Translating resident values in modular façade design

A Value–Indicator Framework for industrialised social housing refurbishment

Research Report
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Acknowledgment

This thesis marks the end of my graduation project in the MSc Building Technology track at the Faculty of Architecture and the Built Environment in Delft. It has been a long, intense, and sometimes difficult process, but also one in which I learned how to position myself as a designer between technical precision and social responsibility. I am happy to finish this period on a positive note, with a final product that I can now share with others.

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This thesis began with a concern that stayed with me throughout: façade renovation is usually discussed through technical performance, while for the person living behind the façade, it is their window, their daylight, their home being changed around them. Those two perspectives rarely meet. I do not expect this work to fully close that gap, but I hope it contributes even in a small way, to a more careful and traceable way of designing renovation systems: ones that are both technically strong and socially meaningful, treating residents as people whose values are worth building in, rather than designing around it.

Abstract

European social-housing refurbishment is under pressure to deliver deep energy upgrades at speed, while also responding more carefully to the residents who live with the consequences of renovation. Industrialised modular façade systems can accelerate retrofit, improve quality control, and reduce on-site disruption, but they also risk reinforcing standardised solutions.

In many renovation processes, resident values are surfaced through engagement but enter too late to influence module configuration, material expression, façade operability or the way the façade meets the street outside and shapes the dwelling inside This thesis addresses this problem as a value–design translation gap: the missing methodological step between identifying what residents value and integrating those values in architectural and technical façade decisions.

The research develops, applies, and evaluates a Value–Indicator Framework for modular façade renovation in social housing. Through literature review and cross-case analysis of eight European social-housing renovation cases, six recurring resident values are identified: comfort, affordability, fairness, empowerment, sustainability, and identity. These values are translated into architectural design indicators that could guide the modular façade design.

The framework is then operationalised through the Value-Integrated Modular Façade System (VIMFS), a two-layer system in which Layer 1 provides a standardised technical performance baseline, including insulation, airtightness weather protection. Layer 2 the adaptive socio-technical interface, carries the bounded resident-facing variation, through value-affinity clusters and a component catalogue.

The framework is tested through Research by Design on a post-war walk-up apartment block in Rotterdam-West. A four-step configuration logic translates value priorities into four traceable design variants: V01 Control and Comfort, V02 Clear and Affordable Upgrade, V03 Ecological Renewal and V04 Community Threshold. All variants share the same Layer 1 standardised performance layer so that every resident receives the same technical envelope, while differentiation is produced through the component selection of layer 2 via the catalogue. In short, layer 1 secures fairness across all dwellings; layer 2 allows residents to express what matters to them.

The variants are evaluated through seventeen key performance indicators (KPIs) to test whether resident values remain visible, measurable, and differentiated at design stage.

The resulting scores are V01 = 15/17, V02 = 12.5/17, V03 = 16/17 and V04 = 15.5/17.

This thesis shows that modular façade renovation does not have to choose between industrialised standardisation and resident responsiveness. If variation is bounded, documented, and technically coordinated, an equal technical baseline can coexist with value-led differentiation.

The contribution is not a fully engineered façade product or a validated participation process, but traceable design-stage method for translating resident values into modular façade renovation design.

In doing so, the thesis positions the façade as a socio-technical interface between building performance, modular construction logic, and everyday residential life.

Keywords: *modular façade renovation, social housing, resident values, socio-technical design, value-indicator framework, value-integrated modular façade system (vimfs), value-responsive façade design, traceable configuration logic, , industrialised refurbishment,*

Table of content

PART I: INTRODUCTION

PART II: THEORETICAL AND EMPIRICAL FOUNDATION

PART III : FRAMEWORK AND SYSTEM DEVELOPMENT

PART IV:APPLICATION AND EVALUATION

PART V : CLOSING

APPENDICES

Chapter 1:Introduction

1.1 Background and context

The decarbonisation of the built environment is a central objective of European climate and energy policy. Buildings account for approximately 40% of final energy consumption and around 36% of greenhouse gas emissions in the European Union, making the existing building stock a critical focus for climate mitigation (European Commission, 2020,BPIE, 2022). Because most of the housing stock that will exist in 2050 has already been built, the challenge is not only to construct better buildings, but to upgrade the performance of those already in use.

