

## **Sneglehusene Housing: Case study based on Bioclimatic Strategies**

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## ABSTRACT

Bioclimatic architecture is a sustainable construction approach that seeks to integrate local climatic conditions in the design of buildings, where one of the main objectives is to maximize thermal comfort and reduce energy consumption through the efficient use of natural resources, such as sunlight, natural ventilation and rainwater collection. To achieve this, materials and construction techniques adapted to the local climate are used, as well as the incorporation of renewable energy systems. This article is the result of research carried out in the Contemporary Bioclimatic Project discipline of the Postgraduate Program in Architecture, Urbanism and Landscaping at the Federal University of Santa Maria, and its purpose is to analyze the bioclimatic strategies applied in the Sneglehusene Housing, located in the city of Aarhus in Denmark. The methodology used for the analysis was based on studies of its implementation, adaptation to the local climate, principles and passive strategies for environmental comfort, landscaping strategies and materiality. Denmark is a world reference on this subject and seeks to encourage a healthier lifestyle in its cities, with the Sneglehusene Housing being an example of a building designed for common well-being and focusing on bioclimatic architecture..

**KEYWORDS:** Bioclimatic architecture. Denmark. Environmental comfort.

## 1. INTRODUCTION

Good architecture must incorporate passive strategies and resources from the first design phases, taking advantage of conditions such as climate, geography and local characteristics. These aspects are directly related to bioclimatic architecture, which aims to harmonize constructions with the external and internal environment, with the integration of passive strategies and resources, that is, those that allow the use of favorable conditions specific to the climate and location, simultaneously offering protection against possible extreme conditions. Therefore, this architecture not only allows the creation of better indoor comfort conditions, but also allows the energy consumption of the building as a whole to be minimized, differentiating it from more conventional approaches.

The Sneglehusene Housing (Figure 1) is a housing complex located in the Nye neighborhood, in the city of Aarhus, the second largest in Denmark, whose project was prepared in 2019 by the office Bjarke Ingels Group (BIG) and completed in 2022, presenting an area total of 9500m<sup>2</sup>, consisting of 6 modules that are repeated and create a checkerboard pattern, in a snail shape and that vary from 1 to 4 floors, totaling 93 housing units, including ground floor units (accessible), two and three floor units, with and without terrace, with the smallest unit measuring 58m<sup>2</sup> and the largest 155m<sup>2</sup>.

Figure 1 – Sneglehusene Housing, Denmark.



Source: Rasmus Hjortshøj. Available at: <https://www.archdaily.com.br/br/990054/edificio-residencial-sneglehusene-big>. Accessed on: 09 dez. 2022.

The project under study is located in the NYE neighborhood in Denmark, located north of Aarhus and was designed to address environmental issues, such as the creation of new green areas, maintenance and management of urban nature, management of rivers and other water

resources, as well as the ecological restoration of degraded ecosystems. Several renowned offices and architects were invited to develop projects for the neighborhood, in order to deliver a project to the community that met its needs and the environmental issues requested. (NYE, 2023).

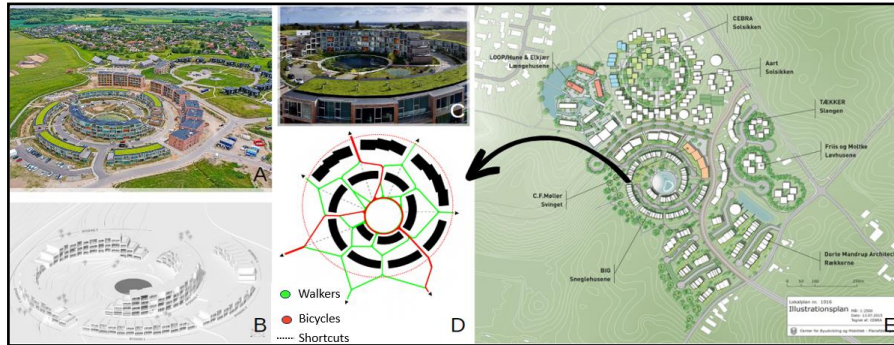
The values established for the NYE neighborhood include: Variety, Balance and Life (NYE, 2023). These points were inserted into the designs of the buildings and open spaces. The presence of these open spaces plays a crucial role in the quality of life of the population residing in urban areas, because as cities grow, green areas lose space for buildings (RAMOS, RAMOS, LYRA, 2019). In contrast to this reality, the NYE project presents a greater concern with the way in which the land is occupied, providing various vegetated leisure areas throughout the buildings that encourage social interactions between users. To the right of Figure 2 (E), there is the neighborhood's implementation plan, with each space and the respective offices responsible for each project. This plan highlights the presence of several vegetated areas and the insertion of artificial lakes. Photos A and C in Figure 2 demonstrate how these areas are presented in the executed project.

