FORM FOLLOWS ENERGY IN SRBY, CZECH REPUBLIC

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Summary

This project aims to challenge the architectural process by developing an integrated approach for a design solution which respects the environment and optimizes energy consumption in residential buildings through the defining of a series of ideal construction methods and conditions in a specific location.

This residential project based in the climatically difficult region (heavy sky coverage) of Srby just outside of Prague, has been developed using all the necessary simulation systems *(SunEye, Relux, COMSOL, Flovent, TRNSYS, and Eco-Invent Databank)* in order to predict the energetic capacity of the building throughout the development of the parametric design process. This has resulted in an aerodynamically optimized architectural form, whose performance is far superior to that defined by current stringent standards, without using expensive 'active' systems such as photovoltaic cells. The consequent energy consumption is calculated at 3.9KWh/m2/year for heating and cooling (compared to Passivhaus ® standard=15KWh/m2/year).

These residential buildings are integrated within a set of existing infrastructures, just 45 minutes by train from Prague's center. Each element of the construction process from design (simulation), resourcing materials (local) & construction (low cost prefabrication) all the way to the usage of the building has been designed with a minimum energy impact in mind. These strategies result in a series of aedicule's designed to directly collect the sun's rays, use natural ventilation for summer cooling, and to control their thermal stability in the winter using thermal mass, thus reducing energetic consumption to a minimum and yielding an architectural and spatial quality specific to the site.

Keywords: integrated design, sustainability, energy rationalization, simulation systems, SunEye, Relux, COMSOL, Flovent, TRNSYS, Eco-Invent Databank, environment, natural lighting, natural ventilation, wind flow, aerodynamics, passive solar gain, C.N.C. milling, timber construction, energy consumption, passive solar gain.

1 Introduction

1.1 Background

Having worked as both an architect and most recently for a renowned engineering company in Switzerland that specializes in energy rationalization, I know well the tendency of architects to paste onto their designs what I call a sustainable afterthought.

This is usually done to try to comply with one or the other energetic requirement, and is frustratingly rare as an instigator in design development.

This project aims to challenge the architectural process by developing an integrated approach for a design solution which respects the environment and optimizes energy consumption in residential buildings through the defining of a series of ideal construction methods and conditions in a specific location. The basis of this project is the environment, and it is through a thorough investigation of the surroundings, that an architecture was formed.

1.2 The Project

This residential project based in the climatically difficult region (i.e. heavy sky coverage) of Srby just outside of Prague, has been developed using all the necessary simulation systems from the outset *(SunEye, Relux, COMSOL, Flovent, TRNSYS, and Eco-Invent Databank)*, in order to predict the energetic capacity of the building throughout the development of the parametric design process. This has resulted in an aerodynamically optimized architectural form, whose performance is far superior to that defined by current stringent standards, without using expensive 'active' systems such as photovoltaic cells. The consequent energy consumption is calculated at 3.9KWh/m2/year for heating and cooling (compared to Passivhaus ® standard=15KWh/m2/year).

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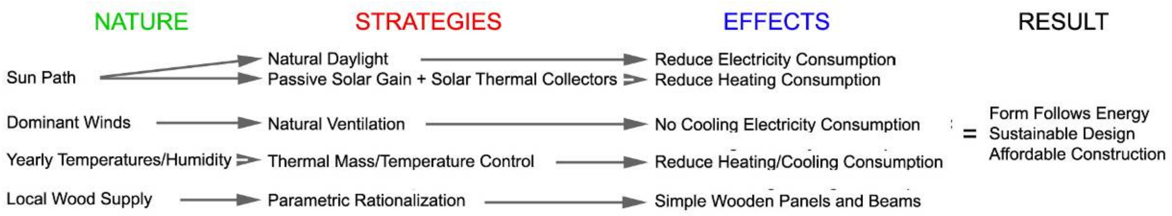


Fig. 1 Design Schematic showing the strategies based on the local conditions in order to produce effect resulting in reduced consumptions and sustainable solutions.

Fig. 2 Clear winter day. View shows the internal fabric solar shading which allows for passive solar gain while avoiding glare.

Fig. 3 From the lake at night showing southerly face after a summer day protected from over-heating by external solar shading.

Fig. 4 Rear view showing the scales, all flat quadratic planar wooden panels with a thin sheet metal for weathering protection.

Fig. 5 Internal view towards Lake Turyňský. On the left the offset and protruding brick wall offering greater surface area for increased thermal mass effect.

2 The Project

2.1 Location & Orientation – Focusing on a site

The project is located in Srby, just outside of Prague, and was chosen because of its current status within the European Union as a recently integrated ex eastern-block country, and the only one with a presently increasing population. Today, 25% of the Czech population lives within the Prague region, and it is projected that 80% of the new incoming population will be incorporated into the city area. The need for new housing is further increased by the fact that the Panelaks which house an enormous part of the population are in general disrepair and these populations need to be relocated. This has allowed for the application of a new building strategy in a country which was once at the forefront of modern technology and is looking to regain this status. The resulting outcome is a series of 'Ideal Construction Methods and Conditions' in Srby, with a focus on integrated environmental respect and optimized energy consumption in residential building.

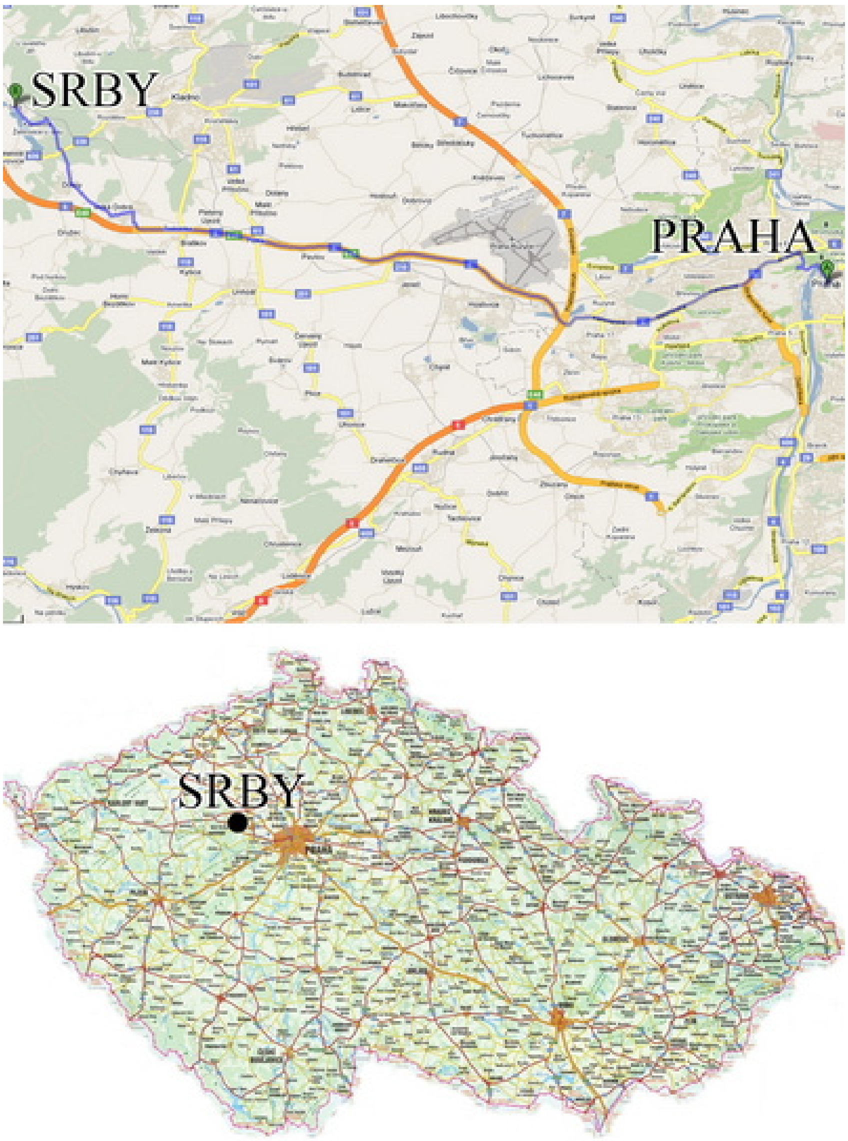


Fig. 6 Srby, Czech Republic.

Fig. 7 Situation Plan showing Lake Turyňský and the town of Srby on its northern tip.

