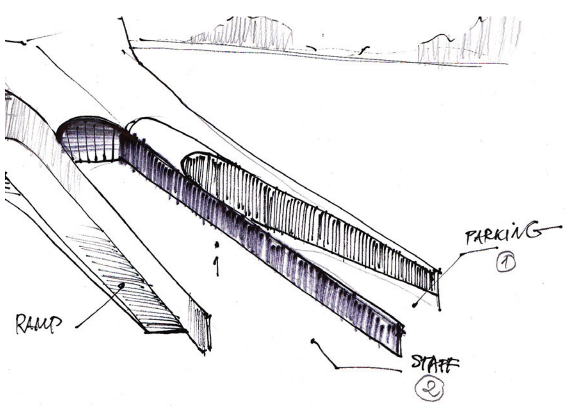
"Tail", entrance to the parking



Ill.249

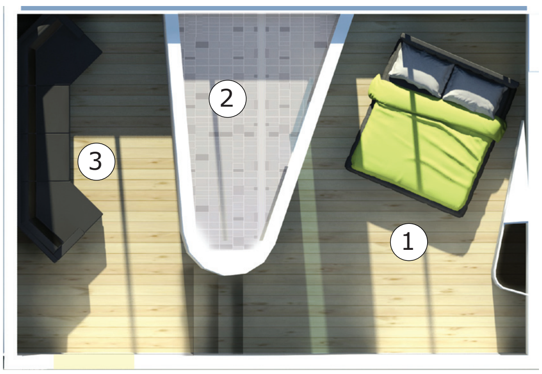


Ill.250



Ill.251

Volume to the north side blends together with landscape. Level difference from tower to the "tail" is symbolizing contrast, meanwhile interaction between urban and suburban, tall and low. Building tail is divided in two parts; one (nr1) is driveway for cars into parking lot, another entrance (nr2) for staff. Both paths turn into tunnel from open space near the entrance to the building.



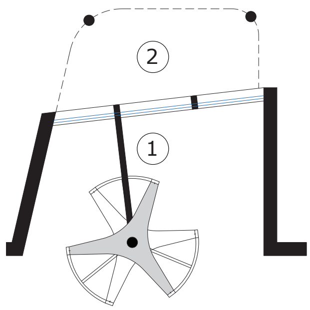
Ill.252

Ill.253

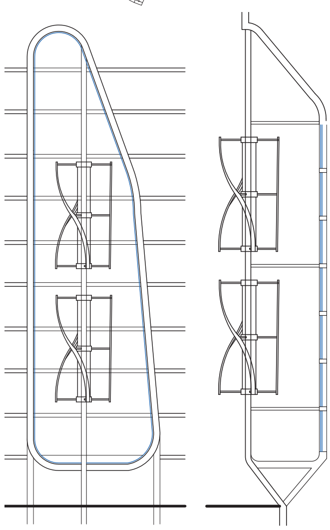
Ill.254

Hotel suite

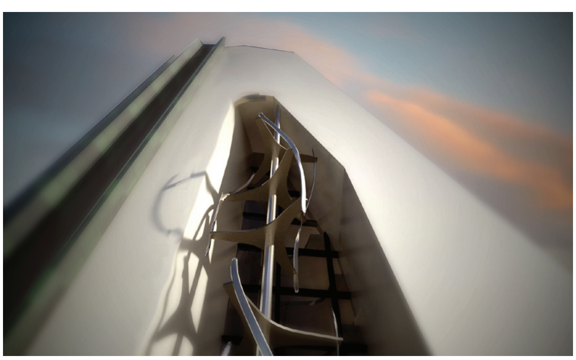
Hotel suits are divided into two groups: standard apartments and luxury ones.
Standard suits size are from 11-17 m2, and they are facing south - west side. It has just sleeping and washing facilities. Even the windows that are facing to the south-west, has glass with less transparency, as southern facade requires less glazing area in order to provide good indoor climate.
Luxury suits are sized around 25 m2 and are situated along west-north-east sides. Each apartment is different, adjusted to the possible shape. Suite includes not just sleeping (ill.252 nr1) and washing facilities (ill.252 nr2), but also lounge area (ill.252 nr3), with possibility to have social activities. Social and sleeping zone is divided by level difference 3 steps high.
These apartments have maximized glazing area in order let in the light. Also bathroom has window, to let people enjoy nice scenery but not get disturbed.



Ill.255



Ill.256



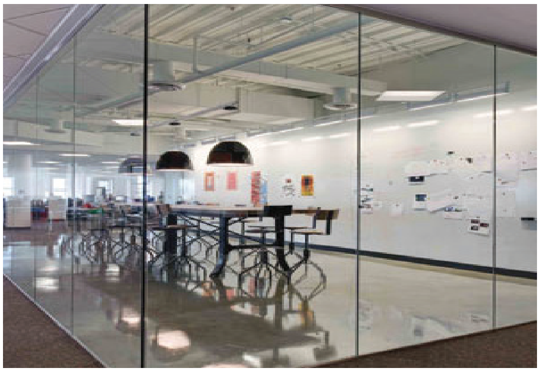
Ill.257

Turbine opening

Turbine opening is cut into the main volume in order to create fully integrated expression. This is the reason why opening is not connected with ground floor, but is elevated one floor up.
There is two opening, facing to the south and west, leading SW wind and letting turbines spin.
Every turbine has 1500 mm safety zone, and they are elevated 7 m from the zone, where people can reach it.
Turbine hole (ill.255 nr1) is extended as inner atrium (ill.255 nr2); both zones is divided by loadbearing element grid and glazing. Element grid will prevent lethal consequences in a case of failure, so the parts of turbine can't enter inside.
As the opening is shaped as trapeze and it is opening to the outside, lighter can be dragged into the building.
To provide stability for turbine column, extra traces is joined with loadbearing grid before and after every turbine.
There is a triangular join, where turbine column is entering ground floor, to provide resistance and maintain curved wall impression.

Ill.258

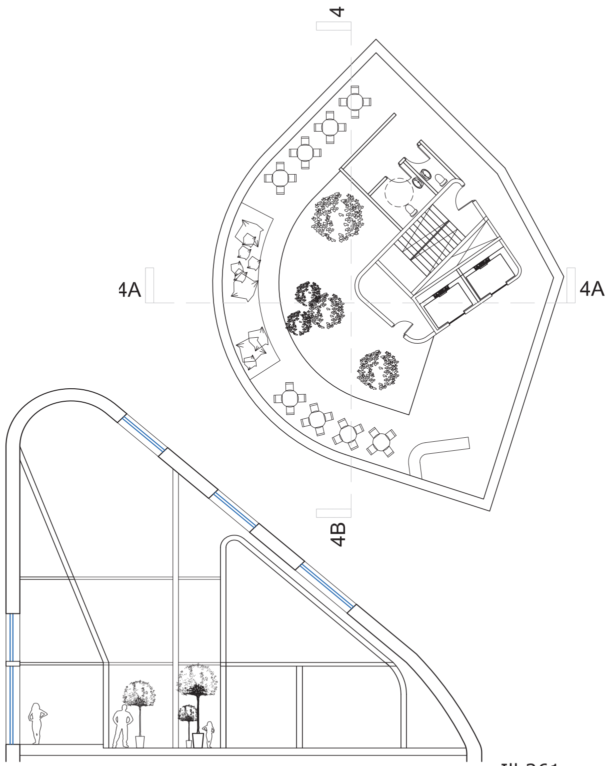
Ill.259
Matt Gibson interior, Australia



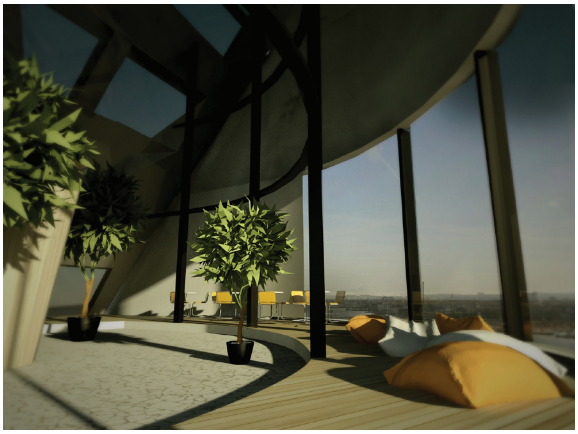
Ill.260
Martin Agency, USA

Social activities

Hotel offers several entertainments for visitors. Hotel restaurant (ill.258) is situated in two levels, having opened space above bar area in order to benefit from skylights. Another light spot is glazing to the hotel front. It makes front facade more open and give an extra daylight to the bar.
At another hotel corner are situate shopping facilities (ill.259). This area has no straight daylight access, therefore intimate and mysterious interior design is given to the shopping pockets. Interior by Matt Gibson for Fame Agenda at Australia is taken as inspirational example. A solid, irregular surface is mixing with glazing and light effects.
One floor above shops is situated disco facilities, with view to the Limfjord. There is bar, dancing place and small stage for live performances.
2nd floor above administration are placed conference blocks (ill.260) that offers visitors to hold meetings and courses. Every block has glass walls in order to let in daylight and brake border between common area and meeting rooms. Glass walls with minimal joints - Martin Agency's office in USA.



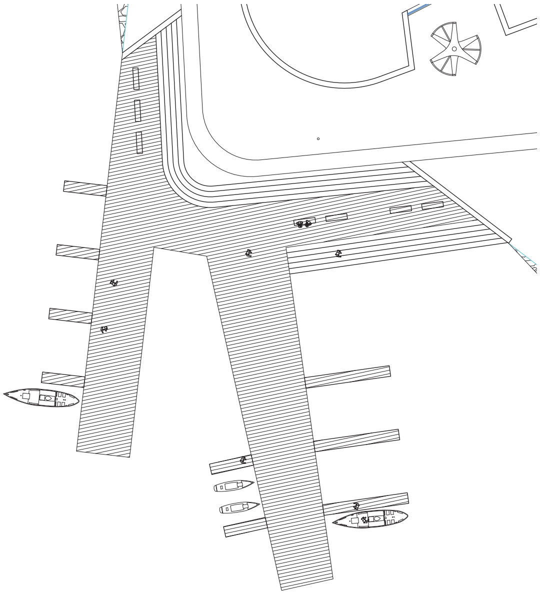
Ill.261



Ill.262

View tower and cafe

Another, however, more public facility is situated on the top of the building. View tower with small cafe, to let people enjoy beautiful scenery - almost 360° view over Aalborg.
Floor plan is divided in two parts - observing zone and inner stone garden. Inner garden is made with purpose to give visitors outdoor space impression, but as weather conditions are not so suitable for outdoor activities all year long, peak was covered with shell.
View spot is oriented to the SW - Egholm, however, opened layout allows to explore areas around - Allborg and Lindholm. View spot is equipped with sitting pillows and audio guide about surroundings.



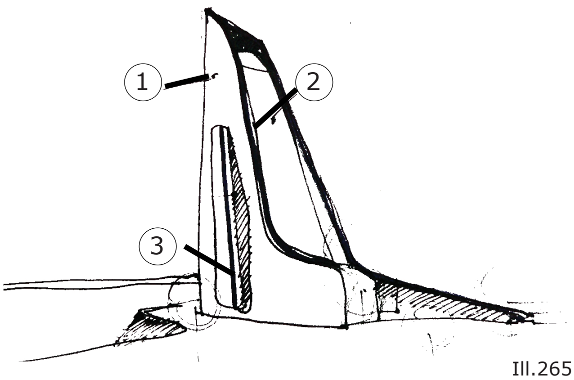
Ill.263

Ill.264

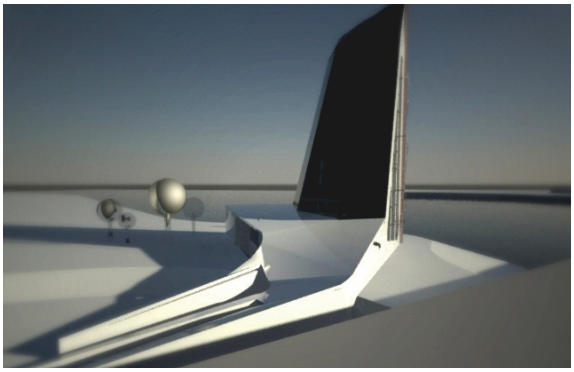
Port

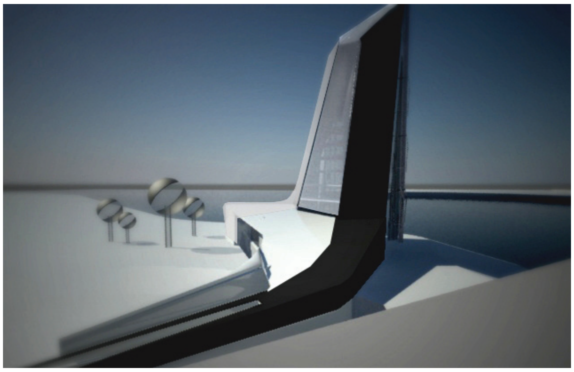
Apart from building, also surrounded area is facilitated. One of the main focuses is paid to the small port. Wooden pier is faced to Aalborg; therefore yachts that are sailing in the Limfjord can have possibility to visit the hotel, cafe or view tower.
Extension of soil, what is base for pier, continues lines from building, therefore both - building and pier - work together to improve visual and functional environment.
Access path on the pier is connected with walking path. Level difference gives benefit, as stairs are established on the coast slope. There is placed several benches, in order to invite people to enjoy the view and water nearness in good weather.