In recent years, there have been increasing discussions regarding available water resources, mainly due to the increase in population and consumption of drinking water. An alternative to saving this water is the use of rainwater for non-potable uses (MARINOSKI, GHISI, 2008). As previously mentioned, the neighborhood project provided for the management of water resources and to meet this demand, an artificial lake was inserted in the center of Sneglehusene Housing, which collects rainwater. This collection is carried out by channeling rainwater collected from gutters and roads near the lake, which is directed to the central lake, where it is pumped to a local treatment point for subsequent reuse.

In addition to collecting rainwater, the central lake makes walks in the development more pleasant and also provides a great meeting point for social interaction and interaction with nature. According to Gehl, in cities where the economy is more developed, the quality of the spaces greatly influences the permanence and occupation of spaces (GEHL, 2013). And in all projects developed for NYE, one can notice the concern with planning places for residents to live, stay and interact. Gehl also explains that spaces for pedestrian circulation are comfortable when they do not present many interruptions or obstacles, meaning that pedestrians can move at an acceptable pace and route (GEHL, 2013). In Figure 2 (D), it is possible to observe how passage flows occur in Sneglehusene Housing, allowing inhabitants to move around more easily and often making the journey more pleasant, due to the integration with open areas.

One of the points that were worked on in the project is the concern with the surroundings of the residence. This care is present in the way in which the project was implemented on the land, observing the images and volume (B) presented in Figure 2, it is noted that the buildings integrate in a complementary way with the surroundings. The contour lines provide movement for the project, bringing different heights, which were alternated with the number of floors contained in each building. The shape of the building becomes a complement to the existing buildings designed by another office. In addition to bringing a variety of shapes, where the layout resembles a snail, with a more organic layout, and the facades feature straighter lines.

Figure 2 – Implementation of the NYE Neighborhood and flow plan of the Sneglehusene Housing.



Source: (A e C) <https://nye.dk/foelg-udviklingen/>. (B) <https://sneglehusene.dk/boligvaelger-kort-3/#kort>. (D) [https://www.archdaily.com.br/br/990054/edificio-residencial-sneglehusene-big?ad\\_source=search&ad\\_medium=projects\\_tab](https://www.archdaily.com.br/br/990054/edificio-residencial-sneglehusene-big?ad_source=search&ad_medium=projects_tab). (E) [https://nye.dk/wp-content/uploads/2020/08/Oversigt-med-navne\\_NY-scaled.jpg](https://nye.dk/wp-content/uploads/2020/08/Oversigt-med-navne_NY-scaled.jpg). Accessed on: 21 jan. 2023. Adapted by the Authors.

The central space, in addition to being a good meeting point, can be used to enjoy good weather days: in this region the summer is pleasant, with partly cloudy skies and the hottest month is July, with temperatures between 12°C and 21°C. Winter is cold, with snow and almost cloudy skies, with February being the coldest month, with temperatures between -2°C to 3°C. Due to these temperatures, contact with the sun is well accepted and can be enjoyed using the leisure spaces presented in the residence, such as the playground and walking spaces (WEATHER SPARK, 2022).

## 2. OBJECTIVES

This article aims to analyze the bioclimatic strategies applied at Sneglehusene Housing, located in the city of Aarhus, Denmark, in order to understand how bioclimatic architecture can maximize thermal comfort and reduce energy consumption in buildings, through efficient use of natural resources and the incorporation of renewable energy systems. The text also seeks to highlight the importance of bioclimatic architecture as a sustainable approach to construction that can encourage a healthier lifestyle in cities.

## 3. METHODOLOGY

The methodology was based on studies and research regarding Sneglehusene Housing, with subsequent data analysis. In addition to the general characteristics of the building, the local characteristics where it is located will be presented, as well as the analysis of ventilation and natural lighting, insolation, materiality and landscaping resources used in the construction of the building.

