RENEWING POSTWAR PORTIEKFLATS

A REGENERATIVE BIOBASED APPROACH TO RENOVATION AND DENSIFICATION OF DUTCH POSTWAR GARDEN CITY NEIGHBOURHOODS

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ABSTRACT

The Netherlands houses a large stock of postwar flats in poor condition, which urgently needs to be tackled. Unfortunately, many postwar portiekflats are currently being demolished to make room for new housing. Additionally, there is a housing shortage in the Netherlands, especially in the social sector. This research paper aims to propose a circular, biobased method to renovate and densify the portiekflat typology. The possibilities of growing the required building materials for this renovation and densification in a local, regenerative forest are examined through a prototyping research method, which includes the transformation design of case study flats. The paper presents data about the site's soil characteristics, suitable tree species and forest types for the site and the required quantities of building materials. Consequently, all this information is combined in a concluding diagram, which depicts how a local, regenerative forest of 10 hectare can provide the needed building materials for the case study transformation within 66 years.

Keywords: *Postwar neighbourhood; Renovation; Densification; Biobased materials; Regenerative Forestry; Ecosystem; Circularity*

I. INTRODUCTION

Urban areas commonly possess characteristics that expose their inhabitants to several health threads like air pollution[1], heat stress[2] and the absence of plants[3]. As there is a high demand for more dwellings, the question of how architecture and construction can contribute to healthy living environments becomes very relevant. The current pressure on the housing market in the Netherlands hits several groups of the population, and the Dutch government has launched the plan to create 900.000 new homes by 2030[4]. The social rental sector, for instance, is facing a housing shortage and part of the current stock is in dire need of renovation[5]. Demolishing these outdated buildings to make room for new construction is a widely adopted approach for housing corporations. Building materials that could possibly have performed sufficiently after renovation or transformation, are wasted in this process. Additionally, the building sector largely contributes to CO_2 emissions[6] and commonly applies scarce and polluting building materials. This unsustainable cycle of demolition and construction is wasteful and causes harm to humans and other living beings.

The deficient state of many social housing blocks in combination with the urgent need for more homes calls for building interventions. This offers a context for sustainable and healthy solutions

[1] European Environment Agency, *Air Quality in Europe: 2017 Report*, vol. 13, 2017, https://www.eea.europa.eu/publications/air-quality-in-europe-2017, 28.
[2] Piracha, Awais, and Muhammad Tariq Chaudhary. 2022. "Urban Air Pollution, Urban Heat Island and Human Health: A Review of the Literature" *Sustainability* 14, no. 15: 9234. https://doi.org/10.3390/su14159234.
[3] Evelise Pereira Barboza et al., "Green Space and Mortality in European Cities: A Health Impact Assessment Study," *The Lancet Planetary Health* 5, no. 10 (October 1, 2021): e718–30, https://doi.org/10.1016/s2542-5196(21)00229-1.
[4] Volkshuisvesting en Ruimtelijke Ordening, "Nationale Woon- En Bouwagenda" (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, March 11, 2022).
[5] "Onderzoek Uitfaseren Corporatiewoningen met Energielabels E, F en G," Publicatie | Inspectie Leefomgeving en Transport (ILT), December 20, 2023, https://www.ilent.nl/onderwerpen/vastgoed/documenten/leefomgeving-en-wonen/autoriteit-woningcorporaties/publicaties-cijfers-en-wetgeving/publicaties/onderzoek-uitfaseren-corporatiewoningen-met-energielabels-e-f-en-g#anker-2-woningen-met-energielabels-e-f-en-g.
[6] Khozema Ahmed Ali, Mardiana Idayu Ahmad, and Yusri Yusup, "Issues, Impacts, and Mitigations of Carbon Dioxide Emissions in the Building Sector," *Sustainability* 12, no. 18 (2020): 7427, https://doi.org/10.3390/su12187427.

instead of harmful ones. Primarily housing blocks in postwar garden city neighbourhoods, from approximately 1945-1965, are currently in poor condition. The approach of renovating and transforming these buildings precludes the use and waste of unsustainable building materials that comes with demolition and new construction. Using regenerative forestry to produce local and biobased building materials could offer possibilities to renovate and densify these neighbourhoods in a way that is healthy for human and non-human inhabitants. Therefore, this paper intends to answer the following question: How can regenerative forestry processes provide the products for a biobased building system for the circular renovation and densification of Dutch postwar garden city neighbourhoods? This research is directed at the typology of the portiekflat, which is a common type of building block in Dutch postwar garden city neighbourhoods and makes up a large share of the social housing stock in the Netherlands.

The aim of the research is to present an exemplary model of a renovation and densification project to provide an impression of the spatiality and temporal aspect of building with biobased materials by use of local, regenerative forestry. The results are presented in three chapters, respectively titled Housing, Building Method and Landscape, by means of the following subquestions:

1. Housing
    a. What are the renovation (and transformation) requirements of housing typologies in Dutch postwar garden city neighbourhoods?
2. Building method
    a. Which biobased building methods are suitable for futureproof renovation and densification projects within postwar neighbourhoods?
    b. Which building elements would be needed for the renovation and densification of a postwar portiekflat?
3. Landscape
    a. What does the ecosystem of an ideal regenerative forest in the Netherlands look like?
    b. How can a regenerative forest for biobased building materials be established and managed?
    c. What are the characteristics of the biobased building materials used for the building elements?
    d. What are the quantities of natural resources that would be required for the renovation and densification of a Dutch postwar garden city neighbourhood?

In the Housing chapter required transformation adjustments for the portiekflat typology are presented, which are found through literature review. Additionally, the feasibility of a transformation approach for this typology is evaluated by use of real-life examples. An existing site is introduced in this chapter, which is used as a case study in a prototyping method throughout the research paper. The Building Method chapter presents a biobased building method for the transformation of portiekflats, based on literature exemplary building projects. Consequently, the building elements that are required for the chosen method are identified by use of the case study. In the Landscape chapter the soil characteristics of the case study site are determined, and Dutch tree species, forest types and ecosystem are listed that are suitable for this soil profile. Literature review is used to describe regenerative forest management and possibilities for a circular application of the chosen building materials. The research paper is concluded with a regenerative forest design that can provide the required building materials for the renovation and densification of the case study buildings and that suits the local conditions.

II. HOUSING

2.1. Renovation requirements housing in Dutch postwar garden city neighbourhoods

After World War II the Netherlands was coping with a housing shortage and a poor economic situation. This context necessitated building the large number of much-needed houses cheaply and in a short amount of time.[7] Industrialisation and standardisation in the building sector led to the emergence of building systems which enabled systematic building at a low cost. This construction approach led to repetitive neighbourhoods with little variety of architecture and floor plans.[8] In the postwar period many new neighbourhoods were established in the Netherlands, which were spatially and socialistically inspired by Ebenezer Howard's concept of the garden city.[9] Dutch postwar garden city neighbourhoods are generally characterised by a clear urbanistic grid and open building blocks organised in repetitional units, called *stempels*.[10] Common apartment block typologies in these neighbourhoods are the *portiekflat* and *galerijflat*. Approximately 267.000 and 64.000 dwellings respectively were built with these typologies in the period between 1945 and 1965.[11] Examples of foregoing characteristics can be viewed in Appendix A and the Dutch terminology will be used throughout the paper.

Thus, there is a large stock of portiek- and galerijflats from 1945-1965 in the Netherlands, a part of which are currently in poor condition and in dire need of renovation. Especially for portiekflats, demolition is often chosen as an approach to deal with the current building deficiencies.[12] Typology specific renovation strategies can be implemented in order to save the existing structure. Many technical and spatial problems that are common to the typology can be solved through the following adjustments: removal of asbestos, addition of internal and external insulation (to increase the building envelope's insulation value and to prevent noise nuisance and mould), replacement of apartment kitchens and bathrooms, adjustment of apartment layout (to fulfil modern housing needs), addition of lift and (re)placement of heating or ventilation system.[13] A renovation with this selection of adjustments would have a comprehensive impact by improving accessibility, living comfort and the adequacy of the floor plan.

According to SBR's research about the lifespan of building materials, concrete construction elements can last for more than 100 years.[14] The exact lifespan of a structure varies from building to building and needs to be assessed. It is important to establish how long a support structure can technically last, so that the housing association can evaluate the time span of the renovation or transformation costs. Examples of recent renovation projects suggests that it may be feasible to renovate postwar flats with standardized building systems and concrete structures. Corporation Stadgenoot in Amsterdam, for example, extensively renovated multiple flats in an area called the Bakemabuurt in Amsterdam[15] and is currently preserving 3 other flats in Osdorp through façade insulation, replacement of window frames and installations, maintenance of balcony floors and more.[16] While initial findings suggest the viability of renovating these flats, further research and comprehensive analysis of the specific flats are necessary to establish a more conclusive understanding of the case study.

2.2. Case study portiekflats

In this research, the renovation and densification of an existing stempel is designed and quantified as an example and representation of Dutch postwar garden city neighbourhoods. The common typology of the portiekflat is chosen for this research method of prototyping. Even though every renovation requires customisation, portiekflats can generally be compared due to the similarities in terms of measurements, construction materials and floor plans (see Appendix B.) A stempel in the west of Amsterdam was selected, with flats that were constructed with Baksteen-Montage-Bouw (BMB), the

[7] Blom, Anita. "Vroeg-Naoorlogse Woonwijken." (Zeist: Rijksdienst voor de Monumentenzorg, May 2004), 2.
[8] Ibid, 3.
[9] Blom, Anita, Bregit Jansen, and Marieke Van Der Heiden. "De Typologie van de Vroeg-Naoorlogse Woonwijken." (Rijksdienst voor het Cultureel Erfgoed, April 2004), 14.
[10] Lörzing, Han, and Arjan Harbers. "Naoorlogse Krachtwijken." (Den Haag: Planbureau voor de Leefomgeving, 2009), 26.
[11] "Documentatie Systeemwoningen '50-'75." (Eindhoven: BouwhulpGroep, September 12, 2013), Module 2, 3.
[12] Blom, Anita, Bregit Jansen, and Marieke Van Der Heiden. "De Typologie van de Vroeg-Naoorlogse Woonwijken." (Rijksdienst voor het Cultureel Erfgoed, April 2004), 3.
[13] Argiolu, Raffael, Koos van Dijken, Jos Koffijberg, Gideon Bolt, Ronald van Kempen, Ellen van Beckhoven, Radboud Engbersen, and Godfried Engbersen. Rep. *Bloei En Verval van Vroeg-Naoorlogse Wijken*. (Den Haag: Nicis Institute, 2008), 16.; Garritzmann Architecten. "Kansen Voor de Naoorlogse Portiekflat." https://www.hparchitecten.nl/, 2015. https://www.hparchitecten.nl/wp-content/uploads/2019/10/Kansen-voor-de-naoorlogse-portiekflat.pdf, 4.
[14] Straub, A. *Levensduur van Bouwproducten: Methode voor Referentiewaarden*. (Rotterdam: SBR, 2011.)
[15] "Vernieuwing Bakemabuurt Klaar," Stadgenoot, December 14, 2021, accessed January 17, 2024, https://www.stadgenoot.nl/vernieuwing-bakemabuurt-klaar.
[16] "Braak En Bosch," Stadgenoot, accessed January 17, 2024, https://www.stadgenoot.nl/Project/braak-en-bosch.

fourth most used postwar building system in the Netherlands.[17] The three portiekflats, located in the neighbourhood Osdorp-Oost, consist of five storeys (see Figure 1 and 2.)

Figure 1. Site map of part of Osdorp-Oost, Amsterdam, with case study flats in red. (Image by author)

Figure 2. Black and white photo of one of three case study portiekflats on the Van Suchtelen van de Haarestraat, Amsterdam.[18]

[17] "Documentatie Systeemwoningen '50-'75." (Eindhoven: BouwhulpGroep, September 12, 2013), Module 2, 2.
[18] *Van Suchtelen van de Haarestraat 98-144. Architect: H. van Vreeswijk. Bouwjaar 1960*, photograph (Amsterdam), Gemeente Amsterdam, accessed January 17, 2024, https://archief.amsterdam/beeldbank/detail/fe20426b-d061-1d17-e6e7-aea042a52775/media/6160b097-544e-ec04-6b10-71f4d6fcb623?mode=detail&view=horizontal&q=Van%20Suchtelen%20van%20de%20Haarestraat&rows=1&page=3.

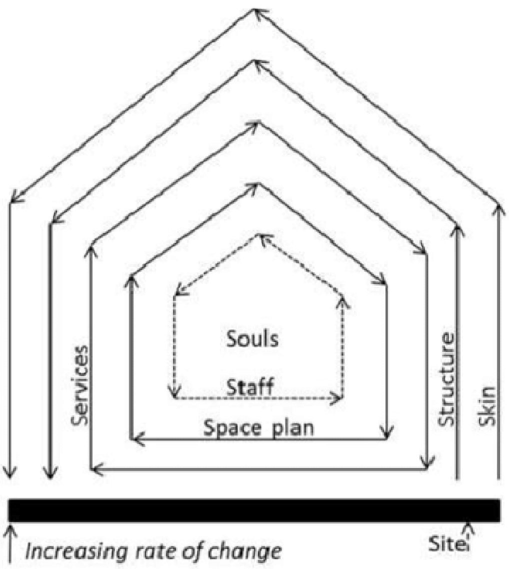
III. BUILDING METHOD

3.1. Biobased building method

The building method for the renovation and densification of the case study portiekflats must comply with two objectives, which are circular building and applicability to the portiekflat typology. Circular construction aims to prevent negative impact on the environment by minimising waste and optimising the use of resources.[19] Additionally, the research focus on local, regenerative forestry calls for exclusive use of building elements that can be constructed from wood. Renovation and densification goals can be met through a lot of different building methods. The renovation design of the case study flats is limited to solving the low thermal insulation value of the buildings by adding an external layer of insulation and replacing windows. The densification objective will be achieved by adding a building storey on top of the existing structure. In a similar transformation project, also located in Osdorp, by Van Schagen Architecten these two building methods are combined.[20]

In the context of augmenting additional building layers onto an existing structure, it is crucial to prioritize lightweight construction methods. Consequently, timber frame construction emerges as the most appropriate building technique for this purpose.[21] The renovation and densification design project SUM of students from TU Delft demonstrates the feasibility of adding up to two new layers on an existing portiekflat with lightweight timber construction.[22] A timber structure is also sufficient for the external insulation of existing buildings. To enable the reuse and recycling of building materials in the future, demountable wood joints can be applied.

3.2. Required building elements renovation and densification postwar portiekflat



Shearing layers	Description	Typical lifespan/activity
Site	Location and context	Permanent
Structure	Bones	30-300 years
Skin	Envelope	20+ years
Services	Lifeblood	7-20 years
Space plan	Interior layout	3 years
Stuff	Furniture and equipment	Under 3 years
Souls	People	Daily

Figure 3. Shearing layers of change by S. Brand.[23]

Brand's framework of shearing layers relates to the different elements that make up a building and their respective lifespans (see Figure 3.) The building elements that are needed for the renovation and densification approach for the case study portiekflats can be identified by use of this model. The renewal

[19] Freek van Eijk, Abdulla Moustafa, and Anca Turtoi, "Circular Buildings and Infrastructure" (European Circular Economy Stakeholder Platform, 2021).
[20] "Complex 50 En 117," Vanschagen Architecten, September 24, 2019, https://www.vanschagenarchitecten.nl/portfolio_page/complex-50-en-117-osdorp/.
[21] Battum, M.T. van. "Enige (on-)Mogelijkheden van Portieketagewoningen Bij Herstructurering van Vroege Naoorlogse Wijken ." (Delft: Faculteit Bouwkunde, TU Delft, February 2002), 167.
[22] "Superduurzame Renovatie Is De Toekomst," TU Delft, May 2022, https://www.tudelft.nl/stories/articles/superduurzame-renovatie-is-de-toekomst.
[23] Danica Stankovic et al., "Reconditioning and Reconstruction: A Second Wind for Serbian Kindergartens," *Procedia Engineering* 117 (2015): 751–65, https://doi.org/10.1016/j.proeng.2015.08.218, 753.

of the existing building envelope can be classified as Skin and the additional construction relates to both Skin and Structure. The content of this research is limited to Skin and Structure, but considering the layers Services, Space plan and Stuff could provide solutions for the other common building problems mentioned in chapter 2.1.

Three groups of building elements are needed for the aforementioned transformation: 1. façade elements, 2. roof elements, and 3. division wall elements (see Figure 4.) The windows and doors are also included in the research, for the existing, as well as the new construction. The three types of building elements consist of different parts (a. exterior door b. window frame c. timber structure d. façade cladding e. wood fiber insulation panel f. OSB panel) and the different compositions and matching performances, depending on the element function and location, are shown in Appendix C. The layer dimensions were chosen in order to comply with Dutch building legislation requirements regarding thermal insulation.[24] Only wooden building materials are mentioned in this paper. Therefore, building parts like roof covering, interior finishing and vapour barriers are missing. Appendix D offers an overview of the required building parts and corresponding suitable tree species, that are native to the Netherlands.

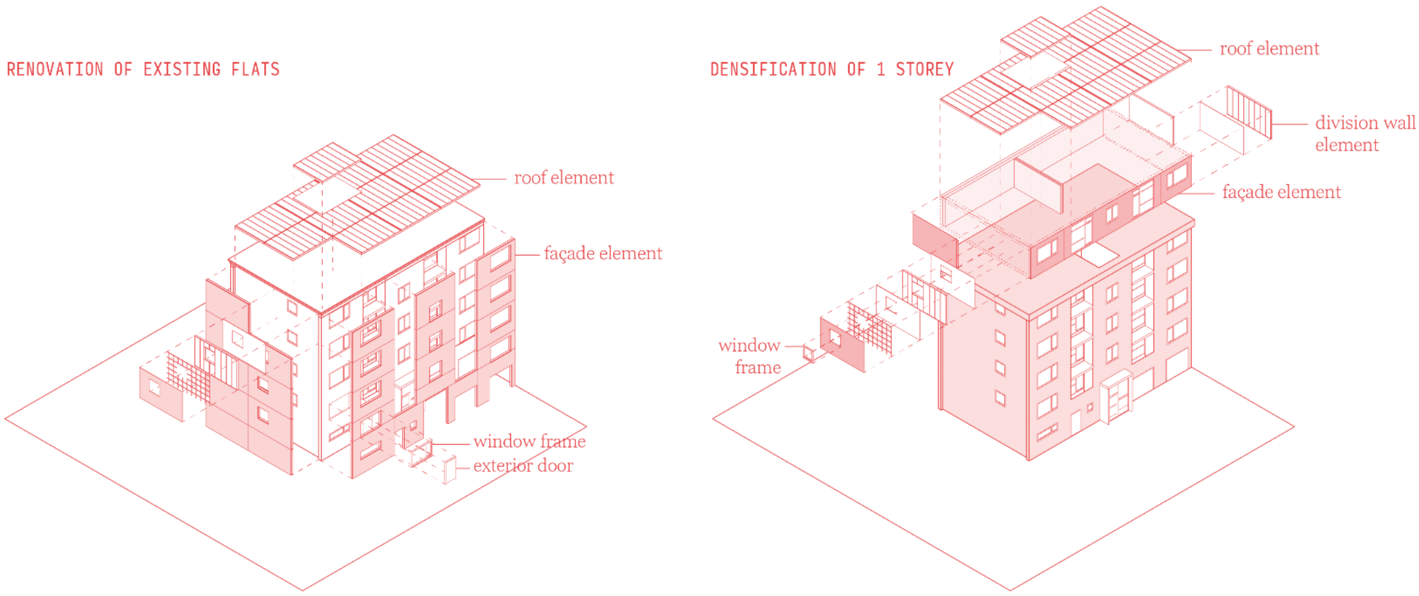


Figure 4. Drawing of case study portiekflat segment (portiek) with the width of two apartments; all apartments in this segment share one stairwell. The left-side diagram shows the elements needed for the building envelope's renovation and the right-side diagram shows the elements of the new construction. The three groups of building elements are specified. (Image by author)

IV. Landscape

4.1. Regenerative forestry

The harmful consequences of conventional agriculture are becoming more evident over time, as biodiversity is declining, soil organic matter is decreasing, and agricultural land is becoming less water resilient.[25] Regenerative agriculture, on the other hand, not only mitigates the detrimental impacts of conventional agriculture but also has the potential to enhance environmental conditions by

[24] "Artikel 5.3. Thermische Isolatie," Bouwbesluit Online, 2012, https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012/hfd5/afd5-1/art5-3?tableid=docs%2Fwet%2Fbb2012%5B35%5D%2Fhfd5%2Fafd5-1&articleid=5.3&fragid=art5.3#art5.3.
[25] David Dent and Boris Boincean, *Regenerative Agriculture: What's Missing? What Do We Still Need to Know?* (Cham: Springer, 2021), ix.; Anderson, Stephanie. *One size fits none: A farm girl's search for the promise of Regenerative Agriculture*. (Lincoln, NE: University of Nebraska Press, 2019.)

fostering the growth of soil organic matter.[26] Similar regenerative outcomes are characteristic of regenerative forestry practices. Although regenerative forestry with a combination of native and non-native species can be successful[27], this research is particularly focused on the value and potential of Dutch native tree species.

Characteristics of the location, like the groundwater balance, microclimate, richness in soil nutrients and soil profile are decisive in establishing the assortment of species to plant.[28] A local soil survey of one to six samples per hectare is advisable to obtain site specific data.[29] As sampling soil is not included in this research, the soil classification and groundwater level are estimated by use of data of the surrounding area.

Peat soil is most common in the city of Amsterdam, which has been raised with a layer of fill sand due to subsidence.[30] Underneath the peat soil, a layer of sea clay soil can be found. The image of soil layers in Amsterdam in Appendix E shows that the soil around Sloterplas, where the case study is located, holds the same composition. The vast majority of built areas is left blank in the soil map of the Netherlands[31], because the soil type often deviates from the original state because of addition and displacement of soil. The soil type, as well as the groundwater level, of the case study site thus remains uncertain and is therefore based on data of adjacent grounds for this paper (see Appendix E.) Appendix F presents a collection of suitable tree species and forest types for the case study location, based on the collected soil type and groundwater data and three books about Dutch forest design. Consequently, trees for the case study project are selected in the same Appendix through comparison of the site-specific suitable tree species and Dutch tree species appropriate for building from Appendix D. The selected tree species and forest type are accompanied by specific plants, animals and other organisms. An overview of all the different organisms in this particular ecosystem is provided in Appendix G, along with characteristics of the selected tree species.

4.2. Regenerative Forestry approaches

Continuous Cover Forestry (CCF) or Close(r)-To-Nature Forest Management (CTNFM) are similar silvicultural approaches to multifunctional forest management, that consider the forest as an ecosystem and aim to improve biodiversity and climate resilience.[32] Even though wood from the forest is used for construction, the main purpose of the forest is not timber productivity. Ideally the applied forestry approach provides a healthy, resilient ecosystem and the harvesting of trees for building materials should be considered as a tool to contribute to the ecosystem's functioning. Soil is an extremely biodiverse habitat, and the performance of ecosystems is positively influenced by a great diversity of soil organisms.[33] CCF and CTNFM have the ability to regenerate the forest soil by way of improving its resilience, carbon storage, fertility and replenishing soil organic matter.[34] Increased soil health in combination with particular forest establishment and management techniques of CCF and CNTFM can benefit the biodiversity of the forest, as well as the adaptability to changing circumstances and resistance

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[26] Craig Elevitch, D. Mazaroli, and Diane Ragone, "Agroforestry Standards for Regenerative Agriculture," *Sustainability* 10, no. 9 (August 4, 2018), https://doi.org/10.3390/su10093337.
[27] Jürgen Bauhus, Klaus J. Puettmann, and Christian Kühne, "Close-to-Nature Forest Management in Europe: Does It Support Complexity and Adaptability of Forest Ecosystems?," *Managing Forests as Complex Adaptive Systems*, February 2013, 187–213, https://doi.org/10.4324/9780203122808-18, 189.; Jørgen Bo Larsen et al., "Closer-to-Nature Forest Management," *From Science to Policy*, April 8, 2022, https://doi.org/10.36333/fs12, 19-20.
[28] Goor, C.P. van, K.R. van Lynden, and H.A. van der Meiden. *Houtsoorten Voor Nieuwe Bossen in Nederland*. (Arnhem: Koninklijke Nederlandsche Heidemaatschappij, 1969), 8.; Jansen, Patrick. *De Aanleg Van Nieuwe Bossen*. (Utrecht: Matrijs, 2009), 85.; Jager, K., and A. Oosterbaan. *Aanleg van Gemengde Loofhoutbeplantingen met Inheemse Soorten*. (Haarlem: Schuyt, 1994), 41.
[29] Jansen, Patrick. *De Aanleg Van Nieuwe Bossen*. (Utrecht: Matrijs, 2009), 85.
[30] Gans, Wim de.v *De bodem onder Amsterdam: Een geologische stadswandeling*. (Utrecht: TNO Geologische Dienst Nederland, 2011), 53.
[31] "Bodemkaart van NL 1:50.000." Map. *Atlas Leefomgeving*. (Wageningen: WENR, 2021.)
[32] Jørgen Bo Larsen et al., "Closer-to-Nature Forest Management," *From Science to Policy*, April 8, 2022, https://doi.org/10.36333/fs12, 4.; E. R. Wilson, "Continuous Cover Forestry: An Introduction" (Silviculture Research International, January 18, 2020).; Jürgen Bauhus, Klaus J. Puettmann, and Christian Kühne, "Close-to-Nature Forest Management in Europe: Does It Support Complexity and Adaptability of Forest Ecosystems?," *Managing Forests as Complex Adaptive Systems*, February 2013, 187–213, https://doi.org/10.4324/9780203122808-18, 187.
[33] Cindy E. Prescott, "Perspectives: Regenerative Forestry – Managing Forests for Soil Life," *Forest Ecology and Management* 554 (February 15, 2024), https://doi.org/10.1016/j.foreco.2023.121674.
[34] Robin Walter, "Regenerative Forestry" (Bristol: Soil Association, January 2022), 32.; Cindy E. Prescott, "Perspectives: Regenerative Forestry – Managing Forests for Soil Life," *Forest Ecology and Management* 554 (February 15, 2024), https://doi.org/10.1016/j.foreco.2023.121674.

to disturbance.[35] Such techniques, that should be implemented to establish and maintain a regenerative forest, are listed in the two following paragraphs.

4.2.1. Regenerative forestry establishment techniques

List of establishment techniques from CCF and CNTFM[36]:

- **Promote the mixture of tree species and genetic diversity.** A combination of broadleaves and N-fixing species is favourable. A mixture of species increases the biodiversity and resistance to storms and decreases the sensitivity to diseases and plagues.
- **Combine native and site adapted non-native species.** This research exclusively includes native species, which generally perform more ecological interactions within the ecosystem. However, this is not always valid and non-native species can have positive effects on the forest's adaptability and biodiversity.