Facade



Ill.265

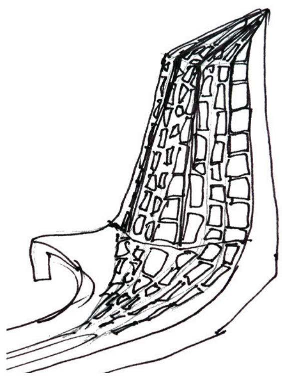

Ill.266


Ill.267

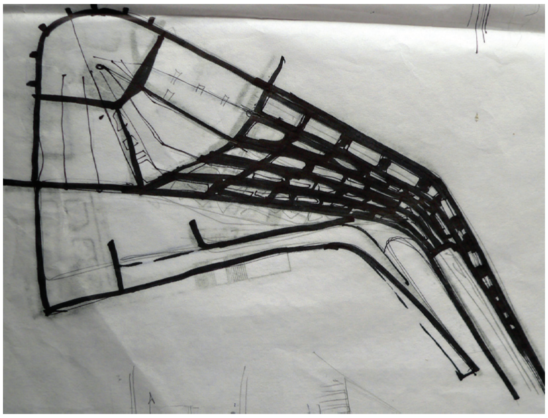
Building volumes should be considered as one unit that consist from two elements: solid shield (ill.265 nr1) with turbine cuts, and filling (ill.265 nr2) to the northern side. Shield is stable, monolith and it reaches highest point. Filling is playful cover, partly transparent and radically changes location from ground level until peak.
South and west sides contain turbine cut (ill.265 nr3), therefore facade should be as monotone as possible to get impression of the cut.
Development of facade included several proposals. Main goal was to create volume visually slender and provide suitable amount of daylight, keeping in mind intention for good indoor climate.

First try (ill.266) was to separate tower and public part, however, it divided volume too much; moreover, idea about shield was interrupted as roof over public part was the same as facades.

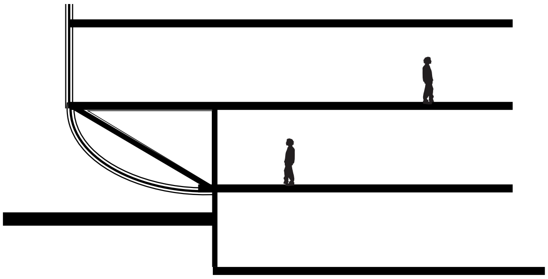
Second try (ill.267) was focusing on slenderness issue by adding connecting line from “tail” until peak. This proposal wasn’t successful because was expressing different architectural intentions than expected. By adding line, part of hotel suits will not get daylight.



Ill.268



Ill.269



Ill.270

Third proposal offered perforated filling that extend into the solid roof over public storeys and tail.
Perforated pattern follows loadbearing structure in the plan and goes up to the tower, when meeting tower borders.
At the meeting point of two volumes openings are the biggest ones and they are getting smaller extending to the both building ends.
Benefit for public part is skylights bring into the building daylight, as western facade is solid and closed in order to emphasize turbines openings.
Benefit for hotel suits is limited window area, giving possibility of privacy.
Connection with ground is made bended in order to make volume look more light and flying. Ground floor at east-west facade is pushed in for several meters and construction is stabilized with triangular element.
Southern facade might have problem with overheating, as there is no overhangs. Therefore, extruded blinds is placed that serves also as ventilation channels to provide efficient natural ventilation intake. More detailed information about ventilation principle can be found on page 167.

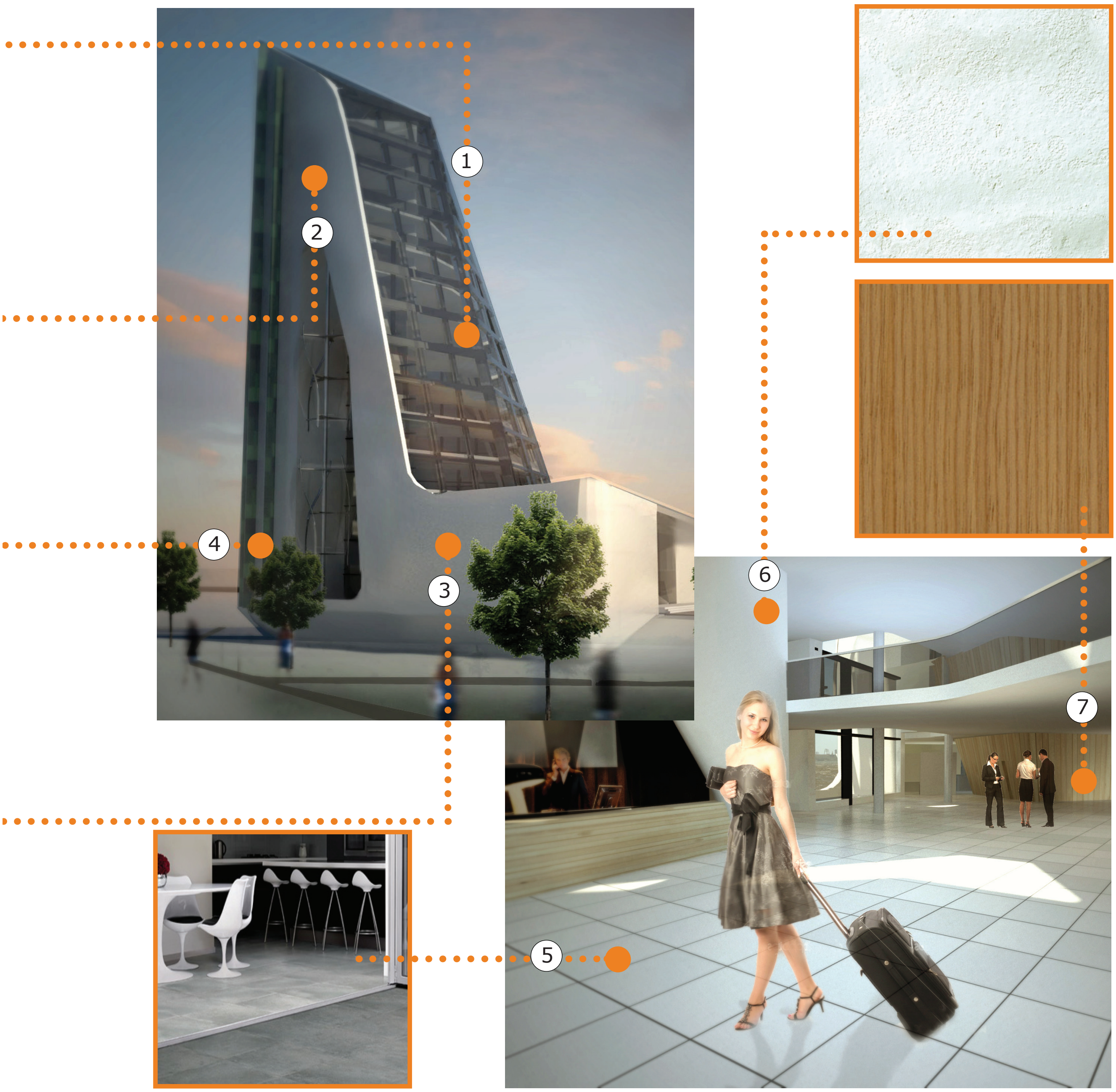
Material specification

Facade covers

1) Transparent glazing to north side is self-cleaning (Active) glass [55], toned black, transparency level adjusted to the lighting necessity.
2) Shield is made of white, solid concrete panels 70mm thick.
3) Windows in the solid shield is installed as integrated Photovoltaic glass that allows sunlight to pass through and building occupants to enjoy views out, while screening out ultra-violet and infra-red radiation [53]. Panels are white, transparency level set until 30%.
4) Ventilation ducts made from green polycarbonate panels, with colour variance.

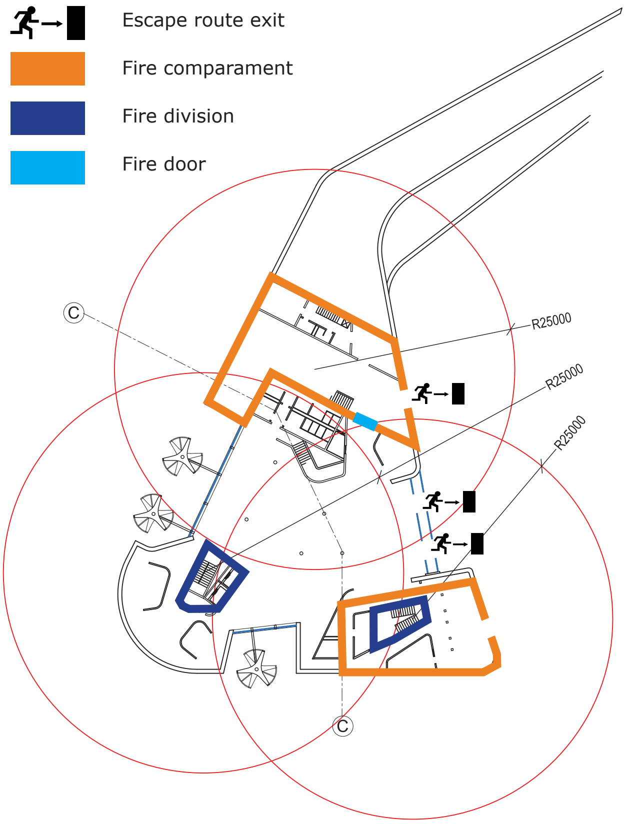
Interior finishes

5) Floor in the public zone and main lounges is covered with grey concrete tiles 60x60cm.
6) Wall is covered with white concrete cladding with delicate texture.. Ceiling has acoustic cladding, to minimaze echo effect.
7) Staircase volume covered with timber decks, fine texture and between boards is situated absorbing membran.
8) Floors in the hotel suites and view tower are cladded with light oak boards.
9) Inner garden covered with stones that fixed with cement.



Ill.271

Fire safety



Ill.272

Building is divided into 3 fire safety zones; each of them covers 25m in radius. Fire compartments are surrounding restaurant and administration zones and has straight exit out of building. Automatic sliding fire door is installed at the restaurant exit. Fire division is main staircase that serves for main lounge and hotel suits. It has exit to the main entrance and exit out in basement level.

Fire safety regulations are important to observe, as some of main rules have influence on layout design. All regulations are taken form EU Fire Standards.

Principle of fire safety is to provide fast and safe evacuation during fire accident. Building consists from fire compartments and divisions (area within a building, which are surrounded with fire-resistant construction [54], and escape routes that are guiding people outside of building or into safe area within the building.

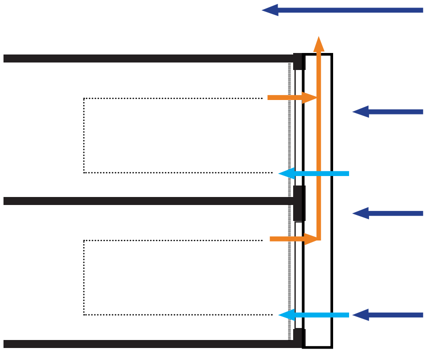
Hotel belongs to the 5th user category, where people are not familiar with layout and escape gates, therefore it is crucial to ensure and guide them through the building. That could be accomplished installing with anti-panic lighting, warning system and indicated escape routes.

One of the most popular fire divisions is staircase that provides safe escape routes within 25m. Corridors, what will be used as escape routes, have to be at least 1,3 m wide, calculating 10mm per every person. Escape corridor's width will be increased, if the flow of people will exceed 130 people. The opening windows in the first floors is used also as rescue openings, however dimensions of the opening have to exceed 0.6x0.6 m.

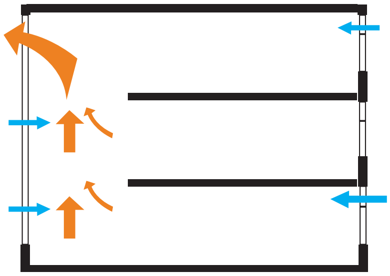
Different material and fire resistant classes is given to walls, roof and doors, according to its function and location.

Ventilation

Ill.273
Westarkade tower Frankfurt, Germany



Ill.274
Thermal bouyancy



Ill.275
Stack ventilation

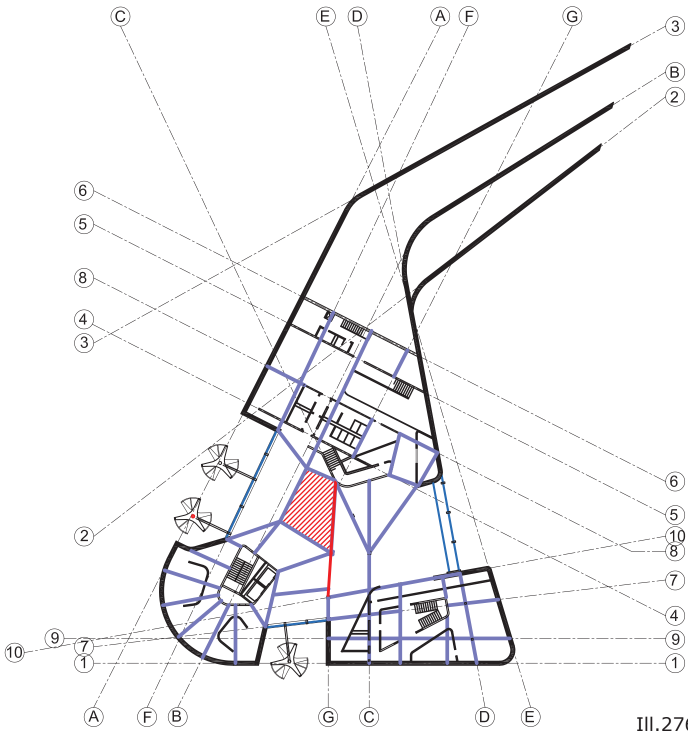
As natural ventilation is important issue to provide good indoor climate and reduce energy consumption. Therefore, the most suitable ventilation strategy is chosen.