#### **4. RESULTS**

According to Zambrano and Castro-Mero (2020), Bioclimatic Architecture is considered as the practice of building coherently and in accordance with the climatic and natural conditions of the location, promoting the recovery and use of available resources in a rational and well-planned manner. Furthermore, it seeks to integrate the built space into the environment, with among its main characteristics the search for environmental comfort in a passive way, the use of intelligent materials and a design that adapts to the user's needs.

According to Bugening and Kamari (2022), Danish architecture, in general, involves a concern with environmental comfort conditions. Kosir (2019) presents the main bioclimatic strategies for passive cooling and heating used in Denmark, which are similar to those used in Brazil, however, with an extremely different climate and with an emphasis on warming and heat retention. Among the strategies presented by the author for passive heating are thermal insulation, the thermal mass of the building, insulation and conductive heat exchange. Furthermore, natural ventilation, landscaping strategies and materiality are fundamental elements considered in the building under study.

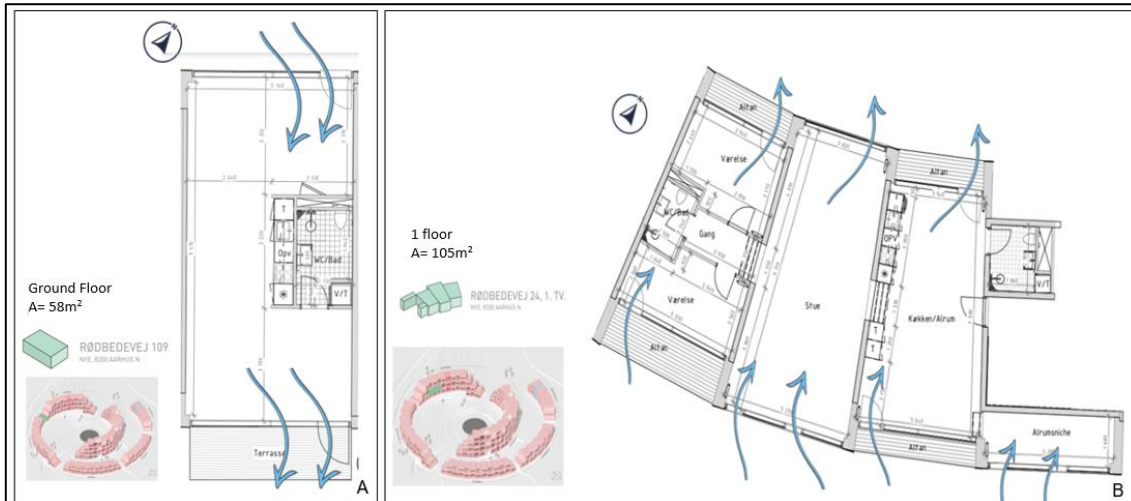
##### **4.1 Natural Ventilation Strategies**

According to Souza and Rodrigues (2012), an adequate natural ventilation project must be evaluated in detail, observing local climatic conditions and wind conditions, so that it is possible to achieve satisfactory results. However, due to the complexity of the surrounding conditions and the unpredictability of natural forces, it is difficult to correctly determine the conditions of wind speed and direction, as these are variable forces that cannot be controlled, as in mechanical ventilation.

The characteristic weather conditions for Aarhus are based on a statistical analysis of historical reports and model reconstructions from January 1, 1980 to December 31, 2016 (Weather Spark, 2022), which present that the average wind speed in Aarhus experiences significant seasonal variations throughout the year. The prevailing winds blow from the west and southwest, for approximately 11 months of the year. The windiest period of the year lasts from September to March, with average speeds above 22.5 kilometers per hour, with the strongest winds reaching a maximum speed of 26.3 km/h in January.

