Chapter

Complementary Building Concept: Wooden Apartment Building: The Noppa toward Zero Energy Building Approach

Markku Karjalainen, Hüseyin Emre Ilgın, Marie Yli-Äyhö and Anu Soikkeli

Abstract

Increasing the construction of wooden apartment buildings has its place as part of preventing climate change. This chapter aims to explore the possibilities of expanding the construction of wooden apartment buildings on plots owned by the City of Helsinki in the Mellunkylä area by developing a series-produced wooden apartment building concept suitable for complementary construction—The Noppa concept. The sustainability of this approach is considered from the perspective of materials, construction methods, adaptability of the designed spaces, and housing design flexibility. In this study, the Noppa wooden apartment building concept with cross-laminated timber (CLT) elements has been developed varying in its facilities and architectural design features through architectural modeling programs to be used for complementary construction. The research findings are based on a theoretical approach that has not yet been practically tested but is proposed considering existing construction practices that need further investigation. It is believed that this chapter will contribute to the spread of wooden apartments to achieve a low-carbon economy as one of the key tools in tackling climate change problems. Particularly, proposed architectural design solutions will contribute to decarbonization of buildings as well as zero energy building (nZEB) approach.

Keywords: apartment building, zero energy buildings (nZEB), architectural design, timber/wood, CLT, Finland

1. Introduction

"Net Zero Energy Buildings" will be the next big frontier for innovation and competition in the world's real estate market and can be promptly scaled in Europe as in North America [1]. In this sense, European energy policies introduced the net zero energy building (nZEB) target [2] to promote the energy transition of the construction sector. EU programs, especially "Horizon 2020," introduce the nZEB design as well as its evolution to positive energy building (PEB) model [3]. Especially

the construction industry is one of the main reasons for this problem due to excessive emissions to the environment [4] resulting from the processes of buildings' heating and cooling systems.

Until recently, Finnish building codes were only an incentive to construct low-energy buildings, and Finland had no legislation or guidelines on life-cycle emissions. However, like other Scandinavian countries working toward regional carbon neutrality, Finland targets carbon neutrality by 2035 and is developing policies, including low-carbon construction legislation [5]. Additionally, the Finnish Ministry of Environment has set a target for building life-cycle legislation to account for CO_2 emissions by 2025 [6]. The aim is to influence the total carbon footprint of the construction and the building heating carbon footprint of the energy used through financial incentives [7, 8]. The Finnish Ministry of Environment is considering financial controls over the life cycle of the building to reduce CO_2 emissions, 50 years building life is a set of target control plans [9, 10]. Like Finland's national goal, the Helsinki-Uusimaa Region aims for climate neutrality by 2035 [11].

In this sense, bio-based materials such as wood come to the fore with many advantages such as good indoor air quality, thermal insulation [12]. Bio-based materials are generally hygroscopic; that is, they retain water molecules until an equilibrium state of water content is reached for the relative humidity of the ambient air [13], which positively affects indoor air quality. The performance of these materials can significantly contribute to microclimate comfort by managing energy and mass (vapor) transfer. Furthermore, wood acts as a thermal insulator while also providing a suitable internal surface temperature. Timber also protects from thermal bridges, as it is one of the very few available materials capable of both load bearing and insulation. Wood's volumetric change due to heat is minimal; therefore, for example, in solid wood structures, in glued arrangements, it is considered a good structural material in many cases [14].

Wood construction stands out as one of our best allies in solving the climate crisis, thanks to its positive environmental characteristics such as low carbon emissions during processing and significant carbon storage in use. Additionally, according to life cycle assessment–based research in the literature [15–17] the selection of wood-based materials has a substantially lower impact on CO_2 emissions in comparison with non-wood-based materials as in the study on the life-cycle assessment of a wooden single-family house in Sweden [18]. Wood construction also supports the Finnish government's bio-economic strategy for a carbon-neutral society by 2035 and addresses European climate policy [19]. In particular, engineered wood products (EWPs) such as cross-laminated timber (CLT) are being used in increasingly demanding applications [20] to meet the sustainable construction challenge [21–23]. The many advantages of CLT include low carbon and high thermal insulation, excellent in-plane and out-of-plane strength, high strength-to-weight ratio, and large-scale and high-rise buildings to be built [24, 25].