Thermal buoyancy is one of the methods to provide fresh air circulation. Fresh air inlet is taken close to the floor, then air warms up and it is extracted out close to the ceiling. To inlet fresh air into the building, opening should be installed into the facade. Unlike the casual automatic ventilation facades, extruded ventilation shafts are created on the SW facade that covers facade all the way up. As the wind from SW is the dominant wind direction, permanent inlet will be provided. To prevent straight wind impact into the building, panel in the front of opening is placed and it is helping to diffused air flow. Extruded air channels helps cool down the wind by accelerating it and it serves also as blinds, shading windows to the south. Especially this facade is exposed to high overheating, as it faces to the south and has no shading from surrounding, the same as reflection from water [52].

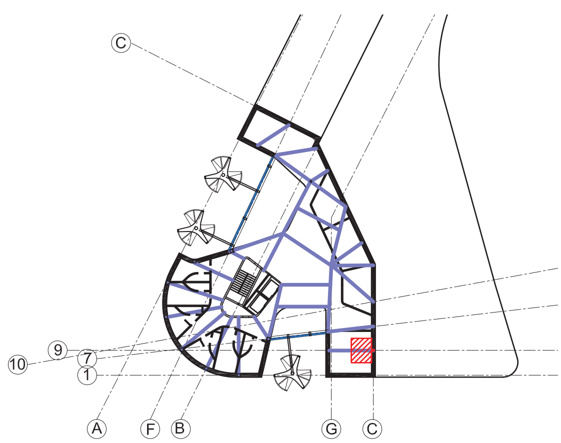
Similar ventilation system is installed in the Westarkade tower in Frankfurt, Germany (ill.273).

Stack ventilation principle is used in for the area around atrium, where polluted air is leaded up and extracted out at the building to level

Structural system



Ill.276
Entrance floor



Ill.277
3rd floor

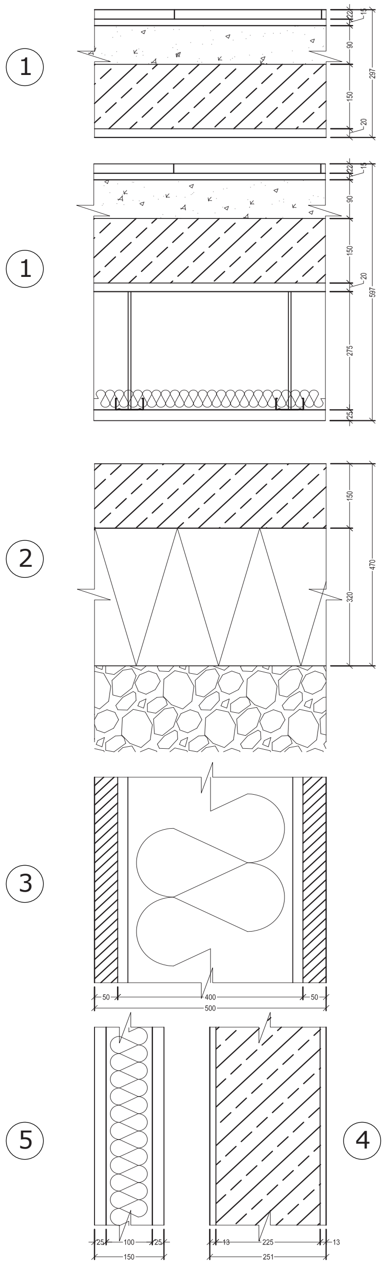
Buildings structural system consists from loadbearing elements that are hidden in structure in order to get surface clarity.

Principle of building structure is closed loadbearing element grid. Loadbearing elements are situated into external walls, inner walls and vertical blocks; these base points support beams and in situ concrete layer that is floor between storeys. External wall consists from bended profiles, that creating taper shape of the building.

Tower is supported by pillar line; footprint of loadbearing elements is organizing public floor flow.

Turbine pillar is supporting roof that grows over turbine opening. Therefore, turbine is fully integrated as loadbearing element from building.

Construction plans shows beam (blue) placement principle and elements that is necessary to calculate (red) in order to understand dimensions and loadbearing capacity.



Ill.278

Construction elements

1) Storey partition

Loadbearing part consists from RC layer 150mm that is supported by steel beam. Difference between concrete surface and top of the beam is filled with floor screed. Floor finished with concrete tiles or timber. Above restrooms and rooms with mechanical ventilation, storey partition is extended with suspended ceiling construction. To fulfil sound insulation, 50mm sound insulation is added.

2) Ground floor

As this element need to fulfil 0,08 W/m2K, EPS insolation is used 320mm thick. Above it is layer of hydro isolation and RC layer to provide good strength for parking lot floor.

3) External wall consist of HEB 400 profiles, that is filled with 400 insulation, providing 0,09 W/m2K. Construction is closed from both sides with 50mm concrete panels.

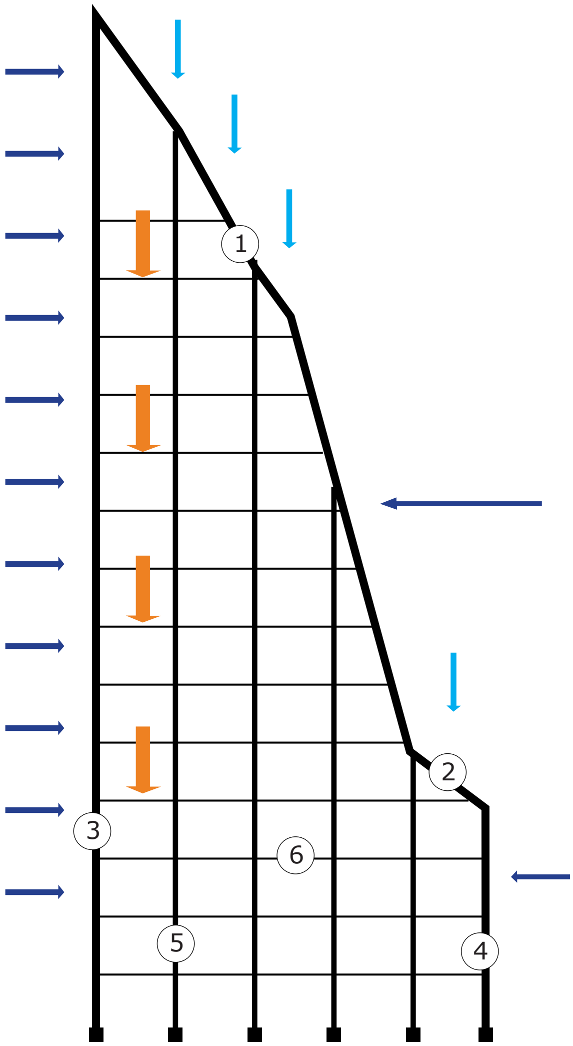
As roof and external wall is the continuing element, both constructions are considered as equal.

4) Loadbearing wall is concrete wall 200mm thick and cladded with plaster.

5) Non-loadbearing walls is double wall gypsum board system, 150mm thick, providing good sound insolation.

Windows and glazing areas are 0,7 W/m^2K.

All constructions fulfill fire demands from BR 10, having 60 or 30 min resistance.



Ill.279

Structural analyses

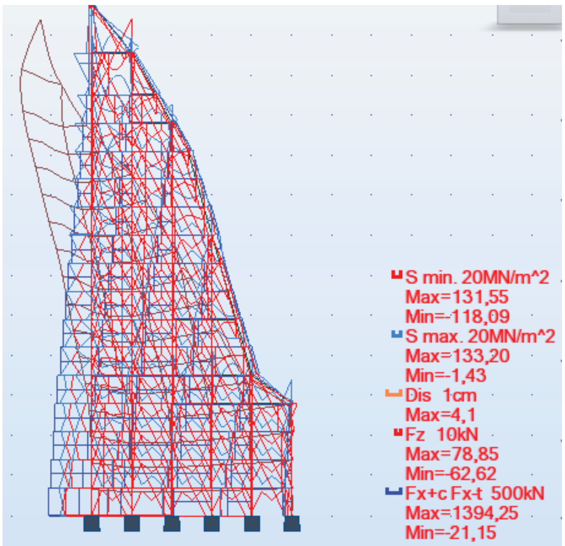
This chapter is short summary for structural analyses. Detailed information can be found on apex nr2.

For FEM analyses have been used Autodesk Robot program, and for simple element dimension calculation TRE-DIM program.
In order to calculate any of sections, loads have been calculated*.

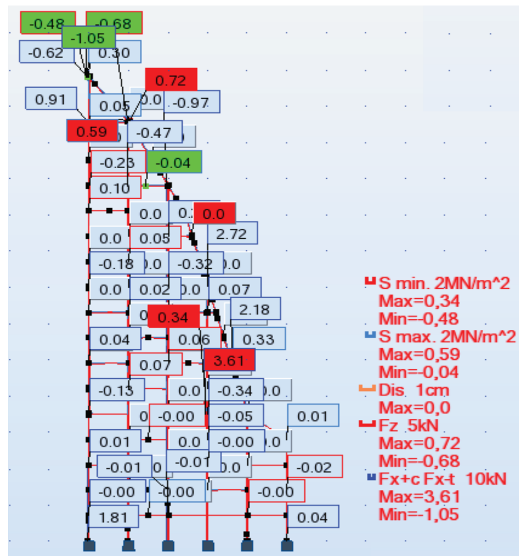
DEAD LOAD - 21,76 kN/m
LIVE LOAD - 7,50 kN/m
SNOW LOAD - 1,08 kN/m (roof less than 30 degree), and 0,28 kN/m (roof 52 degree)
WIND LOAD - 2,7 kN/m, (building height 64m)

Dead load and live load is applied on every horizontal element (nr6), except 2 top ones, as they are placed for stability.
Snow load is calculated for two different roof plates - 52 degree (nr1) and less than 30 degree (nr2).
Wind load is applied to both external walls (nr 3 and 4), and value is taken for worst case at the top of the building.
Inner columns (nr5) and external walls have fixed connection with ground floor. Rests of nodes are not defined and they are by default fixed ones.

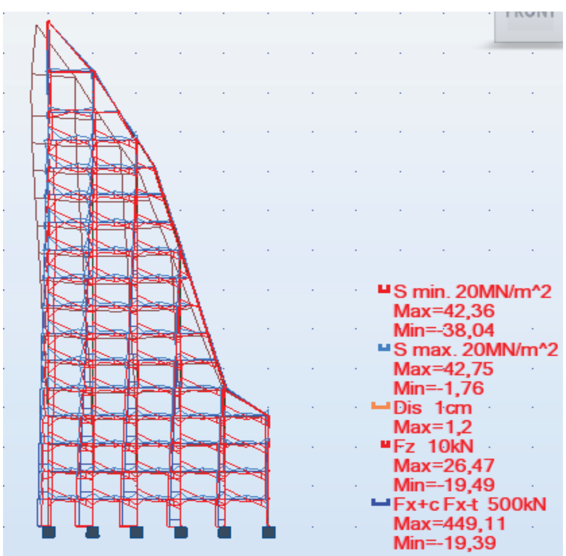
*All calculation is made according Teknisk Stabi and Eurocodes.



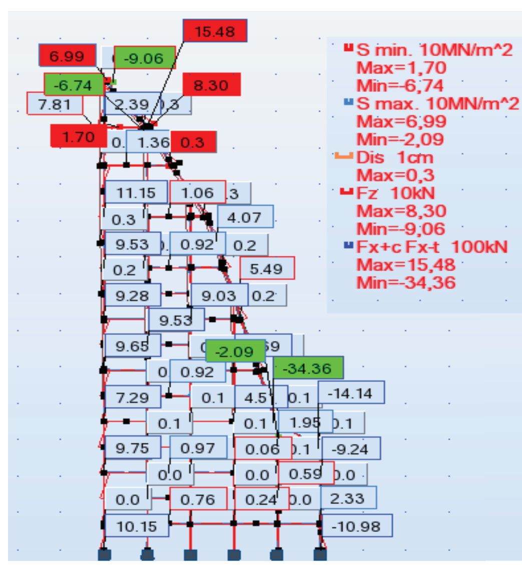
ill.280
Dead load diagram, for displacement, stresses and moments



ill.281
Snow load diagram values



ill.282
Live load diagram, for displacement, stresses and moments



ill.283
Wind load diagram values

Global extremes - reactions

	FX (kN)	FZ (kN)	MY (kNm)
MAX	9,71	1394,25	12,93
Node	1	47	1
MIN	-9,25	-20,66	-10,56
Node	39	53	39

Global extremes - forces

	FX (kN)	FZ (kN)	MY (kNm)
MAX	1394,25	78,85	39,94
Bar	29	15	20
Node	47	29	12
MIN	-34,36	-62,62	-108,96
Bar	22	34	15
Node	40	54	29

Global extremes - displacement

	UX (cm)	UZ (cm)	RY (Rad)
MAX	0,0	0,0	0,002
Node	1	40	2
MIN	-3,7	-1,7	-0,001
Node	46	46	24

Global extremes - stresses MPa

	S max	S min	S max(My)	S min(My)	Fx/Ax
MAX	132,79	130,31	118,86	-0,00	131,55
Bar	29	29	17	31	29
Node	47	47	33	51	47
MIN	-0,95	-118,09	0,00	-118,86	-2,10
Bar	26	17	31	17	32
Node	30	33	51	33	40

Analysing results, trouble zones are at the peak node 46 and 33. It also influence ground support 47 and bar 29. However, ALL SECTIONS ARE SUITABLE AND THERE IS NO INSTABILITY.