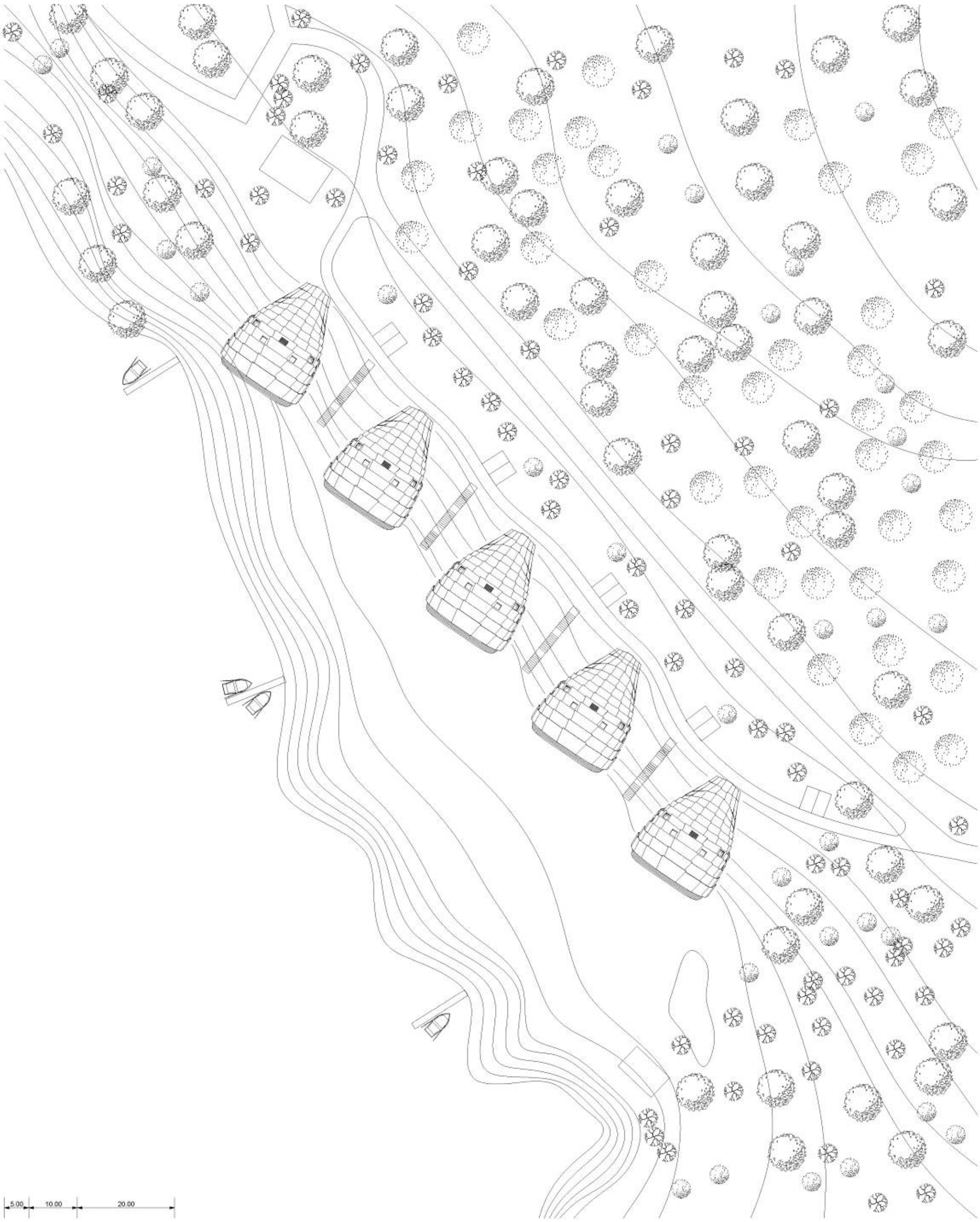


Fig. 8 Pods on the Lake Turyňský with optimized orientation.

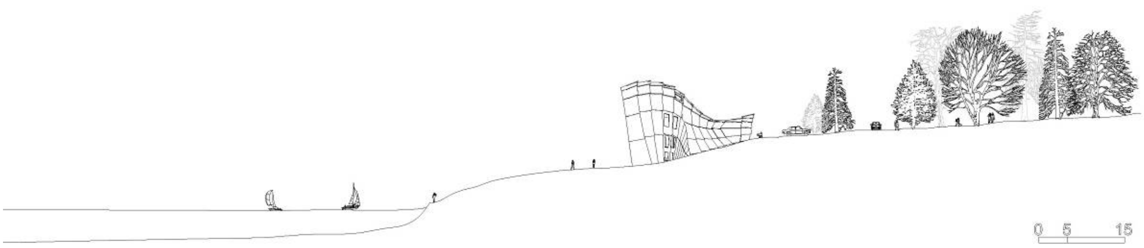


Fig. 9 Section showing the pods and their proximity to the Lake Turyňský.

With an initial focus on new build construction with a maximum reduction of energy consumption, and an emphasis on heating strategies, examples in Austria, Switzerland and Germany have clearly proven that energy consumption can be dramatically reduced. However, most of these examples do not leave the impression that they are designed with an architectural concept in mind, nor that they are integrated or adapted to suit their particular environment. After research on the economic, social and strategically geographic aspects, Srby located on the western edge of Prague has proven to be an ideal location, situated within an existing infrastructure which includes a train that travels to Prague in less than 45 minutes.

2.2 Considering the Environment

From the very beginning, the study was developed using all the necessary simulation systems (SunEye, Relux, COMSOL, Flovent, TRNSYS, and Eco-Invent Databank), in order to precisely predict the capacity of the buildings, and to consequently implement strategies to reduce not only the energy costs, but also the impact of the buildings on the environment. The further the initial investigations developed and the performance improved, the more we were convinced that active systems such as photovoltaic cells and wind or geothermal collectors were not needed. The idea was to design a clever building; one that would directly collect the sun's rays, use natural ventilation for summer cooling, and to control thermal stability through the construction method. The energy bill should be at a minimum, despite the difficulties associated with a temperate/continental climate region.

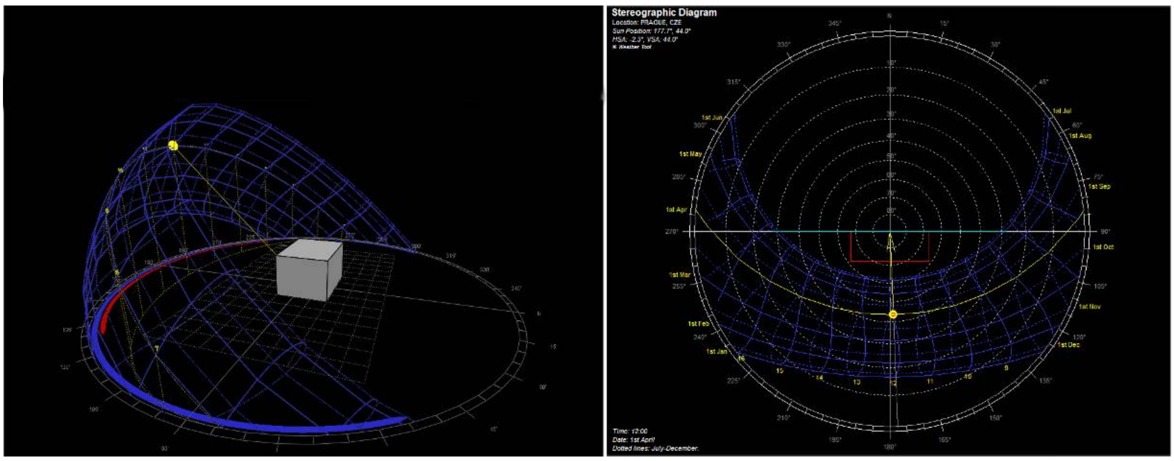
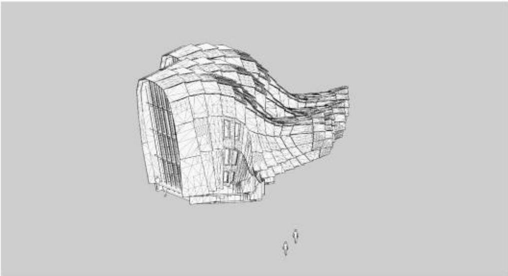


Fig. 10 The Sun path diagram can determine the times of the day and year in which the sun will be available on a particular site. The blue lines running form east to west represent the path of the sun on the 21st day of each month of the year. This study will allow us to see the site as per the sun's point of view and hence start making suggestions and developing strategies in order to maximize our solar gains in cold months and making sure we protect ourselves during the hot and potentially overheated months.