Within this context, social housing represents a particularly urgent and complex refurbishment field. Much of the European social housing stock was constructed in the post-war period and today suffers from inadequate thermal performance, ageing façades, outdated services, and poor indoor environmental quality. (Femenías et al., 2018,BPIE, 2022).
At the same time, social housing residents are often more vulnerable to rising energy costs, indoor discomfort, and renovation-related disruption. (Straver & Mulder, 2020). Refurbishment in this sector is therefore not only a technical question of performance upgrading, but a social and ethical issue that directly affects residents' daily lives.

Industrialised and modular façade systems are increasingly promoted to accelerate refurbishment while reducing on-site disruption and improving quality control. Prefabricated façade systems can integrate insulation, windows, airtightness, cladding, and environmental technologies into a single coordinated intervention. However, while such systems offer clear advantages in speed, repeatability, and technical control, they also risk reinforcing a performance-driven logic in which residents lived experiences are not systematically translated into the façade design itself.

1.2 Problem statement

Despite strong policy ambitions and technological advances, refurbishment outcomes frequently fall short of expectations in practice. A growing body of research demonstrates persistent gaps between predicted and actual performance (Sunikka-Blank & Galvin, 2012), as well as challenges related to user acceptance, comfort, and long-term use of refurbished dwellings. (Guerra-Santin et al., 2025) These shortcomings are particularly visible in social housing refurbishment, where residents typically have limited influence over design decisions yet are most affected by their consequences.

This performance-driven logic dominates current refurbishment practice, which remains expert-led. Decisions are often based on technical indicators such as energy demand, U-values, or cost efficiency, while residents' experiential knowledge and priorities are addressed late in the process or reduced to consultation. As a result, refurbishment solutions may technically comply with performance targets but fail to align with residents' values related to comfort, safety, identity, usability, and control.

In modular façade refurbishment, this tension becomes especially pronounced. While modular systems enable speed and standardisation, they can constrain opportunities for residents to influence façade appearance, operability, and spatial experience. This can lead to resistance, dissatisfaction, and socio-technical misfits in which technically well-performing solutions are poorly integrated into everyday life. The shortfall is not a failure of technology, but of translation: the methodological step between identifying what residents value and shaping the façade around those values is currently missing.

1.3 Research gap

The literature increasingly recognises refurbishment as a socio-technical process shaped by interactions between technologies, institutions, and residents' daily practices.

Research highlights the importance of resident engagement, user-centred design, and participatory approaches in improving refurbishment outcomes. However, a critical gap remains in how these insights are operationalised within industrialised refurbishment systems.

This gap is especially visible in modular façade renovation. Although façade systems play a significant role in both technical performance and lived experience, they are still predominantly treated as technical optimisation problems. Existing research focuses strongly on envelope performance, prefabrication strategies, constructability, and regulatory compliance, while the translation of resident values into façade system logic remains underdeveloped. Engagement methods successfully surface resident priorities, but there is still limited methodological guidance on how these qualitative insights can systematically inform modular façade design.

This thesis addresses that value–design translation gap by developing a structured framework that connects resident values to architectural design indicators, façade criteria, system logic, and modular façade configurations in a traceable and operational way.

1.4 Research aim and objectives

The aim of this thesis is to develop a value-driven design approach for modular façade renovation in social housing. The research seeks to investigate how resident values can be empirically identified, systematically structured, and translated into architectural design indicators and façade-related system parameters that inform modular façade design.

The objectives are:

- to identify recurring resident values across participatory social-housing renovation cases and analyse how they are currently integrated, negotiated, or constrained within industrialised refurbishment practice.
- to translate resident values into façade-related architectural design indicators
- to operationalise these indicators into façade parameters and system logic compatible with modular renovation
- to explore, through Research by Design, how these parameters inform modular façade configurations.
- to evaluate, through measurable indicators linked to the value framework, the extent to which the embedded values are present in the resulting design configurations.