On the other hand, Finnish residents generally welcome timber construction and multistory timber apartment buildings [26]. They attributed the features of timber apartment building residence such as good sound insulation, good indoor climate, beauty, warm atmosphere, and coziness. Furthermore, they wish for more wood as a visible surface material inside the building and more timber apartment buildings.

Thus, wood-based solutions have traditionally held a strong position in Finland's construction industry, with wood accounting for 40% of all building materials, and about 80% of single-family homes are timber-framed. About 12 million cubic meters of sawn wood were produced in Finland in 2018, and about four-fifths of the sawn wood was used for construction. Moreover, the National Wood Building Programme (2016–2022) in Finland aims to increase wood use and long-term carbon storage in

wood structures by promoting the growth of internationally competitive industrial wood building knowledge and production [27].

The Noppa concept will be implemented in the New Housing Forms—Integration of Living Suburbs (AsuMut) project in collaboration with Tampere University and the City of Helsinki. This project is part of a suburban program managed and funded by the Finnish Ministry of Environment. Three of the cities in the Helsinki suburban program relate to the urban reform area, Malminkartano-Kannelmäki, Malmi, and Mellunkylä. The Helsinki suburban program is connected in addition to several strategic programs of the City of Helsinki, such as the Helsinki City Strategy for 2017–2022, Carbon neutral Helsinki 2035 action program, and Implementation program for housing and related land use [28]. The City of Helsinki aims for carbon neutrality by 2035 and uses wood instead of the concrete structure to achieve this. Changing the segregation of existing residential areas to strengthen their attractiveness creates prosperity for the present and future residents of the area. By increasing the construction of wooden apartment buildings in complementary constructions, the naturalness of wood can bring comfort and humanity to the suburbs.

The focus of the study is the wooden structure development of an apartment concept, where complementary construction projects of mass-produced wooden apartments can be designed. Using the concept, it is possible to design wooden buildings in Helsinki and others in the growth centers of our country with an architectural environment that differs in building stock and additional site requirements. This study targets Mellunkylä, one of the Helsinki-owned plots where the possibility of complementary construction is being considered.

In this context, architectural design has an important opportunity to support sustainable development [29]. In Finland, this will also be promoted toward the end of 2020, graduating from the architectural policy program proposal of the Ministry of Education and Culture as well as the Ministry of the Environment [30], with the main theme being combating climate change and sustainability toward sustainable architecture. In this sense, architects can make a great contribution to a constructive building culture by ensuring the ecological quality and sustainability of the living environment.

On the other hand, it is worth mentioning here that as the population concentrates in cities and available land is depleted, housing flexibility is becoming an essential feature in the transformations of our daily lives [31]. Housing flexibility, which is associated with different typologies, provides the opportunity to change buildings spatially or structurally to meet the needs of building occupants by adapting to technological, cultural, and economic changes that have occurred over time [32]. Housing resilience is based on sustainable consumption in line with building life extension, recycling, and waste management [33]. Today, the need for flexibility in the housing field has become very urgent, which is a fundamental feature of architecture [34]. In this study, housing flexibility is also considered an important architectural design input and contributes to the nZEB approach in terms of its resilient features such as recycling.

Overall, this chapter aims to create higher value-added circular economy opportunities to promote the competitiveness of large-scale industrial timber construction at the local level and to support European climate policy as part of a low-carbon economy. It is believed that this study will help the dissemination of wooden apartment buildings for different and innovative architectural applications as one of the key tools to contribute to decarbonization of buildings and nZEB approach.

2. Research method

This study was carried out with architectural modeling methods used in the solution of research and design problems in architectural activities. This method enables architects to think, write, discuss, and disseminate as a bridge from theory to practice [35]. It is widely used in architectural design research where architects use it as a tool for research methodology [36, 37].

Additionally, at present, there is no single approach to making the object and subject of architectural activity, which inevitably leads to significant differences in research methods and architectural design of objects, especially at such important levels of solving this problem [38]. On the other hand, the precise operation of text and project interaction in architectural design research remains a highly debated and relatively unformed topic [39–42].