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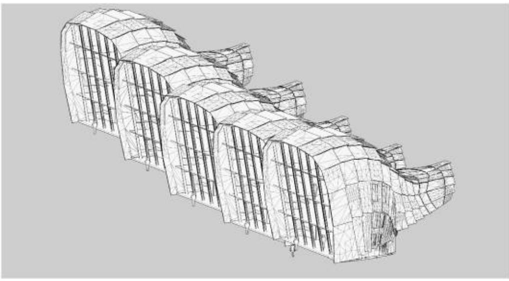

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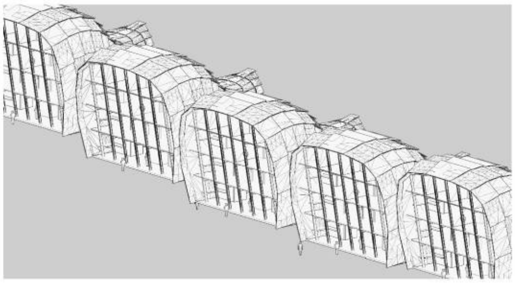

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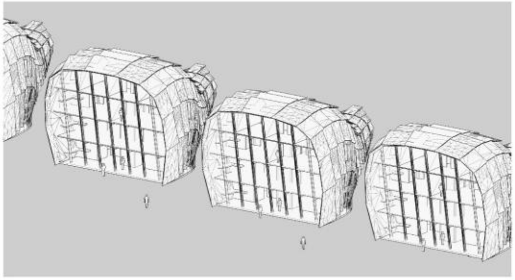

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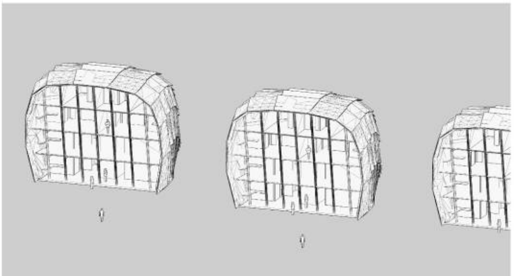

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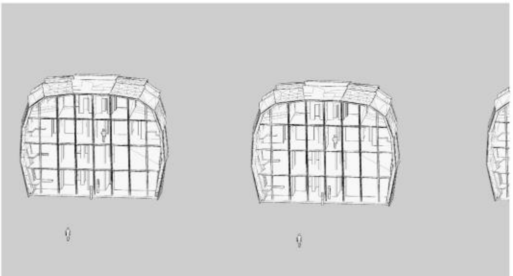

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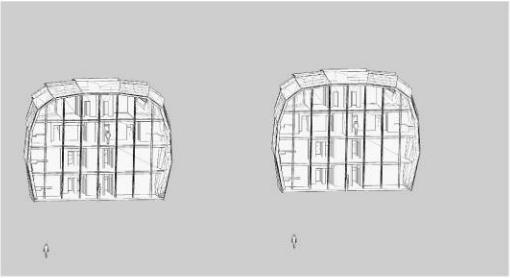

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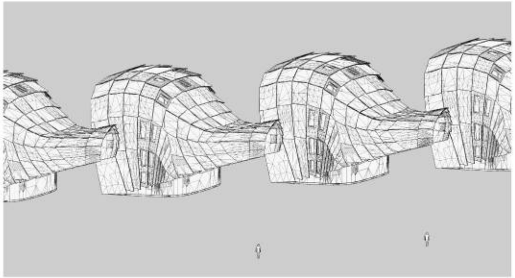

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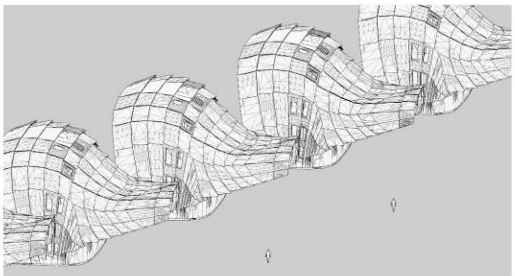

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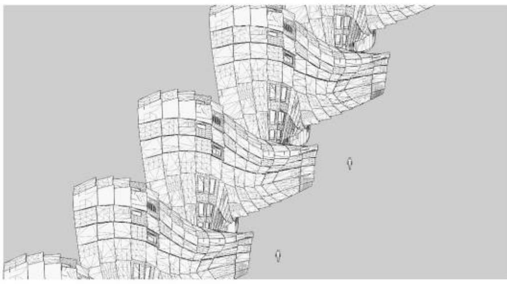

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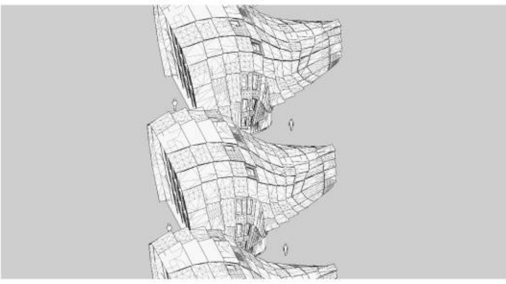

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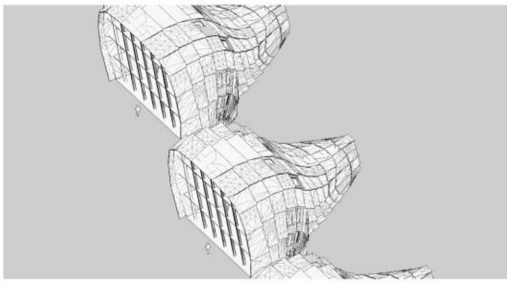

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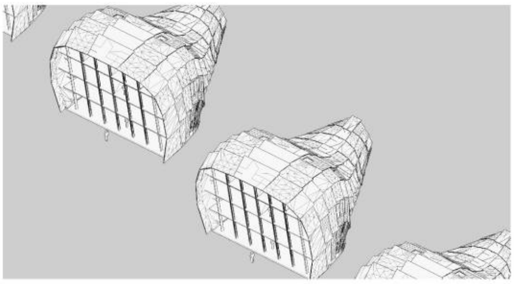

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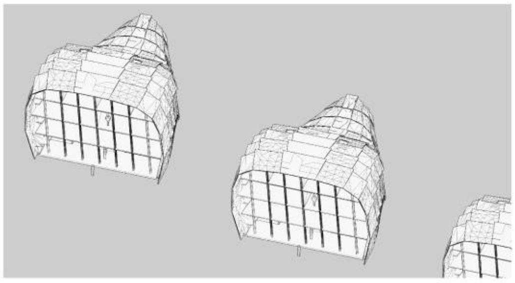

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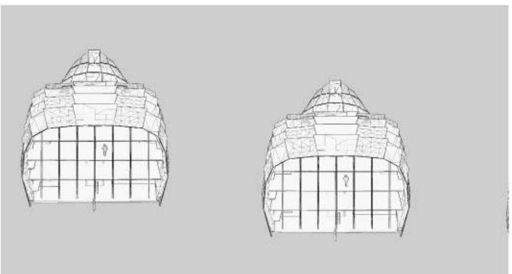

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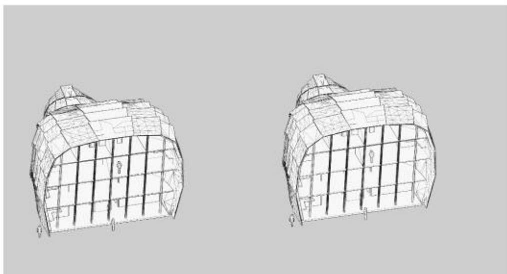

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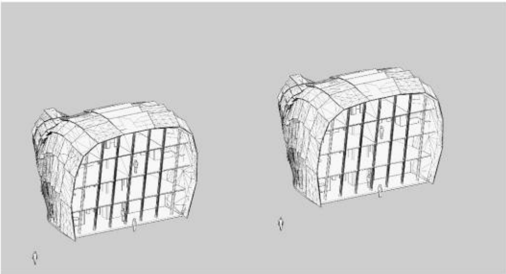

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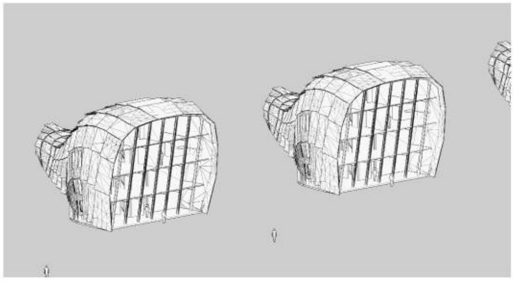

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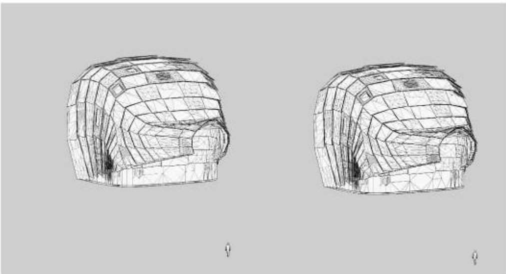

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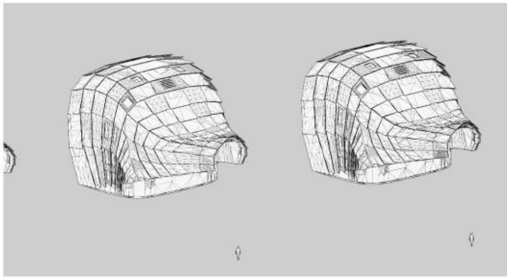

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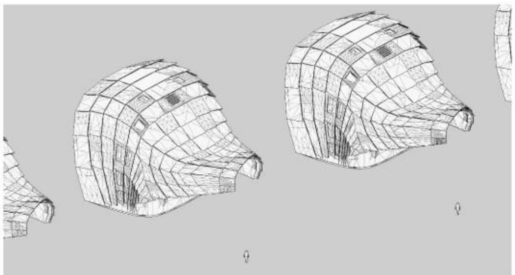

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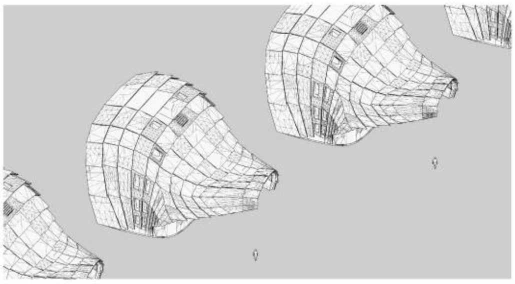