By positioning façade design as a socio-technical mediator between technical performance requirements and lived experience, this research contributes to the development of renovation strategies that support social inclusion, resident ownership, and long-term effectiveness, while remaining compatible with the demands of large-scale modular renovation.

1.5 Research question and sub-questions

This thesis is guided by the following main research question:

How can resident values be systematically integrated into modular façade renovation design in social housing?

To address the main research question, the study is guided by five sub-questions. Each sub-question is answered in a defined chapter or pair of chapters (Table 1). In Chapter 10.2 the answers to each sub-questions and to the main research question will be formulated.

Table 1:Research sub-questions and the chapters in which they are addressed.

	Sub-question	**Addressed in**
1	*Which resident values recur across European social-housing renovation cases, and what currently prevents them from shaping design decisions?*	Chapters 2 and 3
2	*How can these resident values be translated into architectural design indicators for façade renovation?*	Chapter 4
3	*How can these design indicators be operationalised into a modular façade system suitable for industrialised refurbishment?*	Chapter 5
4	*How can a configuration logic translate value priorities into traceable design variants within this system?*	Chapters 6 and 7
5	*To what extent are the resident values visible, measurable, and differentiated across the resulting design variants?*	Chapter 8

1.6 Research methodology

This thesis combines Design Science Research (DSR) with Research by Design (RbD) and uses diagrammatic reasoning as the translational method between the two.
The challenge addressed lies simultaneously in two domains: analytically, resident values must be identified, structured, and translated into design-relevant knowledge; architecturally, these values must be embedded in a modular façade system and made legible through spatial and material design.
Neither domain can be addressed in isolation, and neither DSR nor RbD alone covers both.

The five research phases (Table 1.2) show how the approaches sequence across the thesis. Each subsection below is read once: this section makes the methodological structure explicit, while the chapters that follow apply the methods.

1.6.1 Design science research (DSR)

Design Science Research (DSR) is used to guide the analytical and conceptual development of the thesis. DSR is appropriate for research in the built environment where new models or methods must be developed, tested, and refined in response to real-world challenges (Hevner et al., 2004; March & Smith, 1995).

In this thesis, the central artefacts are not physical products in a narrow engineering sense, but conceptual-operational design instruments: the Value–Indicator Framework, the Value-Integrated Modular Façade System (VIMFS), and the configuration logic together with its bounded component catalogue.

These are not treated as isolated outputs, but as connected artefacts that progressively address the identified value–design translation gap.

The logic of the research is informed by Hevner's three-cycle model of Design Science Research (figure 1,(Hevner, 2007):

The relevance cycle connects the study to the practical context of social housing refurbishment, where technical upgrading often remains weakly aligned with resident experience.

Literature on socio-technical renovation, occupant behaviour, energy poverty, and resident dissatisfaction after renovation demonstrates the inadequacy of purely technical renovation metrics (Lovell, 2005; Gram-Hanssen, 2012; Bouzarovski, 2017).

The design cycle supports the iterative construction of the thesis artefacts by moving from identified values to indicators, from indicators to façade criteria, and from façade criteria to system and configuration logic including the use of the designed component catalogue. (March & Smith, 1995).

The rigour cycle ensures that the framework is anchored in established theoretical knowledge, such as Value Sensitive Design (Friedman & Hendry, 2019), Social Practice Theory (Shove et al., 2012), and socio-technical systems theory (Geels, 2004). These bodies of literature contextualise how values, practices, and material systems co-produce renovation outcomes.

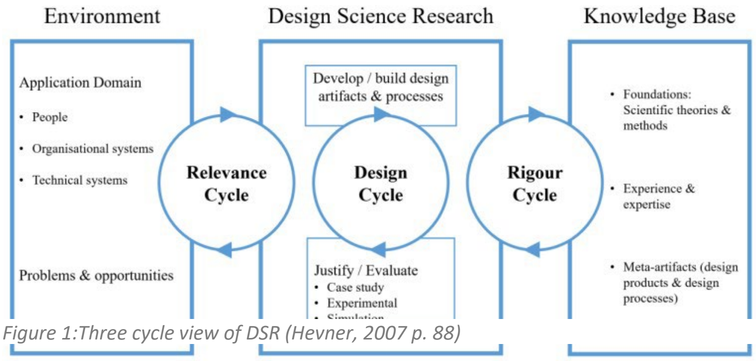


Figure 1:Three cycle view of DSR (Hevner, 2007 p. 88)

1.6.2 Research by design (RbD)

Where Design Science Research (DSR) provides the conceptual and structural foundation, Research by Design (RbD) constitutes the design-based testing environment for the value-translation framework.