4.2.1. Regenerative forestry management techniques

List of management techniques from CCF and CNTFM[37]:

- **Avoid clearfelling.** Clearfelling is the practice of harvesting all the trees in a forest at once, which can decrease the soil's nutrients. An advantage of avoiding clearfelling is the possibility to harvest each tree at their optimal dimension and value.
- **Avoid intensive management operations.**
- **Avoid overgrazing in case of livestock integration.** Grazing can introduce biodiversity benefits for the ecosystem, but excessive implementation comes with the risk of damaging undergrowth and impedes the natural emergence of new trees.
- **Leave dead (parts of) trees in the forest.** Lying dead logs can form a breeding ground for moss, fern, fungi, and insects.
- **Focus on development of individual trees.**
- **Aim for mixed uneven-aged and structurally diverse forests.** Forests with such characteristics tend to have higher stability, above- and belowground biodiversity and resilience.
- **Promote natural tree generation and natural processes.** This objective stimulates the natural emergence of trees, instead of planting.
- **Dose added nutrients consciously (if necessary.)** If fertilization is used to stimulate forest productivity, it should be quantified with consideration to ensure that it does not adversely affect the soil life.
- **Support the presence of different habitats diversity of the landscape on a small scale.** This approach benefits the forest's biodiversity and can be achieved by saving existing habitats and

[35] Jürgen Bauhus, Klaus J. Puettmann, and Christian Kühne, "Close-to-Nature Forest Management in Europe: Does It Support Complexity and Adaptability of Forest Ecosystems?," *Managing Forests as Complex Adaptive Systems*, February 2013, 187–213, https://doi.org/10.4324/9780203122808-18, 194, 199, 202-203; Jørgen Bo Larsen et al., "Closer-to-Nature Forest Management," *From Science to Policy*, April 8, 2022, https://doi.org/10.36333/fs12, 22.; Cindy E. Prescott, "Perspectives: Regenerative Forestry – Managing Forests for Soil Life," *Forest Ecology and Management* 554 (February 15, 2024), https://doi.org/10.1016/j.foreco.2023.121674.

[36] Jørgen Bo Larsen et al., "Closer-to-Nature Forest Management," *From Science to Policy*, April 8, 2022, https://doi.org/10.36333/fs12, 19-20.; Cindy E. Prescott, "Perspectives: Regenerative Forestry – Managing Forests for Soil Life," *Forest Ecology and Management* 554 (February 15, 2024), https://doi.org/10.1016/j.foreco.2023.121674.; Jürgen Bauhus, Klaus J. Puettmann, and Christian Kühne, "Close-to-Nature Forest Management in Europe: Does It Support Complexity and Adaptability of Forest Ecosystems?," *Managing Forests as Complex Adaptive Systems*, February 2013, 187–213, https://doi.org/10.4324/9780203122808-18, 190.

[37] Jørgen Bo Larsen et al., "Closer-to-Nature Forest Management," *From Science to Policy*, April 8, 2022, https://doi.org/10.36333/fs12, 20.; Cindy E. Prescott, "Perspectives: Regenerative Forestry – Managing Forests for Soil Life," *Forest Ecology and Management* 554 (February 15, 2024), https://doi.org/10.1016/j.foreco.2023.121674.; Simon Klingen, "Honderdtwintig Meter Geïntegreerd Bos ," Klingen Bomen, 2024, https://klingenbomen.nl/honderdtwintig-meter-geintegreerd-bos-b.; Klingen, Simon, Marijke Hoenderdos, and Gerda Peters. *Houtfabriek: 21 Misverstanden over Bos en Bomen*. (Doorn: Klingen Bomen, 2022.); Jürgen Bauhus, Klaus J. Puettmann, and Christian Kühne, "Close-to-Nature Forest Management in Europe: Does It Support Complexity and Adaptability of Forest Ecosystems?," *Managing Forests as Complex Adaptive Systems*, February 2013, 187–213, https://doi.org/10.4324/9780203122808-18.;

habitat trees, and by directed thinning to create landscape variation in sunlight, composition etc.

- **Implement partial harvests and sustainable harvesting management.** Avoid creating harvested area further than 10 meters away from a living tree to maintain the diversity of the underground ecosystem. Sustainable management is characterised by harvesting less than the increment and aims to maintain the forest and ensure the future availability of wood.

4.3. Characteristics biobased building materials

Appendix H contains an estimation of the lifespan of the used building materials for the renovation and densification. A cascading method can be implemented to handle materials in a more sustainable and circular way. Cascading aims to apply a resource in the most high-quality application possible and to make use of a resource as long as possible by processing it into different applications through time.[38] This approach can be analysed by use of the R-ladder model, which hierarchically presents different ways of handling resources in a circular economy, with refusing use at the top and recovering energy at the bottom.[39] The cascading approach relates to the R-strategies repurpose and recycle. The wood from the case study project can be used and processed based on the principles of the cascading method and the approximate lifespan of the used elements. High quality wood would first be manufactured into structural beams, window frames or doors. Subsequently, those elements can first be processed into OSB panels and eventually into wood fiber boards. The last step would be burning to recover the last energy embedded in the wood product (see Figure 5.)

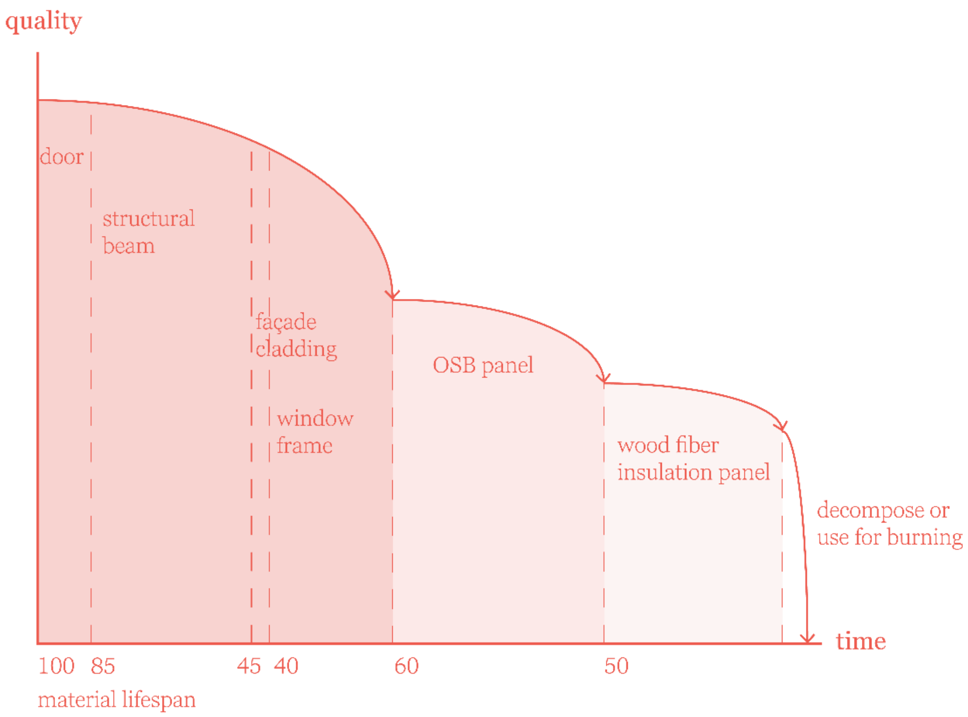

Figure 5. Cascading method diagram related to the case study transformation project. (Image by author, inspired by diagrams by Fraanje & Lafleur[40])

4.4. Quantities natural resources

[38] Fraanje, P.J, and M.C.C Lafleur. *Verantwoord Gebruik Van Hout in Nederland*. Ivam Environmental Research, Nr. 94-08. (Amsterdam: IVAM Environmental Research, 1994), 61.

[39] CIRCULARISE, "R-Strategies for a Circular Economy," November 9, 2023, accessed April 26, 2024, https://www.circularise.com/blogs/r-strategies-for-a-circular-economy.

[40] Ibid.

The required amount of natural resources for the renovation and densification of the case study flats is calculated based on the measurements of the needed building parts. An overview of the determined needed cubic metres of wood is provided in Appendix I. Consequently, Appendix J contains a diagram that presents the connection of the required building materials, matching quantities and the size and timespan of a local, regenerative forest that provides those materials. Additionally, the tree trunks sizes and sawing patterns are presented, that provide the wooden beams needed for the different building parts. In Appendix K an elaborate explanation of the diagram and used research methods is provided. The outcomes of the research demonstrate that a regenerative forest of 10 hectares could provide the needed building materials for the renovation and densification of the three case study portiekflats after 66 years.

V. CONCLUSIONS

In their current state, postwar portiekflats require the following adjustment to meet modern housing conditionds: removal of asbestos, addition of internal and external insulation (to increase the building envelope's insulation value and to prevent noise nuisance and mould), replacement of apartment kitchens and bathrooms, adjustment of apartment layout (to fulfil modern housing needs), addition of lift and (re)placement of heating or ventilation system. This research paper focuses on renewal of the building envelope and densification by adding one storey. The biobased building method of timber frame construction can be applied for both adjustments. The building parts, needed for this transformation approach, that can be manufactured from wood, can be divided into four categories: timber frame construction elements, façade cladding, frames and doors. Apparent soil type and groundwater levels of the case study site offer favourable conditions for specific tree species and ecosystems. An Oak forest combined with Alder, Ash and Poplar trees would respond well to the site characteristics and can provide wood that is appropriate for the needed building elements. Forest establishment and management techniques from the Continuous Cover Forestry (CCF) or Close(r)-To-Nature Forest Management (CTNFM) approaches can be applied to maintain a regenerative forest and to benefit the forest's biodiversity, as well as the adaptability to changing circumstances and resistance to disturbance. A forest with aforementioned tree species and management approach of 10 hectare could provide the building materials for the renovation and densification of the three case study portiekflats in 66 years. When the life expectancy is reached, the biobased building parts of the renovation could be processed into new materials and reused. This cascading method contributes to the circular building objective of the research.

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APPENDIX A.

Visuals of characteristics of Dutch postwar garden city neighbourhoods

Clear urban grid, repetitive neighbourhoods[1]

Portiekflat typology[4]

Open building blocks, organised in 'stempels'[2]

Galerijflat typology[5]

Little variation in architecture and floor plans[3]

[1] Luchtfoto van Geuzenveld in Noordoostelijke Richting; 1968. n.d. Photograph. Van Eesteren Museum. Van Eesteren Museum. https://vaneesterenmuseum.nl/nl/de-tuinsteden/geuzenveld/.
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APPENDIX B.

Dimensions comparison of several Dutch postwar galerij- and portiekflats, that were built with common buildings systems (with historical drawings)

	MUWI - GALERIJ De Heuvel, Leidschendam	BMB - GALERIJ Buitenveldert, Amsterdam	COIGNET - GALERIJ Molenwijk, Amsterdam	RANGE	AVERAGE
depth building [mm]	11.040	10.800	11.060	10.800 - 11.060	10.967
width apartments (centre distance) [mm]	7820	7000 (3 room) 9200 (4 room)	7500 (3 room) 10.500 (4 room)	7000 - 7500 (3 room) 7820 - 10.500 (4 room)	7250 (3 room) 9173 (4 room)
rooms	4 rooms	3/4 rooms	3/4 rooms		
area apartments [m^2]	76	67 (3 room) 78 (4 room)	79 (3 room) 95 (4 room)	67 - 79 (3 room) 76 - 95 (4 room)	73 (3 room) 83 (4 room)
area outdoor space [m^2]	4,8	3,9	11,5 (3 room) 16,2 (4 room)		
width galery [mm]	1300	1300	1540	1300 - 1540	1380
ceiling height [mm]	2570 3020 (gr.)	2567 2555 (gr.) / 3905 (1st)	2640 2400 (gr.)	2570 - 2640	2592
thickness floor [mm]	190 (structural) 230 (total)	170 (structural) 195 (total)	160	160 - 190 (structural) 160 - 230 (total)	173 (structural) 195 (total)
thickness roof [mm]	190 (structural) 340 (total)	170 (structural) 285 (total)	160 (structural) 230 (total)	160 - 190 (structural) 230 - 340 (total)	173 (structural) 285 (total)
thickness façade [mm]	270/360	257/350	200/270 105 (curtain wall)	200 - 270/270 - 360	242/327
thickness loadbearing walls [mm]	210	200	180	180 - 210	197
levels [mm]	6	9	11		

	MUWI - PORTIEK De Heuvel, Leidschendam	BMB - PORTIEK Buitenveldert, Amsterdam	COIGNET - PORTIEK Homerusbuurt, Rotterdam	RANGE	AVERAGE
depth building [mm]	10.600	10.000	10.090	10.000 - 10.600	10.230
width apartments (centre distance) [mm]	8300	8270	6900 (3 room) 9450 (4 room)	6900 (3 room) 8270 - 9450 (4 room)	6900 (3 room) 8673 (4 room)
rooms	4 rooms	4 rooms	3/4 rooms		
area apartments [m^2]	76	69	75 (3 room) 85 (4 room)	75 (3 room) 69 - 85 (4 room)	75 (3 room) 77 (4 room)
area outdoor space [m^2]	10,7	6	7,8		
ceiling height [mm]	2600 2200 (gr.)	2590	2780 (met vloer)	2590 - 2780	2657
thickness floor [mm]	200	170 (structural) 195 (total)	160	160 - 200	185
thickness roof [mm]	270	170 (structural) 285 (total)	160 (structural) 160+25 = 185 (total)	185 - 270	247
thickness façade [mm]	330	260	180 (structural) 180+25 = 205 (total)	205 - 330	265
thickness loadbearing walls [mm]	220	200	180	180 - 220	200
levels [mm]	6	4	5		

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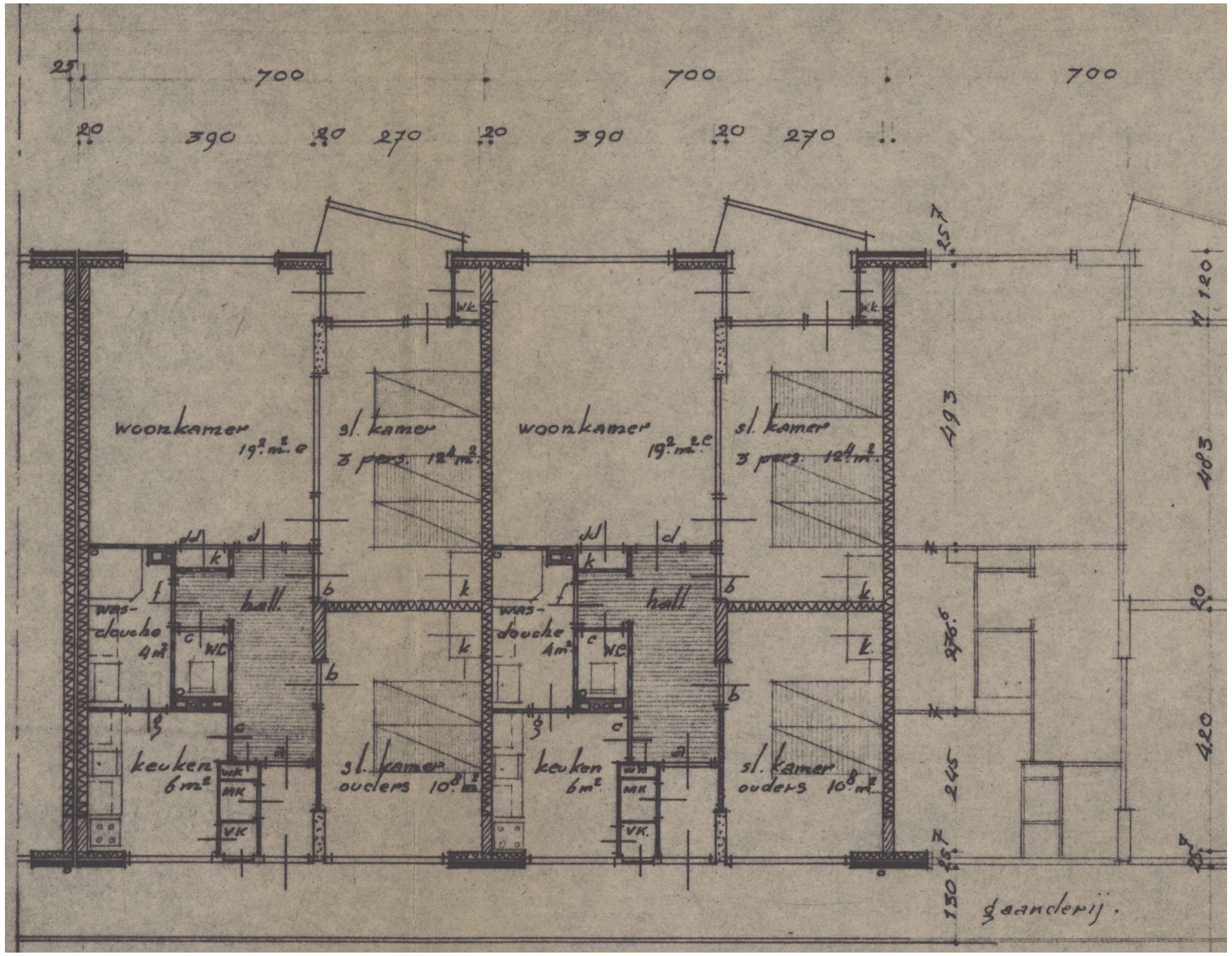
BMB GALERIJ Buitenveldert, Amsterdam (1965)



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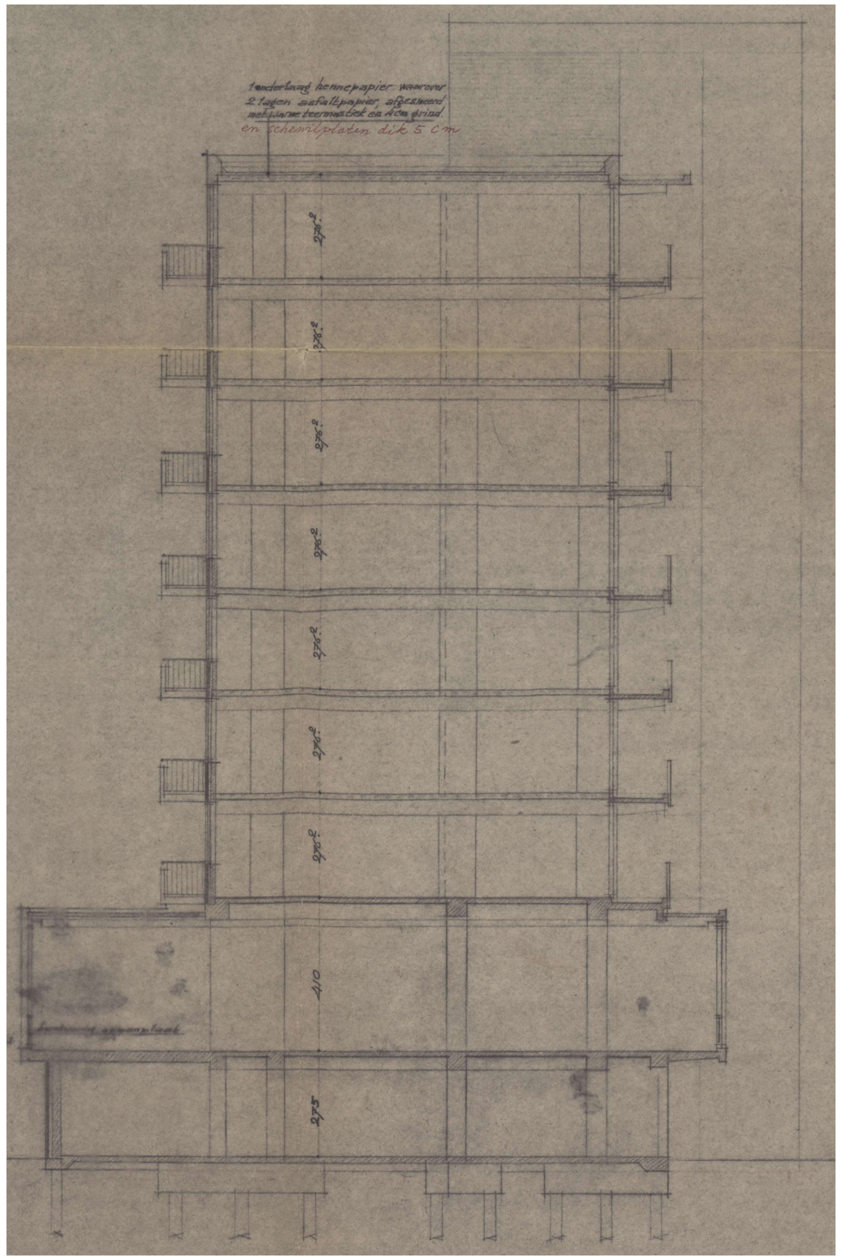

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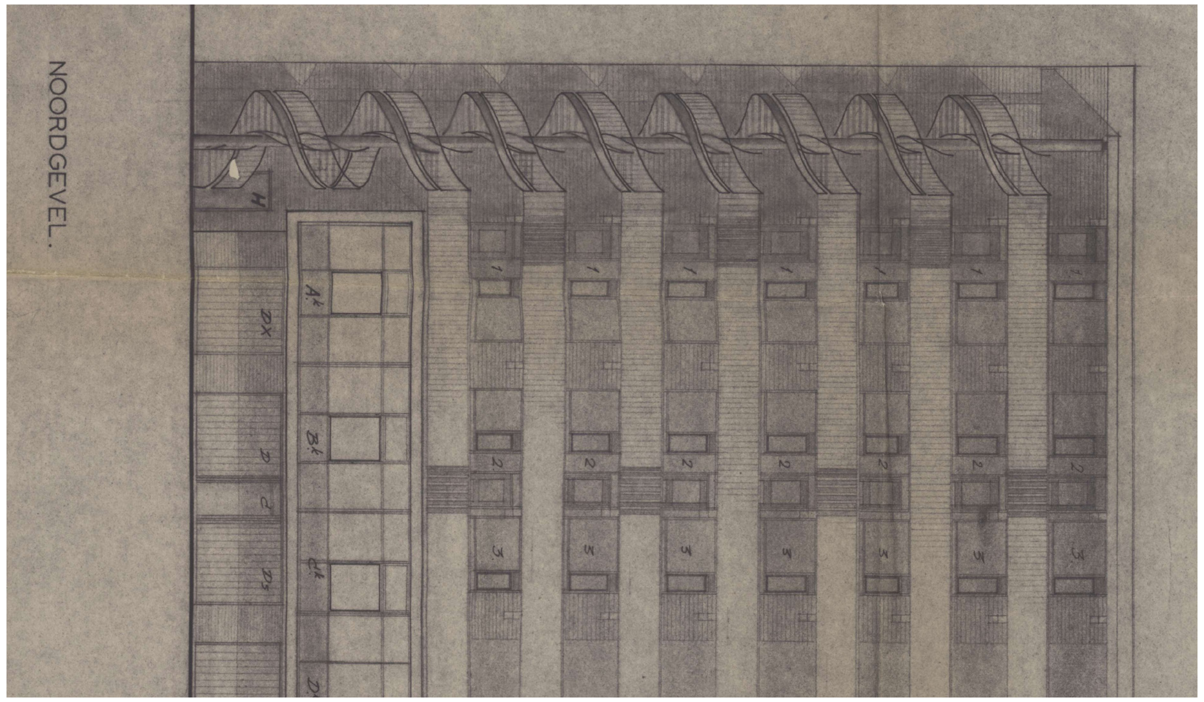

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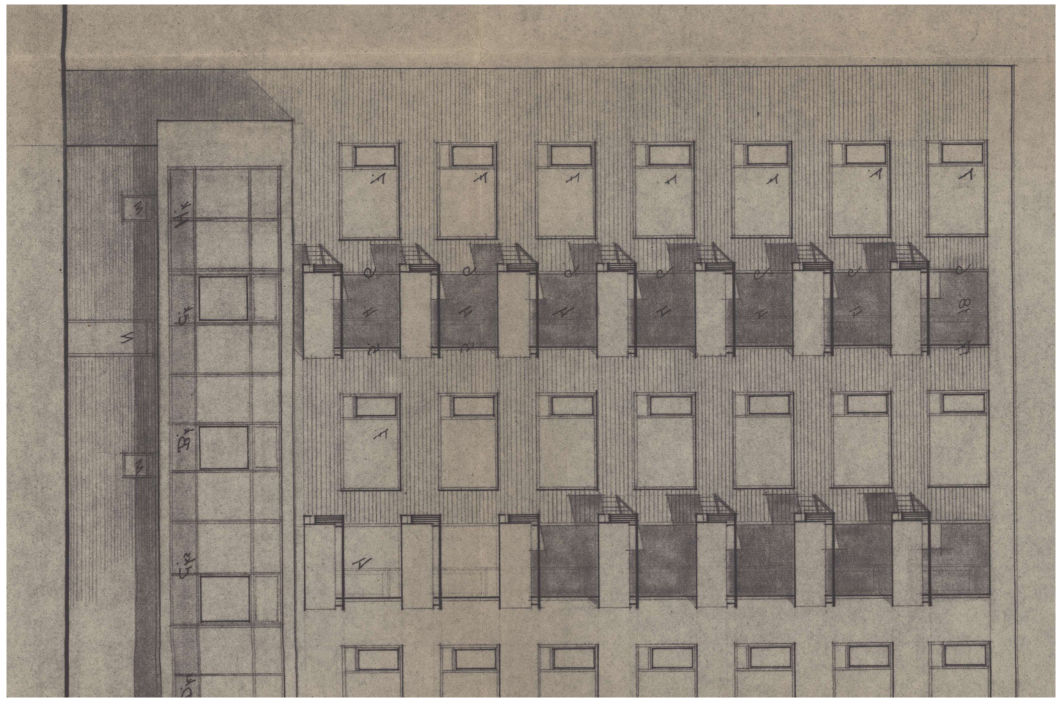

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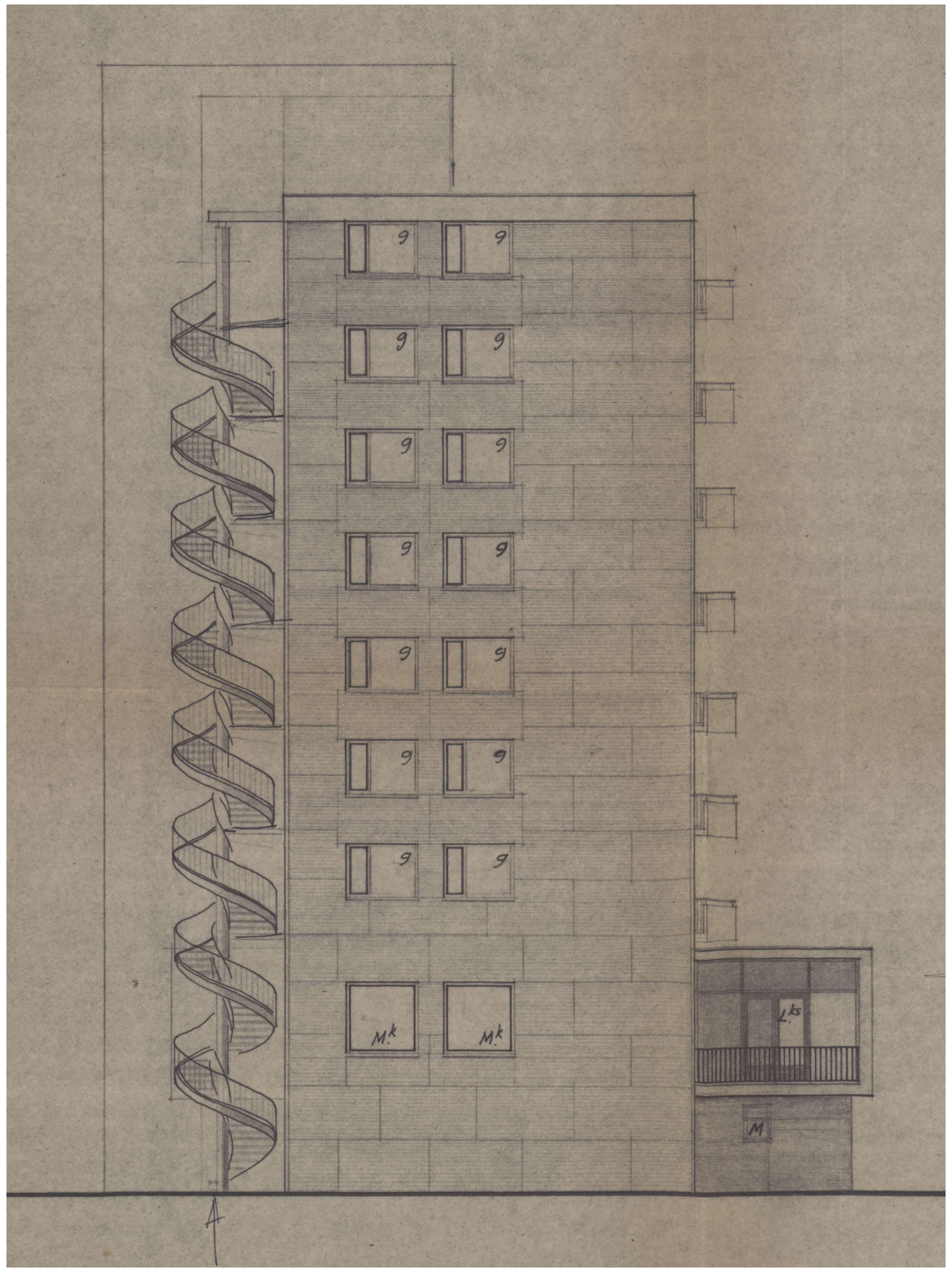
BMB GALERIJ Buitenveldert, Amsterdam (1965)