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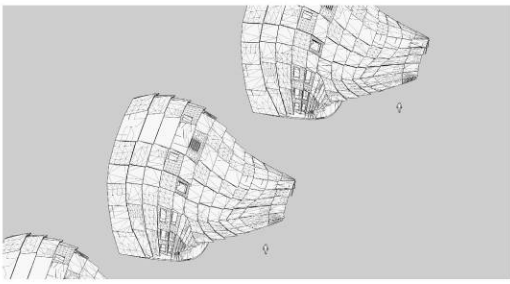

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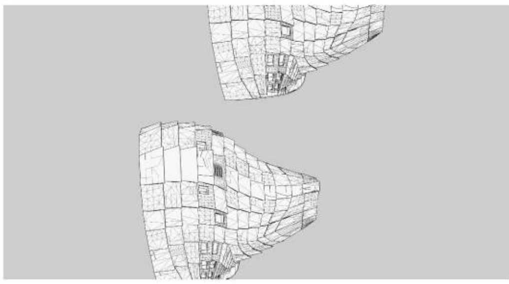

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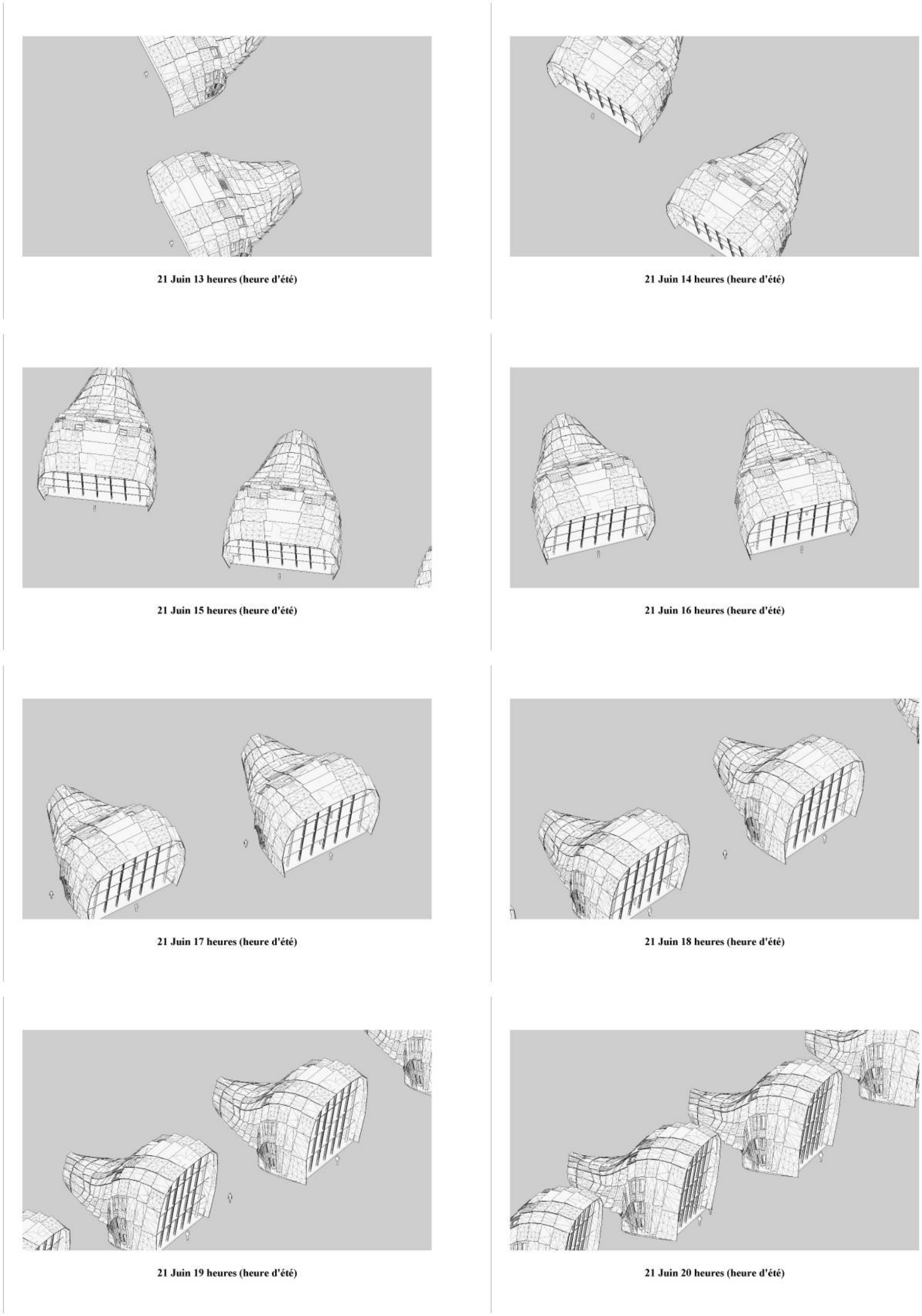
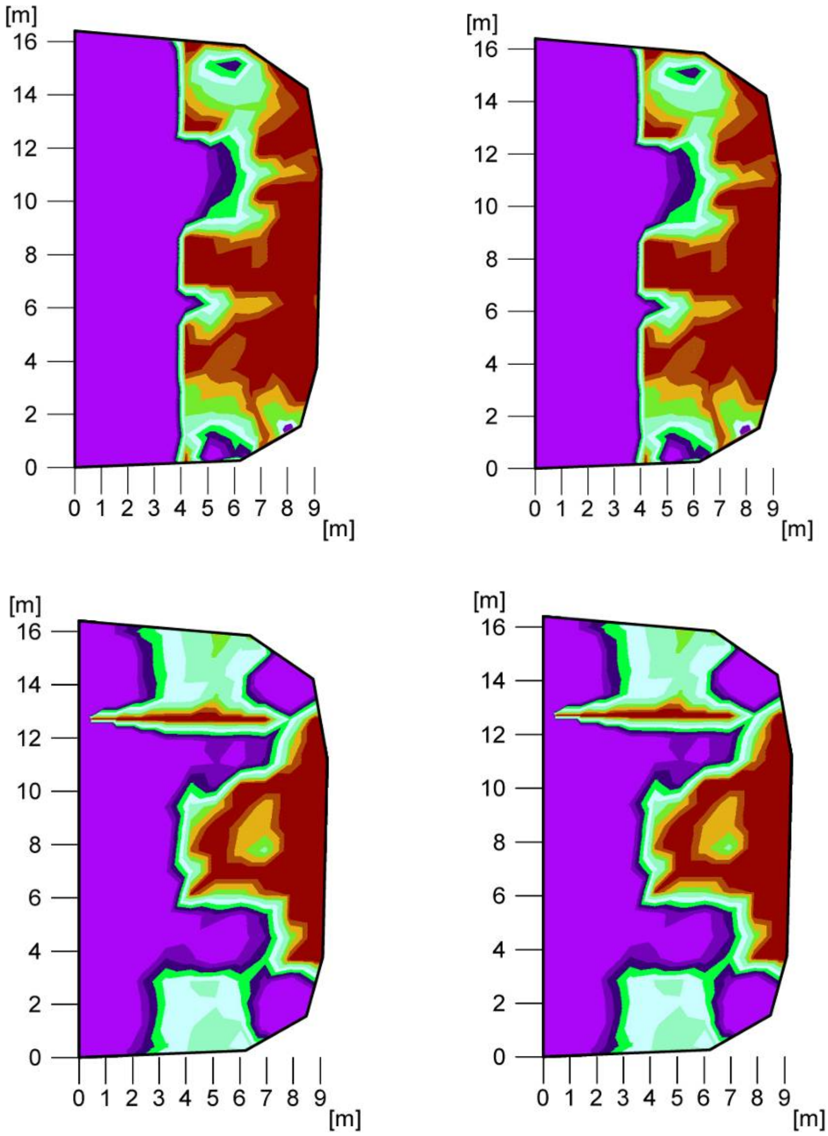


Fig. 11 Sun-eye view revealing orientation and exposure to the sun at different times of the day and year, starting at sunrise and ending at sunset.

Taking these requirements into consideration meant that certain parameters could already be defined. For example, the demand for natural light meant that the depth of the building which is singularly oriented was set to a maximum of 10 meters, with the reflection that certain living spaces such as bedrooms and bathrooms require less natural light. This stipulation lead to a study of ideal ratio's between the envelope and the livable areas, defining the openings within the shell. The result is a 4 storey residential building with over 800m2 of livable space, which can be adapted to different typologies and can accommodate 20-24 people per building. The site is thus densified by the placement of several pods, yet the impact upon the existing energy networks remains minimal.