Therefore, in this study, main business applications such as AutoCAD, SketchUp, parametric modeling and information modeling methodology of buildings, and complex object modeling methods used in modern architectural design applications (e.g., [43, 44]) were employed. Here, creative proposals are realized through a mix of drawings and models as visual representations to encourage a fresh and lively approach to architectural research. **Figure 1** shows the architectural design steps used in this study as the research method with numerous background variables (e.g., client/user needs and aspirations, project philosophy, design idea and inspiration, marketing, project management, material research, operation management).

Starting points were prepared for the Mellunkylä region (**Figure 2**) to establish the design principles, which have been approved by the City of Helsinki's Urban Environment Board as a basis for further planning in September 2020. The aim of

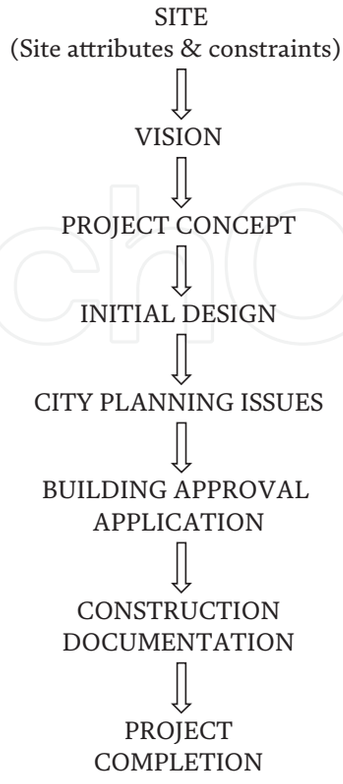


Figure 1.
Architectural design steps used in this study as the research method.