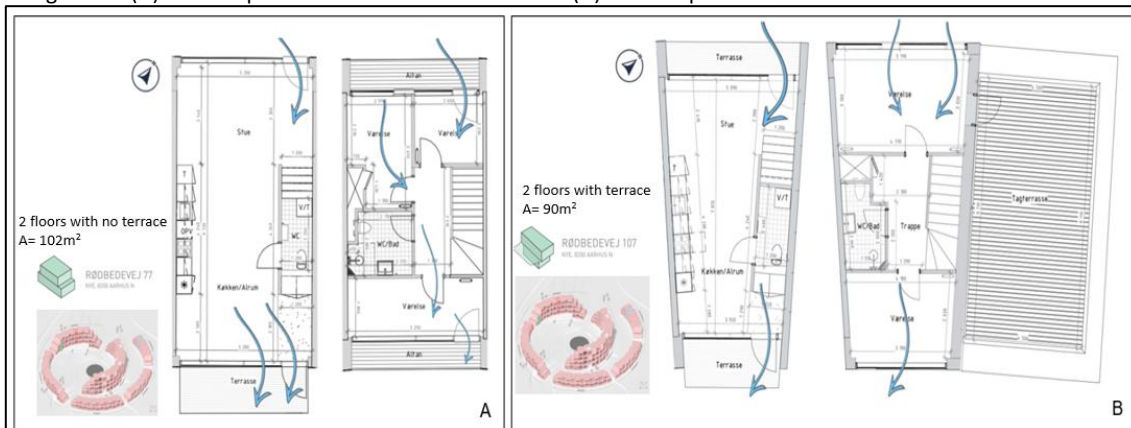
Ventilation corresponds to a strategy for natural cooling of the environment, built through the replacement of warmer internal air and colder external air. Adding these factors to the local climate, cooling ventilation is not necessary, opting only for hygienic ventilation, which aims to maintain healthy conditions in the environment by exchanging internal air. Alloca (2003) states that factors such as number, type, position and size of existing openings for air passage, occupancy profile and position of the building in relation to the predominant wind direction, interfere with the performance of natural ventilation. From the analysis of the incidence of prevailing winds, solar orientation and the positioning of the frames of all housing units, it was possible to conclude that they have effective natural cross ventilation in all rooms, as can be seen in Figures 3, 4 and 5, except in the bathrooms, which use mechanical ventilation through exhaust fans.

Figure 3 – Ground floor apartment with 58m<sup>2</sup> (A). 1-floor apartment with an area of 105m<sup>2</sup> (B)



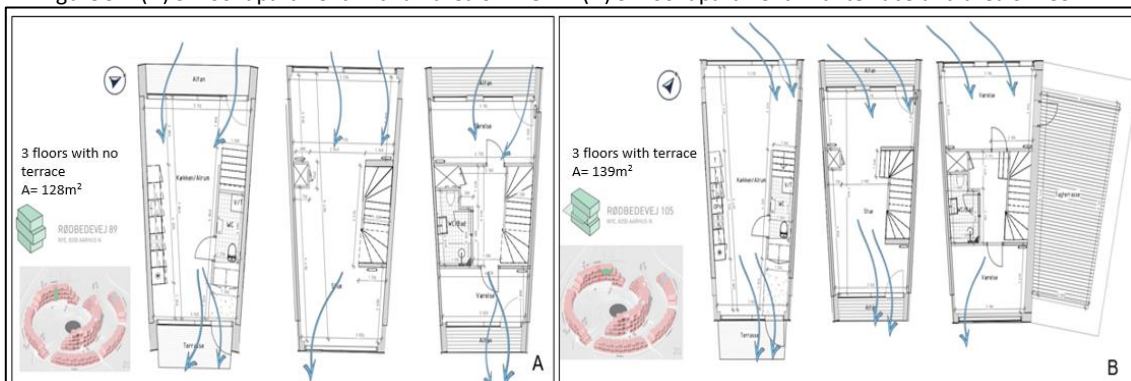
Source: <https://sneglehusene.dk/boligvaelger-kort-1/> Adapted by the Authors. Accessed on: 09 dez. 2022

Figure 4 – (A) 2-floor apartment with an area of 102m<sup>2</sup>. (B) 2-floor apartment with terrace and an area of 90m<sup>2</sup>



Source: <https://sneglehusene.dk/boligvaelger-kort-1/> Adapted by the Authors. Accessed on: 09 dez. 2022

Figure 5 – (A) 3-floor apartment with an area of 128m<sup>2</sup>. (B) 3-floor apartment with terrace and area of 139m<sup>2</sup>



Source: <https://sneglehusene.dk/boligvaelger-kort-1/> Adapted by the Authors. Accessed on: 09 dez. 2022

As can be seen in Figure 6, the windows are of the tilting type, composed of a sheet of glass that opens outwards, with an opening area that allows full use of the opening and with dimensions greater than 1/6 of the floor area.