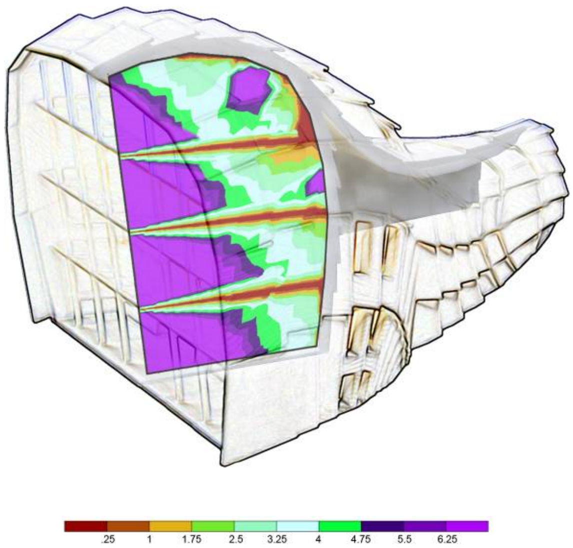


Fig. 12 Relux studies of daylighting within the building

2.3 Heating and Cooling

The buildings are fully exposed to the southern sun for a maximum solar gain in the winter and mid-season months. This principal is further exploited through the placement of open grid internal brick walls, which because of their large contact surface with the air are ideal for providing a mass for thermal gains. Despite average cloud coverage of 85% during the winter months, they gather heat from the sunlight throughout the day, and allow it to disperse into the interior spaces into the evening.

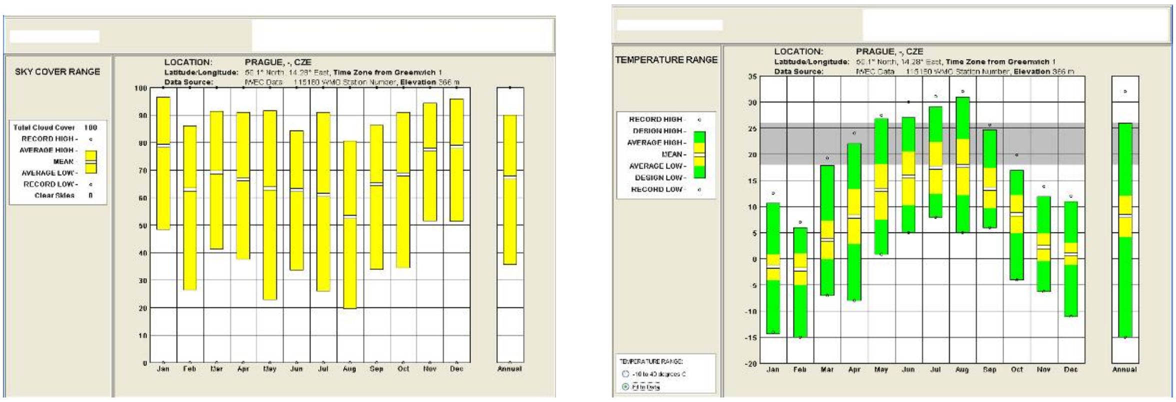


Fig. 13 Sky coverage chart shows heavy sky coverage of 85% in the winter months, and the temperature chart showing extreme conditions in winter and moderate conditions in the summer.

This form of heating device is often viewed as problematic especially during the summer months, when overheating can occur despite the overhanging roof. The simulation program TRNSYS, a dynamic transient environment simulator of thermal systems, shows that the internal temperature in the summer months could reach up to 42 degrees Celsius if no cooling systems were to be put in place. It is for this reason that the envelope of the building is aerodynamically formed.

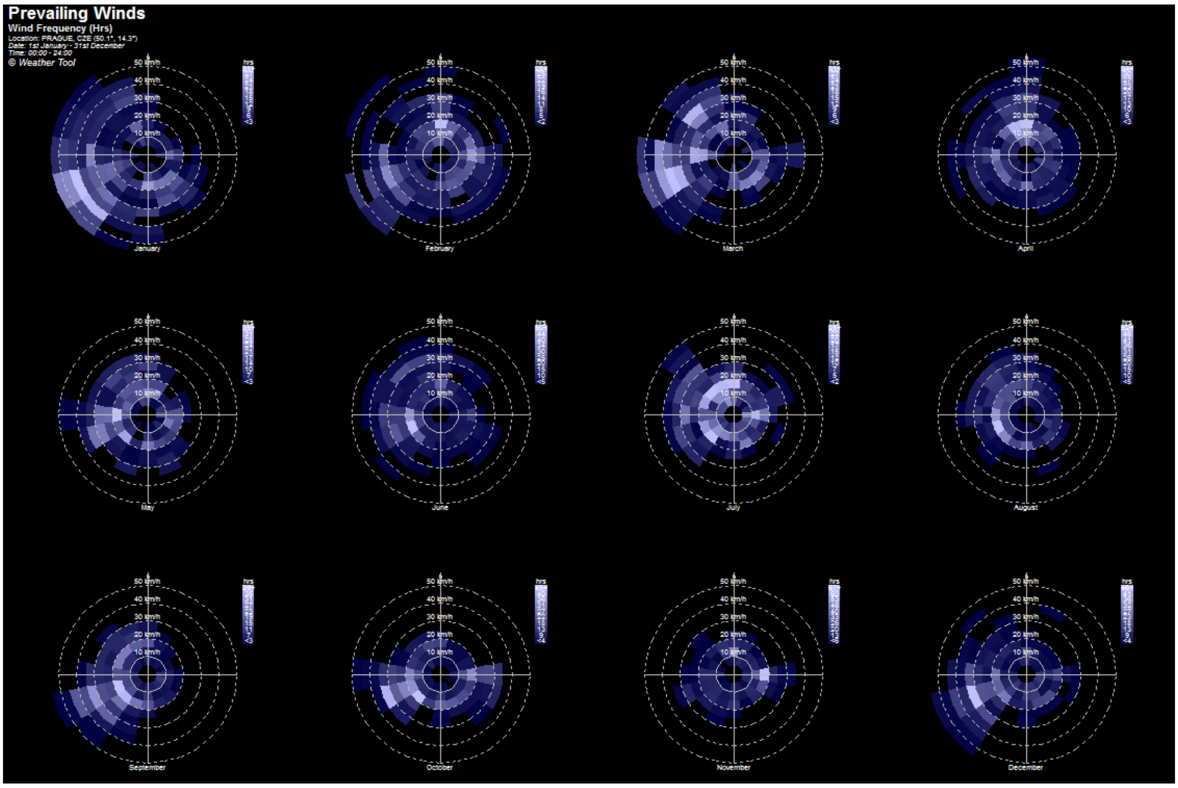


Fig. 14 Wind roses for the western Prague area showing prevailing winds from West/South West.

The wind tunnel testing using COMSOL and Flovent permitted us to optimize the envelope in accordance with the dominant winds and varying wind conditions. This resulted in a form which responds to and even guides the winds, thus allowing a maximum flow of air to naturally ventilate the spaces.

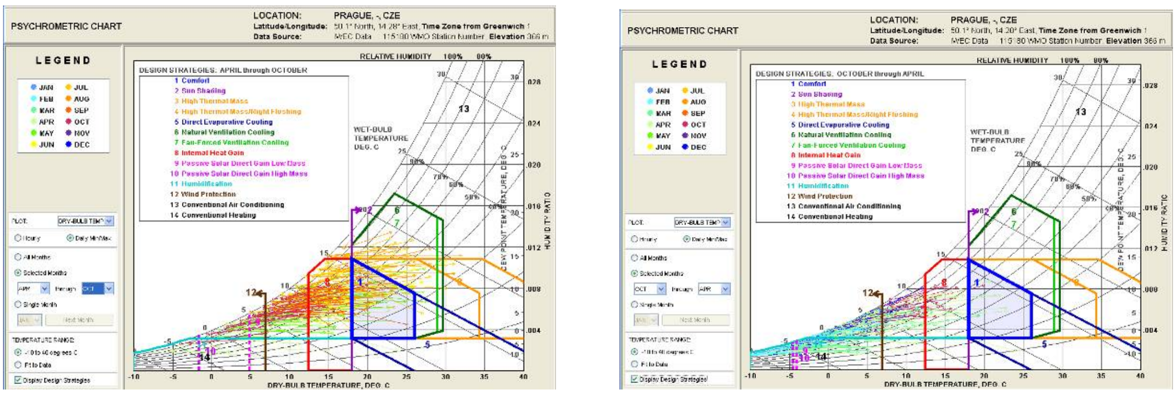


Fig. 15 Summer and winter psychrometric charts showing the relation between temperature, humidity and wind conditions resulting in the specific comfort zones according to the seasons.