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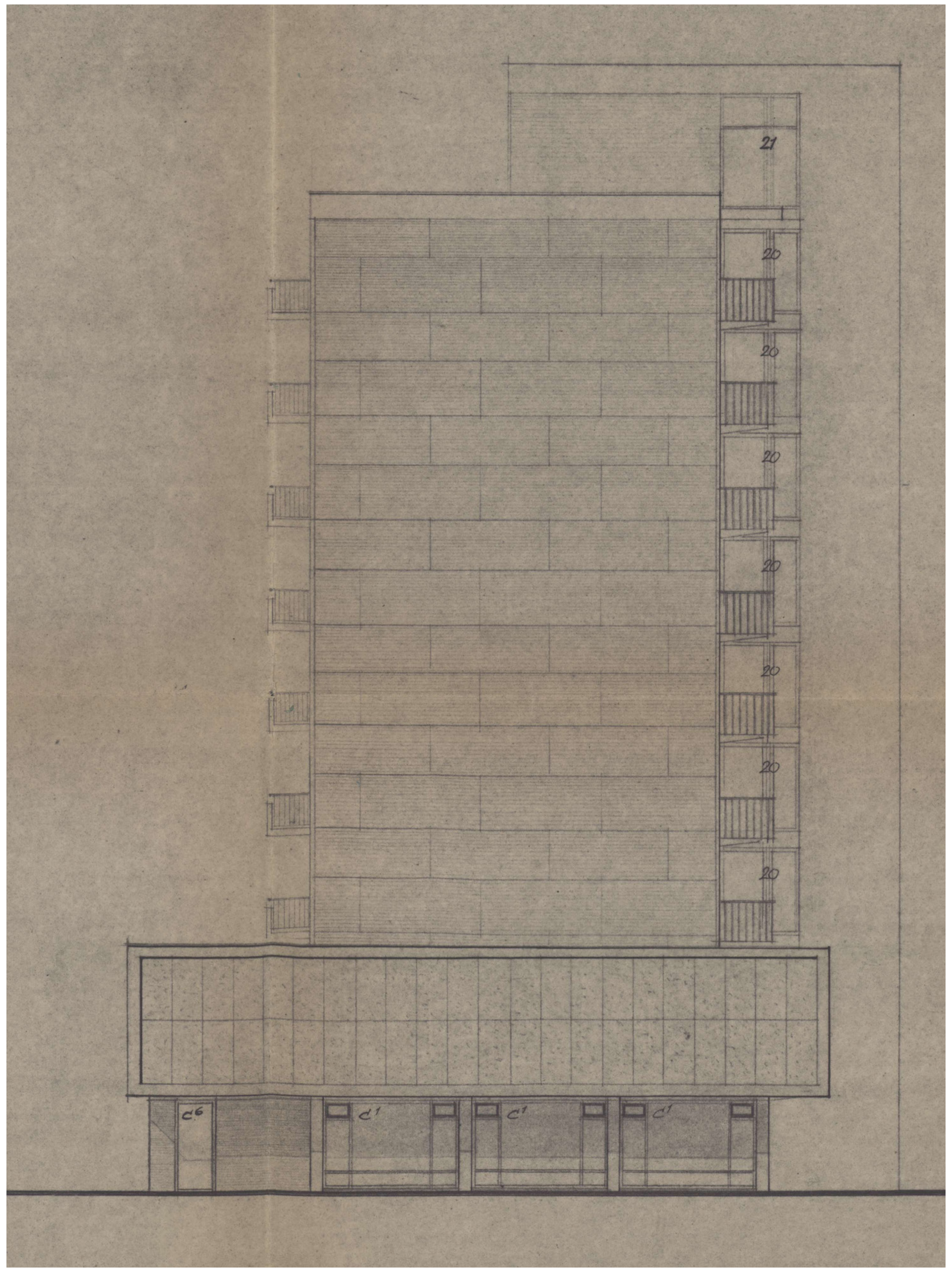

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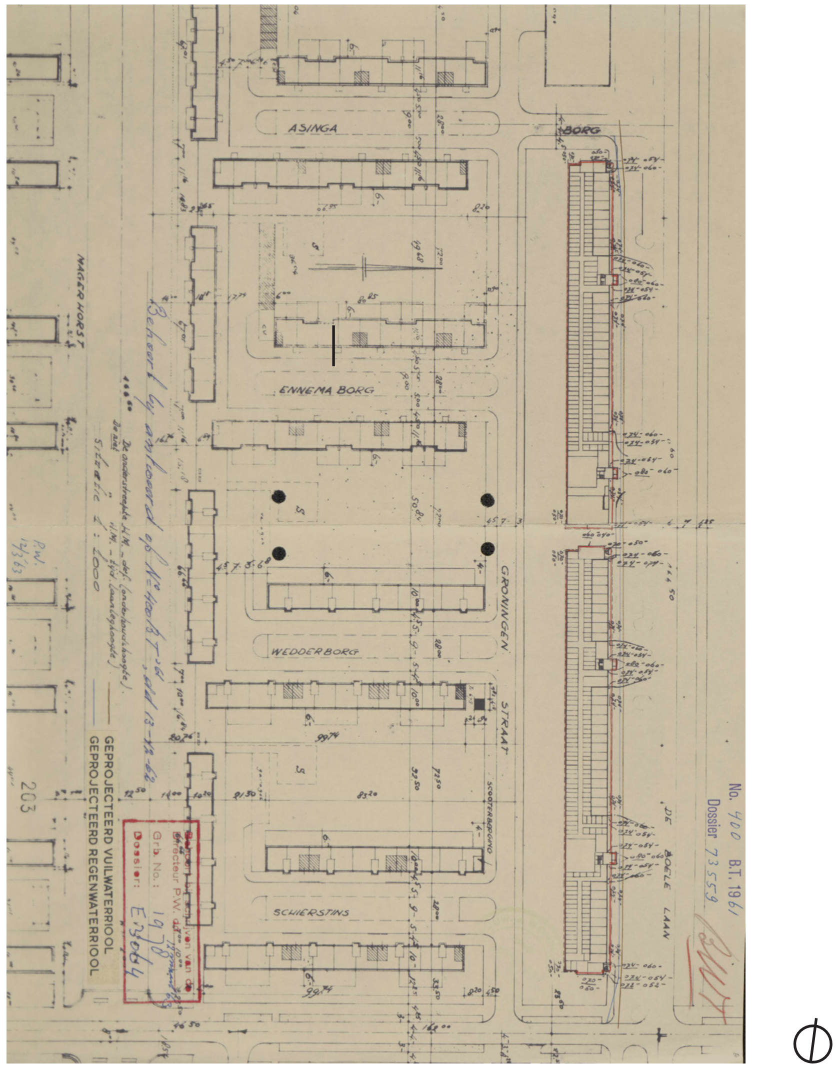

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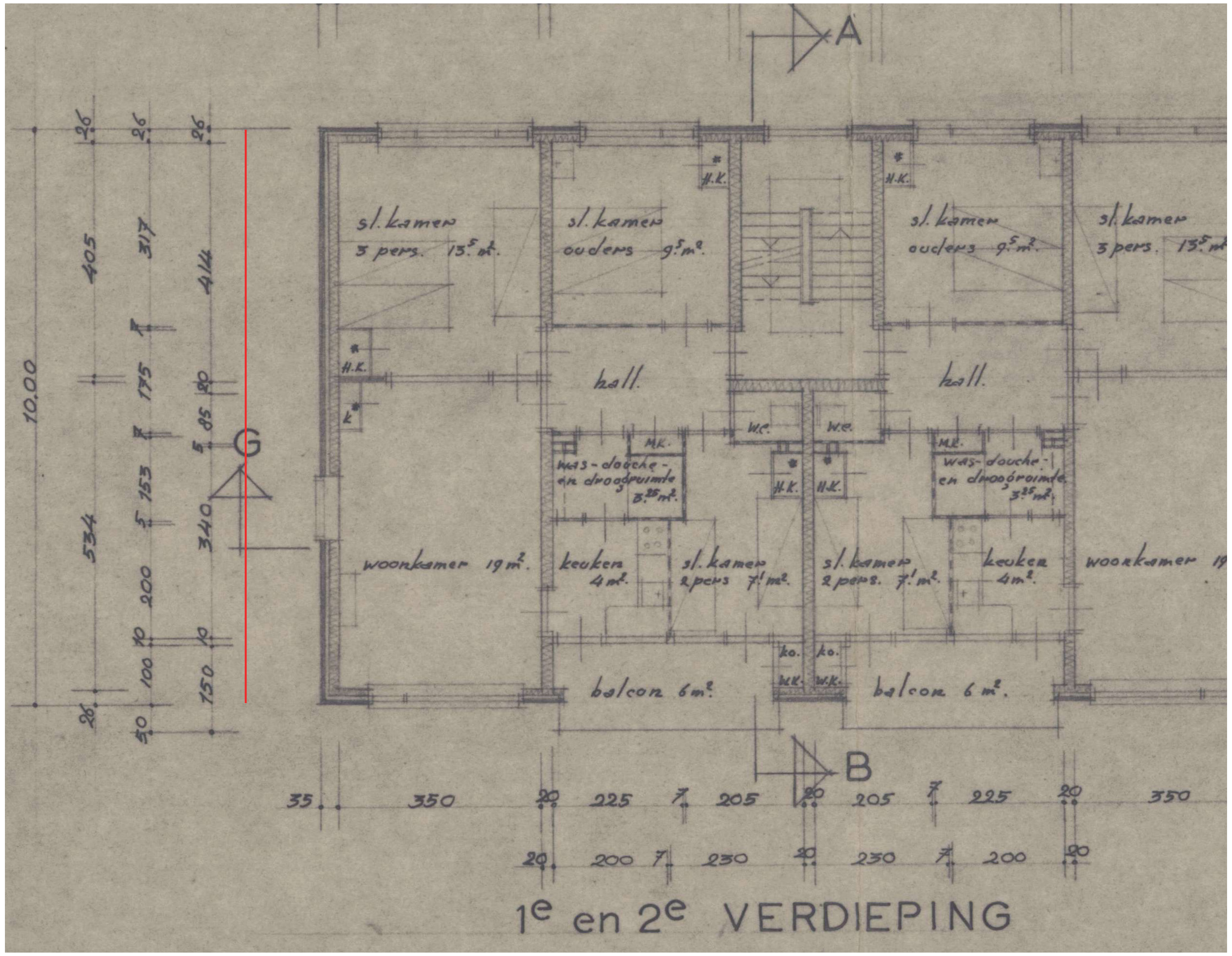
BMB PORTIEK Buitenveldert, Amsterdam (1962)



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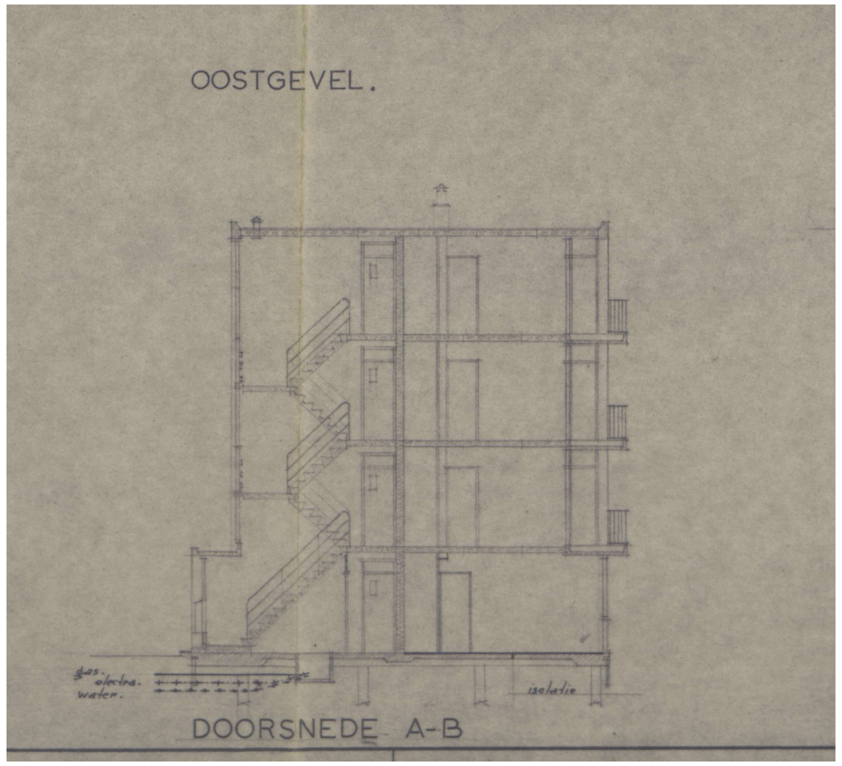

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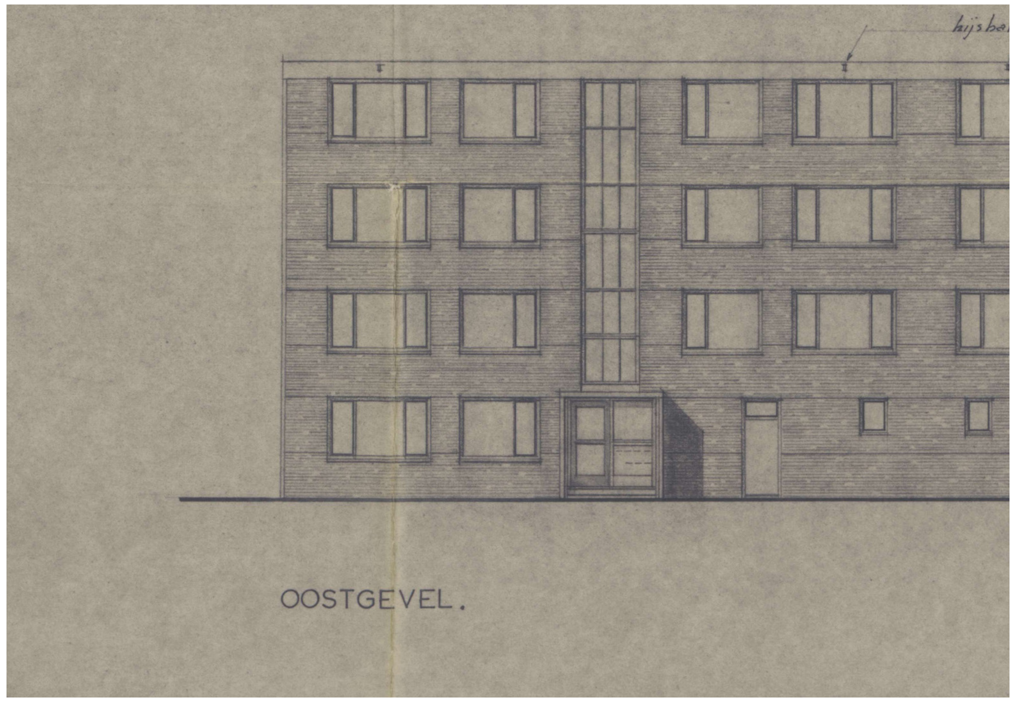

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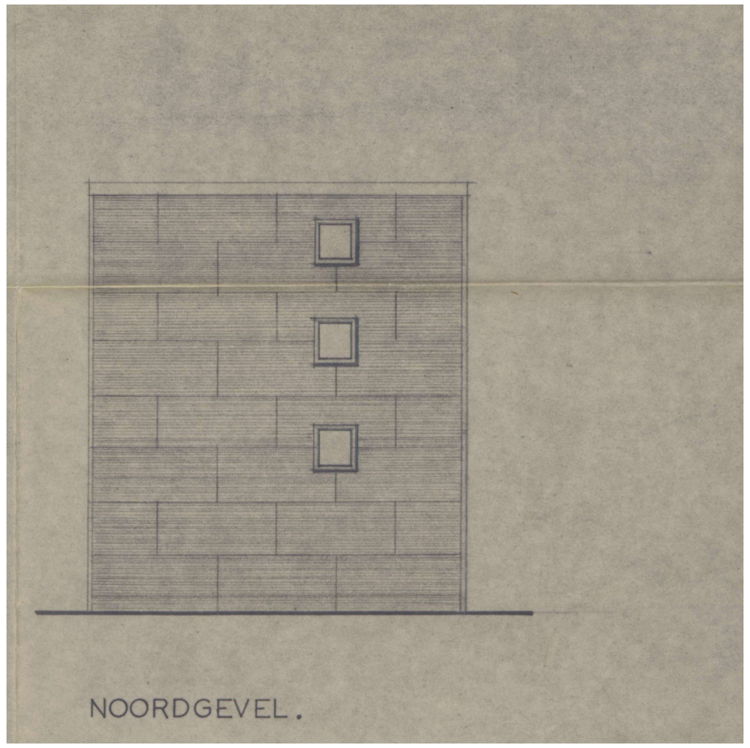

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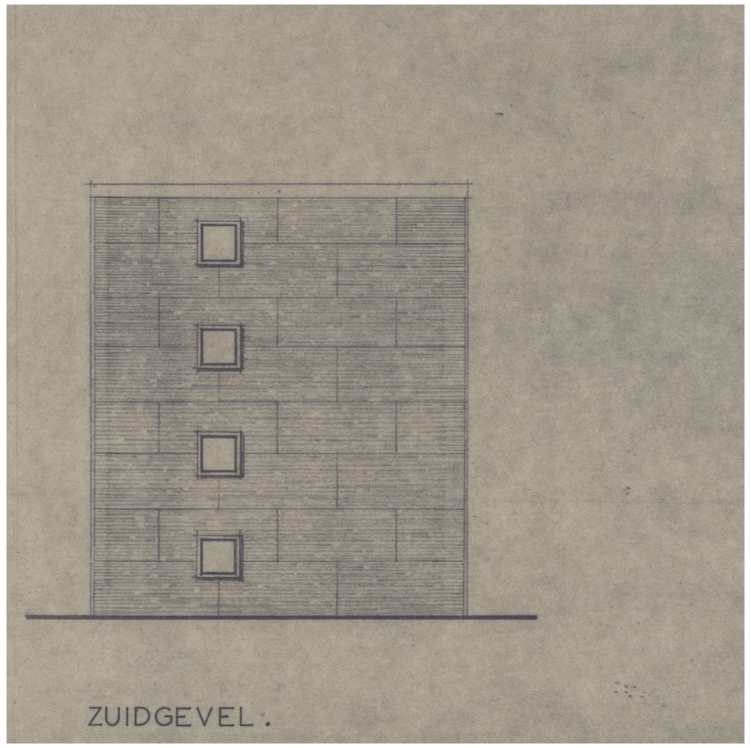

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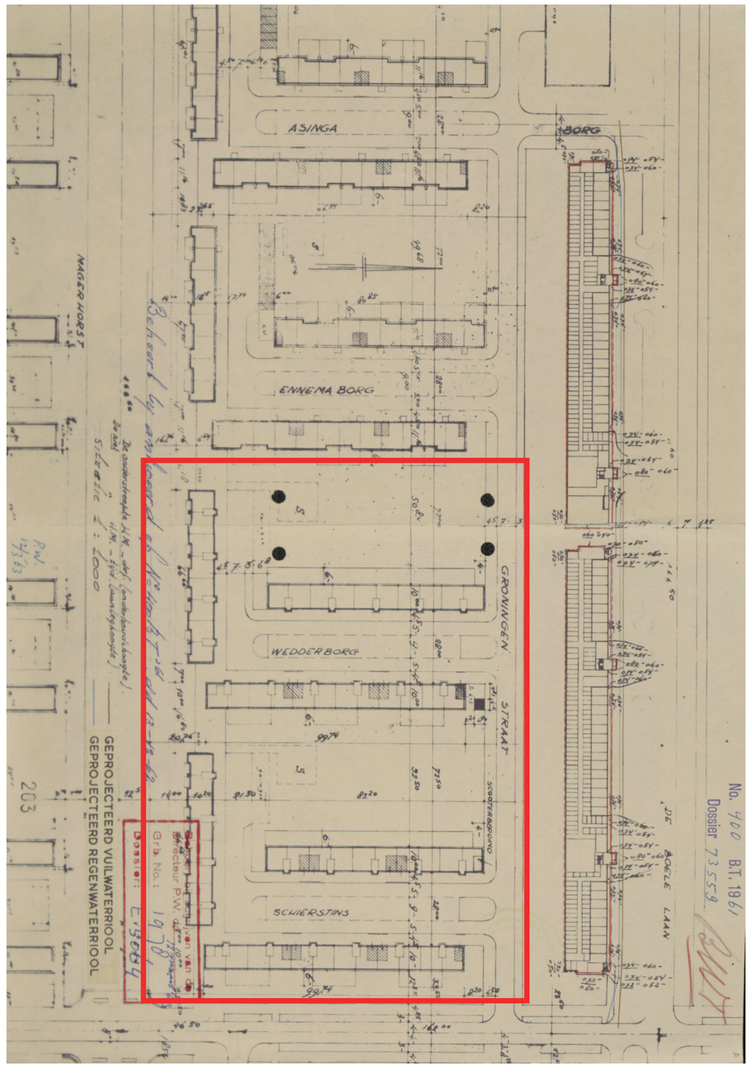

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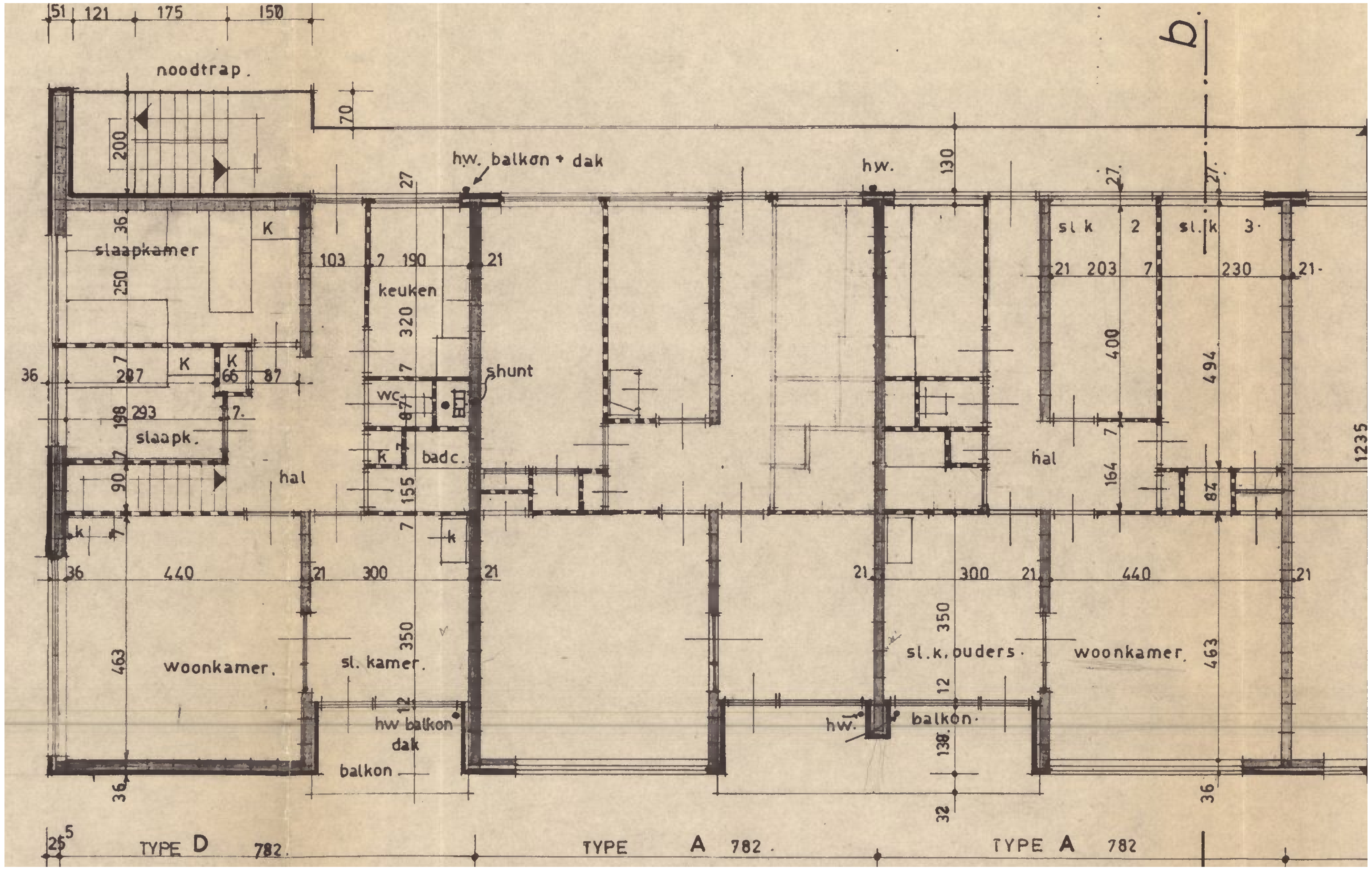
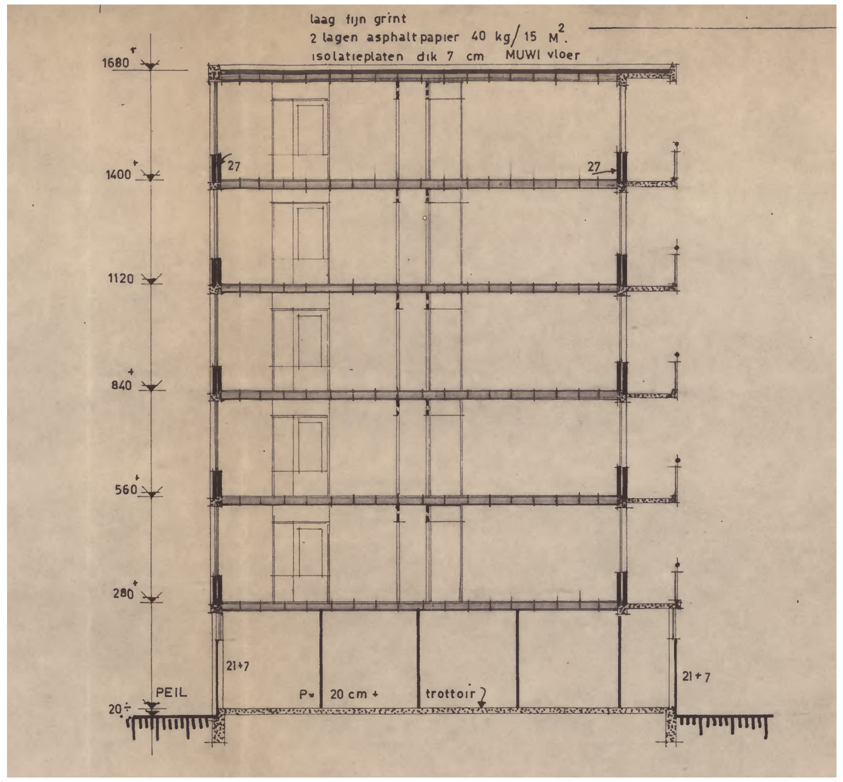


floor plan 1 : 100



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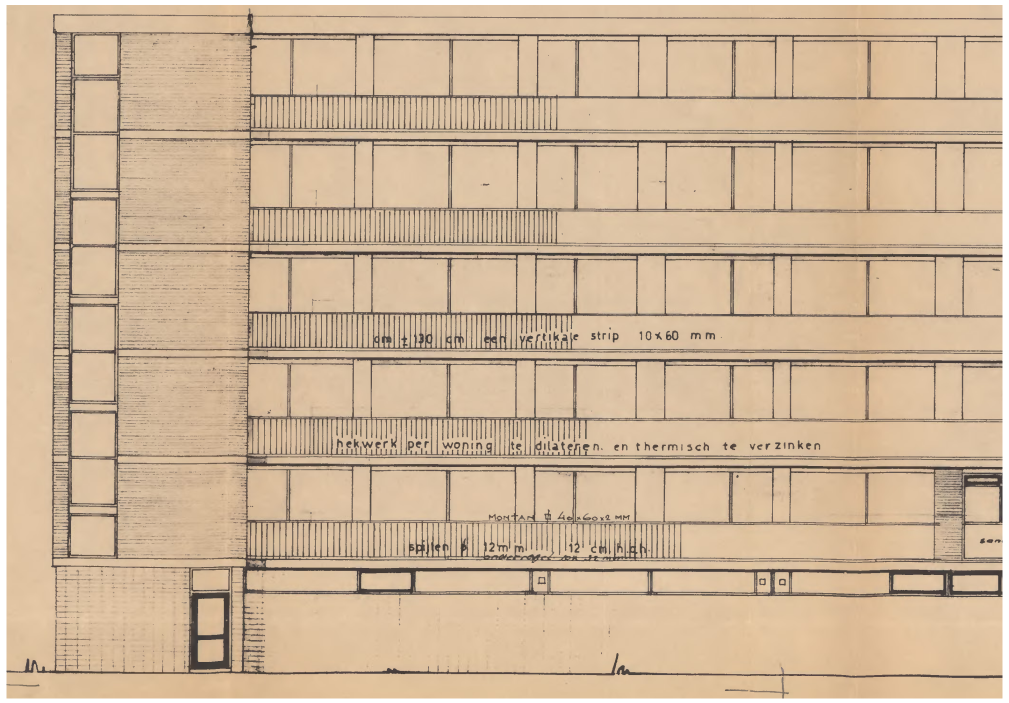