To improve existing results, one more support bar could be added from node 46 to 53. It will stabilize system and also node 33 and bar 17 that is having noticeable stresses values. Also bars 29 section can be increased.

Summary about sections:

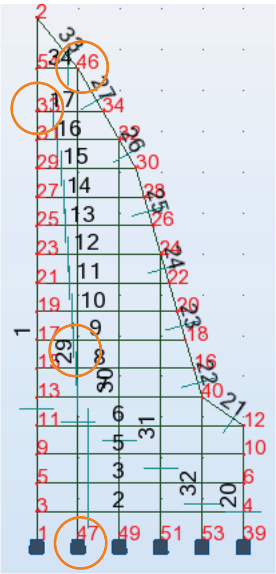
All materials are HEB profiles S355 MPa.

Beams for storey partitions - HEB 240, some bigger span HEB 300;

External walls - HEB 400, top elements after angle changing HEB 300;

Inner columns - HEB 240;

Turbine column - HEB 400.



Ill.284

Productivity

Important input data

Indoor teperature +22°
Min ventilation rate 0,38 l/s/m²
Max u values
wall - 0,09 W/m²K
ground floor 0,07 W/m²K
glazing - 0,7, 0,6 and 0,5 W/m² K

Key numbers, kWh/m² year

Energy frame in BR 2010

Without supplement	Supplement for special conditions	Total energy frame
52,7	0,0	52,7
Total energy requirement		37,4

Energy frame low energy buildings 2015

Without supplement	Supplement for special conditions	Total energy frame
30,1	0,0	30,1
Total energy requirement		30,1

Energy frame Buildings 2020

Without supplement	Supplement for special conditions	Total energy frame
20,0	0,0	20,0
Total energy requirement		22,5

Contribution to energy requirement	
Heat	36,4
El. for operation of bulding	0,4
Excessive in rooms	0,0

Net requirement	
Room heating	16,5
Domestic hot water	19,8
Cooling	0,0

Selected electricity requirements	
Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,1
Heat pump	0,0
Ventilators	0,3
Pumps	0,1
Cooling	0,0
Total el. consumption	31,0

Heat loss from installations	
Room heating	0,0
Domestic hot water	0,1

Output from special sources	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

Ill.285

BE 10

In order to adjust necessary amount of wind turbines, BE 10 energy calculation is made. If initial aim was to reach zero energy frame that is 20 kWh/m2 annually, practise shows that big glazing areas use more energy than planned.

However, building fulfil low building energy frame for 2015 - 30,1 kWh/m2, and nearly hit energy demand for energy frame 2020 22,5 kWh/m2. Excessive in rooms is neutral; therefore it is expected to have suitable indoor climate conditions.

As Be 10 is used just as verifying tool, calculation process will be explained very briefly.

After entering all element areas and necessary input data, energy frame not meet requirements. Excessive in rooms are high. To improve data, natural ventilation rate form 5 l/s/m2 is increased to 8 l/s/m2 and reduced transparency of PV solar windows.

It slightly improves results and to add final touch, ventilation rate is set 10 l/s/m2.

This number will be used as necessary energy consumption in order to calculate amount of turbines.

Power of turbines

A) Power of the wind for Darrieus turbine

Pb=0,5*r*A*Vh^3*Cp

PW_1=	4,0	kW	r	1,25	Air density (kg/m^3)
			A		Swept area (m^2)
PW_2=	5,4	kW	Vh		Actual wind speed (m/s)
PW_3=	6,5	kW	Cp	0,28	Betz coefient (Darrieus turbine)

2) Swept area of vertical WT (egg beater)

A=Dt*0,5*lb

		Dt	5	diameter of turbine (m)
21	m^2	lb	8,4	blade length (m)

3) Actual wind speed

Vh=Vp*((h/Vg)^a

				Vp	16,7	teoritical wind speed
$Vh_{1=}$	12,4	10,3	m/s	h		height
$Vh_{2=}$	22,9	11,4	m/s	Vg	250	coeficent (sea level)
$Vh_{3=}$	33,4	12,1	m/s	a	0,16	height (sea level)

B) Energy consumption from building

Actual energy frame	30,1	kWh/m^2
Building area	7867	m^2
Total kWh/m^2 in the year	236796,7	kWh

Turbine rate sum

T1	3	12,1	kW		
T2	2	10,9	kW		
T3	1	6,5	kW	29,525	kW

kWh annually	258639	kwh

Ill.286

In order to efficiently calculate and monitor productivity issues, turbine amount, excel sheet is made that lets quickly operate with numbers and understand outcome.

To get actual power that might produce turbine, it is necessary to calculate power of the wind for particular wind turbine. It consists from swept area and actual wind speed. Swept area depends on turbine dimensions, but wind speed from location and height above sea level. As building is placed next to the water on flat land, coefficients are very efficient. Therefore, reference wind speed is taken 16,7m/s from meteorological report. Turbines is placed in three different heights - 12,4 m; 22,9m 33,4m. It lets conclude that top turbine will be the most productive one. Result has to be multiplied with Betz coefficient that in this case is 0.28 because of Darrieus turbine productivity.

To compare energy consumption from building and possibility to produce from turbine, actual energy frame value is converted as kWh annually. The same is done with turbine produced kW.

Results show, that 6 turbines can produce enough to fulfill 30,1 kWh/m2 per year.

Solar panels

Total building area	7867	m^2		
Panel type				
Monocrystalline Solar Panels			15	
Optimum plant with high efficiency inverter			0,75	
Integrated in building design				
Efficiency of $1m^2$ of panel	0,15		1*15/100	kW peak
SW verical 30	867			
	2167,5		2.45* 892	kWh/m^2
Yearly performance of 1 panel	243,8		0.75*0.15*2230	kWh
Hourly performance of 1 panel	0,031	kWh/m^2	0,03	kWh
Energy consumption	30,1	kWh/m^2	(from BE10)	
Provided by turbines	32,9	kWh/m^2	(from turbine calculation)	
Applicances	38,7	kWh/m^2	(from Bsim last semester)	
Neccessary solar panels	35,9	kWh/m^2		
Neccessary solar panel area	1158	m^2		

Ill.287

As turbines can't provide building as zero energy building, extra solar cells are installed on buildings SW corner. It solves also architectural issue about window glazing blending into the solid shield.

Solar panels are photovoltaic glass that allows sunlight to pass through and building occupants to enjoy view out, while screening out ultra-violet and infra-red radiation (reference). Panels are white, transparency level set until 30%.

PV cells are situated vertically between ventilation ducts, functioning as windows for apartments.

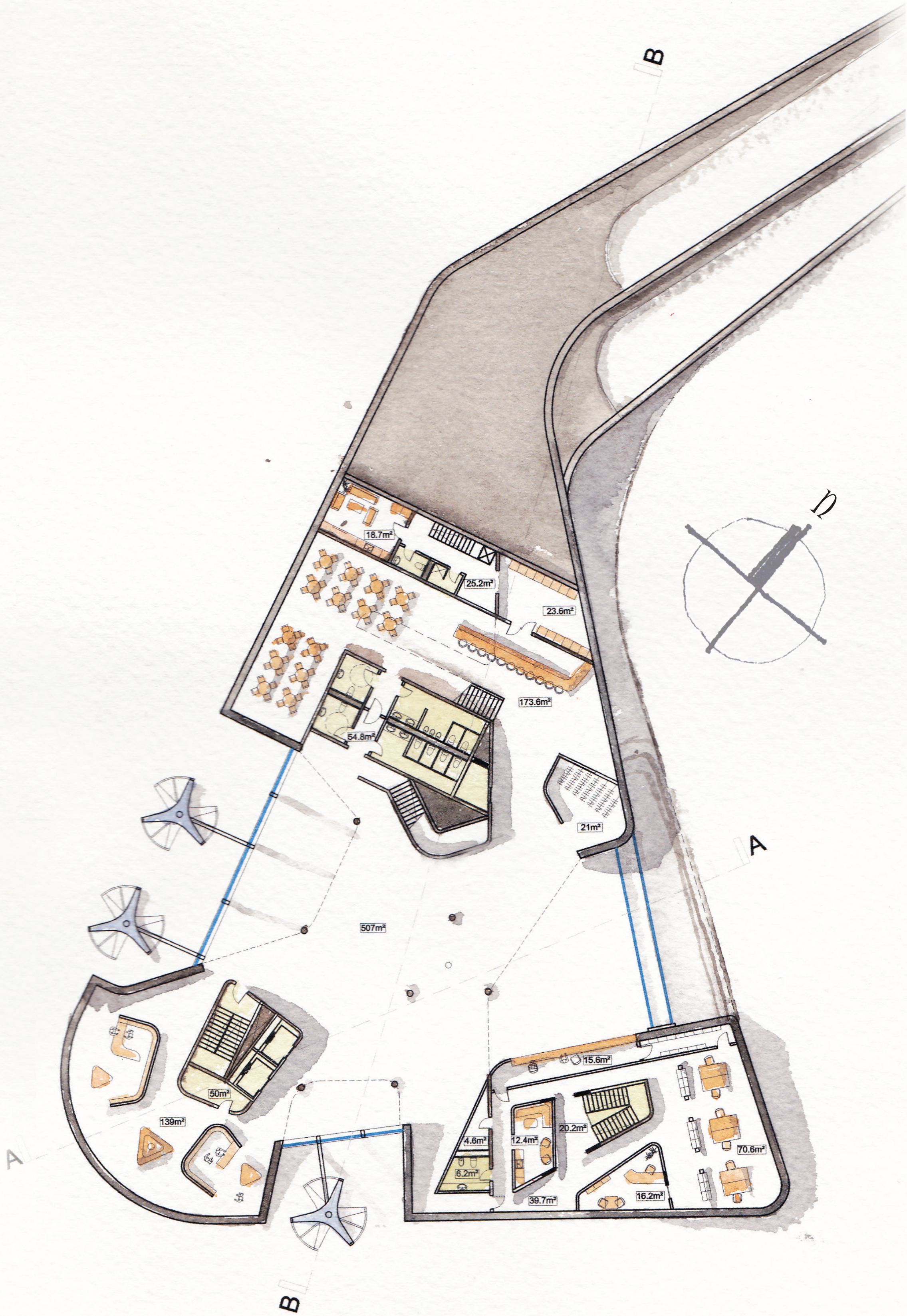
After energy calculation, turbines can provide 32,9 kWh/m2, but adding appliances, necessary solar panels should cover 35,9 kWh/m2. This means that necessary area for installation is 1158 m2.

Presentation


b
c
d
e
a
n

MASTER PLAN

Building is situated at Lindholm, next to the planned highway over Egholm Island.
Hotel footprint takes 1500m2 and entrance to the building (b) is oriented to north towards highway. Next to the parking entrance, another entrance (c) is for staff use.
Arrival to the hotel is also possible with boat, therefore at the SW side on waterfront is located small port (a) that also can be used as qualitative outdoor space.
Main entrance is facing to the NE and just in front of it, lies a small garden (d). It connects flows from staff entrance, main entrance and existing walking paths.



B
18.7m²
25.2m²
23.6m²
173.6m²
54.8m²
21m²
A
507m²
15.6m²
50m²
139m²
20.2m²
4.6m²
12.4m²
70.6m²
8.2m²
39.7m²
16.2m²
A
B

1ST FLOOR

First floor is entrance level that contains public and domestic functions.
Entrance is faced to the NE and, by entering building; visitors can observe turbines operating. Moreover, turbine's cuts are extended as atrium and drag a light into the lounge.
Behind the reception are located administration premises.
SW corner is allocated to the shopping facilities with modern interior in minimalist style.
Restaurant is located at building northern side, extended in two storeys and has skylights from perforated roof structure.
Entrance floor intend to create welcoming atmosphere with light interior finishes and opened layout.