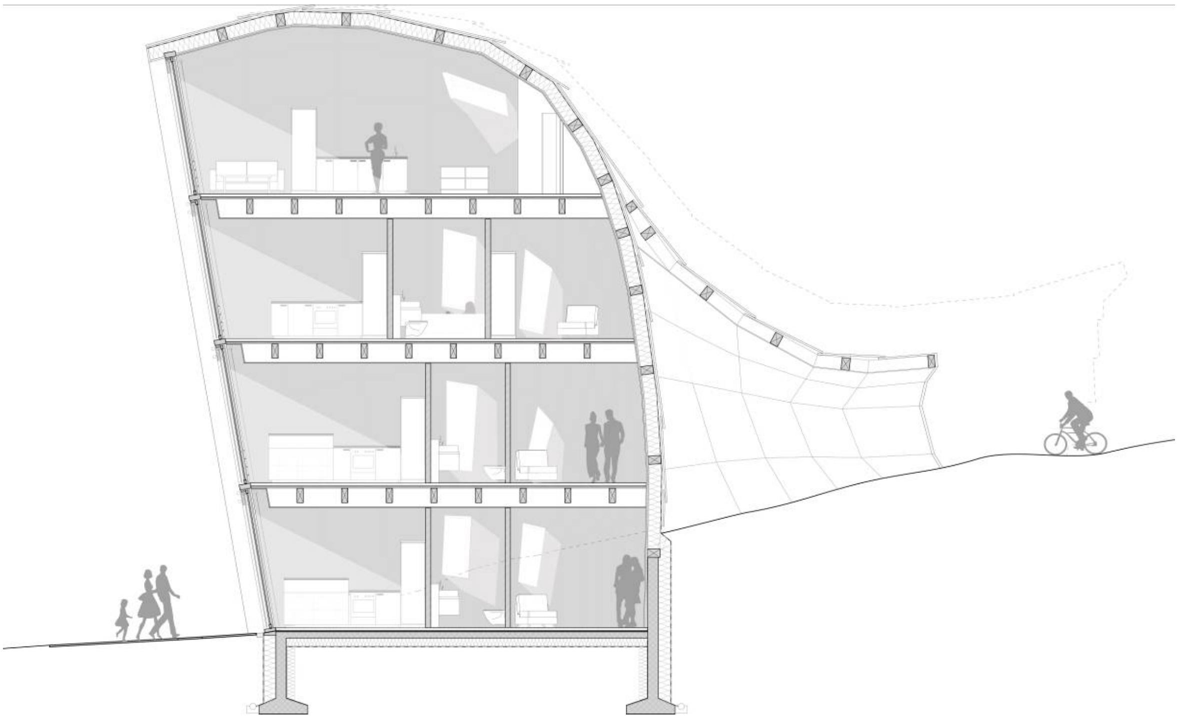


Fig. 16 Section

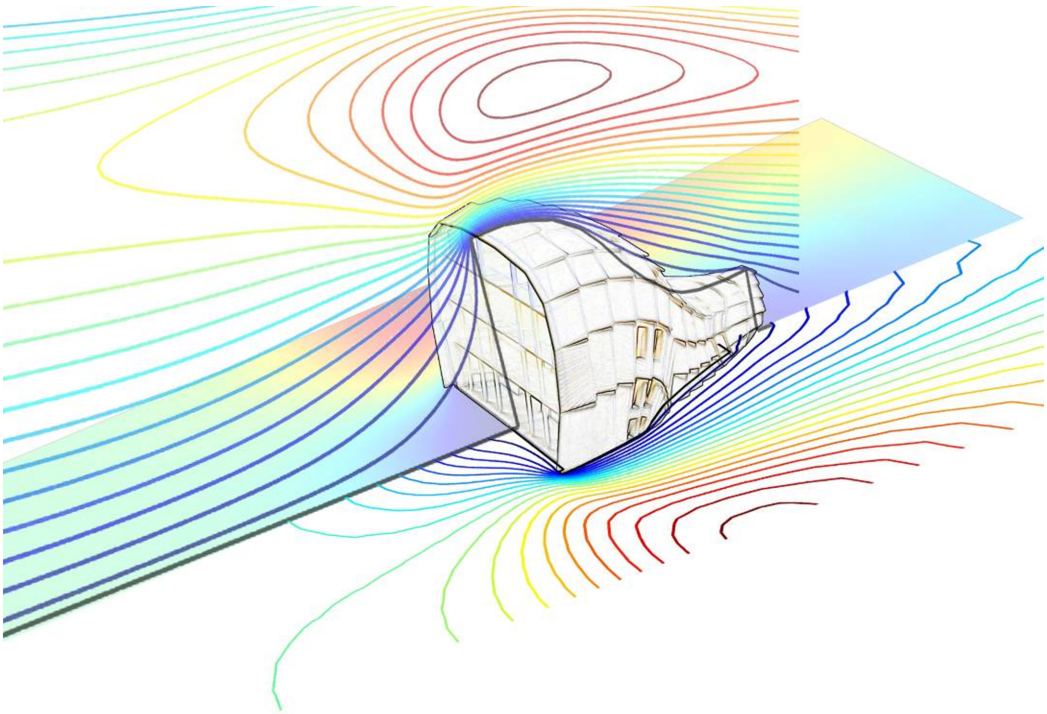


Fig. 17 Aerodynamics

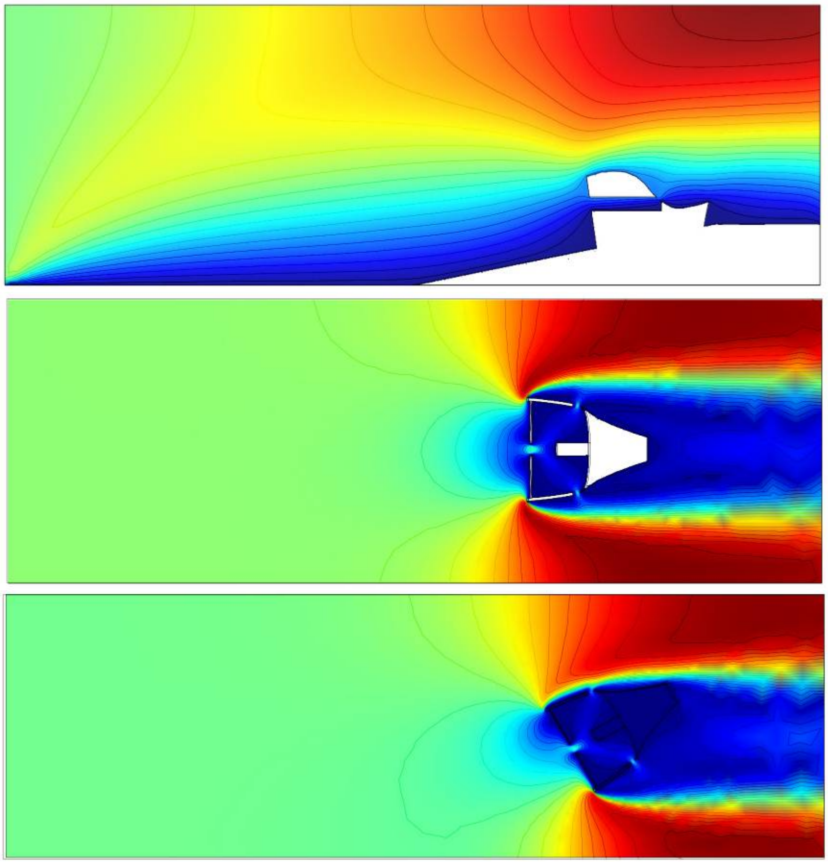


Fig. 18 Ventilation flow

2.4 Materiality & Construction Methods

In terms of materiality, a large part of energetic reasoning lies in the general reduction of the impact of these buildings on the environment by minimizing the grey or embodied energies required for their construction. Timber is the historically traditional choice of construction material within the region, and the large forested areas neighboring Prague therefore become an ideal and logical source of materials. Despite the organic shape of the building, the form has been rationalized, with computer aided technology, into simple quadratic planar panels.

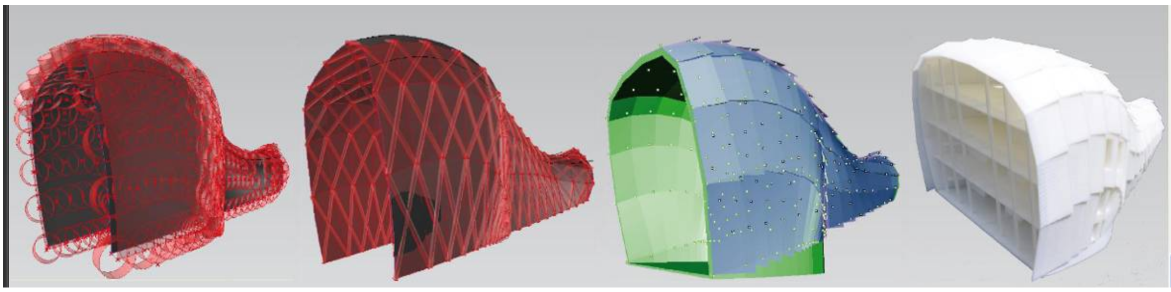


Fig. 19 Detailed 3D analysis and process showing the transformation of the organic form into quadratic planar elements.