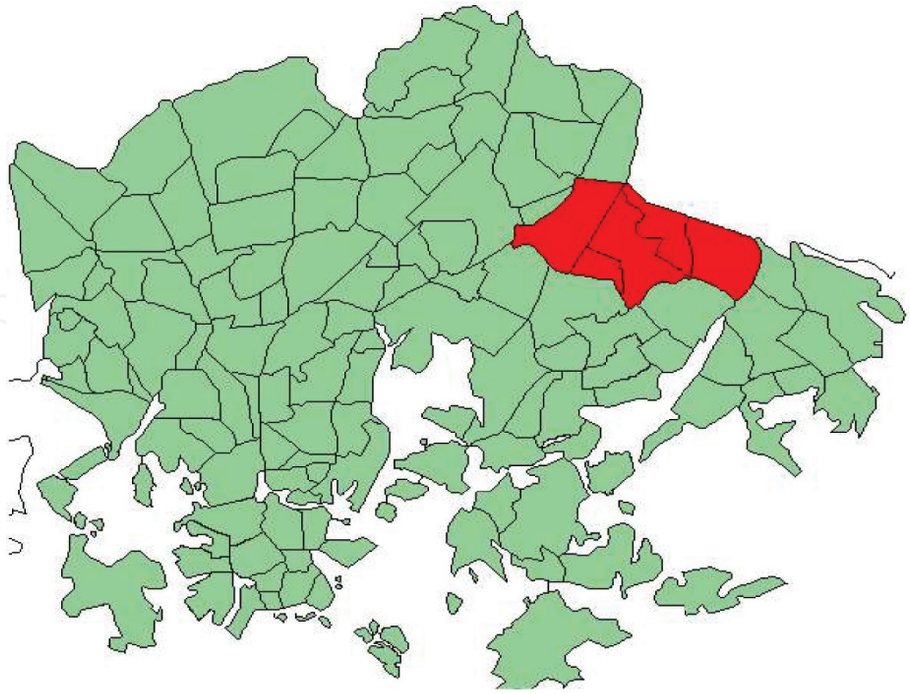


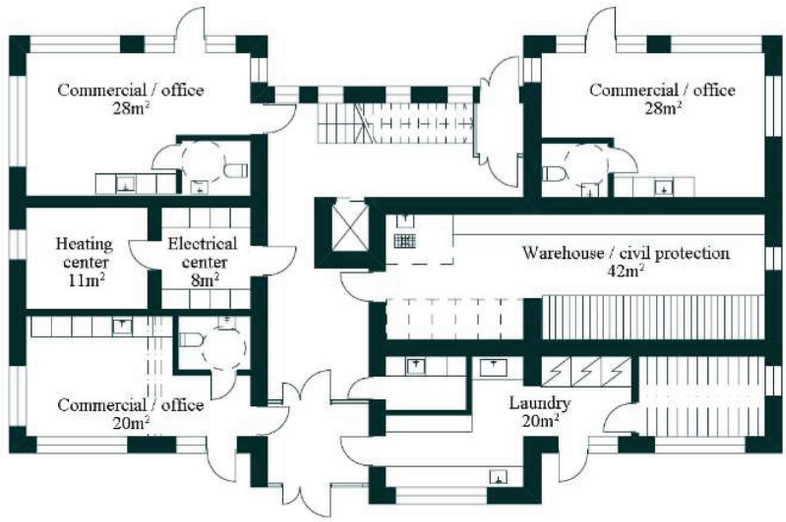
Figure 2.
Mellunkylä region as a district of Helsinki.

the urban reform is to increase the attractiveness of the region by boosting housing and employment, improving accessibility, and enhancing the district public service network together with reducing CO_2 emissions and contributing to nearly zero-energy buildings. According to the design principles in complementary constructions, the aim is to preserve the typical features of the site, as well as their natural environment.

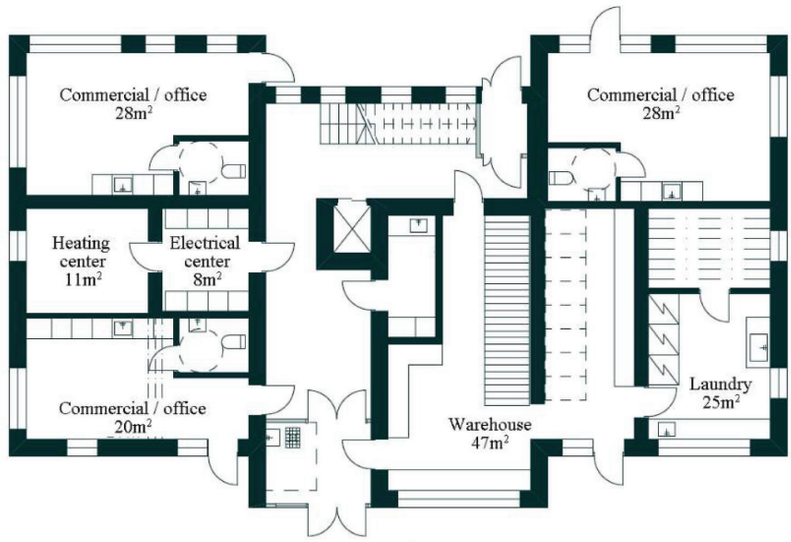
The objective of Noppa approach, the solid house frame apartment concept to be produced in series, is to be a step toward a smoother wooden apartment construction. The starting point of the Noppa concept is to provide functional, aesthetic, and affordable housing facilities with efficient wooden design solutions for different construction site conditions.

As its construction principles, the Noppa approach has a narrow frame and is suitable for its size for well-finished construction sites. If there is space beyond the additional site building, the Noppa apartment building can be converted into an apartment building with two or multiple stairs connecting the short side of the house. The Noppa apartment has a clear basic framework, and its facilities and layout are highly adaptable, where efforts have been made to select feasible structural solutions that are as simple as possible. Standardized structural solutions allow different collaboration of actors in construction chips, and the construction concept can be developed and implemented by several interested parties. The building plan meets the requirements of current legislative building codes in Finland such as the Finnish fire code.

In apartments' floors, volume elements placed on the base layer have 10 apartments of varying sizes (from 53 to 134 m^2) and types. The living areas of the apartments are of reasonable size, and the smallest residences allowed in the regulations cannot be found in the selection of 20 m^2. Adequate sizing of dwellings increases living comfort, the ability of the building to adapt to changing housing needs, and thus longevity. The goal in the design is the premises of the apartment flexible space solutions for functional use. The plan focuses on enabling a diverse mix of housing and transformative spaces within the residences, thereby increasing the value of the



(a)