B
95.5m²
54.8m²
45.7m²
A
264.5m²
15.5m²
50m²
23.2m²
140.2m²
28.7m²
20.2m²
123.5m²
9.8m²
16.2m²
A
B

2ND FLOOR

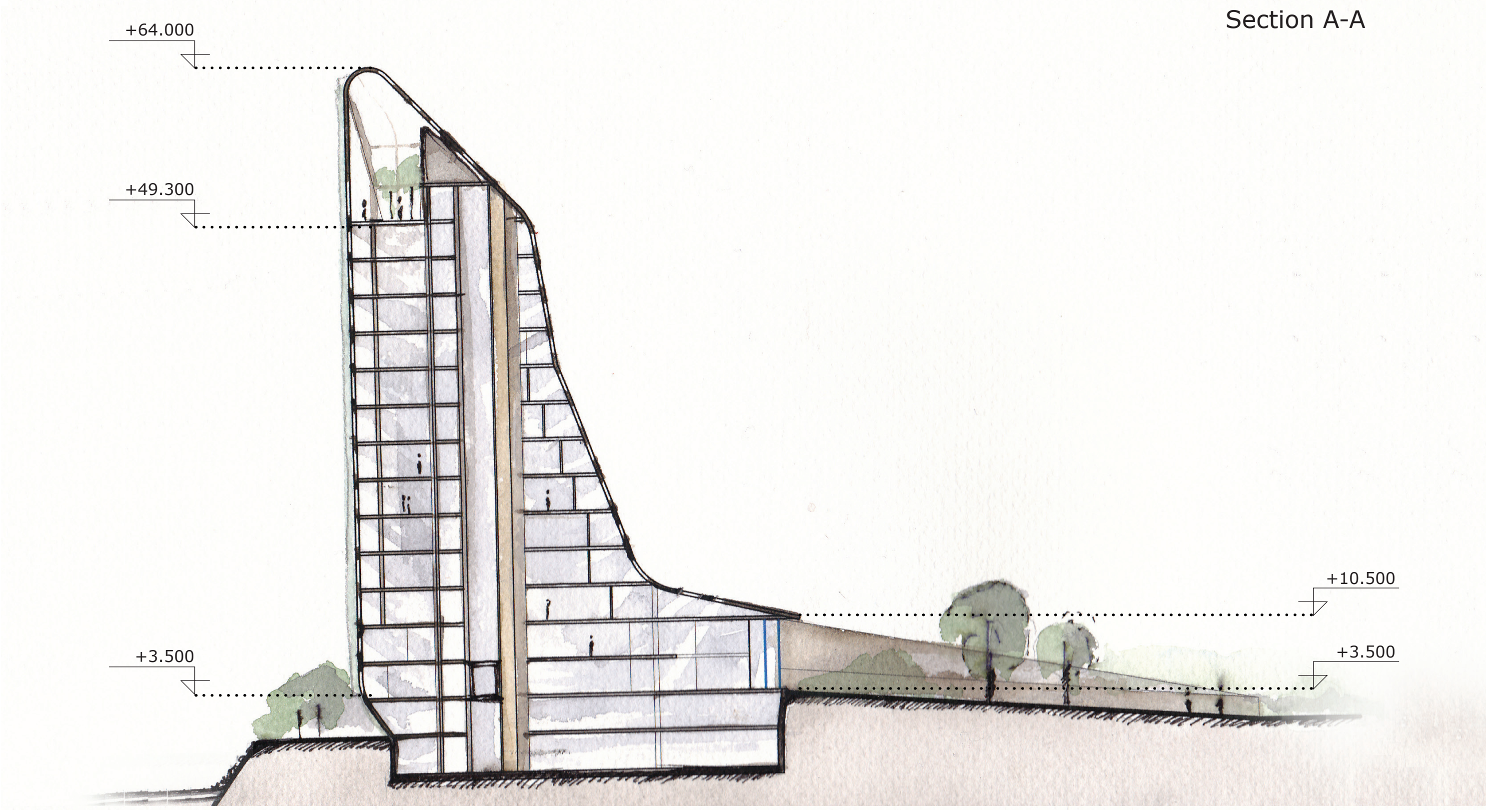
Second floor is continuing public function, having three open connections with other floors - one to the reception area, another two turning into atrium.
Buildings area is decreased by dragging in northern side wall, starting taper process to the building's peak.
In the front of restaurant are situated restrooms, and open staircase, that is repeated from first floor.
Above administration lie conference rooms with straight connection to the main lounge. Behind main vertical communication is situated disco-bar, with view to the waterfront, and small stage that could be used for live performances.
Second floor intention is to add three-dimensional depth for building public part and focus people attention to the turbines.

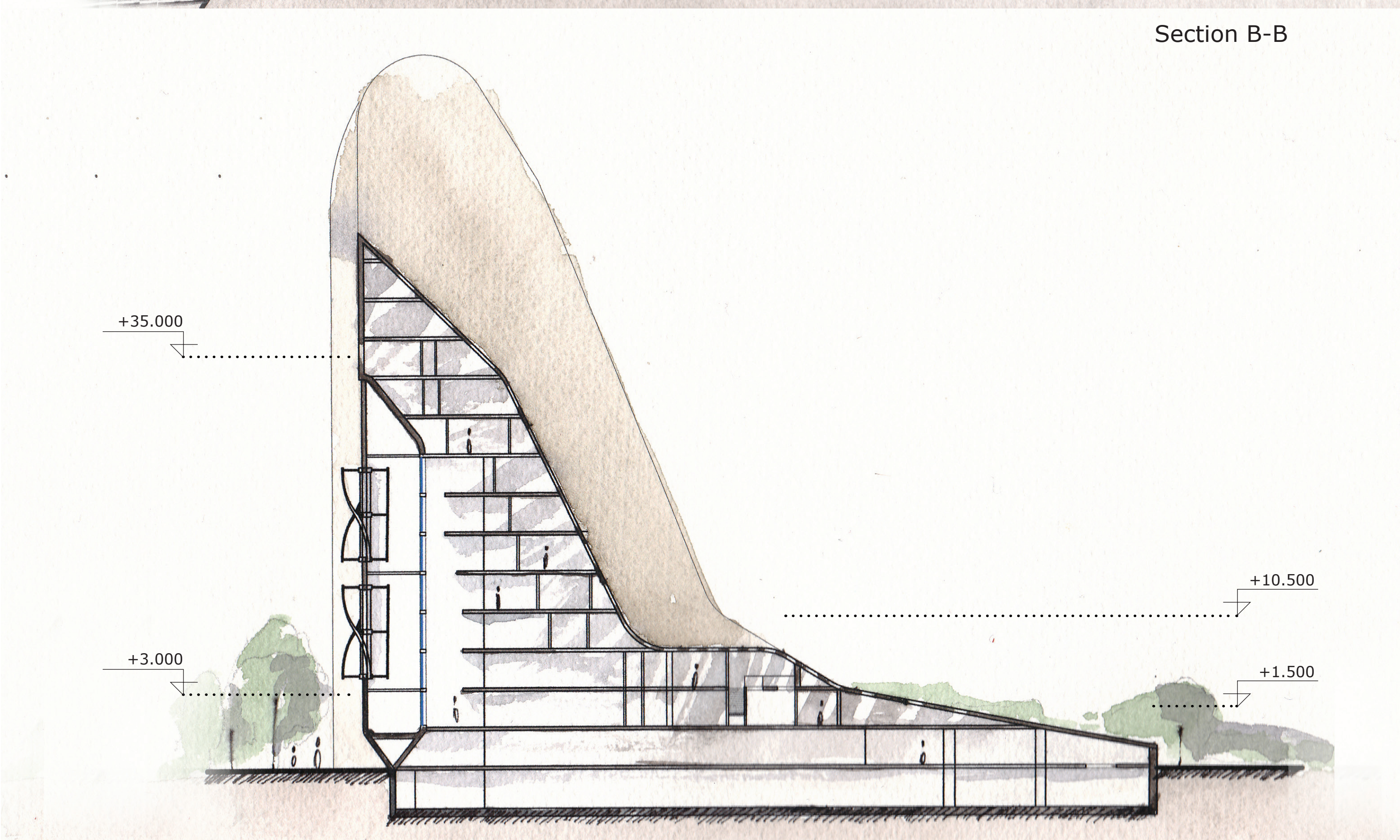

17m²
50m²
56m²
151m²
28.5m²
B
22.7m²
A
24.3m²
198m²
13m²
17m²
24.9m²
13m²
50m²
31.5m²
A
17m²
14.9m²
13.3m²
B

3RD AND 14TH

From third floor until 13th are distributed hotel suites. There is two types of rooms - standard ones and luxury with extended space and possibility of social activities.
Lounge with both atrium provide natural air flow and organize functional layout.
Every next floor has less area, as it taper upwards and hotel suites dimensions are adjusted to the shape.
Hotel visitors have direct visual connection with turbines through the glazing.

14th floor is view tower with inner garden and observation possibilities. Moreover, little and cozy cafe will offer visitors enjoy a cap of coffee while overlooking Aalborg from 60 m height.

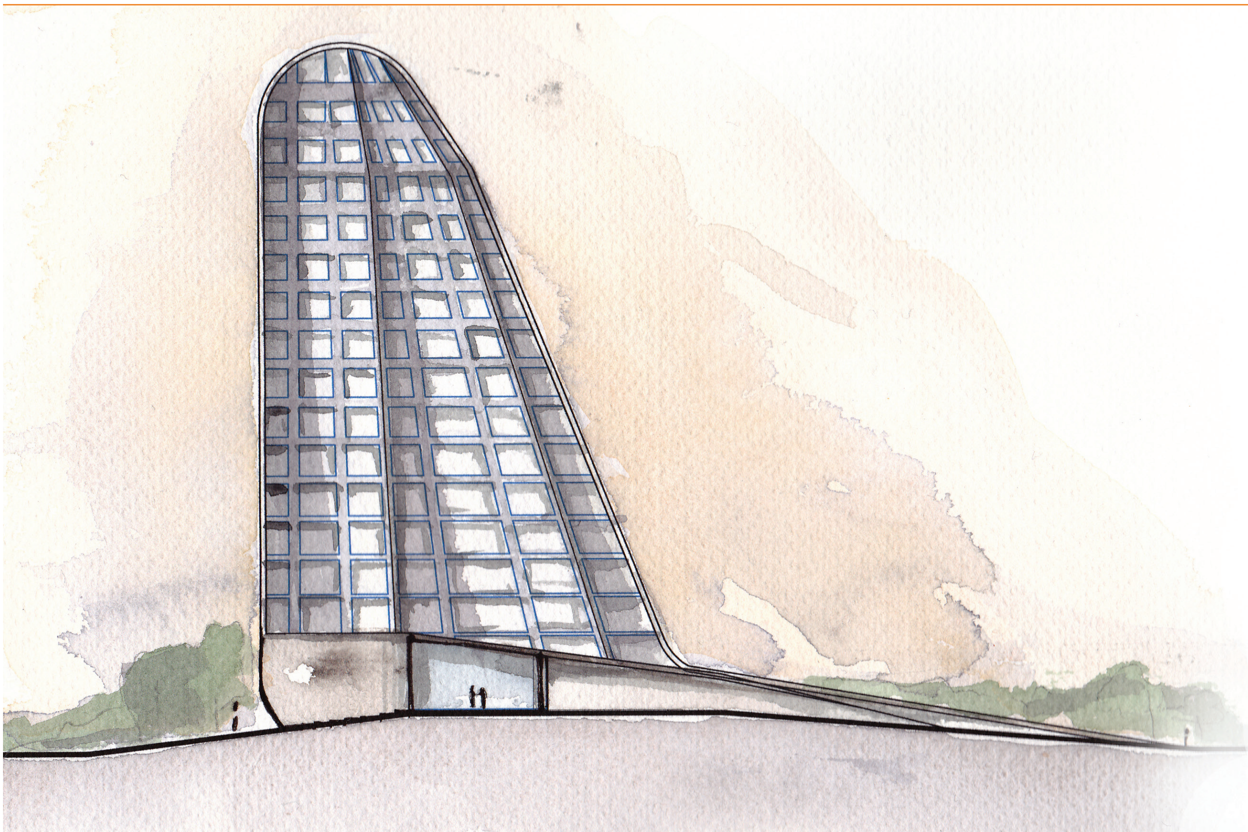

Section A-A
+64.000
+49.300
+3.500
+10.500
+3.500


Section B-B
+35.000
+3.000
+10.500
+1.500

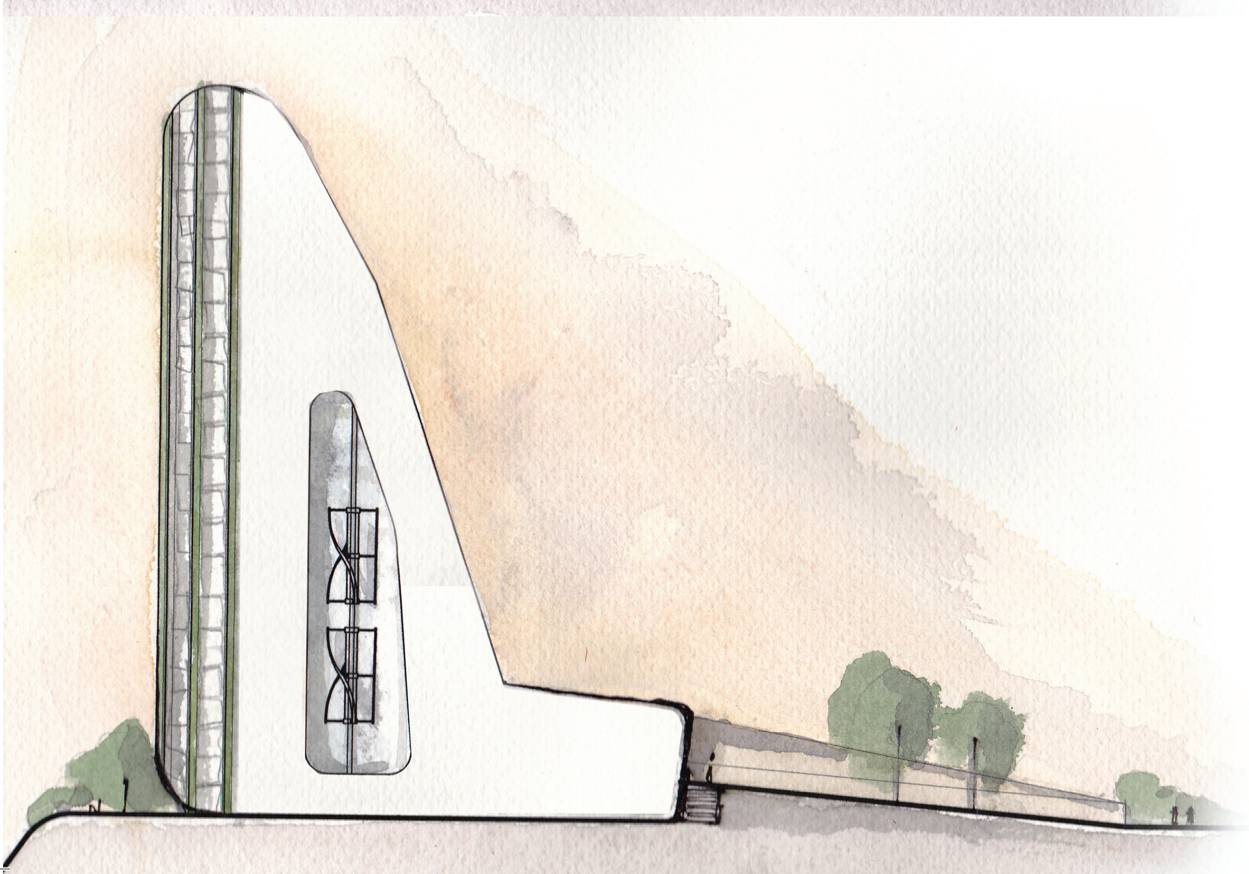
SECTIONS

Building sections presents tapered shape into organic approach.
Section A-A is cut through the SW corner and entrance. It reveals level difference between hotel front and coast side, as main entrance level is elevated in order to provide good wind conditions to turbines and safety for visitors.
Section shows also last floor - view platform that is extended in more floor height.