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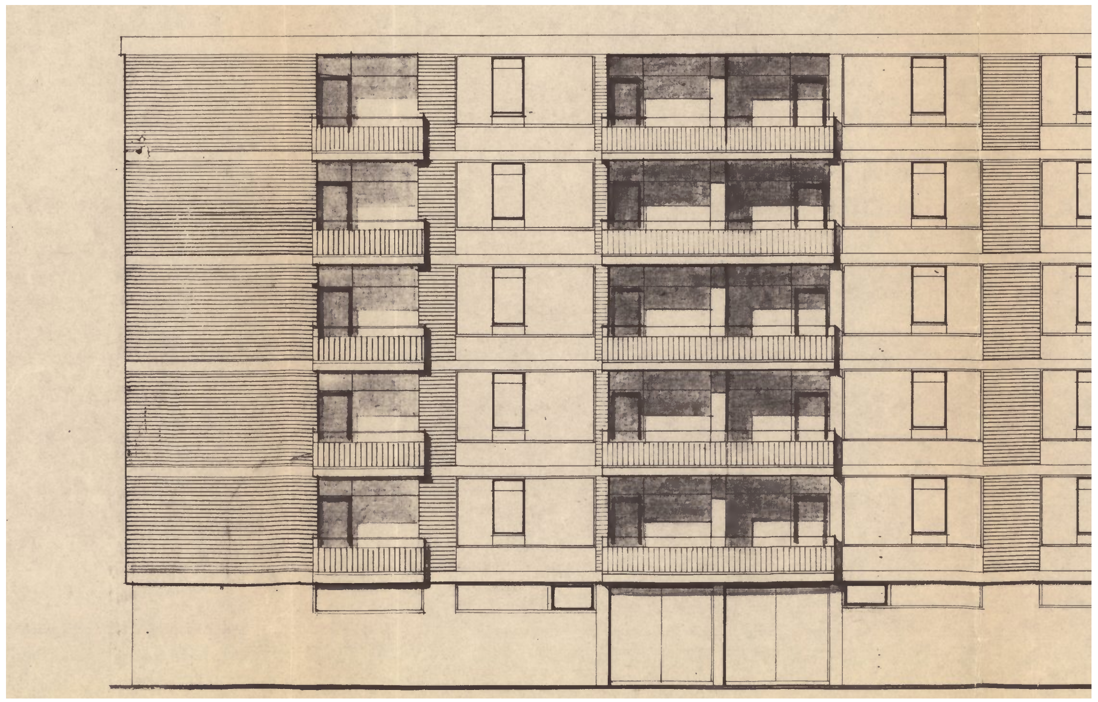

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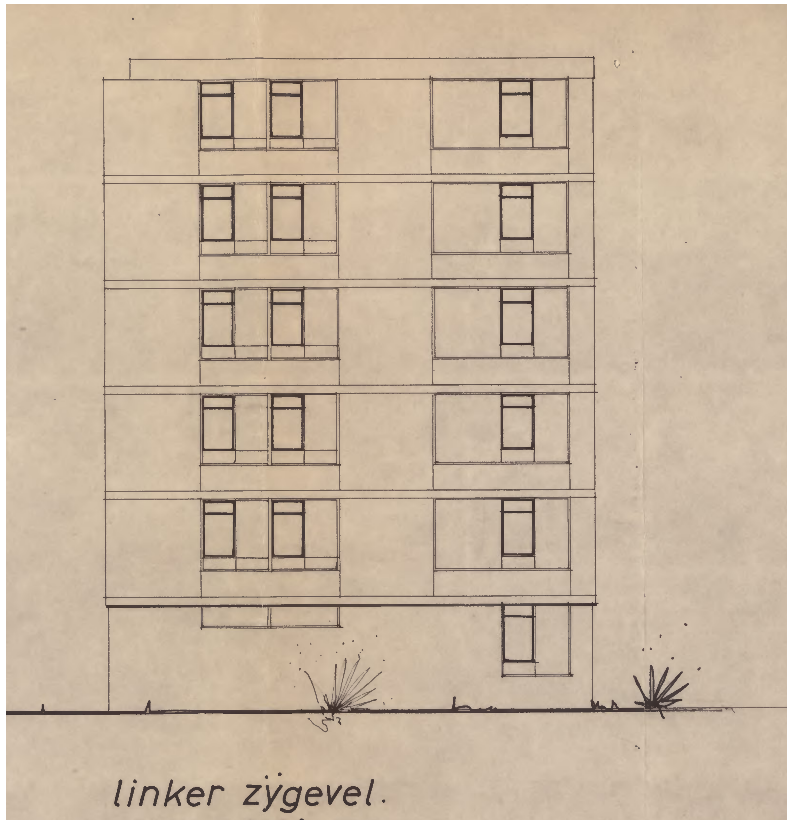

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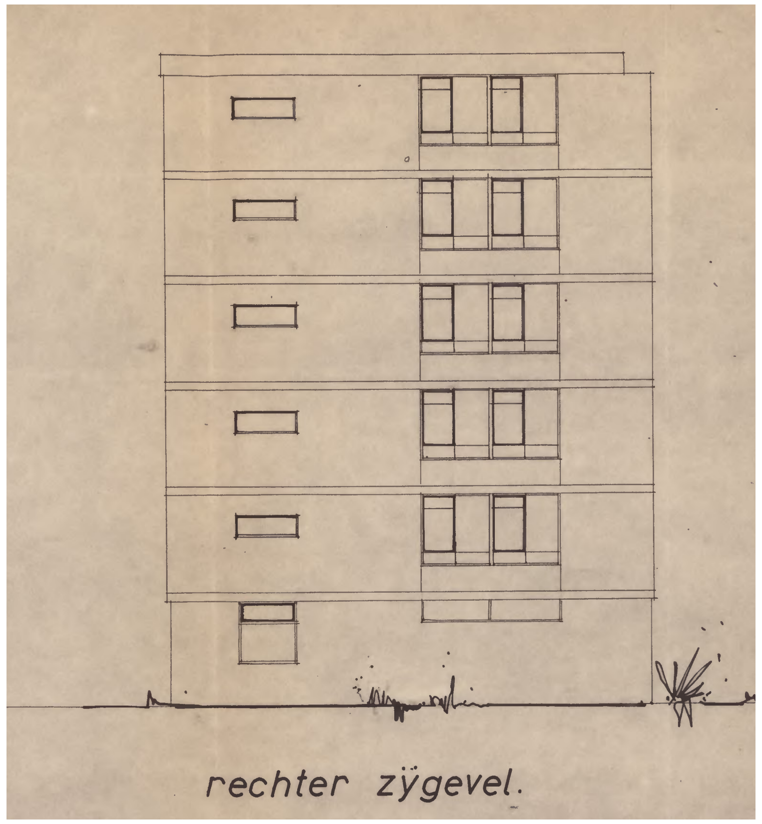

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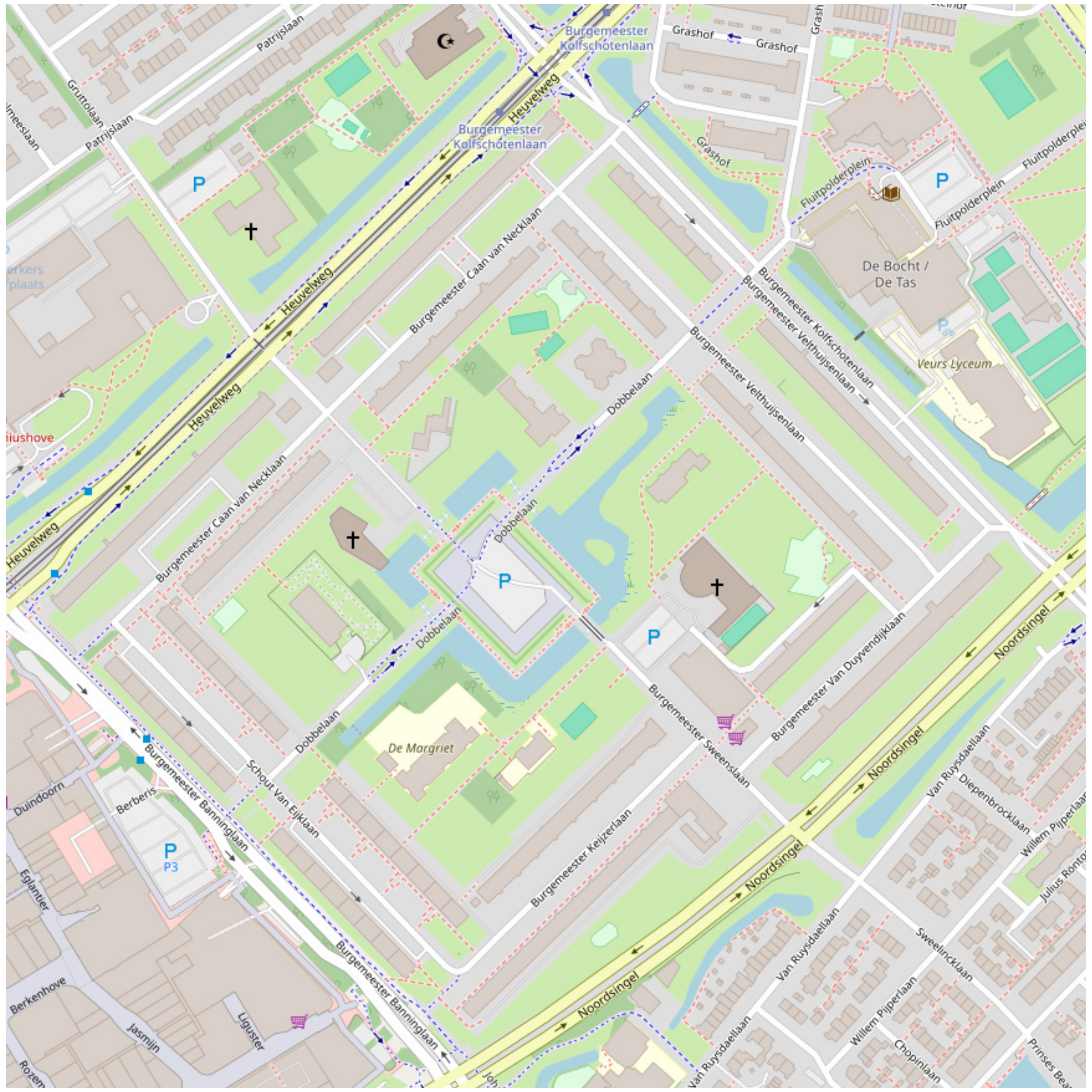

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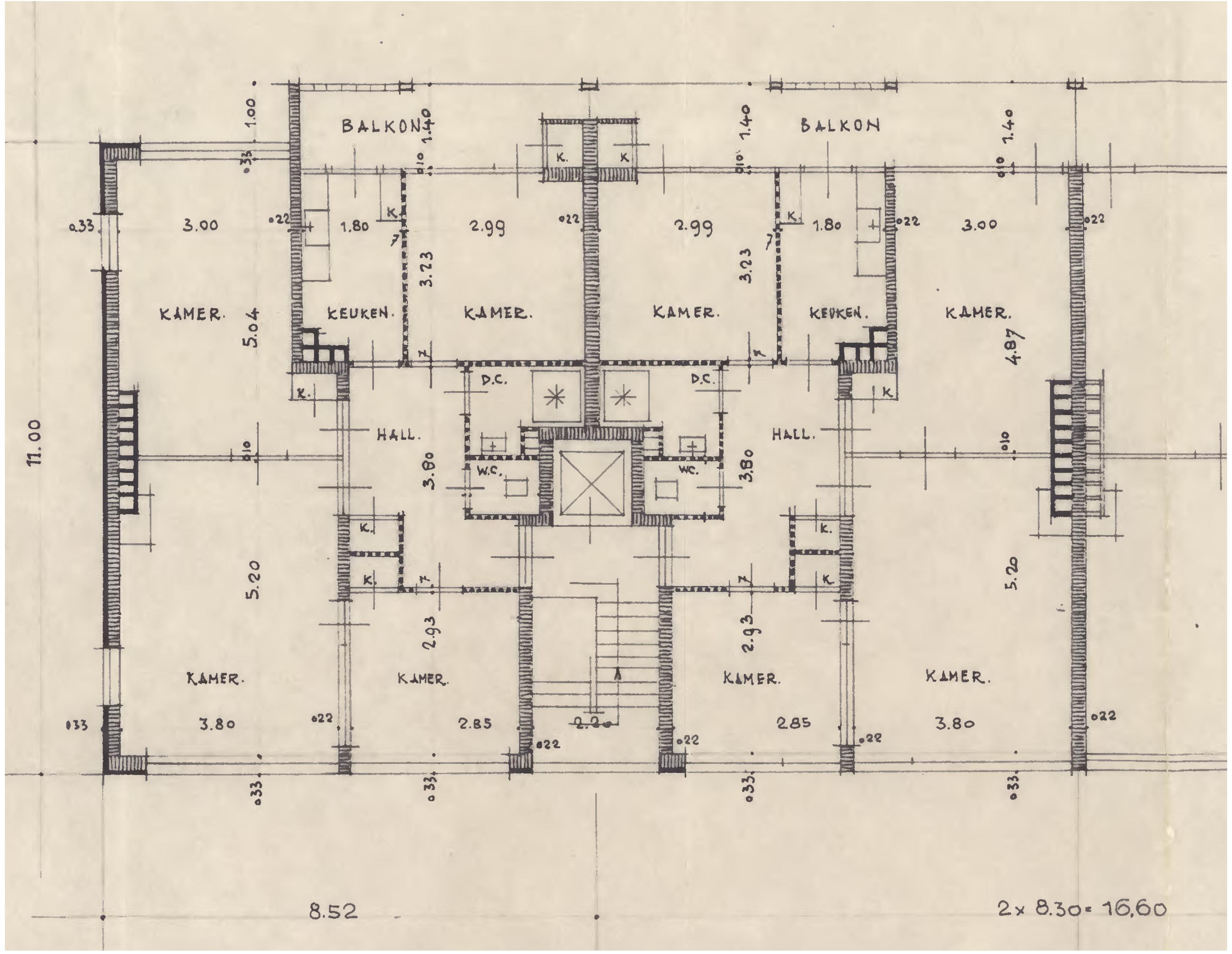
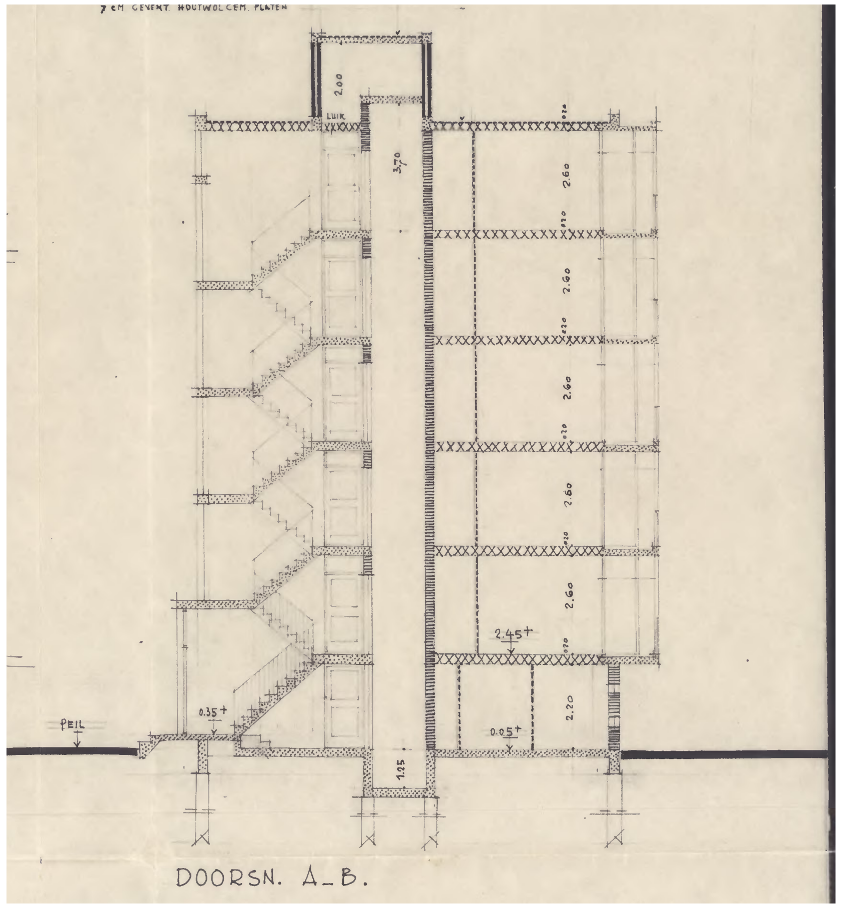


floor plan 1 : 100



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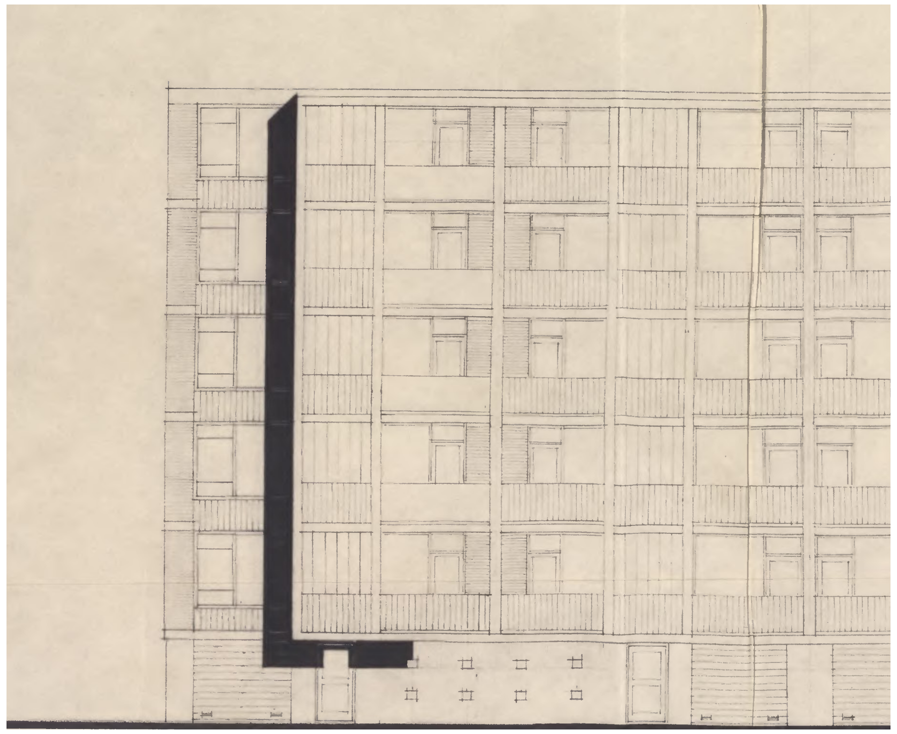

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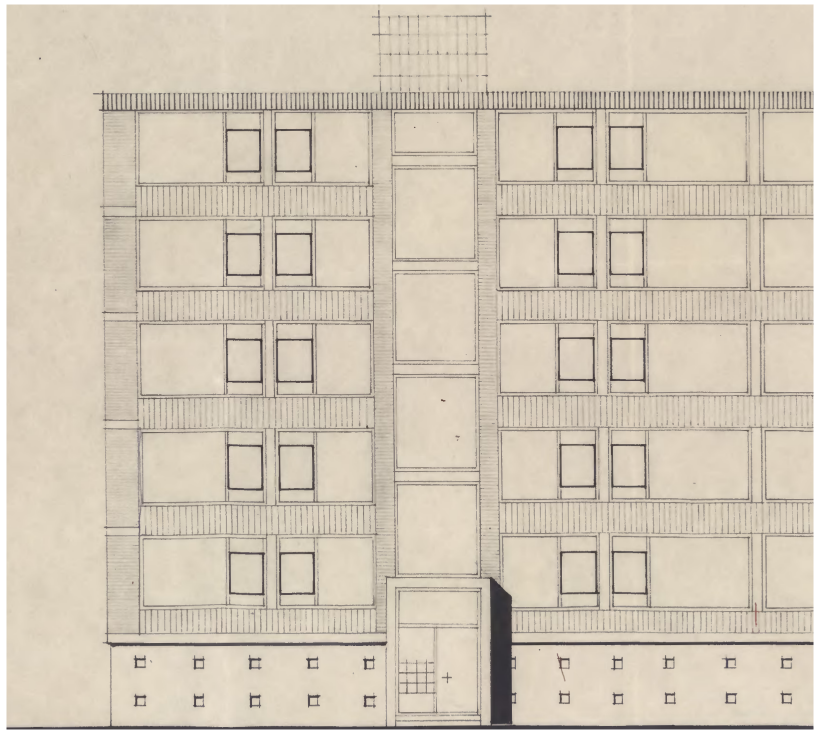