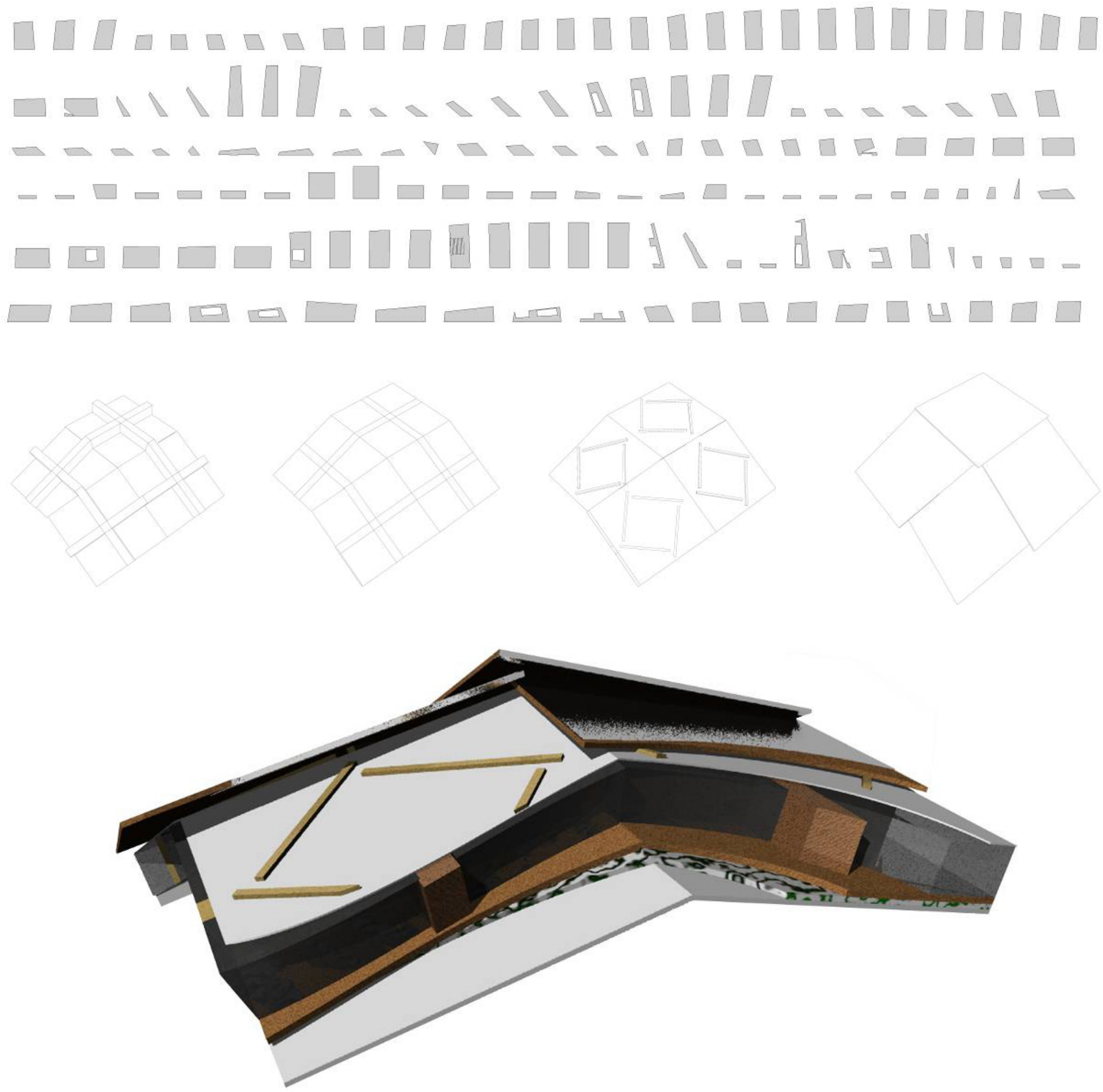


Fig. 20 Individual scales & construction method of the outer shell made from CNC milled flat panels.

This is an obvious solution which allows for an automated production, and the use of C.N.C. machines Computer Numerically Controlled) limits the waste of material, and reduces time of construction both on and off site. Not only the timber cladding scales, but also the structure has been designed in this way, and the skeleton of the shell is composed of only one type of straight beam. An added benefit of this sort of rationalized construction is the reduction of production cost and time, making this sustainable house affordable.

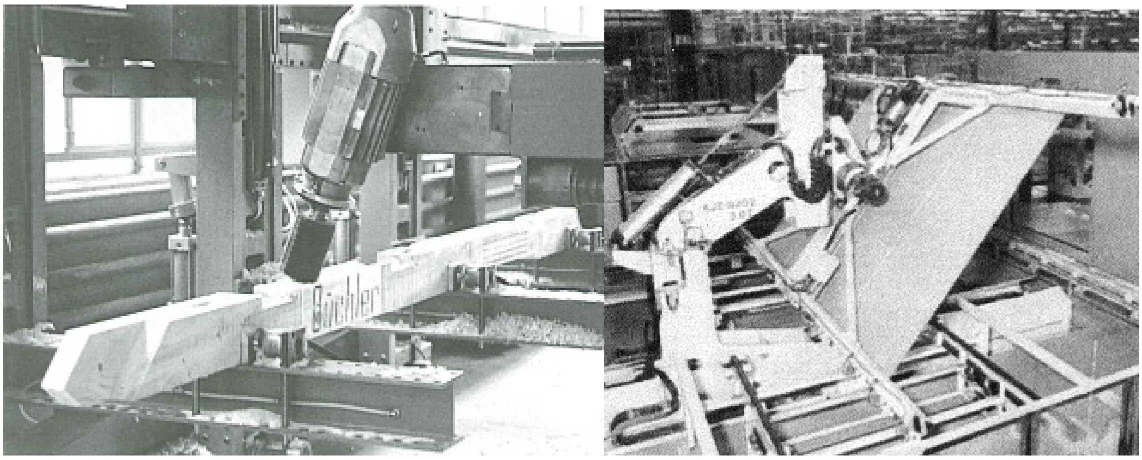


Fig. 21 CNC milling

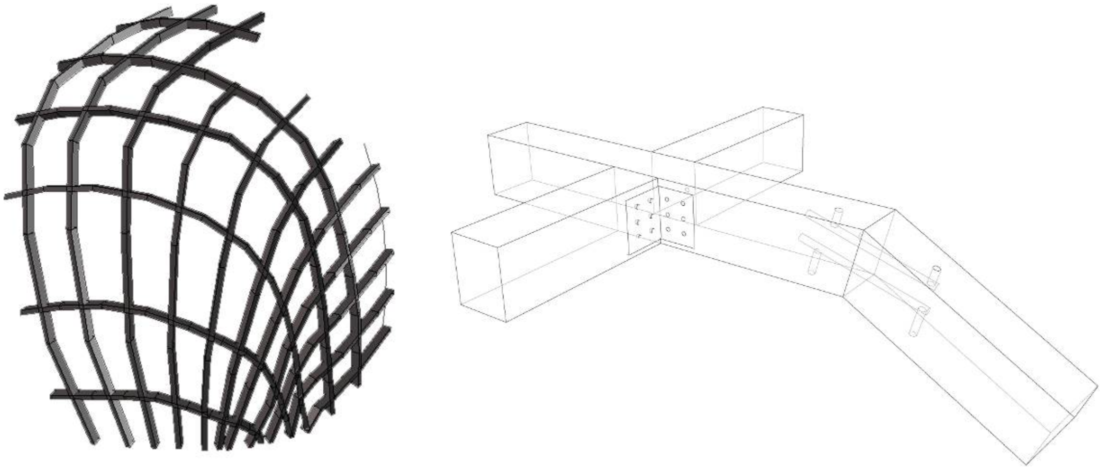


Fig. 22 Structural detailing showing single beam type.

3 Conclusion

In contrast to the usual design process, the goal of this project was to optimize energy consumption by beginning with the scientific notions of climate response and integrating these into the earliest stages of design. From the outset, the focus was on the simple yet necessary elements for comfortable living; natural daylight, views and thermal stability, at the same time conserving architectural value and spatial quality. It is through the analysis of sun movements and wind paths that the orientation and form of this series of aedicule's or aerodynamic pods have emerged upon the shores of Lake Turyňský, profiting not only from the natural elements, but also the beauty of the surrounding landscape. Precise calculations and simulations show that despite an average cloud coverage of 85% during the winter months, with the use of triple glazing the energy consumption of the building (for heating and ventilation) is surprisingly low, calculated at only 3.9KWh/m2/year, as compared to a 'normal' house which consumes between 150-300KWh/m2/year, a result which is far superior even to today's most stringent standards.