Figure 6 – Real photo of two different apartments, with emphasis on the fenestrations.



Source: Rasmus Hjortshøj. Available at: <https://www.archdaily.com.br/br/990054/edificio-residencial-sneglehusene-big> Accessed on: 08 dez. 2022.

Despite the size of the openings being considerably small in relation to the glazed area, they are sufficient to exchange the internal air necessary for hygienic ventilation. However, larger openings positioned at a strategic height, closer to the ceiling, for example, would leave the building with the most effective ventilation, however it is worth mentioning that the wind is the main responsible for the total or partial loss of heat.

#### 4.2 Landscaping Strategies

The landscaping was developed by the BIG office and features green paths and meeting points between and around the buildings, promoting spaces for leisure and interaction between residents. The paths converge towards the center of the project, where the artificial lake is located. The project offers private terraces and balconies with different solar orientations, where residents are free to use in whatever way they see fit. They also feature common spaces, such as sidewalks, the lake, flowerbeds and the playground (BIG, 2022).

As a complement to the other vegetated areas, the project offers a green roof, provided by Nature Impact, which offers a system of modules, where a part is removed at the time of installation, leaving the coverage more uniform (NATURE IMPACT, 2022). As the region's climate presents low temperatures at certain times of the year, this system helps maintain the building's internal temperature and, combined with the floor heating system, allows the internal temperature to be maintained, providing greater comfort for users.

Green roofs bring several benefits to urban centers: they function as a filter against pollution, provide environmental and thermal comfort to building users and also help to save energy, in addition to their aesthetic character (OLIVEIRA, 2009). Many types of vegetated roofs have a thermal insulator in their composition, however, those that do not have it, are able to provide a more thermally comfortable environment, due to their thickness, which creates an additional layer to block heat exchange.

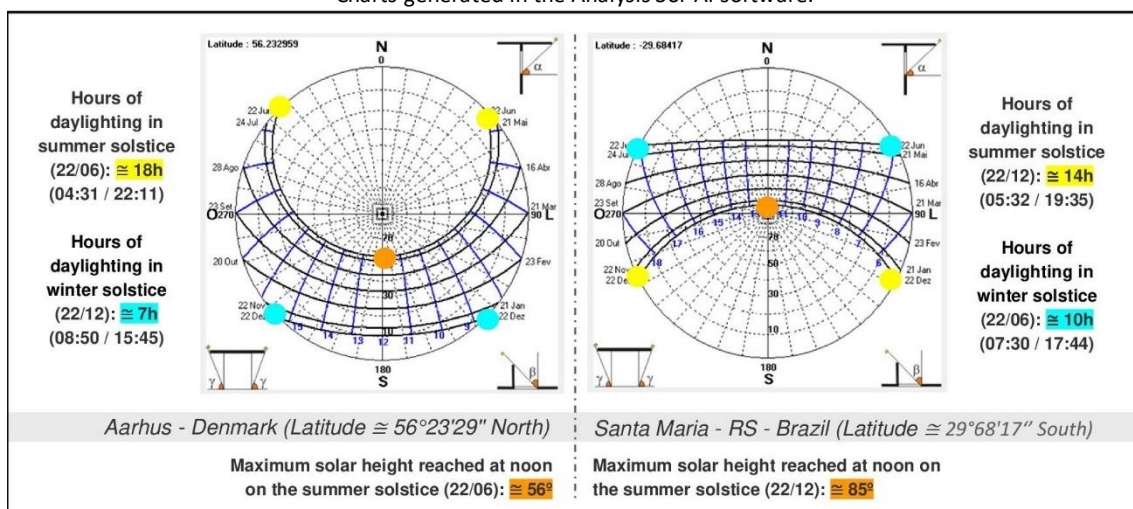
#### 4.3 Natural Lighting and Solar Heating Strategies

According to ABNT NBR ISO/CIE 8995-1 (2013, p.VII), "good lighting provides visualization of the environment that allows people to see, move safely and perform visual tasks efficiently, accurately and safely without causing visual fatigue and discomfort." In this context,

it is important to highlight that natural lighting is perceived in architecture through the apparent trajectory of the sun in relation to the geographic location that this building occupies on the globe, and can be analyzed with the help of solar charts, where you can obtain characteristics such as solar height and direction of solar rays, for certain days and times of the year (LAMBERTS; DUTRA; PEREIRA, 2014).