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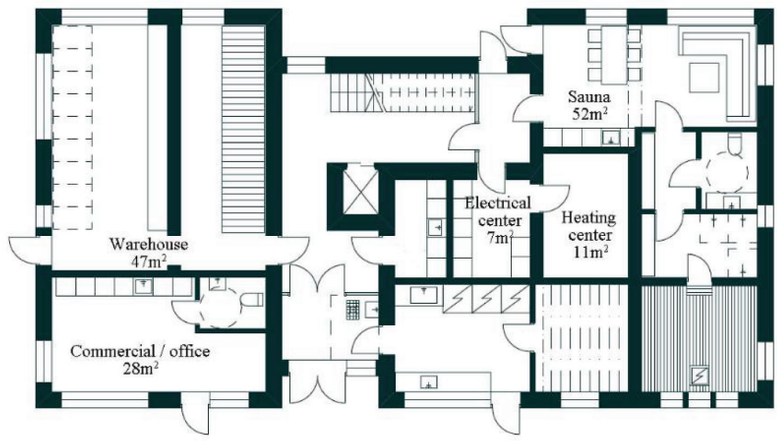

(c)

Figure 3.
Ground floor alternatives: (a) with warehouse/civil protection; (b) no shelter; and (c) with sauna and no shelter.

building in the long run. For ground floors, three different options (**Figure 3**) are provided with all necessary technical services, while many different types of apartments' living floors (**Figure 4**) are proposed.