Section B-B is longitudinal cut through the turbines and part of building tail. Turbine opening joins with main structure at the bottom and above turbines, creating an expression of growing structure.
Perforated facade and roof structures let daylight into the building and casts spectecular shadows.



Front facade



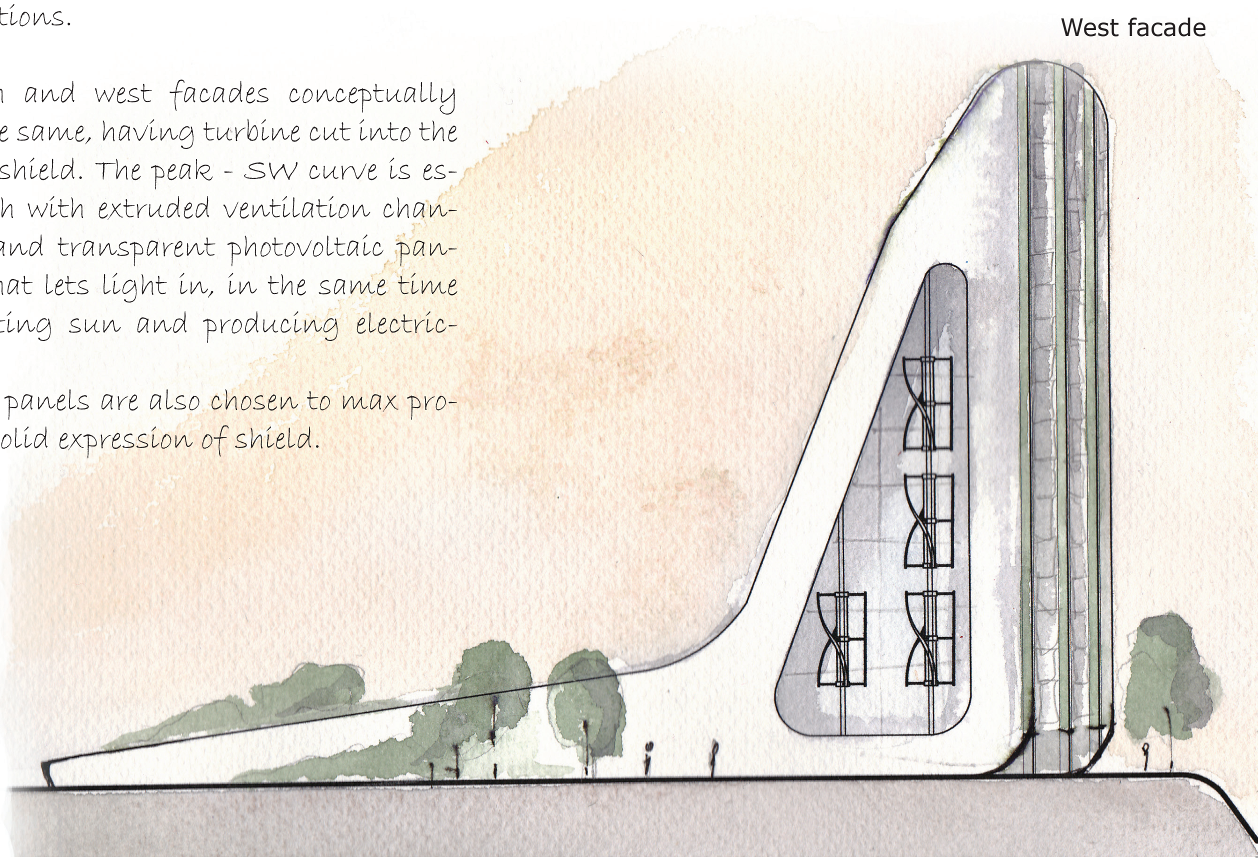
South facade

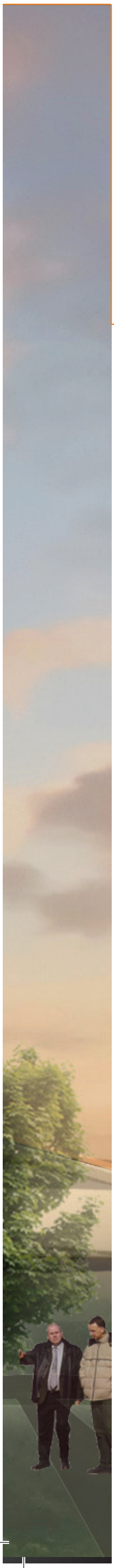
FACADES

As hotel shape is purely three-dimensional, it is complicate to separates where each of facades ends.

Front facade presents building glazed part that is perforated into the external surface. Openings shrink starting from interaction point between roof and tower, where light is needed the most for public facilities. Above entrance lies overhang that protects people during bad weather conditions.

South and west facades conceptually are the same, having turbine cut into the solid shield. The peak - SW curve is establish with extruded ventilation channels and transparent photovoltaic panels, that lets light in, in the same time reflecting sun and producing electricity.
These panels are also chosen to max provide solid expression of shield.



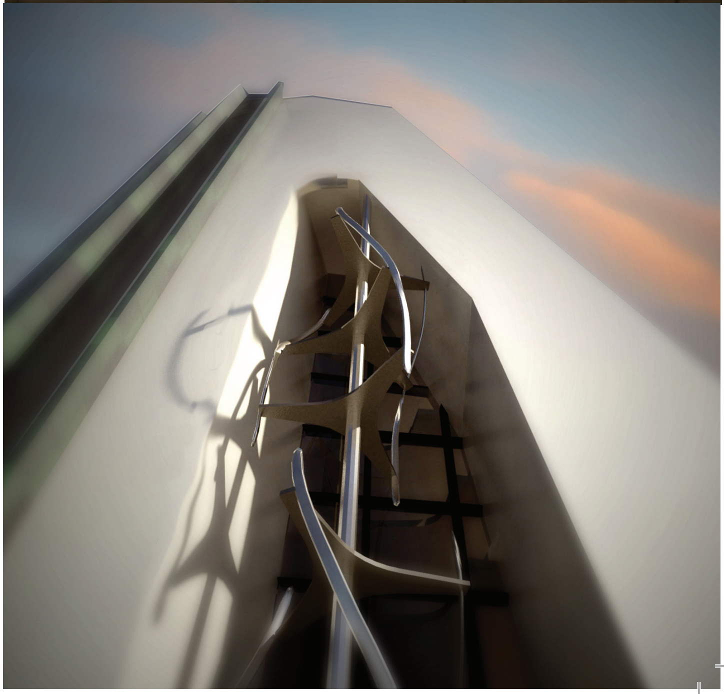


FAR AND CLOSE

Building height is 64m in total, and even ,if it is one of highest towers at Aalborg, this example of wind and architecture integration blends into the landscape next to the Hoje Brugge at Norresundby.

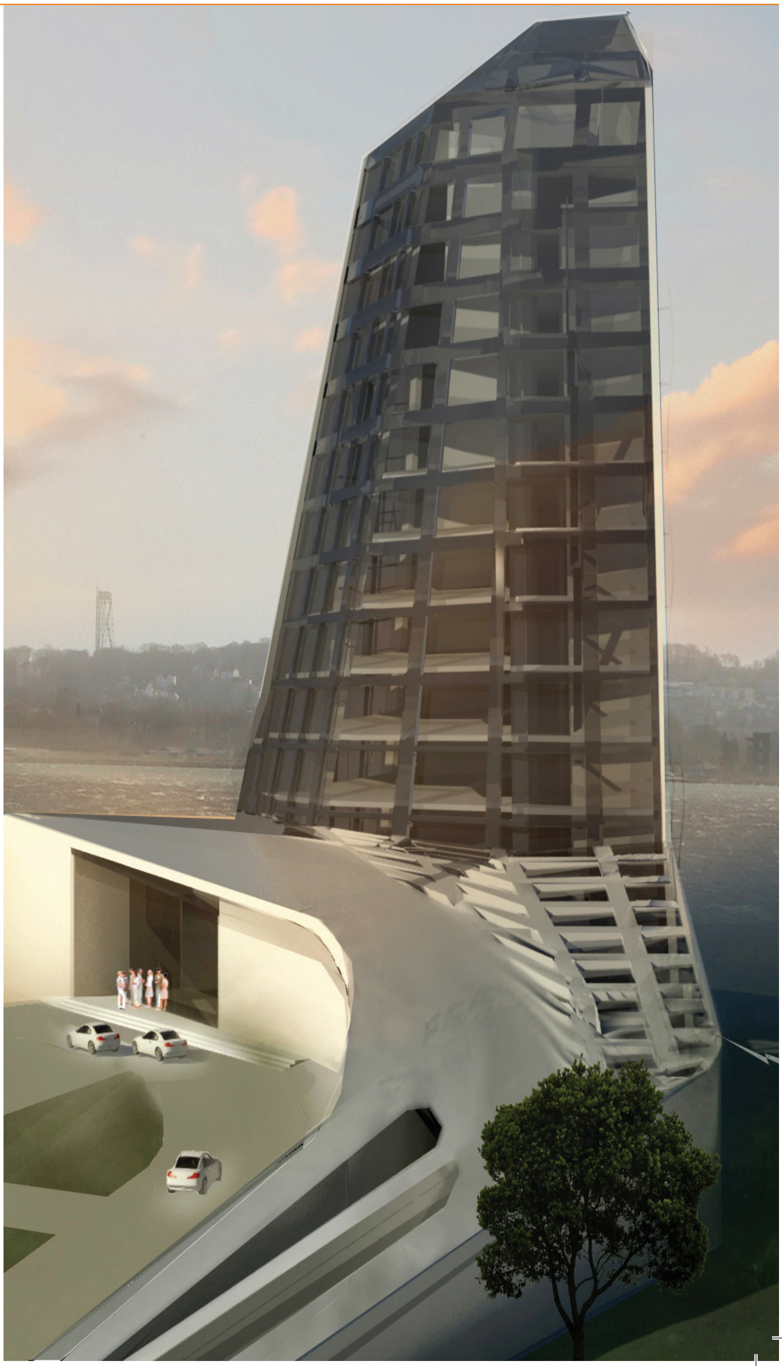
Going closer to the building first noticeable element is turbine opening that is carved into the building volume.
Contrast between transparent glazing area and solid shield gives a little bit mystic expression of overall shape.

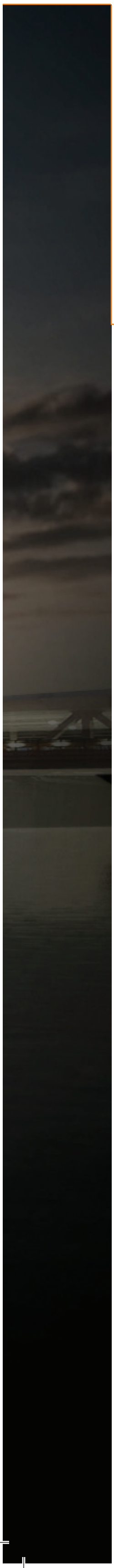
This is the reason, why visitor want to zoom into the details and explore, how turbines is operating form outside and inside.

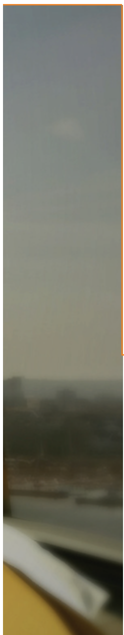


OBSERVE

Certainly building is iconic in close context. Expression of building is brightened with reflection into the water.
As building is purely three-dimensional object, people passing by it on the highway or on the boat, can explore it from almost all view point and always find something new.
By entering building role or watcher changes and visitor can overlook city and surroundings.