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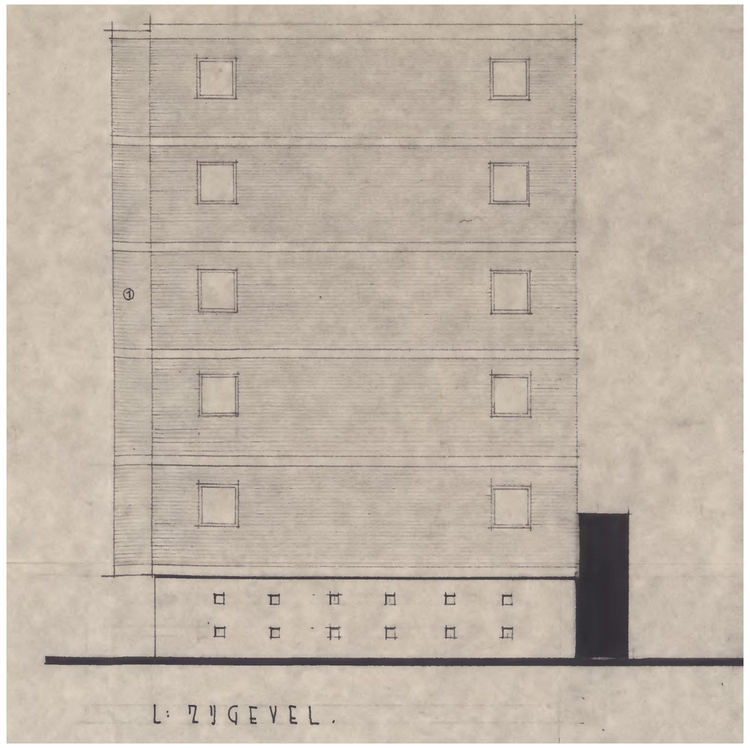
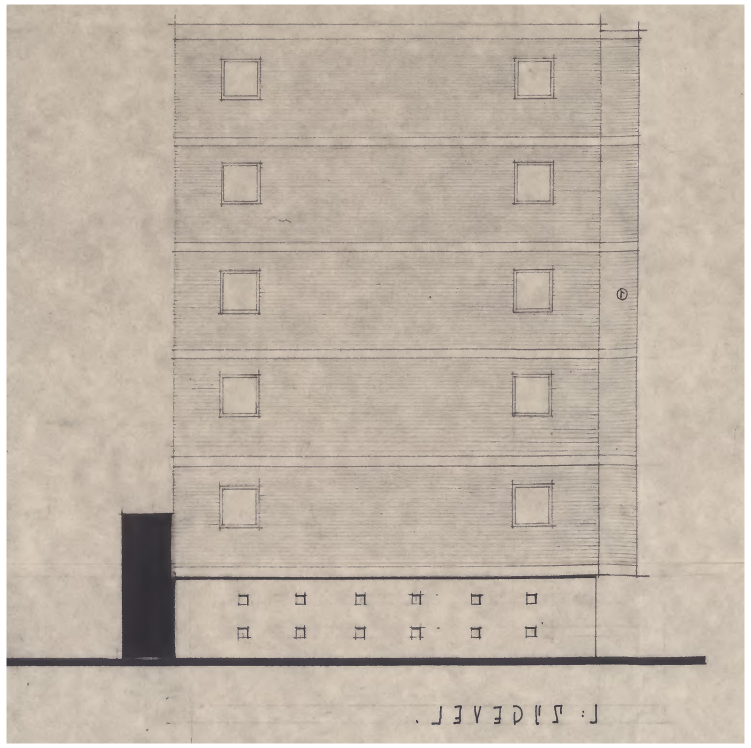
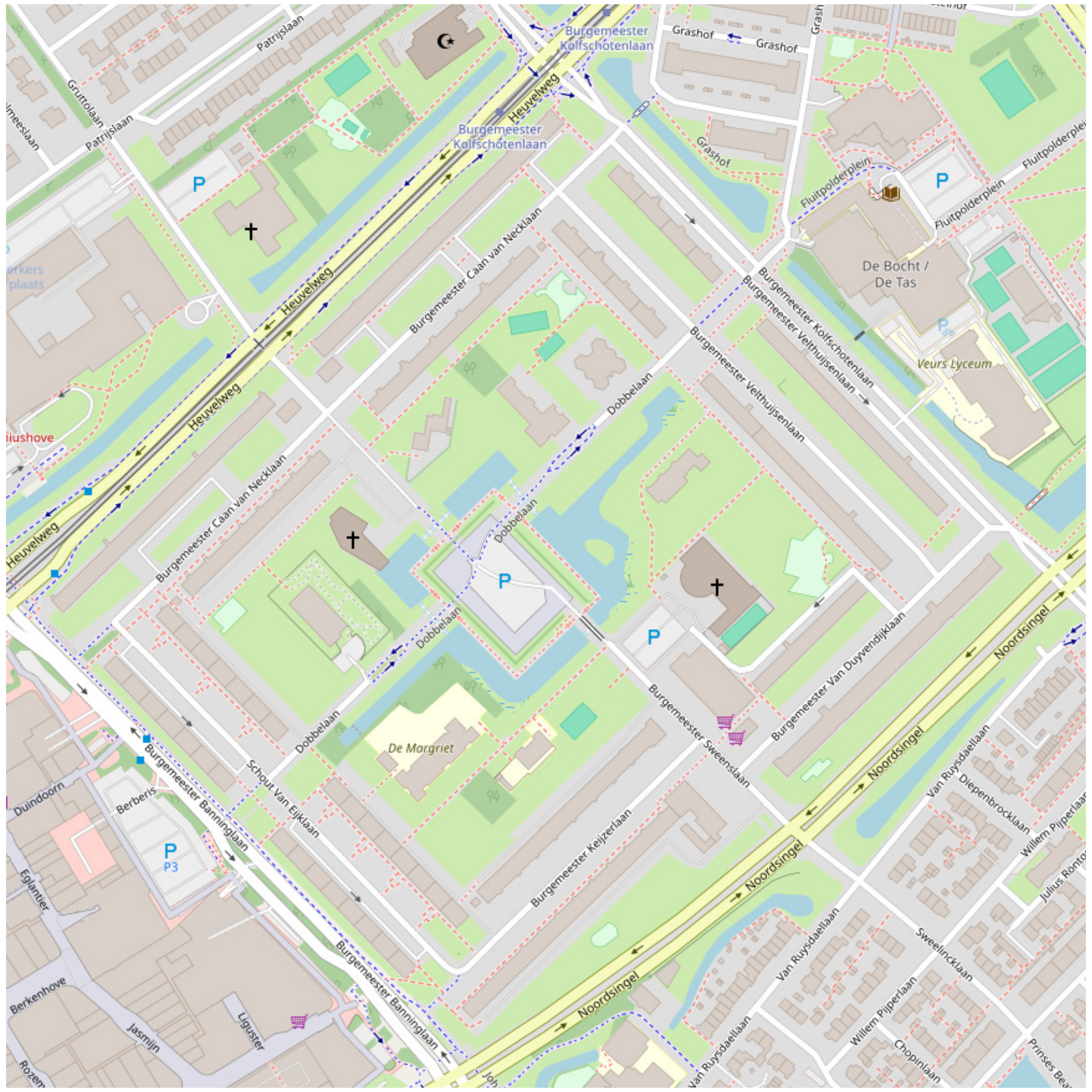
MUWI PORTIEK De Heuvel, Leidschendam (1961)



short facade 1 : 200

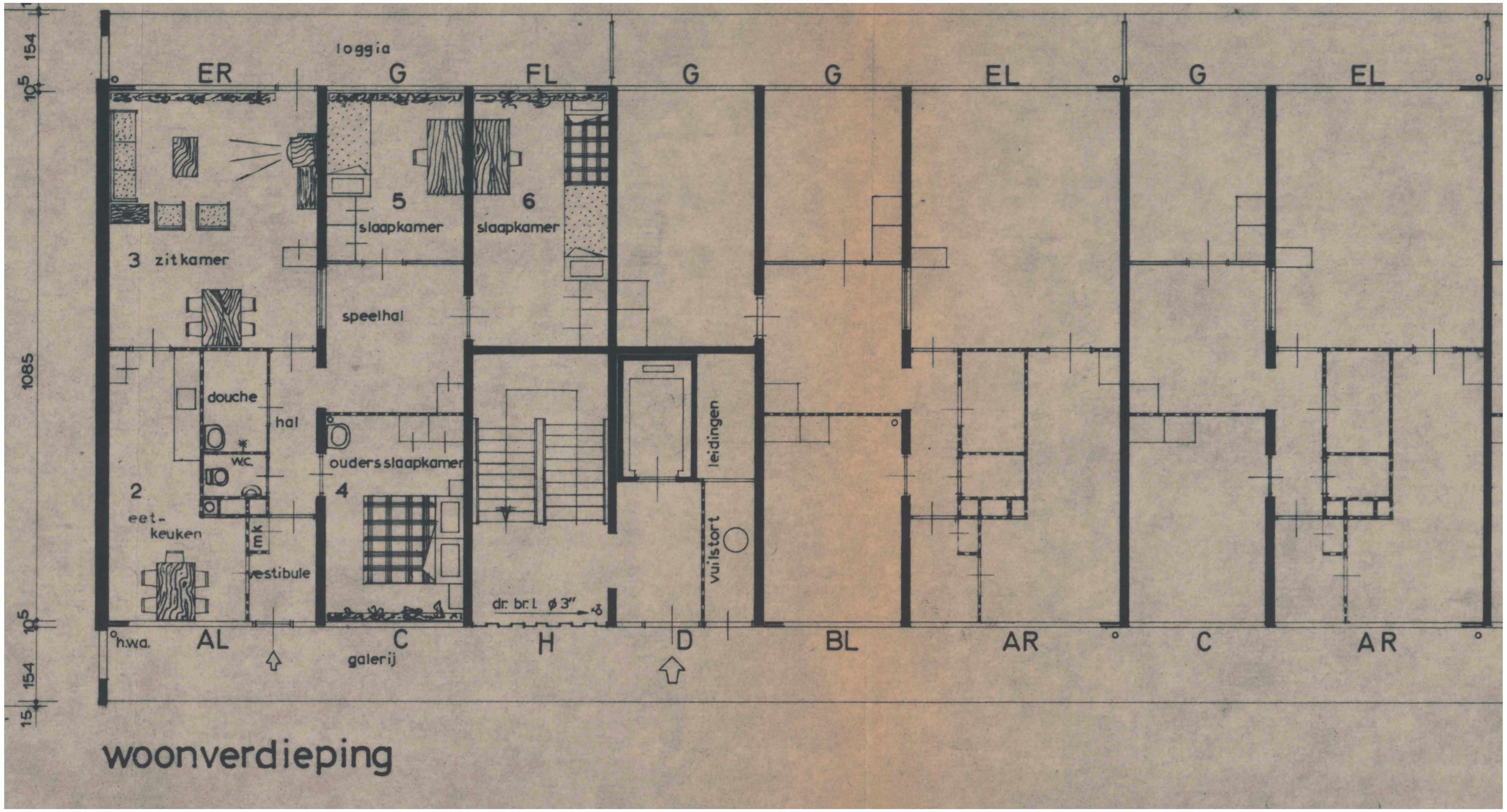


short facade 1 : 200

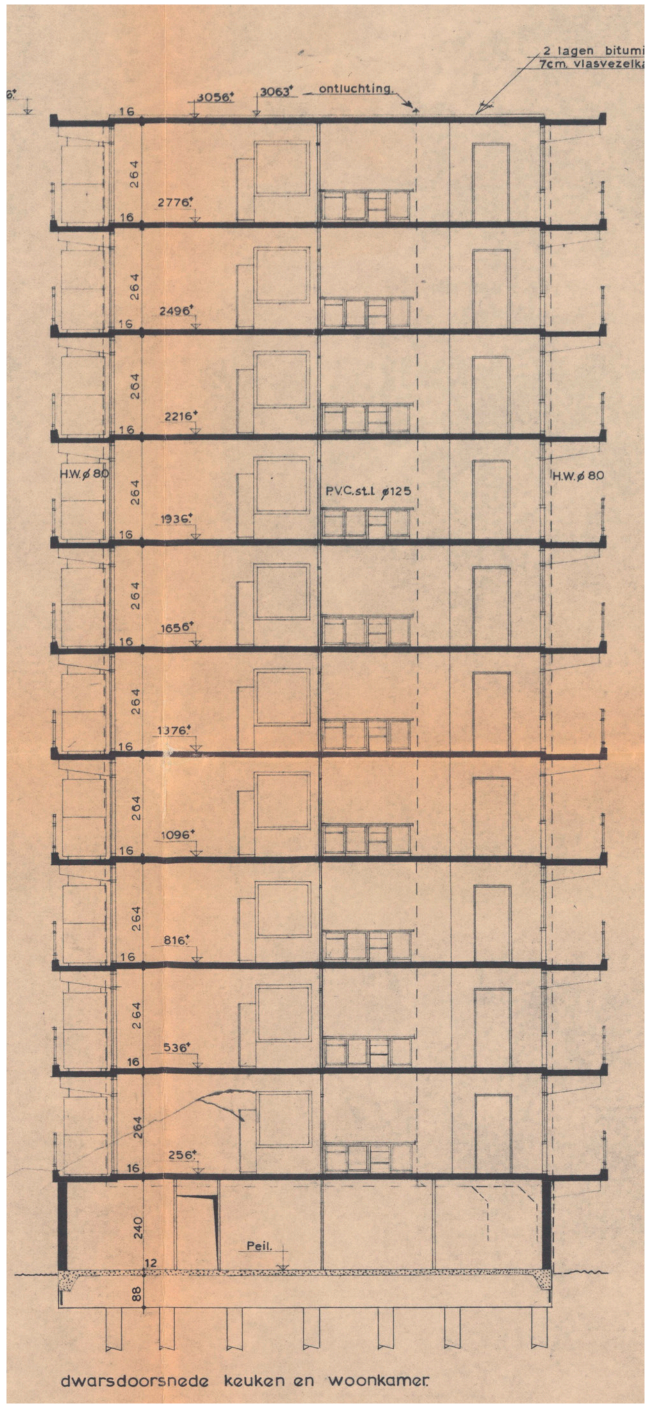


site 1 : 10.000

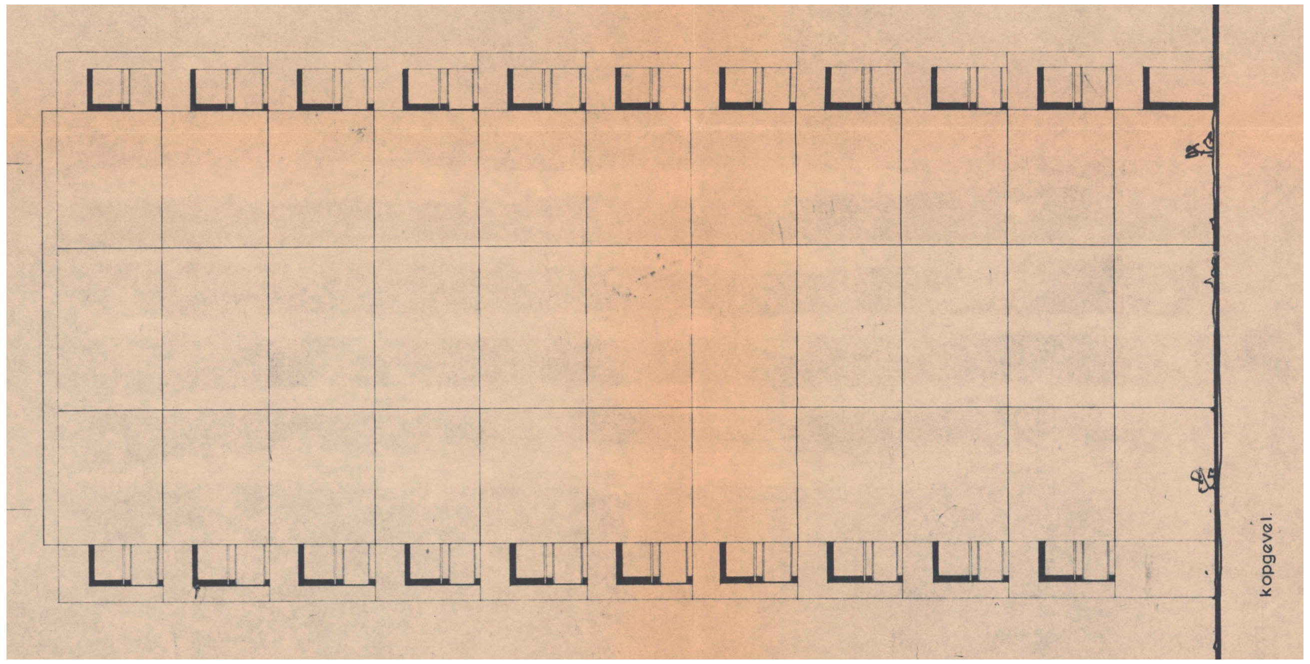
COIGNET GALERIJ Molenwijk, Amsterdam (1966)



floor plan 1 : 100

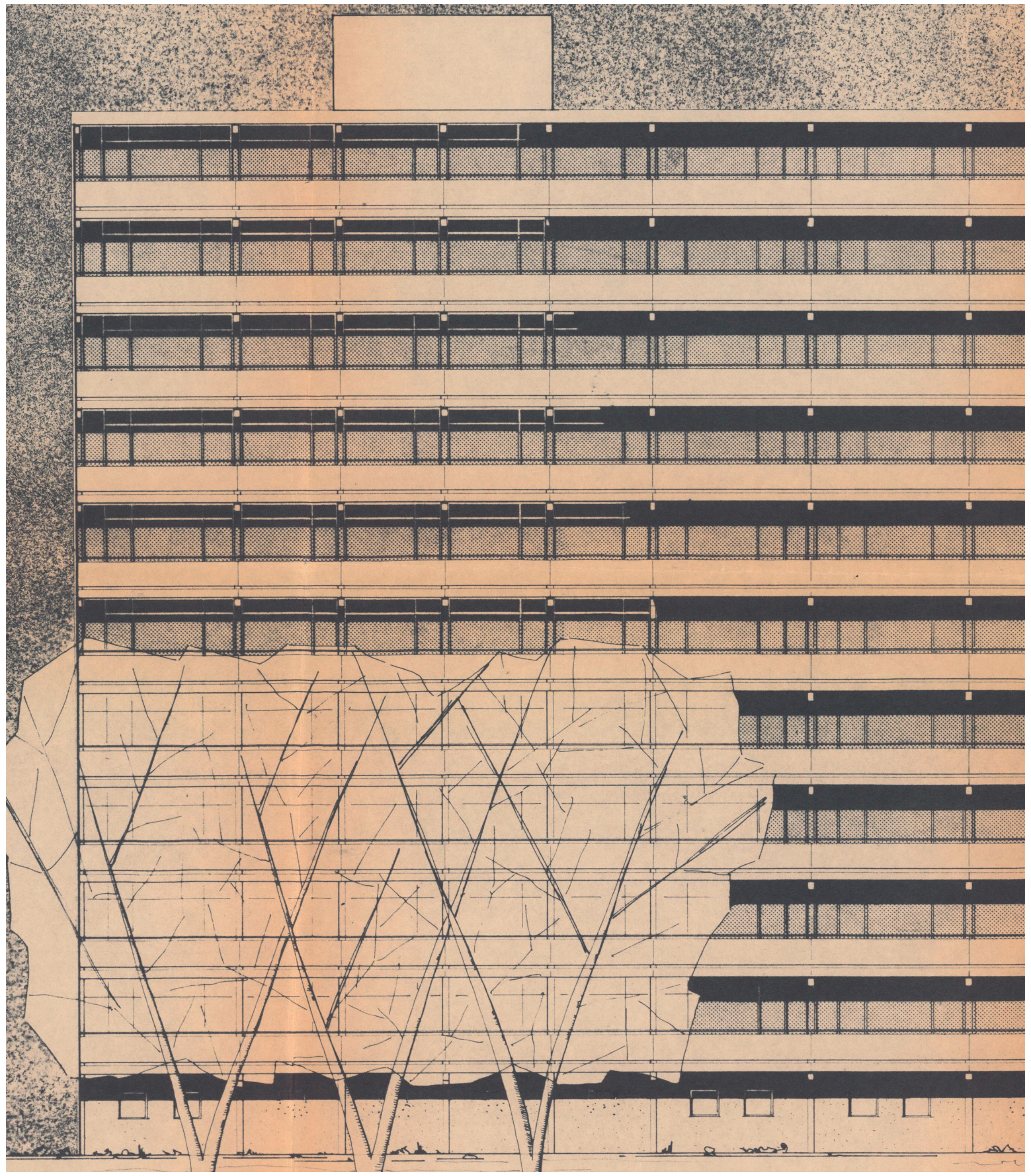


section 1 : 200

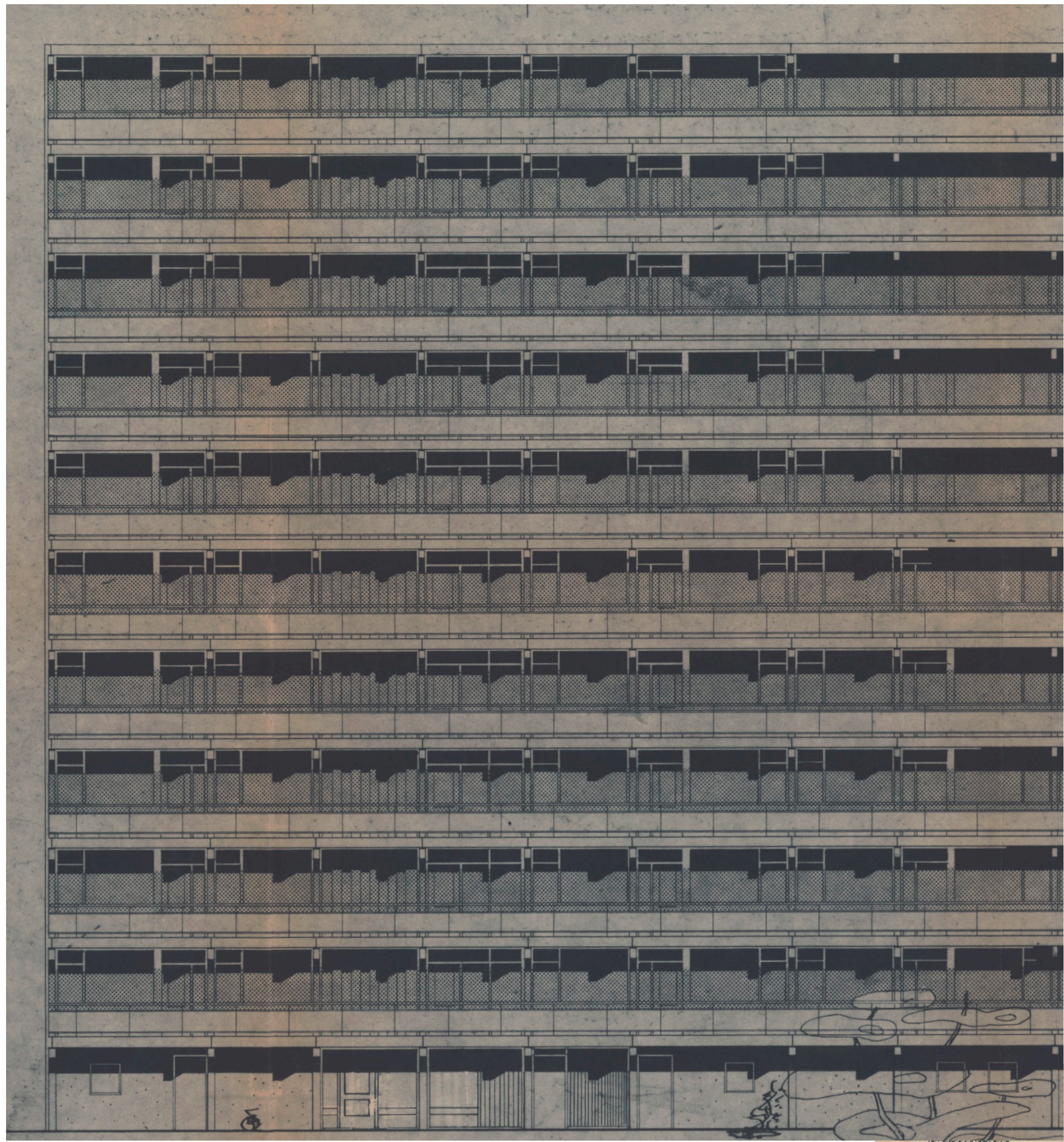


facade 1 : 200

COIGNET GALERIJ Molenwijk, Amsterdam (1966)



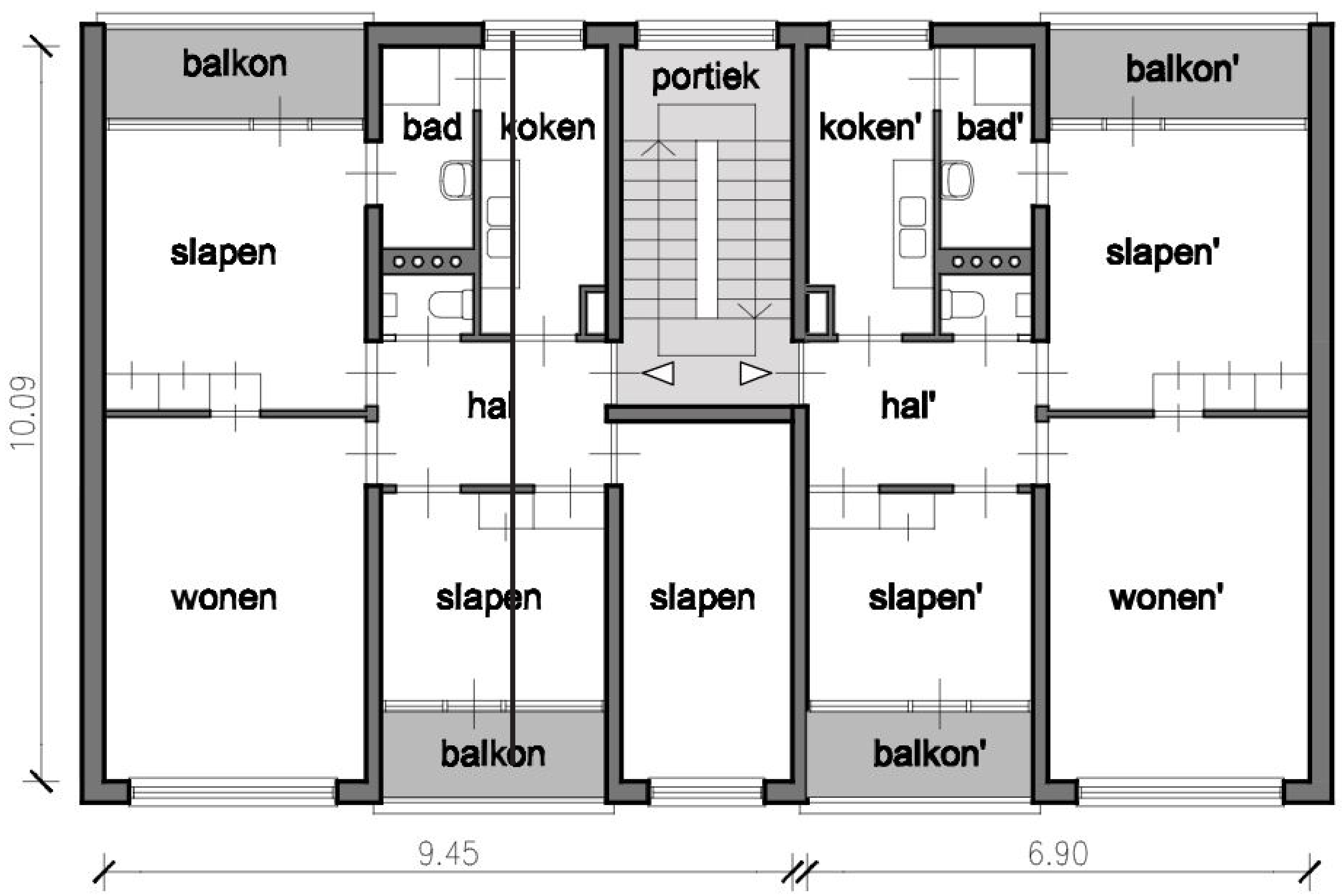
facade 1 : 200
woongevel



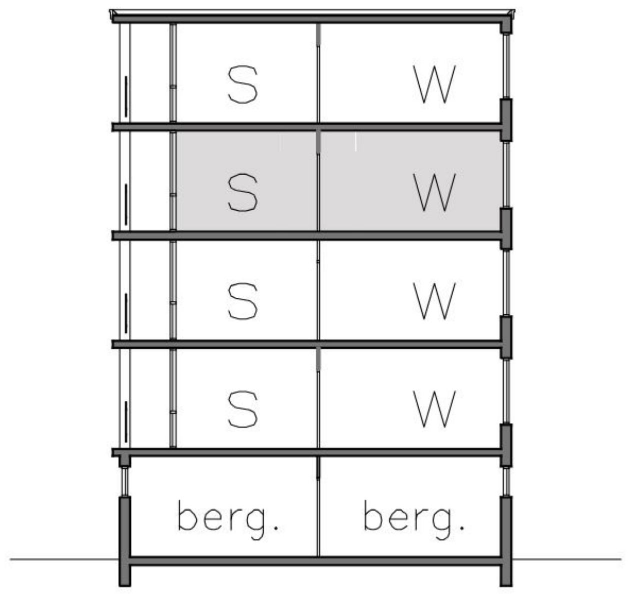
facade 1 : 200
galerijgevel

site 1 : 5000

COIGNET PORTIEK Homerusbuurt, Rotterdam (1959)



floor plan 1 : 100



section 1 : 200

facade 1 : 200

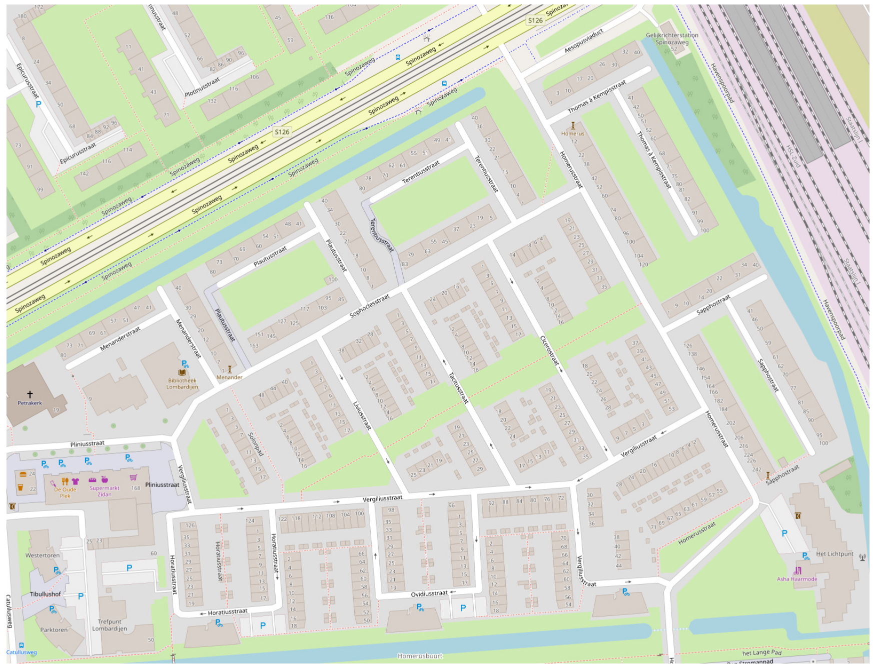
not available

facade 1 : 200

COIGNET PORTIEK Homerusbuurt, Rotterdam (1959)

not available

short facade 1 : 200



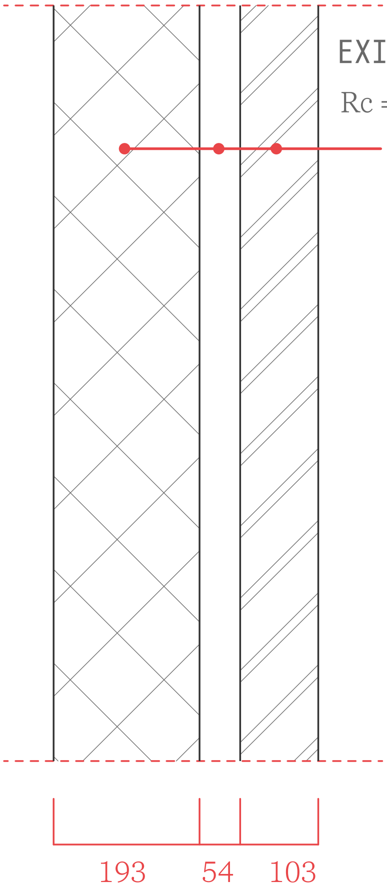
site 1 : 10.000

APPENDIX C.