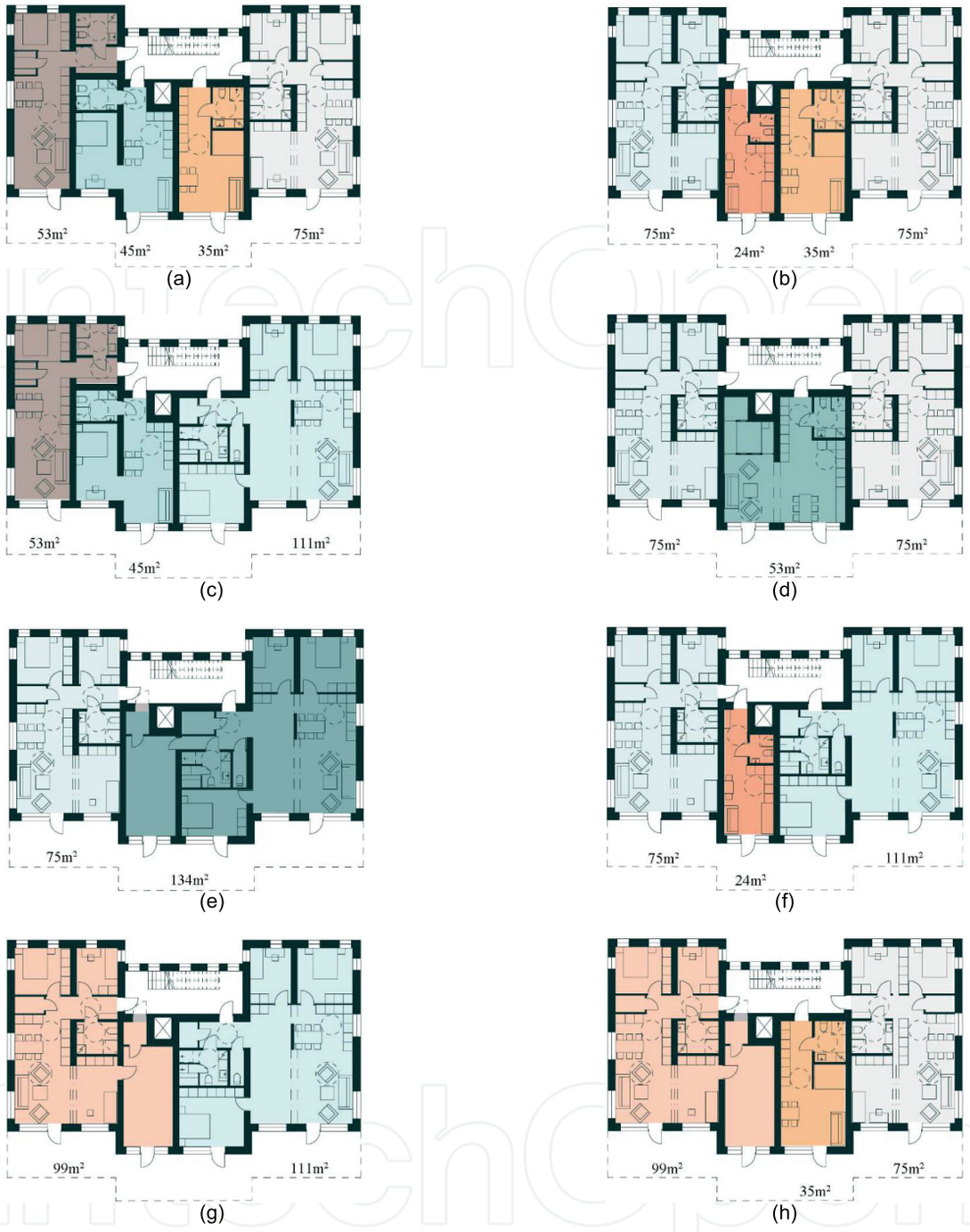

Figure 4.
Living floor alternatives (a–h).

The choice of gable roof supports practical functionality in water management, which is essential for the longevity of a timber-framed apartment building (**Figure 5**). Besides natural ventilation, the use of gravity as a basic solution also requires the shape of the roof to create the height difference necessary for gravity ventilation to be created. The Noppa basic solution has four gable roof options that affect the architecture of the building, for example, the upper tiers space arrangements. There are three balcony solutions, a flat and shaped balcony area across the entire facade, and freestanding, self-contained balcony towers (**Figure 6**).

Figure 7 shows 3D views and typical floor plans of four different alternatives for the Noppa basic solution.