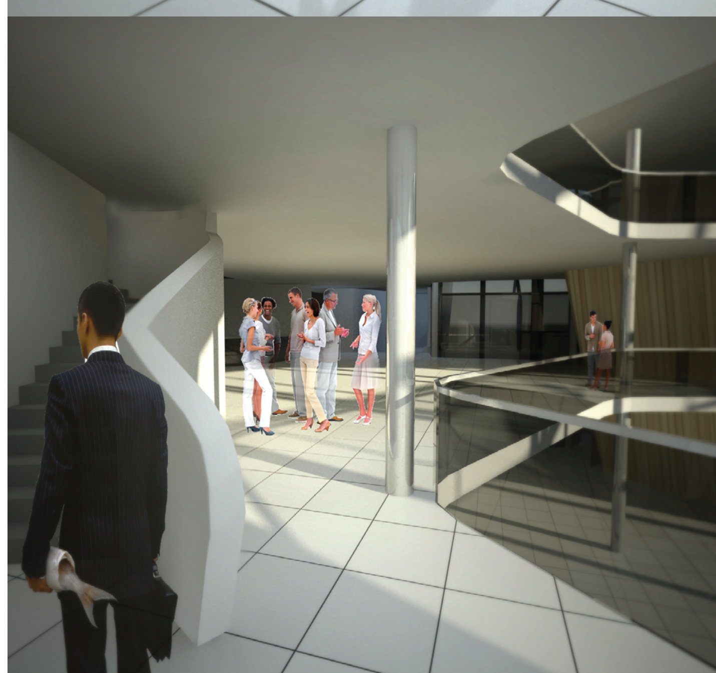






INNER SPACES

Interior is presenting bright and organic approach. Wooden or metal details in the building elements give elegant, minimalistic touch. However, the main and the most powerful interior element is view from the building. View to the turbines, symbolizes new energy approach in urban environment, and view to the magnificent surroundings - from low and natural Egholm Island to the dynamic and urban Aalborg on both sides of Limfjord.



Conclusions and reflections

This chapter will sum up final project proposal and reflect to the research outcome.

Typical attempts to use alternative energy resources to provide energy for human being ends at the solar panels, however, many locations on Earth are more suitable for using wind energy. As one example is taken Denmark, where surrounding waters and flat lands create high winds.

Wind turbines are tool to harvest wind power and it should be elevated above ground floor in order to harvest efficiently. Attempts to find interactions between technology and building clear out many issues. Collaboration between wind and architectural is sensitive and highly important, as aerodynamic approach of the building helps turbines work more productive, meanwhile aerodynamics is wind motion. In the same time, productivity depends on wind direction, strength and quality and placement into the building. The collaboration is called integration in this research, so both main tools is working together and in the best possible way, giving benefits to the building project.

After first semester guidelines was clear out, project phase could began to create an example of wind and architecture collaboration.

Project site was chosen according to the wind conditions; therefore context radically differs from typical building sites for such a building proposals. Building function was chosen according contextual relevance; however it could be developed in another direction, as this is secondary issue. Therefore, it is very important to understand that discussions about context and function is not playing main role.

Hotel volume is made according to the technical concept. Chosen Darrieus turbine requires concentrate wind flow in order to prevent turbine stop. Building peak is facing SW, getting best wind conditions and accelerating wind until turbines that is placed into the carved opening. Both openings are removed part from solid shield that surrounds the building, and its function is to give space for turbines, meanwhile dragging daylight into the building volume. 6 turbines in total are installed on pillar, on top of each other, providing enough energy to cover energy demand for 2015. Middle core not just supports turbines; it is also a structural element that supports volume growing over the turbine opening.

Northern side is perforated layer that tapers upwards until the peak, creating absolutely different approach then southern facade. Northern side is open and has symbolic connection with landscape, slopping volume slightly.

Inner layout is created as open with three vertical blocks that are distributing rest of the rooms around it. First 4 floors, including basement is public of intended for staff premises. This building part is horizontally organized. Rest of 12 floors are hotel suits and is organized around tower middle core. Exception is top floor, where is placed view tower and cafeteria. The top floor is extended in several floors height, and dynamically reducing width of the volume.

Difficulties during the project were to create overall shape. It had to function for productivity issues and give appropriate architectural proposal. And as every designing tool depends on each other, it was issue to find the best solution. Creating overall shape had difficulties because, the lack of digital tools. It could be great help to use parametric designing tool in order to create clear shapes. Digital programs were replaced with modelling clay that came out to be very handy.

Layout design is very convincing and outcome is decent, as flow is working very functionally and giving project lightness. However, access area to the hotel suites has some waste areas. It might be considered as benefit as daylight is dragged in and layout is more irregular, however, from economical viewpoint it raise the price of the building.

Expression of turbine openings is giving expected, especially in the view from east, where is visible contrast between glazing and solid surface.

Connection with ground need to be developed more from constructional point, as architecturally it might need to increase curving effect, but there is no necessary engineer knowledge to ensure structural stability.

Development is needed also for building peak, adding extra beams to provide better static conditions; however, this issue was discussed in robot analyses.

Extra considerations could be good to make about acoustics and daylight factor. However, project has limited time; therefore just most important aspects were examined closely.

All productivity analyses about turbines is made according to the research and consultations, however, wind power science is very complicate and need extended knowledge to test and verify chosen turbine efficiency.

Appendix

01 Area calculation

As main hotel function is accommodation, bedroom size and proportion of other functions are main values that changes final area. Therefore, excel sheet is created in order to easily change parameters and calculate new areas.

Total initial area of hotel is 6791 m2, where 3396 m2 are hotel suites and rest for other facilities. Other areas are divided according ration.

Actual area is for 3% more because of building shape and necessity to organize logical flow. This gives ratio of 47% rooms and 53% other.

In order to calculate initial parking area, staff member amount has been calculate. Parking area has to provide 1 car per every suite plus 1 car for every 3 staff members. Extra places have to be added because of cafe, but as hotel is close to the airport, it is predicted, that part of customer will use taxi or public transport services to travel until hotel. Therefore, calculated parking place amount might be enough to satisfy all customers.

Total building area is 9367 m2, but for productivity calculation parking area in not included, as it is not heated.

Rooms			
		pcs	total m2
Suites	ord	81	782
	lux	33	1175
Access			1438
	Total	114	3396

Hotel		
	part	m2
Hotel	1	6791
Rooms	0,5	3396
Other	0,5	3396

Staff	
Administration	8
Kitchen, cafe	7
Room service	5
Other	10
Total	30

Areas			
	%	planned	actual
Public	0,15	1019	1991
Cafe	0,07	475	476
Conference	0,03	204	218
Domestic and repair	0,21	1426	1463
Administration	0,02	136	184
Shop, kiosk	0,02	136	139
Total		3396	4471
		Actual area m2	7867

Parking			
	amount	m2	
Cars	124	1488	
	Total	1488	1500

Total area	
m^2	9367

02 Room program

	Space	Clear height (m)	Net area (m^2)	Daylight	Venti-lation	Sound isolation
B	parking	3,5	1500	partly	M	yes
G	staff zone	3,2 & 2,9	1388,8	partly	N+M	yes
1st	lounge	3,2	507	yes	N	no
	wardrobe	3,2	21	no	N	no
	restrooms	2,9	54,8	no	M	no
	restaurant	3,2-6,4	173,6	yes	N	no
	kitchen	2,9	23,6	yes	N+M	yes
	staff zone	2,9	25,2	yes	N	no
	staff zone	2,9	18,7	yes	N	no
	shops	3,2	139	partly	N	no
	reception	3,2	15,6	yes	N	no
	restroom	2,9	6,2	no	M	no
	achive	3,2	4,6	no	N	no
	dinning room	2,9	12,4	no	N	no
	office	3,2	19,2	yes	N+M	yes
	open office	3,2	70,6	yes	N+M	no
	lounge admin.	3,2	39,7	yes	N	no
2nd	lounge	3,2	264,5	yes	N	no
	restrooms	2,9	54,8	no	M	no
	restaurant	3,2	95,5	yes	N	no
	lounge 2	3,2	45,7	yes	N	no
	disco	3,2-2,9	123,5	yes	N+M	yes
	wc	2,9	15,5	no	M	no
	restrooms	2,9	9,8	no	M	no
	meeting room 1	3,2	16,2	yes	N	yes
	meeting room 2	3,2	23,2	yes	N	yes
	meeting room 3	3,2	28,7	yes	N	yes
	lounge conference	3,2	140,2	yes	N	no
3rd	Access area	3,2	198	yes	N	no
	Suite 1	3,2-2,9	28,5	yes	N	yes
	Suite 2	3,2-2,10	22,7	yes	N	yes
	Suite 3	3,2-2,11	24,3	yes	N	yes
	Suite 4	3,2-2,12	24,9	yes	N	yes
	Suite 5	3,2-2,13	31,5	yes	N	yes
	Suite 6	3,2-2,14	14,9	yes	N	yes
	Suite 7	3,2-2,15	17	yes	N	yes
	Suite 8	3,2-2,16	13,3	yes	N	yes
	Suite 9	3,2-2,17	13	yes	N	yes
	Suite 10	3,2-2,18	17	yes	N	yes
	Suite 11	3,2-2,19	13	yes	N	yes
4th	Access area	3,2	186	yes	N	no
	Suite 1	3,2-2,9	30,4	yes	N	yes
	Suite 2	3,2-2,10	25	yes	N	yes
	Suite 3	3,2-2,11	24,3	yes	N	yes
	Suite 4	3,2-2,12	20,7	yes	N	yes
	Suite 5	3,2-2,13	26	yes	N	yes
	Suite 6	3,2-2,14	14,9	yes	N	yes
	Suite 7	3,2-2,15	17	yes	N	yes
	Suite 8	3,2-2,16	13,3	yes	N	yes

	Space	Clear height (m)	Net area (m^2)	Daylight	Venti-lation	Sound isolation
	Suite 9	3,2-2,17	13	yes	N	yes
	Suite 10	3,2-2,18	17	yes	N	yes
	Suite 11	3,2-2,19	13	yes	N	yes
5th	Access area	3,2	170	yes	N	no
	Suite 1	3,2-2,9	29,2	yes	N	yes
	Suite 2	3,2-2,10	21,5	yes	N	yes
	Suite 3	3,2-2,11	24	yes	N	yes
	Suite 4	3,2-2,12	20,7	yes	N	yes
	Suite 5	3,2-2,13	30,4	yes	N	yes
	Suite 6	3,2-2,14	14,9	yes	N	yes
	Suite 7	3,2-2,15	17	yes	N	yes
	Suite 8	3,2-2,16	13,3	yes	N	yes
	Suite 9	3,2-2,17	13	yes	N	yes
	Suite 10	3,2-2,18	17	yes	N	yes
	Suite 11	3,2-2,19	13	yes	N	yes
6th	Access area	3,2	154	yes	N	no
	Suite 1	3,2-2,9	28	yes	N	yes
	Suite 2	3,2-2,10	19,2	yes	N	yes
	Suite 3	3,2-2,11	23,7	yes	N	yes
	Suite 4	3,2-2,12	20,7	yes	N	yes
	Suite 5	3,2-2,13	19	yes	N	yes
	Suite 6	3,2-2,14	14,9	yes	N	yes
	Suite 7	3,2-2,15	17	yes	N	yes
	Suite 8	3,2-2,16	13,3	yes	N	yes
	Suite 9	3,2-2,17	13	yes	N	yes
	Suite 10	3,2-2,18	17	yes	N	yes
	Suite 11	3,2-2,19	13	yes	N	yes
7th	Access area	3,2	143,8	yes	N	no
	Suite 1	3,2-2,9	23	yes	N	yes
	Suite 2	3,2-2,10	22	yes	N	yes
	Suite 3	3,2-2,11	22,6	yes	N	yes
	Suite 4	3,2-2,12	12,7	yes	N	yes
	Suite 5	3,2-2,14	14,9	yes	N	yes
	Suite 6	3,2-2,15	17	yes	N	yes
	Suite 7	3,2-2,16	13,3	yes	N	yes
	Suite 8	3,2-2,17	13	yes	N	yes
	Suite 9	3,2-2,18	17	yes	N	yes
	Suite 10	3,2-2,19	13	yes	N	yes
8th	Access area	3,2	115,8	yes	N	no
	Suite 1	3,2-2,9	25,5	yes	N	yes
	Suite 2	3,2-2,10	24	yes	N	yes
	Suite 3	3,2-2,11	22,5	yes	N	yes
	Suite 4	3,2-2,12	20,4	yes	N	yes
	Suite 5	3,2-2,13	11,7	yes	N	yes
	Suite 6	3,2-2,14	14,9	yes	N	yes
	Suite 7	3,2-2,15	17	yes	N	yes
	Suite 8	3,2-2,16	13,3	yes	N	yes
	Suite 9	3,2-2,17	13	yes	N	yes
	Suite 10	3,2-2,18	17	yes	N	yes