4 Annex

Building Srby 3-juin-09

Opaque Elements

Element descriptions	Composition	Thickness [m]	Value α [W/m²-K]	Value λ [W/m-K]	Value R [m²-K/W]	Value U (k) [W/m²-K]
1 Walls with thermal bridges						**0.25**
1 Walls		**0.390**			**4.54**	**0.22**
	Inside	-	8	-	0.13	
	Plasterboard	0.01	-	0.700	0.01	
	Insulation					
	Béton	0.22	-	1.800	0.12	
	Isolation	0.160	-	0.038	4.21	
	Extérieur	-	15	-	0.07	
2 Mur enterré		**0.350**			**2.99**	**0.33**
	Intérieur	-	8	-	0.13	
	Enduit	0.01	-	0.700	0.01	
	Béton	0.22	-	1.800	0.12	
	Isolation	0.120	-	0.044	2.73	
	Contact	-	-	-	0.00	
Désignation de l'élément	**Composition**	**Epaisseur** [m]	**Valeur α** [W/m²-K]	**Valeur λ** [W/m-K]	**Valeur R** [m²-K/W]	**Valeur U (k)** [W/m²-K]
5 Toiture		**0.480**			**5.95**	**0.17**
	Intérieur	-	8	-	0.13	
	Plâtre	0.010	-	0.400	0.03	
	Beton armé	0.22	-	1.800	0.12	
	Isolation	0.20	-	0.036	5.56	
	Gravier	0.050	-	0.700	0.07	
	Extérieur	-	20	-	0.05	
5 Sol terrasse		**0.470**			**5.38**	**0.19**
	Intérieur	-	8	-	0.13	
	Plâtre	0.010	-	0.400	0.03	
	Beton armé	0.22	-	1.800	0.12	
	Isolation	0.18	-	0.036	5.00	
	Chape	0.060	-	1.100	0.05	
	Extérieur	-	20	-	0.05	
6 Sol sur NC		**0.305**			**3.83**	**0.26**
	Intérieur	-	8	-	0.13	
	Revêtement sol	0.02	-	0.160	0.09	
	Chape	0.05	-	1.500	0.03	
	Isolation	0.02	-	0.036	0.56	
	Beton armé	0.22	-	1.800	0.12	
	Isolation	0.10	-	0.036	2.78	
	intérieur	-	8	-	0.13	
7 Sol sur préau avec ponts thermiques						**0.22**
7 Sol sur préau		**0.465**			**5.42**	**0.18**
	Intérieur	-	8	-	0.13	
	Revêtement sol	0.02	-	0.160	0.09	
	Chape	0.05	-	1.500	0.03	
	Isolation	0.02	-	0.036	0.56	
	Beton armé	0.22	-	1.800	0.12	
	Isolation	0.16	-	0.036	4.44	
	Extérieur	-	20	-	0.05	
8 Pont thermique pied de façade					[W/m-K]	**0.17**
9 Pont thermique acrotère					[W/m-K]	**0.03**
Désignation de l'élément	**Type**			**τ** [-]	**g** [-]	**Valeur U (k)** [W/m²-K]
10 Vitrages normal	TV+			**0.70**	**0.55**	**0.50**
11 Huisserie	Bois					**1.50**
12 Fenêtre		13.8	% cadre			**0.64**
13 Pont thermique intercalaire					[W/m-K]	**0.07**
14 Pont thermique raccord encadrement					[W/m-K]	**0.10**

Fig. 23 Element descriptions, compositions and U-Values.

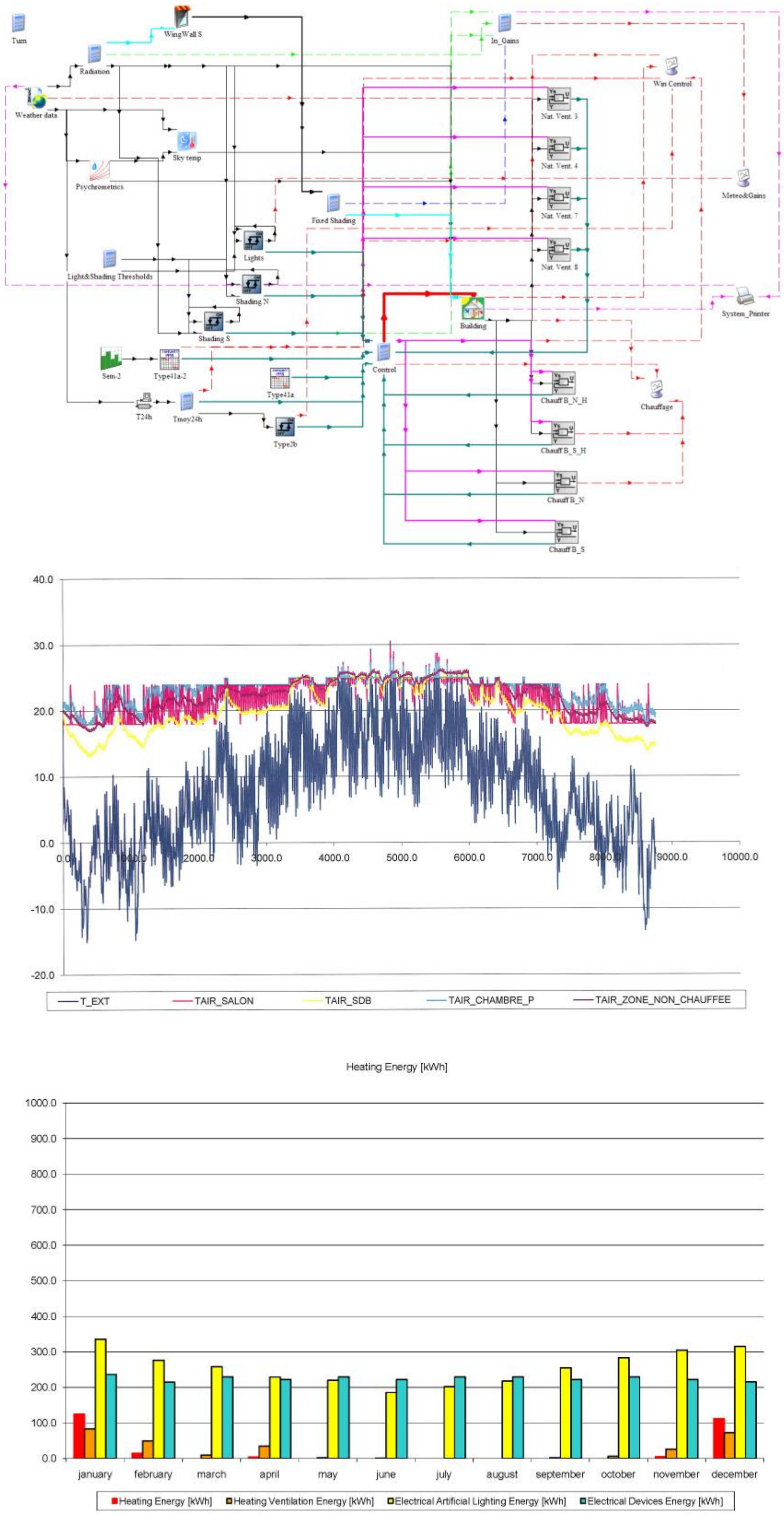


Fig. 24 Organigram and results of the TRNSYS model for the four storey residential building, with the building and all its values of insulation, orientation, etc. at the centre. Around it are the systems such as controlled natural ventilation, but also the heating systems (including internal and solar passive gains), all revolving around a Psychrometric chart taking into consideration all relations between humidity and temperature.

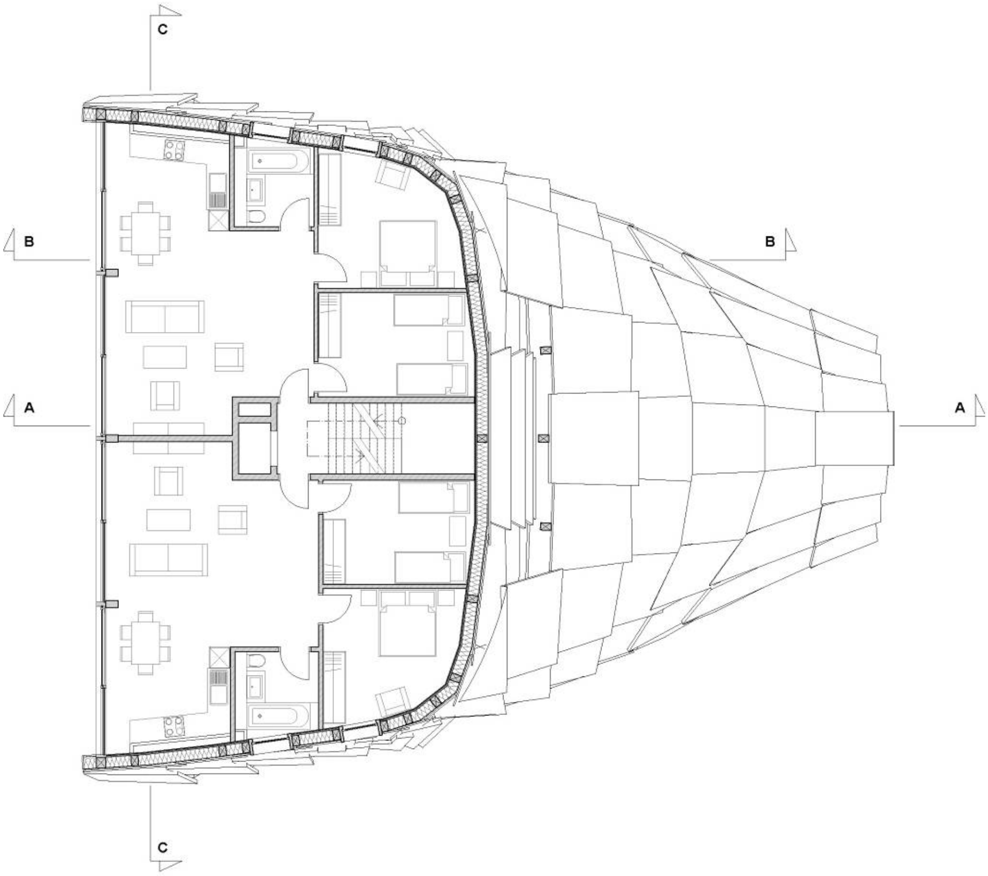


Fig. 25 Floor plan of one of the possible typologies.

Fig. 26 Longitudinal section.