By carrying out this type of analysis it is possible to identify, for example, the number of daily hours of sun exposure of the building, how the sun's rays behave when falling on each facade and generate comparisons with other locations, in order to relate thermal issues between human perception of temperature and solar height. In Figure 7, a comparison of solar exposure between Aarhus (Denmark) and Santa Maria / RS (Brazil) is presented, using Solar Charts generated in the Analysis Sol-Ar software.

Figure 7 – Comparison of solar exposure between Aarhus (Denmark) and Santa Maria / RS (Brazil), using Solar Charts generated in the Analysis Sol-Ar software.



Source: Authors' collection. 2023

Considering Figure 7, it can be seen that Aarhus (Denmark), Latitude  $\cong 56^{\circ}23'29''$  North, does not reach high temperatures, due to the low solar height, even on the summer solstice, at noon, the maximum point of solar height throughout the year for this location, which is approximately  $56^{\circ}$ , highlighted in orange in Figure 7.

It is important to note that the smaller the solar height angle, the farther the sun will be from the earth's surface. This can be observed when making a comparison with a city with well-defined seasons, as is the case of Santa Maria / RS (Brazil), Latitude  $\cong 29^{\circ}68'17''$  South, where the summer solstice, at noon, is the maximum point of solar height throughout the year for this location, with approximately  $85^{\circ}$ .

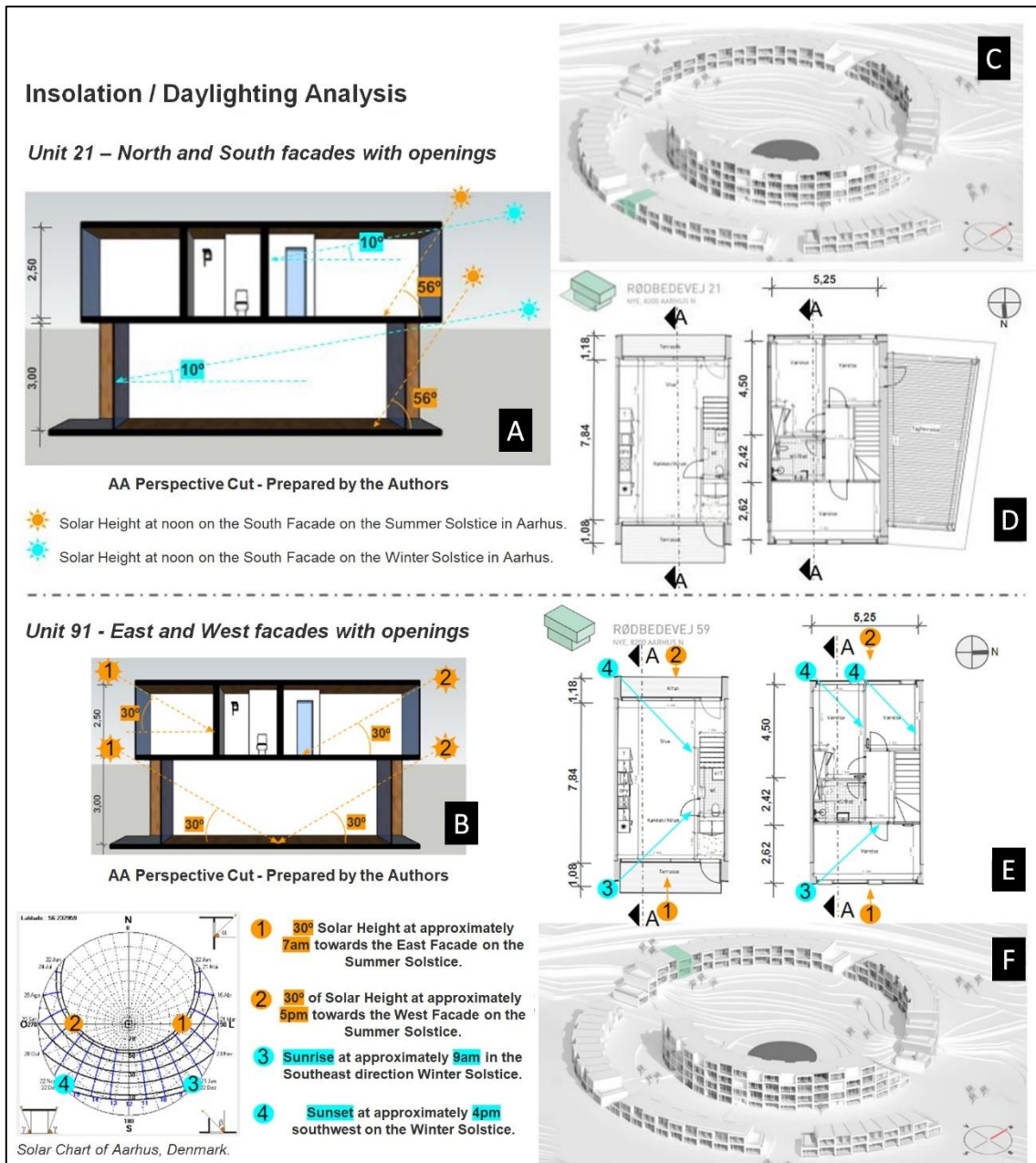
To analyze the solar exposure of the facades and the penetration of solar radiation inside the buildings with the main solar orientations, schematic sections were created in perspective in two housing units: unit 21, whose north and south facades are glazed and the east and west facades have opaque closures; unit 91, whose east and west facades are glazed and the north and south facades have opaque closures. Both are presented in Figure 8.