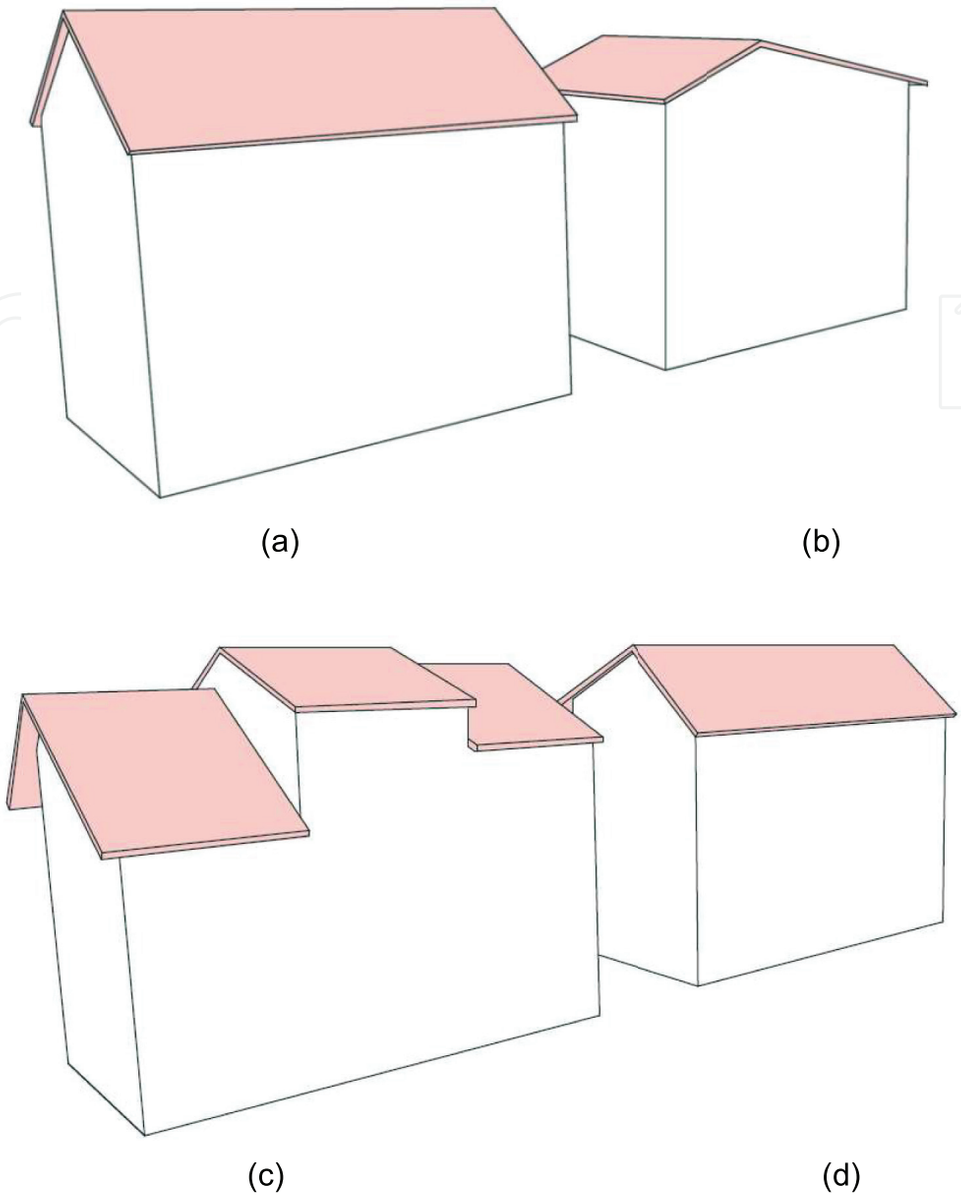

Figure 5.
Gable roof alternatives: (a) symmetrical gable roof; (b) inverted gable roof; (c) partitioned gable roof; and (d) asymmetrical gable roof.

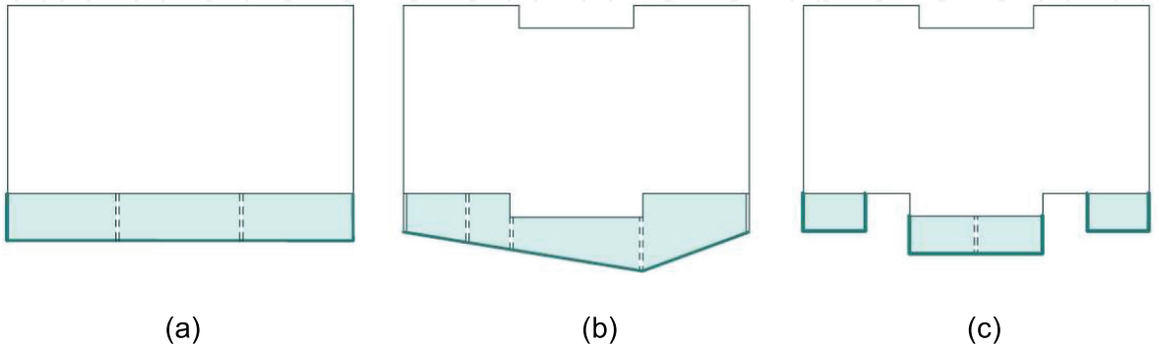

Figure 6.
Balcony alternatives: (a) full facade balcony; (b) shaped balcony; and (c) individual balconies.

(a)

(b)

Figure 7.
Different design alternatives for the Noppa basic solution (a–d).

3. Conclusion

This chapter aimed to search for the possibilities of expanding the construction of wooden apartment buildings in the Mellunkylä region by developing a mass-produced wooden apartment concept suitable for complementary construction—"The Noppa concept." The sustainability of this concept was considered from the perspective

of materials, construction methods, the adaptability of the designed spaces as well as design flexibility. The results were the architectural design proposals based on a theoretical approach considering contemporary applications in the wooden apartment construction market, but further research such as life-cycle assessment will be done as part of other studies.

As a country with a sustainable social structure, a well-educated population, and a high level of technological expertise, Finland has an excellent opportunity to rebuild itself in line with the principles of sustainable development and zero energy building as in the case of Mellunkylä region. Advances in research and product development related to (engineered) wood products with high processing value and long carbon storage times, sustainable use of industry side streams, and ensuring transparency and efficiency in the timber market will contribute to this sustainable development. Furthermore, encouragement of wood structures to function as carbon storage, endorsing material neutrality in fire regulations to reduce the need for double fire protection of wood buildings, and industries and other private investors' contributions to sustainable development by focusing on improving existing processing technologies and making them more resource and energy-efficient play a critical role in this progress.

In this sense, it is believed that this chapter will contribute to the spread of wooden apartments to achieve a low-carbon economy as one of the key tools in tackling climate change problems. In particular, the proposed architectural design solutions will support the decarbonization of buildings and a zero-energy building approach.

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