	Space	Clear height (m)	Net area (m^2)	Daylight	Venti-lation	Sound isolation
	Suite 11	3,2-2,19	13	yes	N	yes
9th	Access area	3,2	109	yes	N	no
	Suite 1	3,2-2,9	24,2	yes	N	yes
	Suite 2	3,2-2,10	14,8	yes	N	yes
	Suite 3	3,2-2,11	19,2	yes	N	yes
	Suite 4	3,2-2,12	20,7	yes	N	yes
	Suite 5	3,2-2,13	11,2	yes	N	yes
	Suite 6	3,2-2,14	14,9	yes	N	yes
	Suite 7	3,2-2,15	17	yes	N	yes
	Suite 8	3,2-2,16	13,3	yes	N	yes
	Suite 9	3,2-2,17	13	yes	N	yes
	Suite 10	3,2-2,18	17	yes	N	yes
	Suite 11	3,2-2,19	13	yes	N	yes
10th	Access area	3,2	105	yes	N	no
	Suite 1	3,2-2,9	22,8	yes	N	yes
	Suite 2	3,2-2,10	20,8	yes	N	yes
	Suite 3	3,2-2,11	11	yes	N	yes
	Suite 4	3,2-2,12	10,8	yes	N	yes
	Suite 5	3,2-2,14	14,9	yes	N	yes
	Suite 6	3,2-2,15	17	yes	N	yes
	Suite 7	3,2-2,16	13,3	yes	N	yes
	Suite 8	3,2-2,17	13	yes	N	yes
	Suite 9	3,2-2,18	17	yes	N	yes
	Suite 10	3,2-2,19	13	yes	N	yes
11th	Access area	3,2	85	yes	N	no
	Suite 1	3,2-2,9	20,4	yes	N	yes
	Suite 2	3,2-2,10	10	yes	N	yes
	Suite 3	3,2-2,11	11	yes	N	yes
	Suite 4	3,2-2,12	15	yes	N	yes
	Suite 5	3,2-2,14	16,2	yes	N	yes
	Suite 6	3,2-2,15	17	yes	N	yes
	Suite 7	3,2-2,16	13,3	yes	N	yes
	Suite 8	3,2-2,17	13	yes	N	yes
	Suite 9	3,2-2,18	17	yes	N	yes
	Suite 10	3,2-2,19	13	yes	N	yes
12th	Access area	3,2	86,5	yes	N	no
	Suite 1	3,2-2,9	18,4	yes	N	yes
	Suite 2	3,2-2,10	11	yes	N	yes
	Suite 3	3,2-2,11	15	yes	N	yes
	Suite 4	3,2-2,12	16,2	yes	N	yes
	Suite 5	3,2-2,15	17	yes	N	yes
	Suite 6	3,2-2,16	13,3	yes	N	yes
	Suite 7	3,2-2,17	13	yes	N	yes
	Suite 8	3,2-2,18	17	yes	N	yes
	Suite 9	3,2-2,19	13	yes	N	yes
	Access area	3,2	85	yes	N	no
	Suite 1	3,2-2,9	18	yes	N	yes

	Space	Clear height (m)	Net area (m^2)	Daylight	Venti-lation	Sound isolation
13th	Suite 2	3,2-2,10	11	yes	N	yes
	Suite 3	3,2-2,11	15	yes	N	yes
	Suite 4	3,2-2,12	16,2	yes	N	yes
	Suite 5	3,2-2,15	17	yes	N	yes
	Suite 6	3,2-2,16	13,3	yes	N	yes
	Suite 7	3,2-2,17	13	yes	N	yes
	Suite 8	3,2-2,18	17	yes	N	yes
	Suite 9	3,2-2,19	17	yes	N	yes
14th	garden	differs	56	yes	N	no
	restrooms	2,9	17	no	M	no
	cafe-view tower	differs	151	yes	N	yes
Stairs	Staircase main	2,9	50	no		
	Staircase admin	2,9	20,2	no		

03 Element calculation

Load calculation for singular elements

LOAD - steel beam/ in situ concrete	Load calculation			Char.load (kg)	Design load kN/m
	thickn. M	density	Load area (T) for 1m		
I DEAD LOAD					
In situ concrete					
Concrete tiles	0,022	1500	1,0	33,0	0,40
Tile glue	0,015	1	1,0	0,0	0,00
Floor screed	0,090	2300	1,0	207,0	2,48
Concrete monolyte	0,100	2300	1,0	230,0	2,76
					5,64
Beam 15,2m					
Concrete tiles	0,022	1500	82,5	2722,5	32,67
Tile glue	0,015	1	82,5	1,2	0,01
Floor screed	0,020	2300	82,5	3795,0	45,54
					78,22
Beam with column					
1) Concrete tiles	0,022	1500	17,2	567,6	6,81
Tile glue	0,015	1	17,2	0,3	0,00
Floor screed	0,020	2300	17,2	791,2	9,49
					16,31
2) Concrete tiles	0,022	1500	43,3	1428,9	17,15
Tile glue	0,015	1	43,3	0,6	0,01
Floor screed	0,020	2300	43,3	1991,8	23,90
					41,06
3) Concrete tiles	0,022	1500	22,0	726,0	8,71
Tile glue	0,015	1	22,0	0,3	0,00
Floor screed	0,020	2300	22,0	1012,0	12,14
					20,86

Column for turbine			x3 floors			
Concrete tiles	0,022	1500	84,9	2801,7	42,03	
Tile glue	0,015	1	84,9	1,3	0,02	
Floor screed	0,090	2300	84,9	17574,3	210,89	
Concrete monolyte	0,100	2300	84,9	19527,0	234,32	
Column	47,000	117		5499,0	65,99	
Beam V=				x3 floors	2.250,00	
Turbines				x3 floors	52,20	
					2.855,44	
Column under beam						
Concrete tiles	0,022	1500	42,3	1395,9	16,75	
Tile glue	0,015	1	42,3	0,6	0,01	
Floor screed	0,090	2300	42,3	8756,1	105,07	
Concrete monolyte	0,100	2300	42,3	9729,0	116,75	
Beam V=					750,00	
Column	24,500	117		2866,5	34,40	
				x7 floors	**2.454,46**	
Column for wall						
	0,022	1500	8,7	287,1	3,45	
Tile glue	0,015	1	8,7	0,1	0,00	
Floor screed	0,090	2300	8,7	1800,9	21,61	
Concrete monolyte	0,100	2300	8,7	2001,0	24,01	
					49,07	
II LIVELOAD						
Category C				5,00	**7,50**	T.S. P167
III WIND LOAD						
building h 70 (peak) 27m/s					**2,7**	T.S fig4,2 P169
IV SNOW LOAD						
roof <30 degree	0,8	0,9		0,72	**1,08**	T.S P168
roof 52 degree	0,21	0,9		0,19	**0,28**	T.S P169

Load calculation for Robot

	Load calculation			Char.load (kg)	Design load kN/m	
	thickn. M	density	Load area (T) for 1m			
I DEAD LOAD						
Average span						
Concrete tiles	0,022	1500	1,0	33,0	0,40	
Tile glue	0,015	1	1,0	0,0	0,00	
Floor screed	0,090	2300	1,0	207,0	2,48	
Concrete monolyte	0,150	2300	1,0	345,0	4,14	
Steel column	3,500	117	1,0	409,5	4,91	
Steel beam	7,000	117	1,0	819,0	9,83	
					21,76	
II LIVELOAD						
Category C				5,00	**7,50**	T.S. P167
III WIND LOAD						
building h 70 (peak) 27m/s					**2,7**	T.S fig4,2 P169
IV SNOW LOAD						
roof <30 degree	0,8	0,9		0,72	**1,08**	T.S P168
roof 52 degree	0,21	0,9		0,19	**0,28**	T.S P169

In-Situ concrete thickness calculation

l=	8	m
q=	13,14	Kn
$M=q*l^2/8$	105,1	*kN*m*

concrete class	C30 ($f$ck=37 Mpa)
reinforcement class	B400 (f_{sk}=400 MPa, fsd=400/1,15=374 MPa)

1. Design value of compressive cylinder strength of concrete

fcd=Acc*fb/γc=0,85*37/1,5 — 20,97 Mpa

Acc	0,9	
γc	1,5	
η	1,0	T.S table 5.17 p201
λ	0,8	T.S table 5.17 p201

2. Dimension on slab(m)

h=	0,15
b=	1
a=	0,03
d= h-a=	0,12

3. Pressure zone admissible height

ξu=Xu/d=δ-k1/k2 Xu/d= 0,648

δ=	1
k1=	0,44
k2=	1,25

4. Friction module

$\mu ed=Med/fcd*b*d^2=170{,}5kN*m/20{,}97*10^3kN/m*1m*(0{,}07m)^2$ — 0,348

5. Pressure zone height

ξ=X/d=1-(√1-2*μed/η)/λ= (1–√1-2*0,361/1)/0,8= — 0,311

6. Comparment

ξ<ξu

<u>**0,311**</u> < <u>**0,648**</u>

7.Reinforstment crosscut area

$As_I=b*d*x/d*fcd/fsd=$		0,00261689	m^2 =	26,17 cm^2
*Asmax=0,04*b*h=*	*0,006* m^2			
Asmin=Asmax*(0,26*fb/fsk*d*2,5)=		0,00004329	m^2 =	0,433 cm^2

8. Comparment

As_I	>	Asmin
26,17	>	0,433

Steel bars 8,33 Ø20for 1m, with step of 120mm; As=26,20cm² *T.S. p193*

In -Situ concrete with tickness 150mm and 8,33 Ø20 mm steel bars provide bending and crosscut strenght.

Column under beam

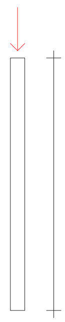
TRE-DIM Versjon 10.0 SØYLE

TRE-KONSTRUKSJONS DIMENSJONERING

- er programmert av ingeniør Ingvar Skarvang

Materialfaktor: 1

Pålitlighetsklasse: 3



LAST: 2454.00 kN (Bruddlast)

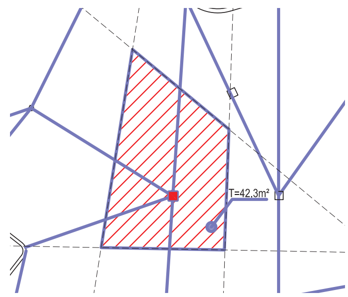
TYPE SØYLE: HEB 240 S355

KNEKKLENGDE = 3.500 m om Y-akse: 115 mm

KNEKKLENGDE = 0.000 m om Z-akse: 115 mm

KNEKNING om sterk akse: (N + Mx) 69.3 % utnyttelse OK

KNEKNING om svak akse: (N + My) 94.3 % utnyttelse OK



BEREGNINGSREGLER:
NS-EN 1995 - NS-EN 1993 - NS-EN 1990 - NS-EN 1194 - NS-EN 338

Profile size is HEB 240

Turbine column

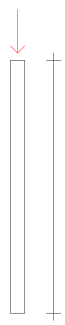
TRE-DIM Versjon 10.0 SØYLE

TRE-KONSTRUKSJONS DIMENSJONERING

- er programmert av ingeniør Ingvar Skarvang

Materialfaktor: 1

Pålitlighetsklasse: 3



LAST: 2855.00 kN (Bruddlast)

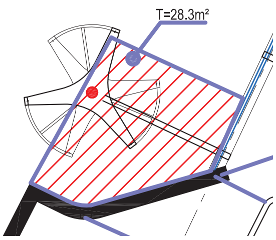
TYPE SØYLE: HEB 300 S355

KNEKKLENGDE = 5.000 m om Y-akse: 115 mm

KNEKKLENGDE = 0.000 m om Z-akse: 115 mm

KNEKNING om sterk akse: (N + Mx) 58.5 % utnyttelse OK

KNEKNING om svak akse: (N + My) 86.7 % utnyttelse OK



BEREGNINGSREGLER:
NS-EN 1995 - NS-EN 1993 - NS-EN 1990 - NS-EN 1194 - NS-EN 338

Profile size is HEB 300 but to prevent unwanted vibration, profile is chosen HEB 400.

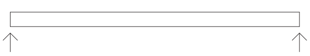
Beam 15.2 m

TRE-DIM Versjon 10.0 BJELKE
TRE-KONSTRUKSJONS DIMENSJONERING

- er programmert av ingeniør Ingvar Skarvang

600 HEB S355
L = 15.20 meter

Materialfaktor: 1.1
Pålitlighetsklasse: 3



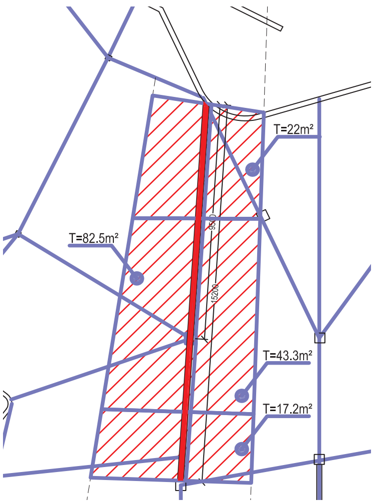
Bjelkens : 0.0°

JEVNT FORDELT LAST PÅ DRAGER:

NYTTELAST :	8.580	kN/m
EGENLAST :	80.340	kN/m
BRUDDLAST :	109.278	kN/m

Nedb. 172 mm
L/88
15200

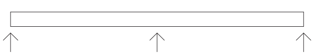
Oppleggskraft:
830.5 kN 830.5 kN



SNITTKREFTER:	KAPASITET.		OPPTREDENDE.		UTNYTTELSE.	
Moment :	1839.5	kNm	3155.9	kNm	171.6	%
Skjærkraft :	1538.5	kN	830.5	kN	54.0	%

Deformation is too big, therefore column is added.

360 HEB S355
L = 15.20 meter



Bjelkens : 0.0°

JEVNT FORDELT LAST PÅ DRAGER:

NYTTELAST :	7.500	kN/m
EGENLAST :	79.620	kN/m
BRUDDLAST :	106.794	kN/m

Nedb. 18 mm 18 mm
L/428 L/428
7600 7600

Oppleggskraft:
309.7 kN 1014.5 kN 309.7 kN

SNITTKREFTER:	KAPASITET.		OPPTREDENDE.		UTNYTTELSE.	
Moment :	774.5	kNm	771.1	kNm	99.5	%
Skjærkraft :	750.7	kN	507.3	kN	67.6	%

Deformation is acceptable, profile is HEB 360

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