1. Façade elements: building layers and performance

FAÇADE ELEMENT

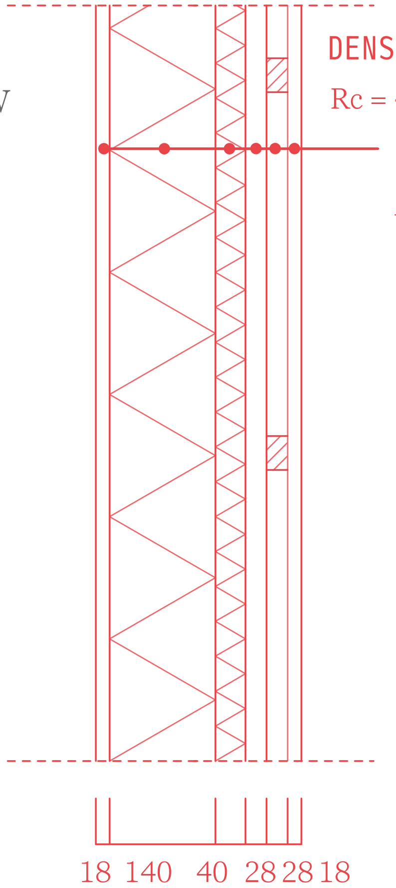
required thermal performance for new construction: Rc = 4,7 m²K/W



EXISTING

Rc = 0,87 m²K/W

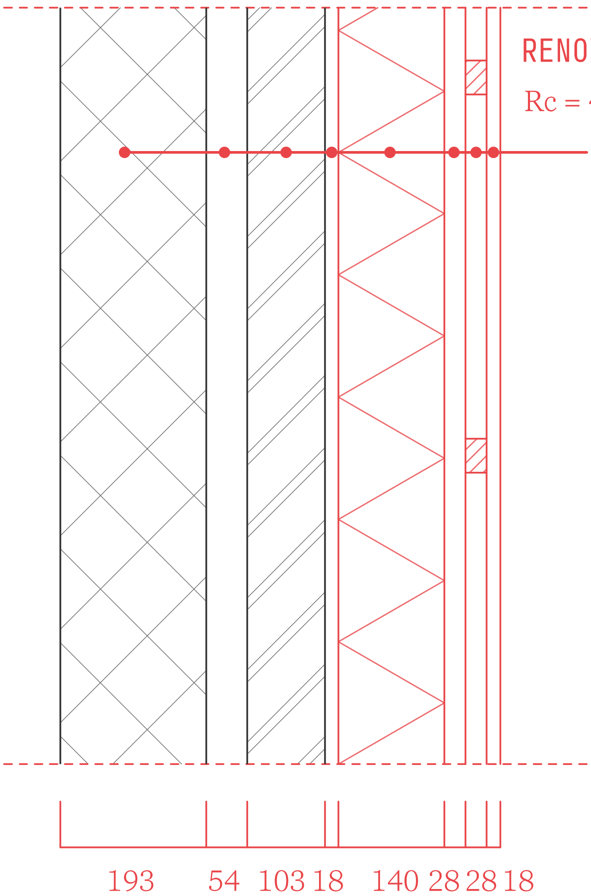
.concrete
.cavity
.brick



DENSIFICATION

Rc = 4,8 m²K/W

.OSB panel
.timber frame (140x38 mm elements) with wood fibre insulation
.wood fiber insulation panel
.vertical and horizontal wood battens (28x45 mm)
.wood façade cladding



RENOVATION

Rc = 4,5 m²K/W

.concrete
.cavity
.brick
.OSB panel
.timber frame (140x38 mm elements) with wood fibre insulation
.vertical and horizontal wood battens (28x45 mm)
.wood façade cladding

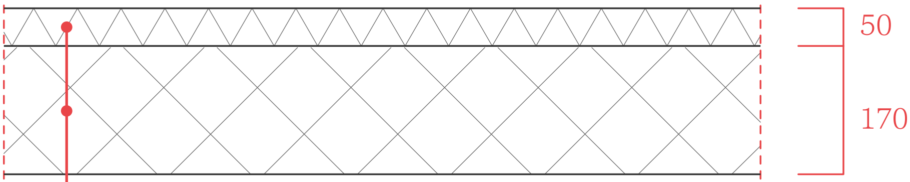
2. Roof elements: building layers and performance

ROOF ELEMENT

required thermal performance for new construction: Rc = 6,3 m^2K/W

EXISTING

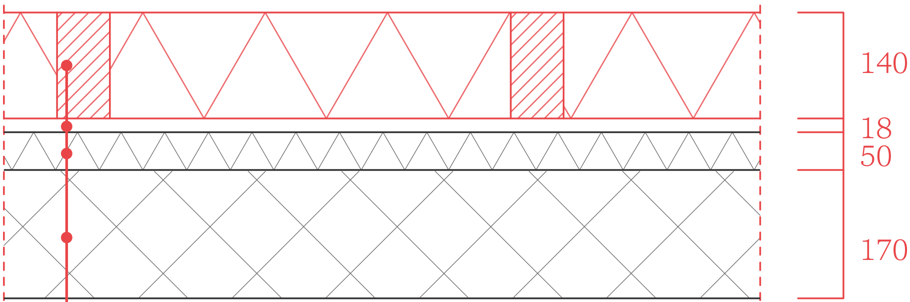
Rc = 0,62 m^2K/W



.flax fiber board
.concrete slab

RENOVATION

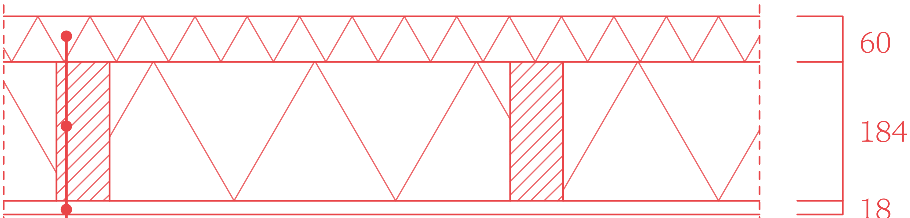
Rc = 5,9 m^2K/W



.timber frame (140x38 mm elements) with wood fibre insulation
.OSB panel
.flax fiber board
.concrete slab

DENSIFICATION

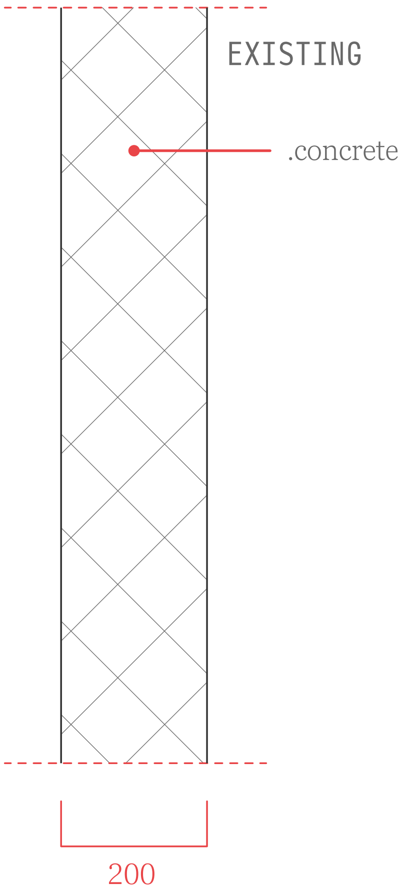
Rc = 6,4 m^2K/W

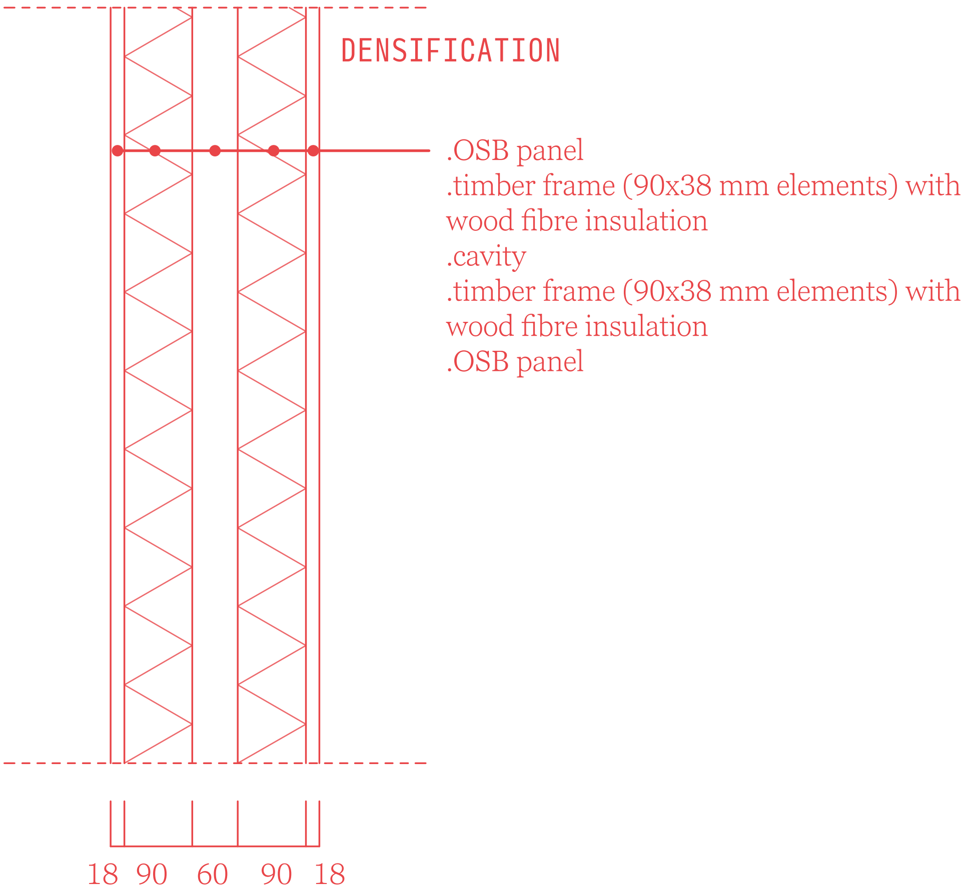


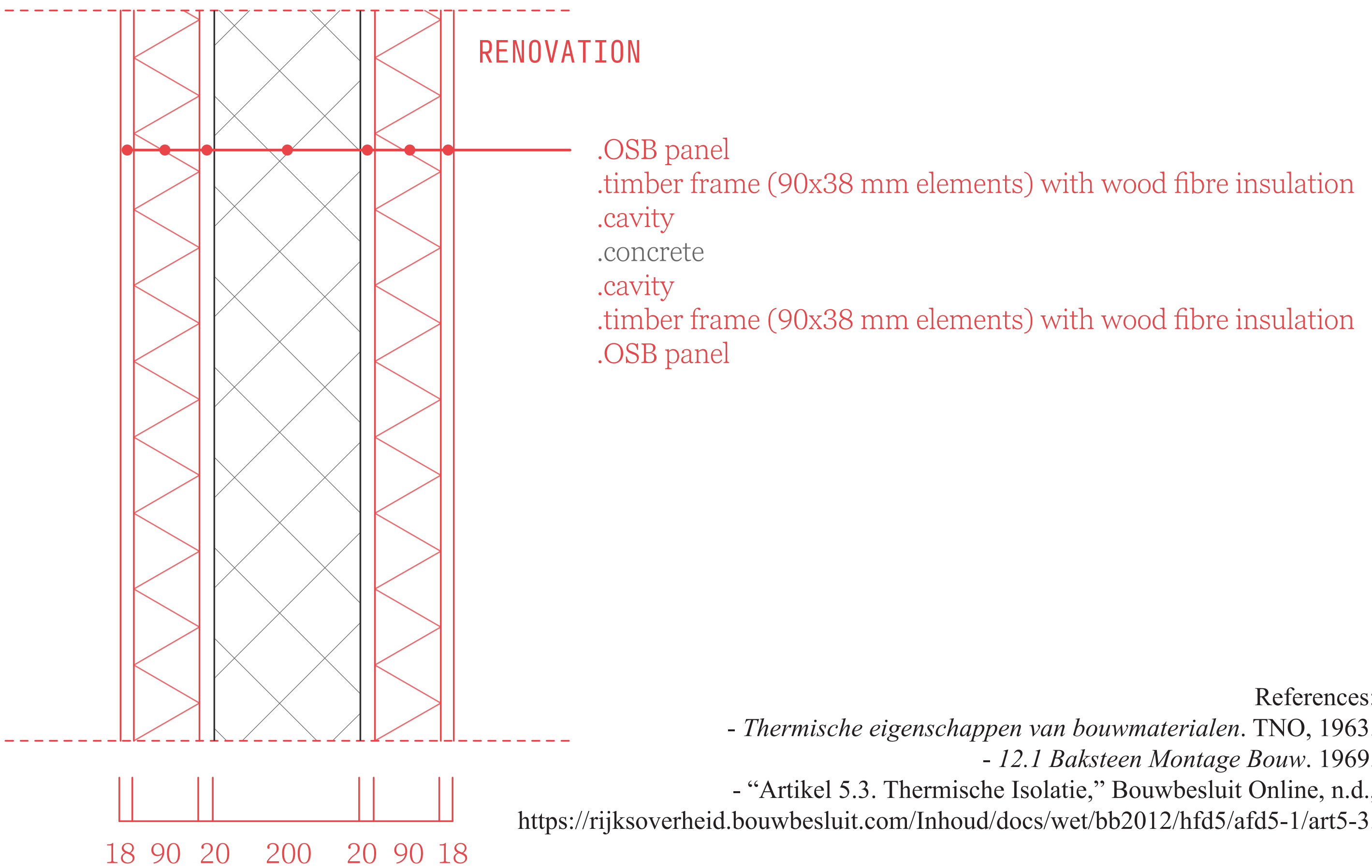
.wood fibre insulation panel
.timber frame (140x38 mm elements) with wood fibre insulation
OSB panel

DIVISION WALL ELEMENT

required acoustic performance for new construction: airborne sound < 52 dB; impact sound < 32 dB



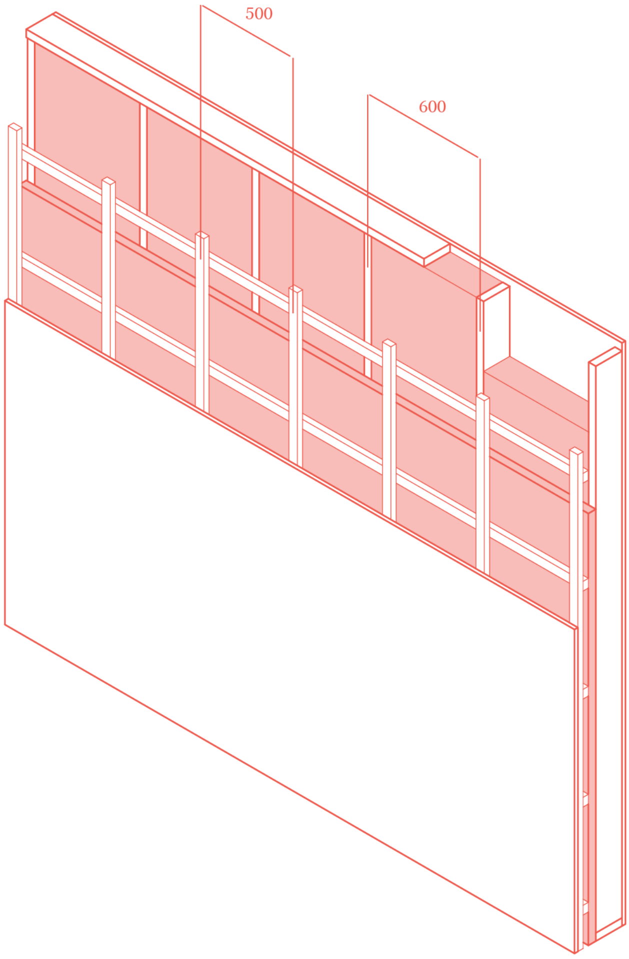




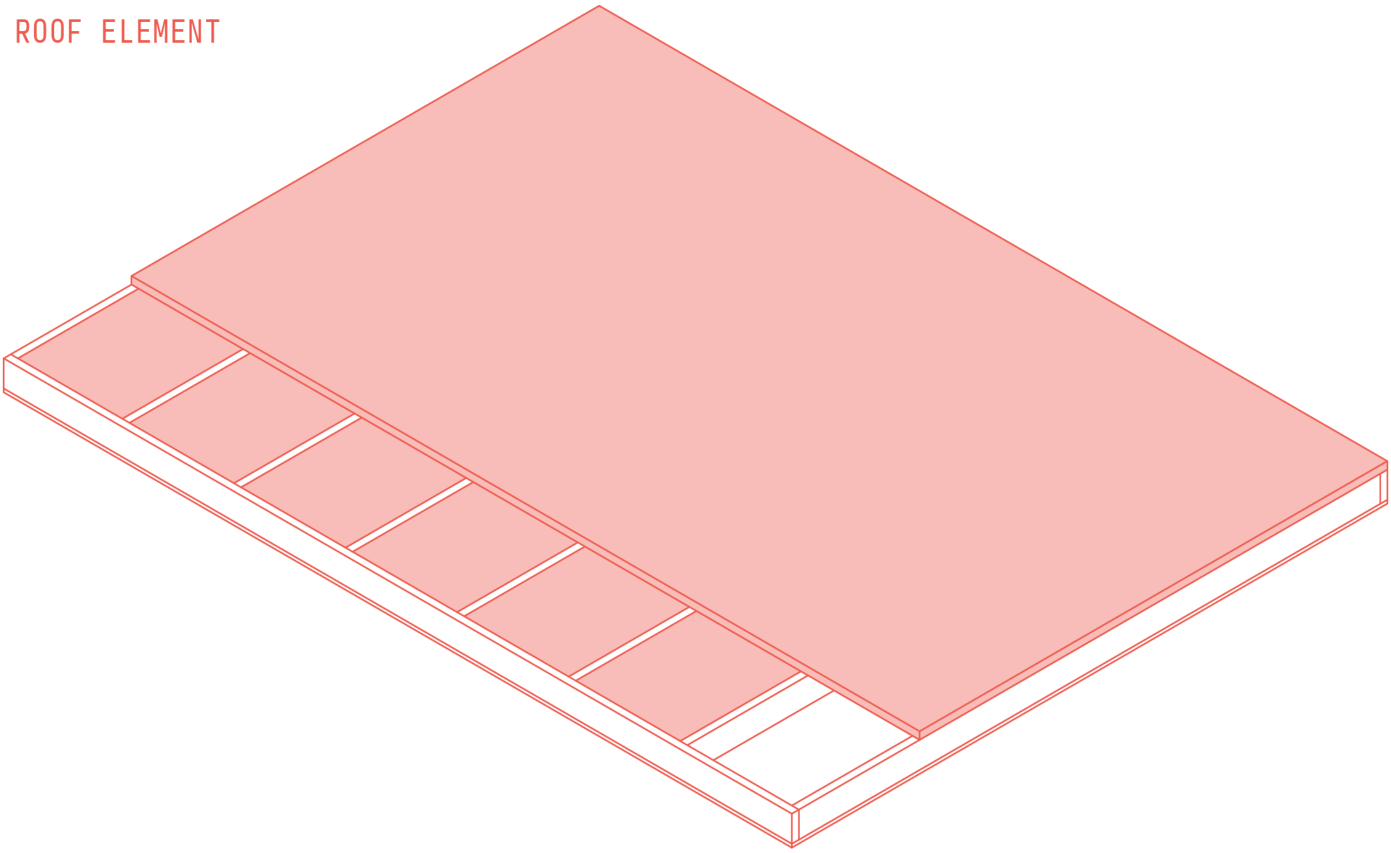
References:
- *Thermische eigenschappen van bouwmaterialen*. TNO, 1963.
- *12.1 Baksteen Montage Bouw*. 1969.
- "Artikel 5.3. Thermische Isolatie," Bouwbesluit Online, n.d., https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012/hfd5/afd5-1/art5-3.

3D visualisation of façade and roof elements

WALL ELEMENT



ROOF ELEMENT



APPENDIX D.

Suitability of Dutch native trees for different building elements

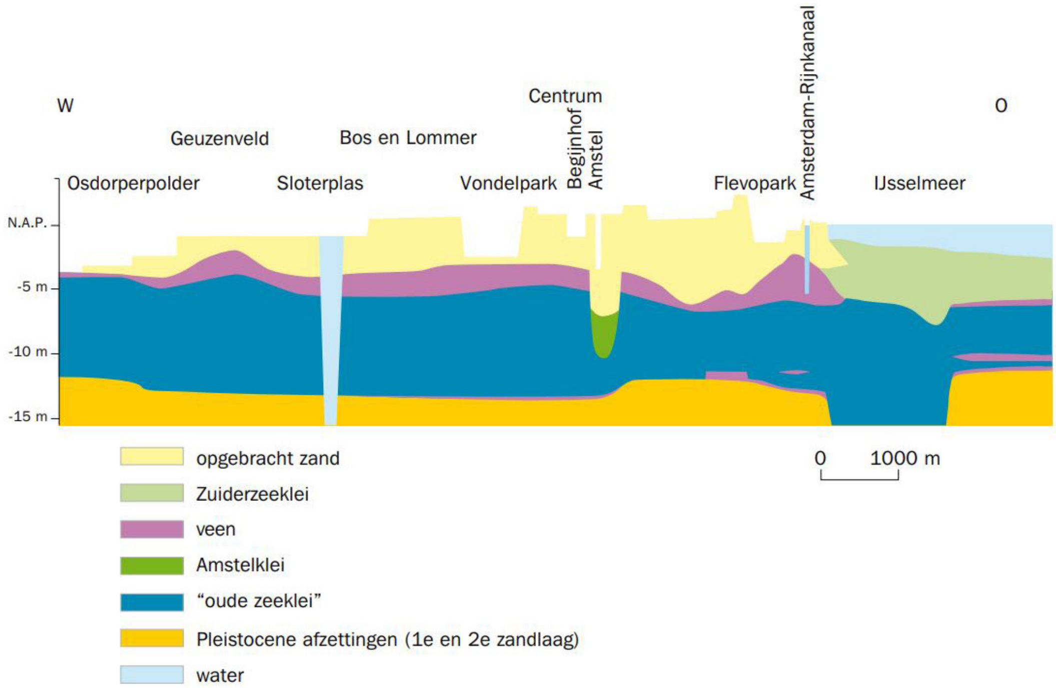
Building application	**Suitable tree species**
a. Window frame	Douglas fir, Oak, Ash, Spruce, Honeylocust, Larch, Pine, Black locust, Chataignier
b. Exterior door	Douglas, Oak, Spruce, Elm, Larch, Pine, Black locust, Chataignier
c. Timber structure	Douglas fir, Oak, Spruce, Larch, Pine, Black locust, Chataignier
d. Façade cladding	Douglas, Oak, Alder, Ash, Spruce, Larch, Pine, Poplar, Black locust, Chataignier, Common walnut, Silver fir
e. Wood fiber insulation panel & f. OSB panel	Any rest wood

References:
- Fraanje, P.J, and Henk Pel. *Natuurlijk Bouwen Met Hout : 33 Boomsoorten Die Zich Thuisvoelen in Nederland*. Utrecht: Van Arkel, 1999.

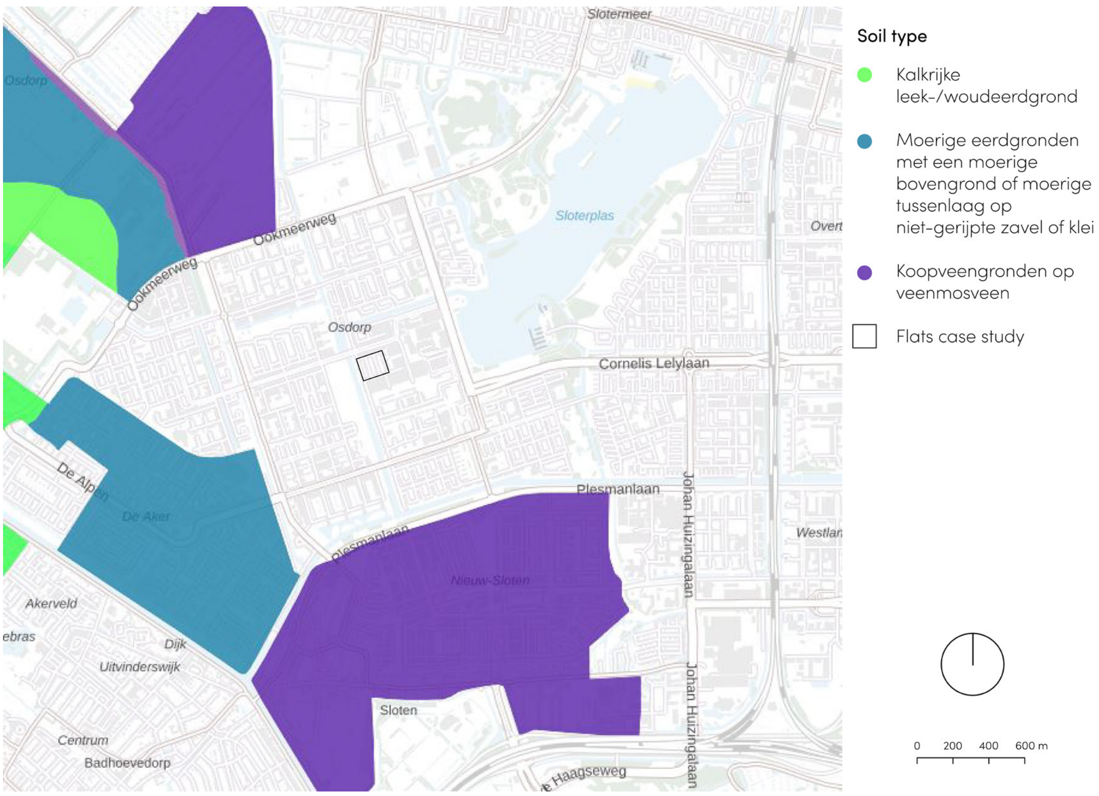
*Wood fibre panels are used for the insulation of the existing and new structure. These panels are made from residual flows of wood processing.