When analyzing the insolation in housing units of Sneglehusene Housing, low solar height angles can be observed, which reflects the low temperatures in the region, estimated between  $-2^{\circ}C$  and  $21^{\circ}C$  throughout the year (WEATHER SPARK, 2022), when considering the



south façade, at noon, has a solar height of 56° at the summer solstice, falling to 10° at the winter solstice. If we consider the east and west facades, they will have sunlight in a perpendicular direction to the facades with a solar height of 30° in the summer, in the east at 7am in the morning and in the west at 5pm in the afternoon. On the winter solstice, there will be no sunlight perpendicular to the east and west facades, due to sunrise being around 9am and sunset being around 4pm, as can be seen highlighted in blue in numbers 3 and 4 of the Figure 8.

Figure 8 – Perspective sections of Units 21 and 91 of the Sneglehusene Housing, in Aarhus, with solar height indications for their location (A and B). Floor Plans of Units 21 and 91 of the Sneglehusene Housing and Perspectives of the same building with Units 21 and 91 highlighted (C, D, E and F).



Source: (A e B) Authors' collection, 2023. (C, D, E, F) Available at: [https://sneglehusene.dk/wp-content/uploads/2021/04/Sagsnr\\_201.pdf](https://sneglehusene.dk/wp-content/uploads/2021/04/Sagsnr_201.pdf). Accessed on 10 jan. 2023. Adapted by the Authors.

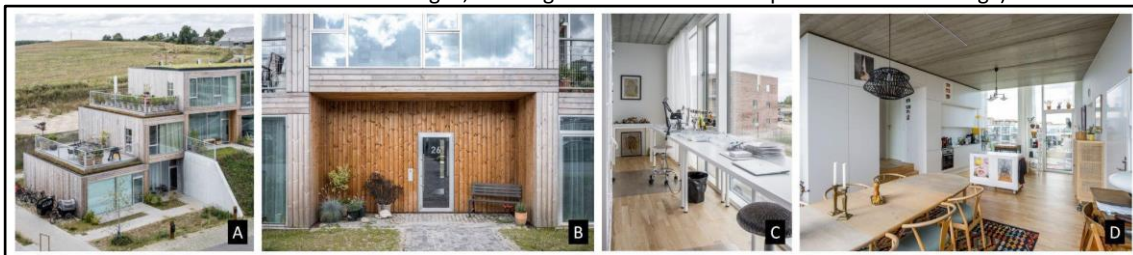
Once we have an understanding of the solar geometry present in the envelope of Sneglehusene Housing and, consequently, the low temperatures that Aarhus presents, we begin an analysis of the materiality and striking characteristics of the built work.