APPENDIX E.

Soil characteristics of project site



Thickness of fill sand in Amsterdam and other soil layers[1]



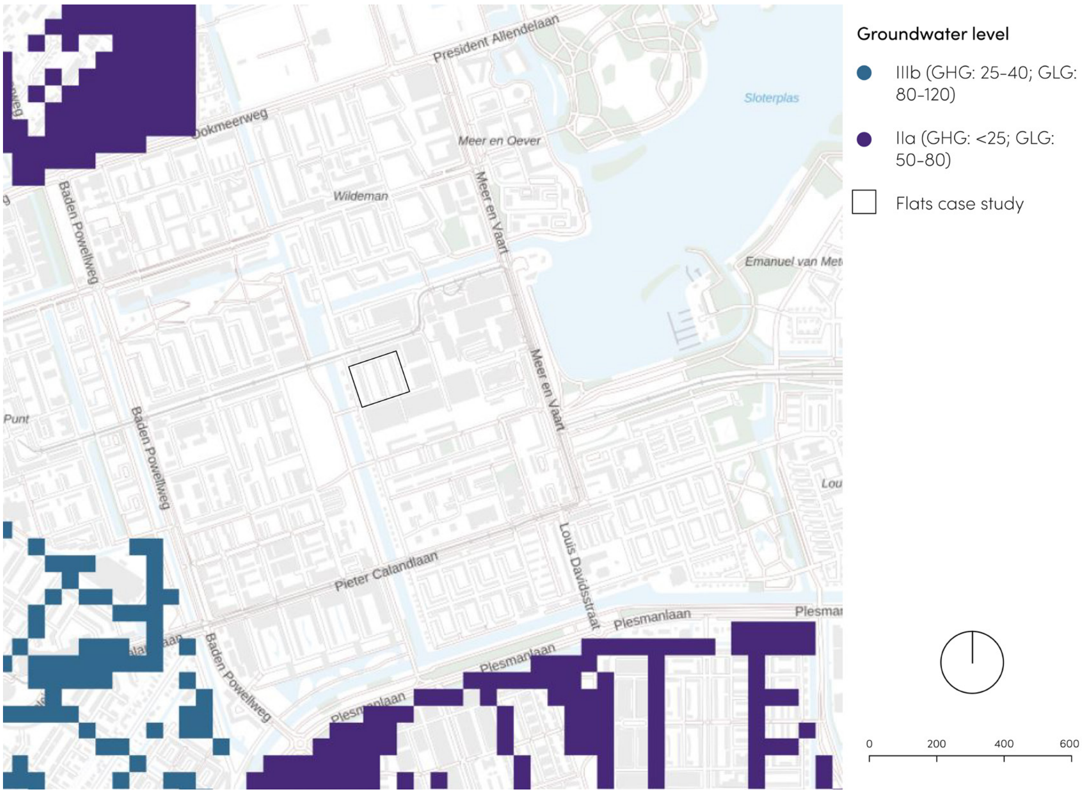
Soil types around case study site in Osdorp-Oost, Amsterdam. (Image by author, edited from Bodemkaart[2])

[1] Gans, Wim de. *De bodem onder Amsterdam: Een geologische stadswandeling*. (Utrecht: TNO Geologische Dienst Nederland, 2011), 53.

[2] "Bodemkaart van NL 1:50.000." Map. *Atlas Leefomgeving*. (Wageningen: WENR, 2021.)

APPENDIX E.

Soil characteristics of project site



Groundwater levels around case study site in Osdorp-Oost, Amsterdam. (Image by author, edited from Bodemdata[3])

[3] *Grondwatertrappen*, map, *Bodemdata.Nl* (Wageningen: Wageningen Environmental Research, 2018).

APPENDIX F.

Selection of tree species and forest type based on soil characteristics of case study site

	Kalkrijke leek-/ woudeerdgronden; klei	**Moerige eerdgronden met een moerige bovengrond of moerige tussenlaag op niet-gerijpte zavel of klei**	**Koopveengronden op veenmosveen**	**Tree species / forest type corresponding with soil characteristics**	**Tree species suitable for required building elements***
De aanleg van nieuwe bossen[1]	Zavel- en kleigronden, zand of veen met een kleidek			Es, Gewone Esdoorn, Beuk, Zoete Kers, Populier, Wilg, Zwarte Els, Zomer- en Wintereik, Haagbeuk, Linde (hoogte: 25-40 m)	Alder, Ash, Cherry, Oak
		Moerige zandgronden en 'arme' veengronden	Moerige zandgronden en 'arme' veengronden	Zomereik, Zachte Berk, Zwarte Els, Grove Den (hoogte: 14-22 m)	
Houtsoorten voor nieuwe bossen in Nederland[2]	Klei- en zavelgronden			Populier, Abeel, Wilg, Els, Berk, Es, Esdoorn	Alder, Ash, Poplar
		Veengronden in West- en Noordwest-Nederland – Bosveengronden		Populier, Wilg, Els, Berk, Es	
Aanleg van Gemengde Loofhoutbeplantingen met Inheemse Soorten[3]*	Groep 9.7 Lichte en zware kleigronden – leek/woudeerd en poldervaag in oude rivierafzettingen			Tree species: Zachte of Ruwe Berk, Esdoorn, Zomer- of Wintereik, Zwarte Els, Es Forest types: Elzenrijk Essen-Iepenbos, Eiken-Haagbeukenbos, Kamperfoelierijke Eiken-Haagbeukenbos, droog Essen-Iepenbos;	Alder, Ash, Oak
		Groep 2.2 Moerige gronden - moerpodzol met zavel of kleidek >20 cm, plaseerd op gerijpte of ongerijpte zavel, broekeerdgrond met of zonder zand- of kleidek		Tree species: Zachte of Ruwe Berk, Esdoorn, Zomer- of Wintereik, Zwarte Els, Es Forest types: Ruigt-Elzenbos, Elzenbroekbos (rijkere grond), Elzen-Berkenbroek (armere grond), Elzen-Eikenbos	
			Groep 1.1 Veengrond - aarveen, koopveen, weideveen en waardveen	Tree species: Zachte of Ruwe Berk, Esdoorn, Zomer- of Wintereik, Zwarte Els, Es Forest types: Ruigt-Elzenbos, Elzenbroekbos, Elzen-Berkenbroek	

Selection of tree species and forest type based on soil characteristics of case study site

Building application	**Selected tree species**
a. Window frame	Ash, Oak
b. Exterior door	Oak
c. Timber structure	Alder, Ash, Oak, Poplar
d. Façade cladding	Oak
e. Wood fiber insulation panel & f. OSB panel	Any rest wood

[1] Jansen, Patrick. De Aanleg Van Nieuwe Bossen. (Utrecht: Matrijs, 2009), 103.
[2] Goor, C.P. van, K.R. van Lynden, and H.A. van der Meiden. *Houtsoorten Voor Nieuwe Bossen in Nederland*. (Arnhem: Koninklijke Nederlandsche Heidemaatschappij, 1969), 98-110.
[3] Jager, K., and A. Oosterbaan. *Aanleg van Gemengde Loofhoutbeplantingen met Inheemse Soorten*. (Haarlem: Schuyt, 1994), 41-59.
[4] *Grondwatertrappen*, map, *Bodemdata.nl* (Wageningen: Wageningen Environmental Research, 2018).

*As opposed to the two other sources, this book considers the groundwater level as a parameter for the choice of tree species. Subsequently, the noted results in the table above are suitable for the groundwater level types: IIIb (GHG: 25-40; GLG: 80-120) and IIa (GHG: <25; GLG: 50-80.)[4]
*From the collection of site-specific suitable tree species, the species are selected that can be used for the required building elements from Appendix C.

APPENDIX G.

Ecosystem organisms

Tree species for building
Black Alder (Alnus glutinosa), Ash (Fraxinus excelsior), Penduncluate Oak (Quercus robur), Poplar (Populus)
Additional tree species
Zachte Berk, Schietwilg, Zoete Kers, Esdoorn, Kraakwilg

Shrub species
Vlier, Vogelkers, Hazelaar, Eenstijlige Meidoorn, Kornoelje Liguster, Vuilboom, Lijsterbes, Grauwe Wilg, Hulst, Bergvlier

Undergrowth
Zwarte Bes, Aalbes, Framboos, Braam, Dauwbraam, Krent, Kamperfoelie, Draadzegge, Eenarig Wollegras, Galigaan, Glanzend Veenmos, Hoogveenveenmos, Kamvaren, Kleine Veenbes, Koningsvaren, Laurierwilg, Lavendelhei, Moeraslathyrus, Moeraswolfsmelk, Paardenhaarzegge, Poelruit, Rood Veenmos, Rijsbes, Slank Wollegras, Slanke Zegge, Sterzegge, Stijf Veenmos, Stijve Zegge, Violet Veenmos, Wateraardbei, Waterdrieblad, Waterviolier, Wilde Gagel, Wrattig Veenmos, Aardbeiganzerik, Alpenheksenkruid, Besanjelier, Bittere Veldkers, Bosgeelster, Bosmuur, Bospaardenstaart, Boswederik, Daslook, Driekantige Bies, Eenbes, Gele Monnikskap, Geveerd Diknerfmos, Gewone Vogelmelk, Gladde Zegge, Grote Keverorchis, Gulden Sleutelbloem, Hangende Zegge, Heelkruid, Klein Heksenkruid, Knikkend Nagelkruid, Kruidvlier, Kruisbladwalstro, Maarts Viooltje, Moeraskruiskruid, Moerasstreepzaad, Moeraswolfsmelk, Muskuskruid, Paarbladig Goudveil, Reuzenpaardenstaart, Rivierkruiskruid, Schaafstro, Slangenlook, Slanke Sleutelbloem, Slanke Zegge, Spindotterbloem, Torenkruid, Verspreidbladig Goudveil, Welriekende Agrimonie, Wilde Kievitsbloem, Witte Rapunzel, Zomerklokje, Zwartblauwe Rapunzel

Birds
Appelvink, Blauwborst, Boomklever, Boomkruiper, Fluiter, Groene Specht, Grote Bonte Specht, Keep, Kleine Bonte Specht, Matkop, Middelste Bonte Specht, Nachtegaal, Sijs, Vuurgoudhaan, Wielewaal, Zwarte Specht, Gekraagde Roodstaart, Grauwe Vliegenvanger, Wielewaal

References:
- Jager, K., and A. Oosterbaan. *Aanleg van Gemengde Loofhoutbeplantingen met Inheemse Soorten*. (Haarlem: Schuyt, 1994), 194 ,197-199.
- Goor, C.P. van, K.R. van Lynden, and H.A. van der Meiden. *Houtsoorten Voor Nieuwe Bossen in Nederland*. (Arnhem: Koninklijke Nederlandsche Heidemaatschappij, 1969.)
- BIJ12. "N14.01 Rivier- en beekbegeleidend bos," December 19, 2023. Accessed January 15, 2024. https://www.bij12.nl/onderwerp/natuursubsidies/index-natuur-en-landschap/natuurtypen/n14-vochtige-bossen/n14-02-hoog-en-laagveenbos/.
- BIJ12. "N14.02 Hoog- en laagveenbos," December 19, 2023. Accessed January 15, 2024. https://www.bij12.nl/onderwerp/natuursubsidies/index-natuur-en-landschap/natuurtypen/n14-vochtige-bossen/n14-02-hoog-en-laagveenbos/.
- BIJ12. "N16.04 Vochtig bos met productie," December 15, 2023. Accessed January 15, 2024. https://www.bij12.nl/onderwerp/natuursubsidies/index-natuur-en-landschap/natuurtypen/n16-bossen-met-productiefunctie/n16-04-vochtig-bos-met-productie/.
- Jansen, J.J., A. Oosterbaan, G.M.J. Mohren, Paul Copini, and J. Den Ouden. "Groei En Productie van Zwarte Els in Nederland," January 1, 2018. https://doi.org/10.18174/444099.
- Jansen, J.J., A. Oosterbaan, G.M.J. Mohren, and J. Den Ouden. "Groei En Productie van Zomereik in Nederland," January 1, 2018. https://doi.org/10.18174/444093.
- Jansen, J.J., L. Goudzwaard, A. Oosterbaan, G.M.J. Mohren, and J. Den Ouden. "Groei En Productie van Es in Nederland," January 1, 2018. https://doi.org/10.18174/444100.
- Jansen, J.J., G.M.J. Mohren, P. Schmidt, L. Goudzwaard, A. Oosterbaan, and J. Den Ouden. "Groei En Productie van Populier in Nederland," January 1, 2018. https://doi.org/10.18174/444097.

Characteristics of selected trees

Black Alder (Alnus glutinosa)

Average growth: 6-10 m^3/year/ha
Plant distance: 1,5-2 m (= 2500-4500 trees per ha)
Density of fresh Alderwood: 680-1000 kg/m^3 (at 12% humidity 550 kg/m^3)

Their maximum age is around 150 years.
Regular thinning is needed for the Alder and the thin wood (7-30 cm diameter) is suitable for processing to fibers.
The Alder tree is a n-fixing species and has a high soil-improving ability. The tree captures nitrogen (60-100 kg/year/ha) with root rubers through symbiosis with Frankia bacteria.
The Alnus glutinosa is indigenous to the Netherlands, unlike the Alnus incana.
The Alder tree can reach a height of 20-25 m, the diameter is eventually between 0,3-1,2 m.
The wood of the Alder tree is very suitable and sustainable when applied under water and underground, as a foundation for example. Alderwood was often used in roofstructures in the Netherlands, due to its hard character. 40-60 year old Alderwood can be used for poles.

Wood characteristics: lightly coloured, heavy, flexible, hard wood with a beautiful grain and silky shine; very sustainable under water and in the ground

Applications pile, structure (beams or roundwood), gutter, interior door, panelling, furniture

Additionally, the bark, seed heads and galls can be processed into black ink/colouring. The bark also contains elements that can treat throat problems.

“Black Alder Texture ID5402,” CadNav, accessed April 18, 2024, https://www.cadnav.com/textures/5402.html.

- Fraanje, P.J, and Henk Pel. *Natuurlijk Bouwen Met Hout : 33 Boomsoorten Die Zich Thuisvoelen in Nederland*. Utrecht: Van Arkel, 1999.
- Goor, C.P. van, K.R. van Lynden, and H.A. van der Meiden. *Houtsoorten Voor Nieuwe Bossen in Nederland*. (Arnhem: Koninklijke Nederlandsche Heidemaatschappij, 1969.)

Characteristics of selected trees

Ash (Fraxinus excelsior)

Average growth: 8,4 m^3/year/ha (in year 40-70) and 7,4 m^3/year/ha (afterwards)
Plant distance: 1,25 m (= 6500 trees per ha)
Density of fresh Ashwood: 750-1115 kg/m^3 (at 12% humidity 510-830 kg/m^3)

The Ash tree is a slow grower.
Ideally, the Ash tree should be planted alone, as monoculture.
Thinning wood from between 25-70 years can exclusively be used for fibers.
The Ash tree needs similar circumstances as nettle, so these two usually grow together.
Ash trees grow best in small groups on 15-20 are in an Oakforest.
The Ash tree can reach a height of 20-30 m, the diameter is eventually between 0,4-0,9 m.
Ashwood is particularly sustainable when applied inside. Ashwood is suitable for bending.

Wood characteristics: lightly coloured, heavy, flexible, hard wood with a beautiful grain and silky shine

Applications: structure (beams or roundwood), flooring, exterior and interior window frame, interior door, stairs, panelling, furniture, veneer (from heartwood after 40 years); the thin, straight sticks after pollarding can be used for a variety of products

Wood production data (from real production forest)

Age	**Number of trees per ha**	**Height [m]**	**Diameter at 1,3 m height [cm]**	**Total woodproduction incl. thinning [m^3/ha]**
20	5300	9,5	6	32
40	912	19,5	17,8	241
60	509	25	25,6	399
90	336	29	33	544
120	235	31,4	40	636

- Fraanje, P.J, and Henk Pel. *Natuurlijk Bouwen Met Hout : 33 Boomsoorten Die Zich Thuisvoelen in Nederland*. Utrecht: Van Arkel, 1999.
- Goor, C.P. van, K.R. van Lynden, and H.A. van der Meiden. *Houtsoorten Voor Nieuwe Bossen in Nederland*. (Arnhem: Koninklijke Nederlandsche Heidemaatschappij, 1969.)

“Ash,” Architextures, accessed April 18, 2024, https://architextures.org/textures/730.

Characteristics of selected trees

Penduncculate Oak (Quercus robur)

Average growth: 6,3 m^3/year/ha
Plant distance: 1,25-1,5 m (= 4500-6500 trees per ha)
Density of fresh Oakwood: 900-1200 kg/m^3 (at 12% humidity 700 kg/m^3)

The Oak tree is a slow grower.
This species can be easily mixed with others.
In the first 30 years the thinning wood can not be used or sold. Thinning wood of 10-30 cm diameter can be used for fibers and, of 30-60 cm can in some cases be used as lumber. Only after about 120 years the Oak's diameter reaches 60 cm and those stems are valuable.
To multiple the number of Oak trees, sowing is necessary. The Oak tree is sensitive to shadow, so the young trees will compete in the beginning. It is recommended to sow between 600-700 kg of acorns per ha (250-350 acorns per kg.)
Oak trees in Europe are between 18-30 m high with a maximum of 45 m. The diameter can reach between 1,2-1,8 meters and it takes around 150 years for an Oak tree to develop a diameter of 60 cm.
The Oak tree flowers every 2 to 3 years.
Oakwood is suitable for bending. Wood of the Quercus robur is more resistant to external factors than wood of the Quercus petraea.

Wood characteristics: fine, considerably hard wood with a clear grain

Applications: structure (beams or roundwood), façade elements, roof cladding, flooring, exterior and interior window frame, exterior and interior door, stairs, panelling, veneer

Additionally, the bark, leaves, acorns and oak apples contain tannin, which has a high medicinal value. The oak apples can also be processed into black ink.

Wood production data (from real production forest)

Age	**Number of trees per ha**	**Height [m]**	**Diameter at 1,3 m height [cm]**	**Total woodproduction incl. thinning [m^3/ha]**
20	5600-3200	6-8	5-7	25-50
40	900-600	13-16	15-19	190-260
60	370-260	17-21	24-30	330-440
90	175-125	22-25	36-44	520-660
120	100-70	24-28	49-59	680-850

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Characteristics of selected trees

Poplar (Populus)

Average growth: 12,3 m^3/year/ha
Density of fresh Poplarwood: 880 kg/m^3 (at 12% humidity 430 kg/m^3)

Poplar trees are fast growers, the most fastgrowing species that can be used in the Netherlands.
Their crowns let light through which leads to a rich ground cover.
Poplar seedlings should be planted at a far distance as thinning is usually not done, every tree is supposed to grow into a mature one. The poplar mixes well with Ash trees.
Poplar for wood production: average growth of 11 m^3/year/ha (with circulation time of 25 years.)
Poplarwood can last long when used inside, outside it is not very sustainable. So, if Poplarwood is used in a structure, it should be protected from moisture.

Wood characteristics: lightly coloured, fine, soft, odourless, flexible wood; wood barely moves with humidity changes

Applications: structure (beams or roundwood), flooring, interior window frame, panelling, furniture, veneer, small products like: matches, paper, kitchen products, clogs

Additionally, the Poplar offer good charcoal and the resin can be used as an external medicin. Young bark and leaves can be turned into yellow/green colouring.

Wood production data (from real production forest)

Age	**Number of trees per ha**	**Height [m]**	**Diameter at 1,3 m height [cm]**	**Total woodproduction incl. thinning [m^3/ha]**
10	350	13,5	16,2	37
15	350	19,9	21,7	101
20	242	23,9	29,6	158
40	112	33,4	53,5	352
60	61	36,9	74,9	432

- Fraanje, P.J, and Henk Pel. *Natuurlijk Bouwen Met Hout : 33 Boomsoorten Die Zich Thuisvoelen in Nederland*. Utrecht: Van Arkel, 1999.
- Goor, C.P. van, K.R. van Lynden, and H.A. van der Meiden. *Houtsoorten Voor Nieuwe Bossen in Nederland*. (Arnhem: Koninklijke Nederlandsche Heidemaatschappij, 1969.)

Tutum, "Houtsoorten Detail," Houtbedrijf Van Laer, accessed April 18, 2024, https://www.houtbedrijfvanlaer.be/Fineer/VL-34/Populier.

APPENDIX H.

Lifespan estimation of building parts

Building element	Estimated lifespan (years)
a, Window frame	40
b. Exterior door	100+
c. Timber structure	85
d. Façade cladding	45
e. Wood fiber insulation panel	As long as the building's lifespan
f. OSB panel	60

References:
- "Typical Life Expectancy of Building Components." Perth: Cerclos, 2015.
- "Estimated Life Expectancy Chart for Commercial Building Systems and Components - CCPIA." Certified Commercial Property Inspectors Association, April 25, 2023. https://ccpia.org/estimated-life-expectancy-chart-for-commercial-building-systems-and-components/.
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- "InterNACHI's Estimated Life Expectancy Chart." Chesapeake: National Association of Residential Property Managers, 2006.

*In some cases, the used sources provided different life expectancies for the same building materials, in which case, the average amount of years was calculated.

APPENDIX I.

Required natural resources for renovation and densification of case study flats Osdorp-Oost

Totals

	Natural resources for 1 portiek [m^3]	**Natural resources for 1 flat [m^3]**	**Natural resources for 3 flats [m^3]**
Renovation	108	661	1966
Densification	11	75	223
Total	119	735	2204

Per tree species

		Natural resources for 1 portiek [m^3]	**Natural resources for 1 flat [m^3]**	**Natural resources for 3 flats [m^3]**
Renovation	**Oak**	10	62	186
	Poplar	6	38	114
	Rest	89	550	1650
Densification	**Oak**	2	10	30
	Poplar	1	4	12
	Rest	8	59	175
Total	**Oak**	8	51	216
	Poplar	7	42	126
	Rest	99	608	1825

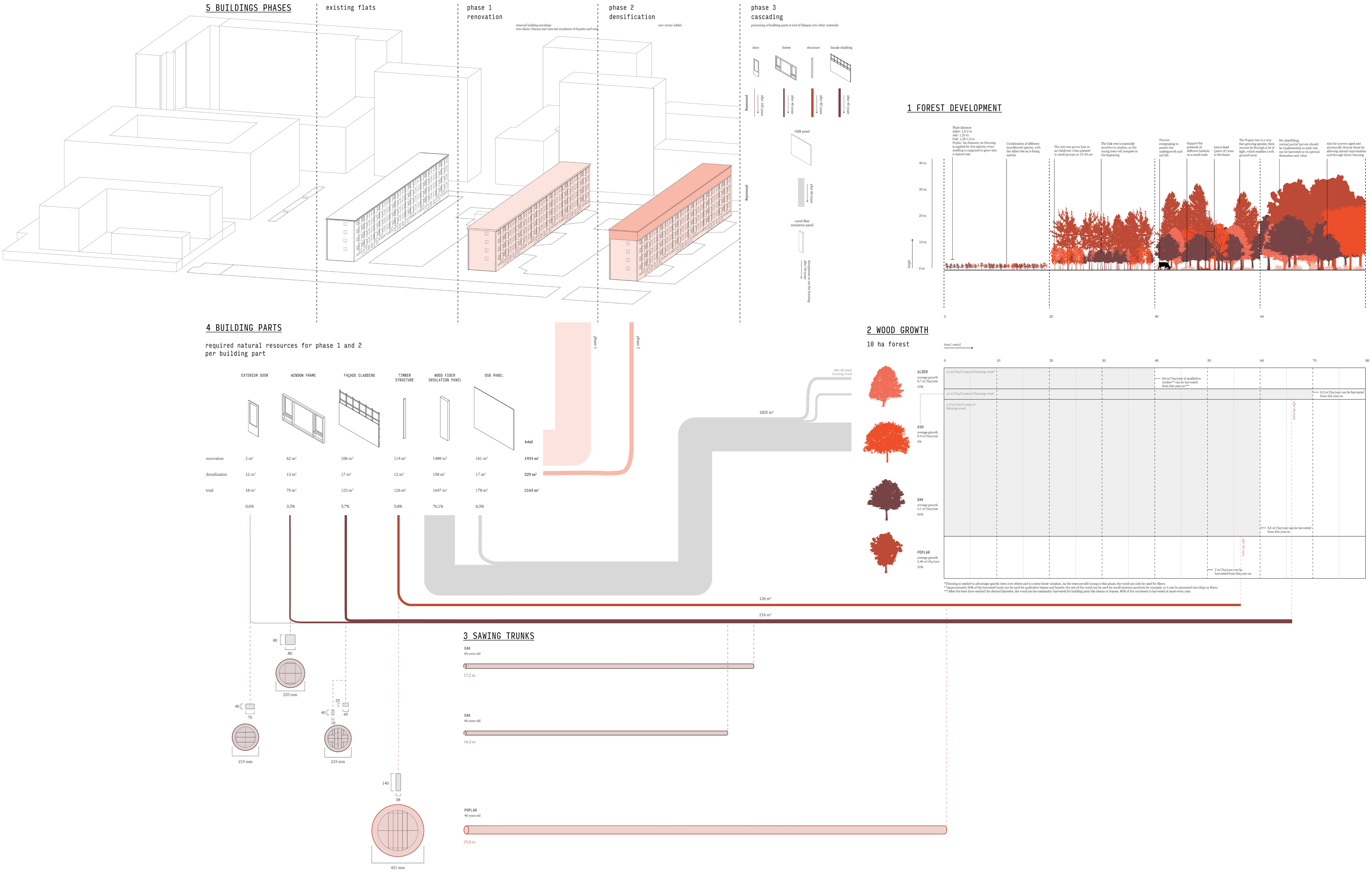
Required natural resources for renovation and densification of case study flats Osdorp-Oost

Per building part

		Natural resources for 1 portiek [m³]	**Natural resources for 1 flat [m³]**	**Natural resources for 3 flats [m³]**
Renovation	**a. Exterior doors**	1	6	18
	b. Window frames	3	21	62
	c. Timber structure	6	38	114
	d. Façade cladding	6	35	106
	e. Insulation panel	81	496	1489
	f. OSB panel	9	54	161
Densification	**a. Exterior doors**	0	0	0
	b. Window frames	1	4	13
	c. Timber structure	1	4	12
	d. Façade cladding	1	6	17
	e. Insulation panel	7	53	158
	f. OSB panel	1	6	17
Total	**a. Exterior doors**	1	6	18
	b. Window frames	4	25	75
	c. Timber structure	7	42	126
	d. Façade cladding	7	41	123
	e. Insulation panel	89	549	1647
	f. OSB panel	10	59	178

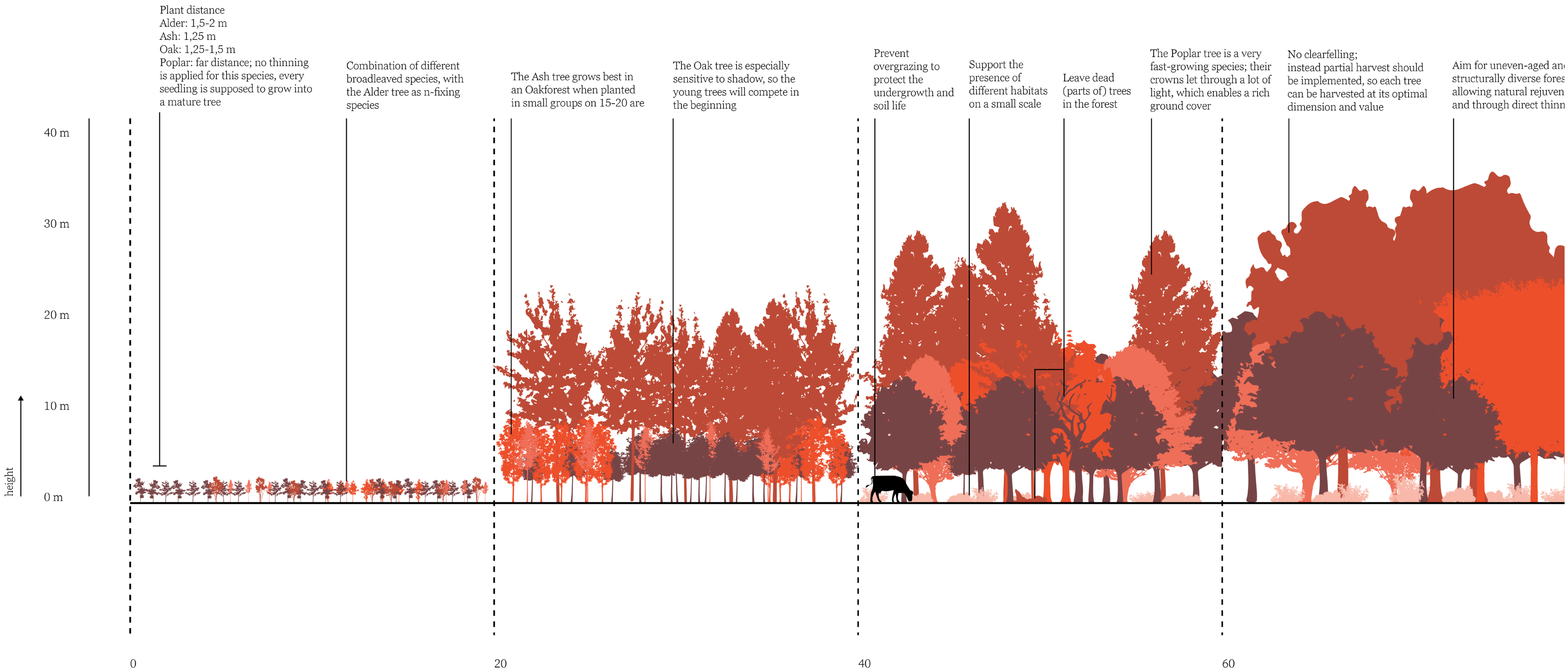
APPENDIX J.

Regenerative forest design for renovation and densification of case study portiekflats in Osdorp-Oost, Amsterdam



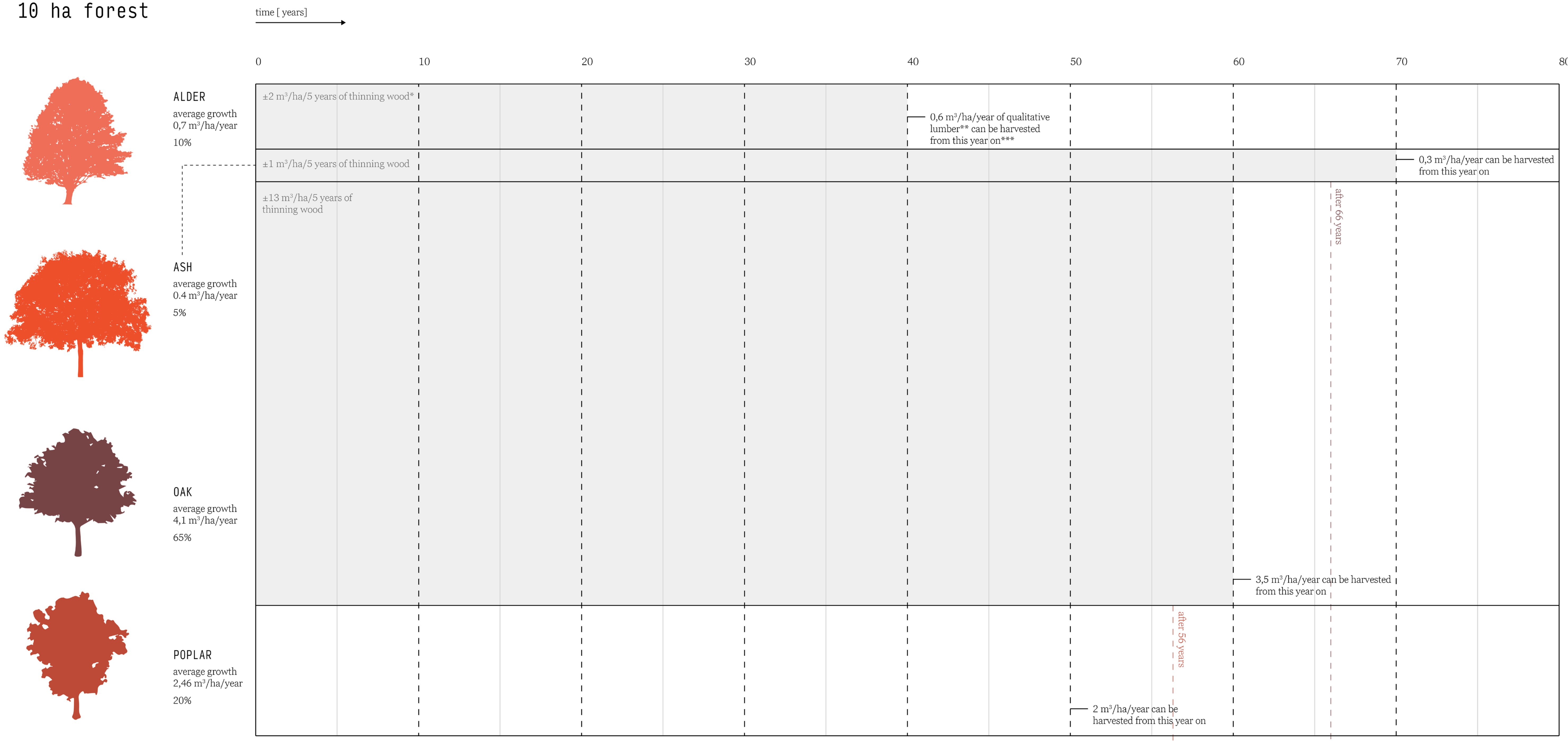
	EXTERIOR DOOR	WINDOW FRAME	FAÇADE CLADDING	TIMBER STRUCTURE	WOOD FIBER INSULATION PANEL	OSB PANEL	total
renovation	2 m³	62 m³	106 m³	114 m³	1489 m³	161 m³	**1934 m³**
densification	12 m³	13 m³	17 m³	12 m³	158 m³	17 m³	**229 m³**
total	18 m³	75 m³	123 m³	126 m³	1647 m³	178 m³	**2163 m³**
	0,6%	3,5%	5,7%	5,8%	76,1%	8,3%	

1 FOREST DEVELOPMENT

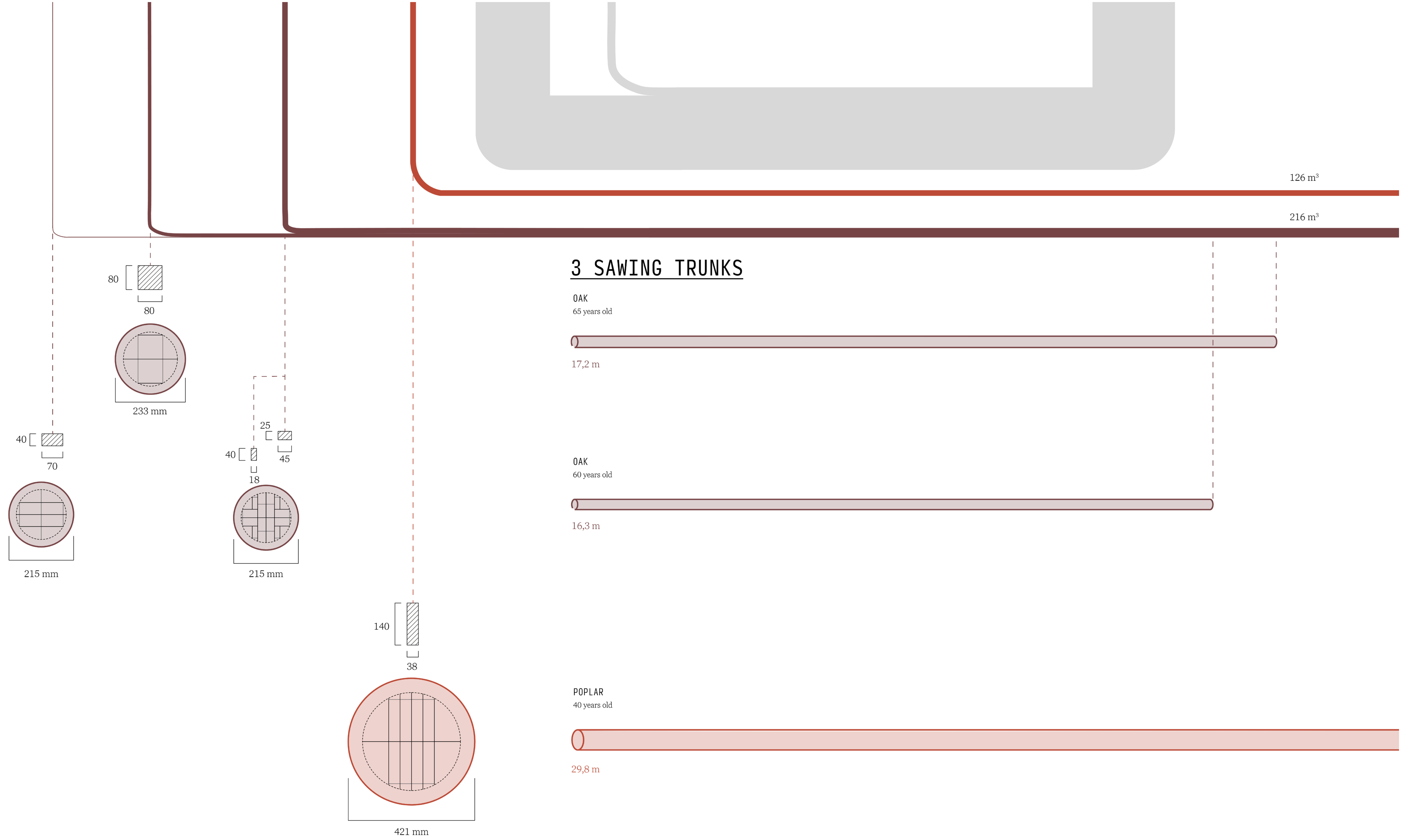


2 WOOD GROWTH

10 ha forest

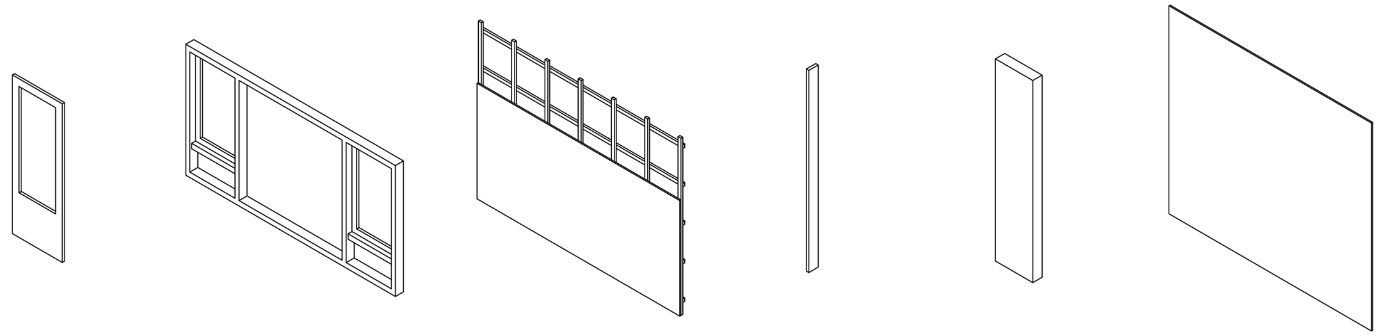


*Thinning is needed to advantage specific trees over others and to create forest variation. As the trees are still young in this phase, the wood can only be used for fibers.
**Approximately 50% of the harvested trunk can be used for qualitative beams and boards, the rest of the wood can be used for small interiors products for example, or it can be processed into chips or fibers.
***After the trees have reached the desired diameter, the wood can be sustainably harvested for building parts like beams or frames. 80% of the increment is harvested at most every year.

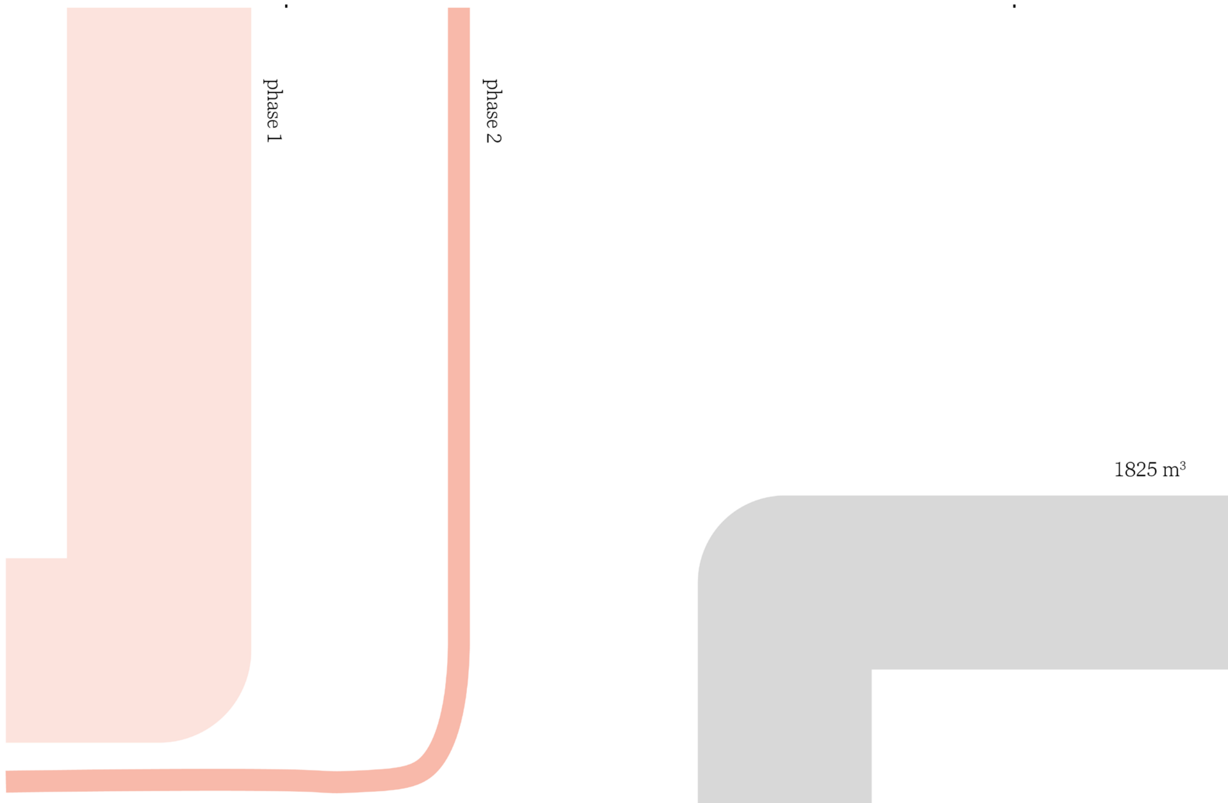

126 m³
216 m³
3 SAWING TRUNKS
OAK
65 years old
17,2 m
OAK
60 years old
16,3 m
POPLAR
40 years old
29,8 m
80
80
233 mm
40
70
215 mm
25
45
40
18
215 mm
140
38
421 mm

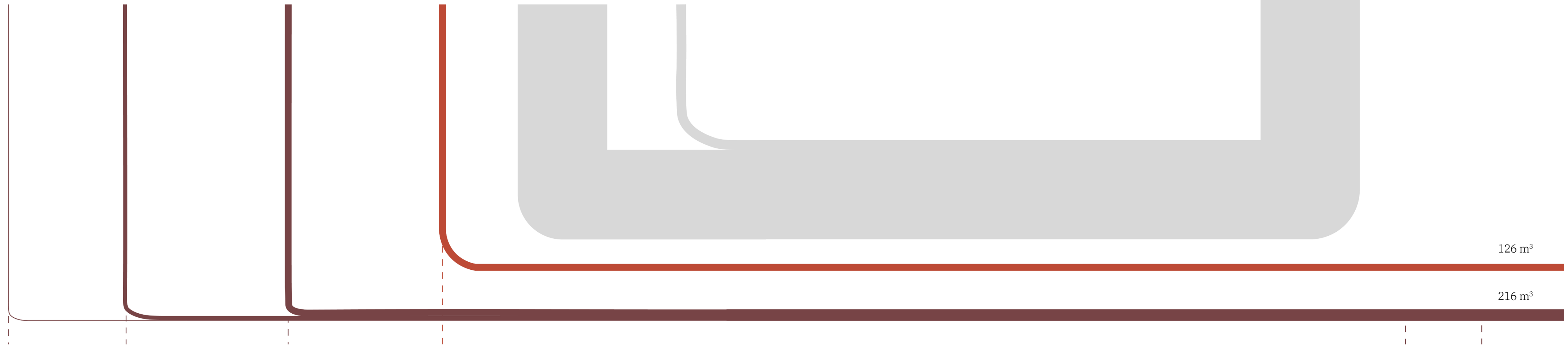
4 BUILDING PARTS

required natural resources for phase 1 and 2
per building part

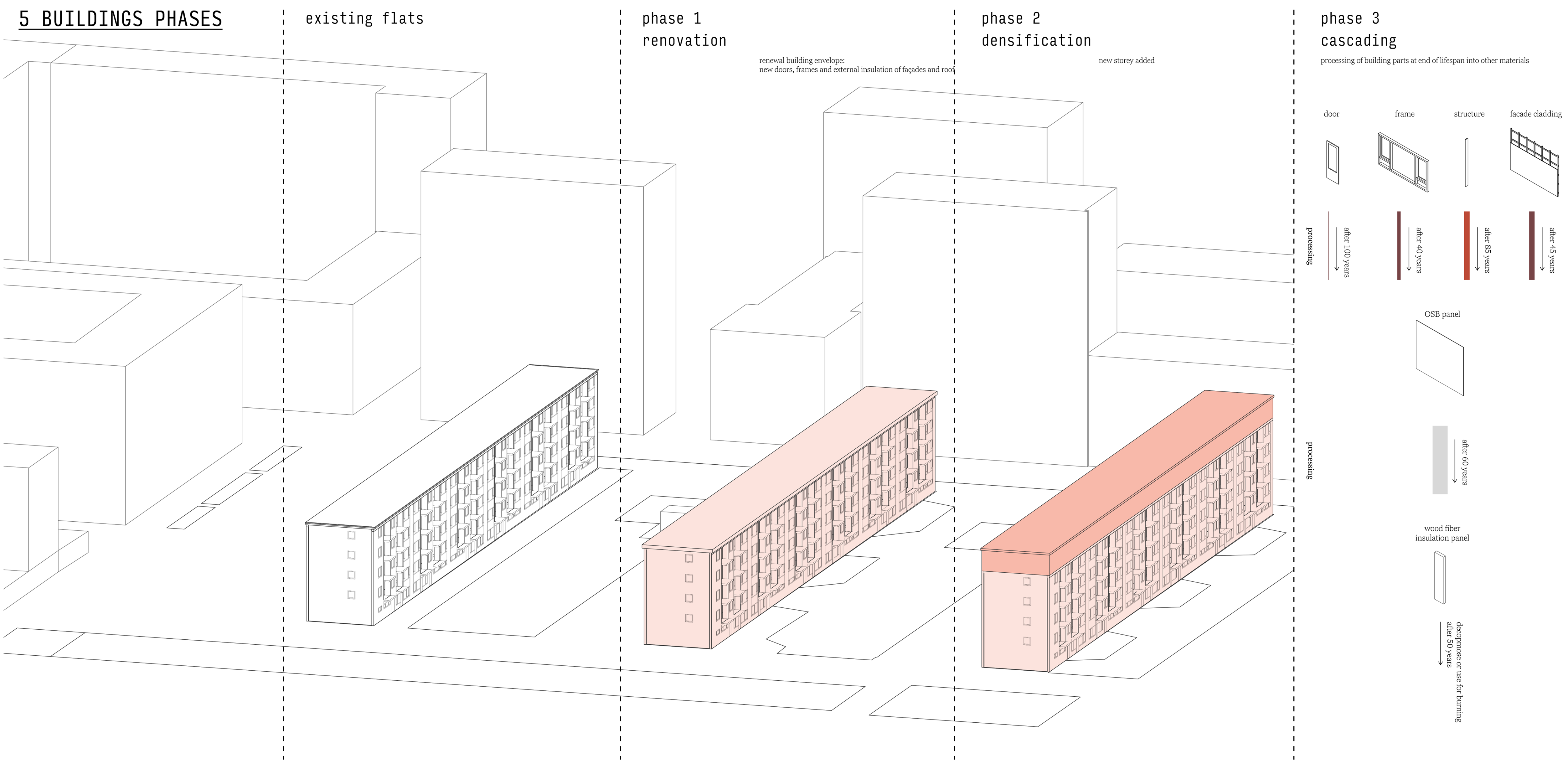


	EXTERIOR DOOR	WINDOW FRAME	FAÇADE CLADDING	TIMBER STRUCTURE	WOOD FIBER INSULATION PANEL	OSB PANEL	total
renovation	2 m³	62 m³	106 m³	114 m³	1489 m³	161 m³	**1934 m³**
densification	12 m³	13 m³	17 m³	12 m³	158 m³	17 m³	**229 m³**
total	18 m³	75 m³	123 m³	126 m³	1647 m³	178 m³	**2163 m³**
	0,6%	3,5%	5,7%	5,8%	76,1%	8,3%	





5 Building phases



APPENDIX K.

Explanation for regenerative forest design of Appendix J.

Appendix J. shows a multifaceted diagram of the renovation and densification of the postwar flats in relation to a regenerative forest and it's wood. This appendix explains what is shown in the different parts of the diagram and how the information for the diagram was collected.

1 Forest development

This part of the diagram shows the development of the regenerative forest through time. Four moments (0, 20, 40 and 60 years) in time were chosen to display in this overview. The height and diameter of the trees are based on growth data of trees in the Netherlands from WUR. The diagram also contains additional information about the establishment and management of the forest that are in line with Continuous Cover Forestry (CCF) and Close(r)-To-Nature Forest Management (CTNFM.)

2 Wood growth

This table shows the ratio of the different tree species (which is based on Dutch forest establishment sources), the period of time when the harvested wood is not yet usable for products yet (in grey) and the moment when the trunks would be ready to be used for sawing. From the average growth (m^3/ha/year) of every tree species and the ratio of the different species in the forest, the quantities of wood the can be harvested were calculated. Thinning is necessary (for some tree species) to promote the growth of specific trees and maintain the health and biodiversity of the forest. The wood that is harvested from thinning can be used for wood chips and fibers, and the material flows from the thinning period are shown in grey left of the table. Four buildings parts (a. exterior door b. window frame c. timber structure and d. façade cladding) require qualitative tree trunks. Trunks from the Poplar and the Oak are used for these parts and the material flows for this wood are presented under the table. For the period after thinning the yearly increment is used to decide how much wood can be harvested. To maintain a healthy, biodiverse and full forest, only 70-80% of the increment should be harvested each year. Additionally, only about 50% of the harvested trunk should be considered as wood, that is appropriate for beams and boards. Both of these margins were incorporated in the calculation of the wood flows that come from the 10 ha regenerative forest. In conclusion, a 10 ha regenerative forest with these four tree species and with this configuration could provide the building materials for the renovation and densification (of one storey) of the three case study portiekflats in 66 years, whilst remaining a healthy, biodiverse ecosystem.

3 Sawing trunks

The diameter and length of the harvested trunks at a specific age (from WUR data) are shown in this part of the diagram. Tree trunks can be sawn in different patterns, which consequently create beams or boards with different qualities. Plain sawing creates boards with a beautiful grain, but these wood parts tend to bend more. Quarter sawing creates more stable parts. Parts a. exterior door and c. timber structure definitely require quarter sawing. The diameters of the trunks are shown with the required sawing lines and the beams that are retrieved from it. Subsequently, these beams are used for the different building parts.

Explanation for regenerative forest design of Appendix J.

4 Building parts

The six different building parts (a. exterior door b. window frame c. timber structure d. façade cladding e. wood fiber insulation panel f. OSB panel) are shown in this part of the diagram, along with the needed quantities (in m^3) for the renovation and densification phase. Parts e and f are made from residual wood flows (in grey) and parts a-d are made from qualitative tree trunks from the Oak and Poplar. After the production of the parts, the parts are assembled into the different building elements and eventually the materials flow to the renovation and densification of the portiekflats.

5 Building phases

The building project is divided into three phases. Phase 1 is the renovation of the existing flats by insulating them from the outside. Phase 2 is the densification by adding one storey made from timber construction elements. And phase 3 is cascading and can be described as the multiple reprocessing of wood into new products. Cascading has a circular aim as it firstly used the wood at its optimal form and afterwards looks for ways to make use of the wood in a slightly lower form instead of disposing it.

Remarks

With regard to this regenerative forest diagram, it is important to realise that this is not a realistic portrayal of the management and harvesting. In real life trees are usually considered as qualitative once they reach a 60 cm diameter. So the small trunks shown in the diagram would not be used in a real situation, although the wood is already in a good state. So, realistically the needed time frame for harvesting the needed building materials would be longer than 66 years.

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APPENDIX L.

Referred tree species names (Dutch, English, Latin)

Dutch name	English name	Latin name
Berk	Birch	Betula
Douglas	Douglas fir	Pseudotsuga menziesii
Eik	Oak	Quercus
Els	Alder	Alnus
Es	Ash	Fraxinus excelsior
Fijnspar	Spruce	Picea abies
Gleditsia	Honeylocust	Gleditsia triacanthos
Haagbeuk	Hornbeam	Carpinus betulus
Iep	Elm	Hollandica
Kers	Cherry	Prunus
Lariks	Larch	Larix
Pijnboom	Pine	Pinus sylvestris
Populier	Poplar	Populus spec.
Robinia (Acacia)	Black locust	Robinia pseudoacacia
Tamme kastanje	Chataignier	Castanea sativa
Walnoot	Common walnut	Juglans regia
Wilg	Willow	Salix alba
Zilverspar	Silver fir	Abies alba