#### 4.4 Materiality

The Sneglehusene, or “snail houses”, consists of two types of modules approximately 5.5m wide by 8m and 10m long, depending on the position, stacked and repeated to create the characteristic checkerboard pattern. Long wooden planks cover the facade on all sides, highlighting the modules and alternating to accentuate the pattern. The two types of housing modules with ceiling heights varying from 2.5 to 3.5 meters, respectively, are stacked to create generous internal spaces, floor-to-ceiling double-glazed windows, and an outdoor terrace in each house (AASARQUITETURA, 2022).

In Figure 9 it is possible to observe the concrete modules covered in wood on the outside, overlapping and/or covered by a green roof or terraces, as well as the glazed facades, and the interiors, with wooden floors and exposed concrete ceiling.

Figure 9 – Photographs of the Sneglehusene Housing (A: External image, showing the concrete modules covered in wood, some terraces and green roofs. B: External image, showing the wooden coverings and double-glazed windows. C and D: Interior images, showing wooden floors and exposed concrete ceilings).



Source: Rasmus Hjortshøj. Available at: <https://www.archdaily.com.br/br/990054/edificio-residencial-sneglehusene-big>. Accessed on: 08 dez. 2022.

The characteristics presented in materiality are intended for the thermal conditioning of the building in low temperature climates, considering the wide range of heavy opaque closures covered by wood, and the presence of double glazing in translucent closures, combining the stimulation of natural lighting in the interiors with thermal insulation. Furthermore, the green roof and wooden floor also help reduce heat loss.

#### 5. FINAL CONSIDERATIONS

In the current context we are living in, it is no longer possible to think about architecture without prioritizing sustainable development strategies. Bioclimatic architecture is increasingly on the agenda, and brings with it the concern to develop projects that better suit the climate, with respect for the environment, buildings and their occupants. Denmark has always been a global reference, both in terms of architecture and in relation to sustainability, being a model of sustainable design and cultural changes, always seeking to encourage a healthier lifestyle in its cities.

The residential project was designed within the environmental issues established for the NYE Neighborhood. Due to this characteristic, the concern with the location where the project was implemented and also with the environment is notable. More and more people are looking

for sustainable environments, but there are few that, in addition to being sustainable, are integrated with nature, which can be found in Sneglehusene Housing. Its landscaping encourages interactions in external areas and the reuse of rainwater is a good example of sustainable practice.

The characteristic climatic conditions of Aarhus lead us to very cold situations, which require strategies more focused on heating and maintaining heat inside the building. Regarding natural ventilation, it was possible to verify that all housing units have a natural cross-ventilation system in all rooms, with the exception of the bathrooms. From the analysis of air flows, it was concluded that, even with a considerably small size in relation to the rooms, the openings present in the housing units are sufficient to exchange the internal air necessary for hygienic ventilation. Larger openings positioned horizontally, closer to the roof of buildings, could bring greater air flow to the interior, without directly reaching the occupants and optimizing cross ventilation. However, considering that the purpose of climate openings in Denmark would only be to renew the air, it is believed that they would cause greater and faster loss of heat inside the building.

When analyzing the insolation of the building, one can see the great difficulties in relation to heating, naturally, through the sun's rays, since Aarhus (latitude of approximately 56° north of the Equator) has low solar height angles, and consequently, a relatively greater distance than countries or cities close to the Equator (Latitude 0). Therefore, the designers opted for a heavy material, which encourages thermal insulation through thermal inertia in order to avoid heat loss, compensating for low temperatures and the resulting low intensity of solar radiation. At the same time, it is important to highlight that even though temperatures are softened by the distance from the sun in relation to the location of the project on the earth's surface, it can be seen from the solar chart that in the period close to the summer solstice in Aarhus, the days are approximately 18 hours of daily exposure to the sun, which is well utilized by the large double-glazed windows on the facades.

Sneglehusene Housing can be considered a beautiful example of a building designed with common well-being in mind and with a focus on bioclimatic architecture. With a variation of residential typologies, it brings a diversity of public to the Nye neighborhood, in Aarhus, its formal design and snail-shaped implementation favors natural lighting, air currents for hygienic ventilation, and the relationship with the environment. Its materiality encourages thermal insulation, and whenever possible, solar heating, in a place with a predominantly cold climate. This is a successful contribution from the renowned BIG Group to its own country.

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