RbD approaches design as a method for producing knowledge, not merely as a means for producing architectural outcomes. This orientation is grounded in Schön's (1983) concept of reflection-in-action, where designers iteratively test ideas through drawing and modelling, learning through cycles of action and reflection.

RbD is also aligned with design cognition research, which shows that knowledge evolves through representational acts such as sketching, diagramming, and prototyping (Oxman, 2006; Goldschmidt, 1991; Lawson, 2004).

In this thesis, RbD is most visible in the configurational phase, where the framework and system logic are translated into façade design variants.

Through iterative design studies, the research tests how resident values become spatially and materially legible when expressed through façade modules, threshold elements, cladding choices, opening logic, and system combinations.

These design iterations are not treated as final solutions to be optimised, but as epistemic tools: they reveal how the framework behaves once it is materialised, where tensions emerge, and how bounded variation can be structured within one shared modular logic.

Research by Design also supports abductive reasoning: the research moves back and forth between conceptual expectations and design consequences, which allows unexpected spatial or technical effects to feed back into the framework itself.

1.6.3 Diagrammatic reasoning

Diagrammatic reasoning plays a significant role in connecting Design Science Research and Research by Design. In this thesis, diagrams are not used only as representational instruments, but as analytical and generative tools that support translation across various stages of the research. They enable the study to move from qualitative resident values to structured design logic without reducing the complexity of the problem too early.

Three types of diagrammatic representation are used throughout the thesis:

Conceptual diagrams:
Represent relationships between resident values. They synthesise literature and case insights by revealing value clusters, tensions, and dependencies.

Translation diagrams:
Translate values into façade-related design criteria. They show how abstract resident values are reformulated into design-relevant parameters such as openness, rhythm, modularity, material expression, and user control.

Axonometric configurational drawings:
Explore how these criteria are spatially and materially composed within the modular façade system. They are used to compare component relations, layer logic, and scenario-based configurations.

Together, these diagram types provide methodological continuity across the thesis. They connect the empirical and conceptual work of DSR to the configurational exploration of RbD, and they make the research process more explicit and traceable.

1.6.4 Research trajectory

The methodology is structured as a five-phase research trajectory in which each phase corresponds to a specific sub-question and methodological approach.
The phases are analytical rather than strictly chronological: they overlap and inform one another, but each has a dominant task, a dominant method, and a main output(Table 1.2)

Table 1.2: Research trajectory explanation table (own work)

Sub-Question	Main Methodology	Research Phase	Main Output	Addressed In Chapter(S)
SQ1: Which resident values recur across European. social-housing renovation cases, and what currently prevents them from shaping design decisions?	Literature review and cross-case analysis within DSR	Analytical	Six empirically grounded resident value dimensions	Chapters 2 and 3
SQ2: How can these resident values be translated into architectural design indicators for façade renovation?	DSR supported by diagrammatic reasoning	Translational	Value–Indicator Framework	Chapter 4
SQ3: How can these design indicators be operationalised into a modular façade system suitable for industrialised refurbishment?	System mapping, layered logic development, and design synthesis	System	Modular Façade System: two layers, three Layer 1 base platforms, four Layer 2 clusters	Chapter 5
SQ4 : How can a configuration logic translate value priorities into traceable design variants within this system?	Research by Design through system development to catalogue navigation, component selection, and scenario composition	Configurational	Configuration logic and four case-study design variants	Chapters 6 and 7
SQ5: To what extent are the resident values visible, measurable, and differentiated across the resulting design variants?	Comparative evaluative assessment	Evaluative	Scored evaluation matrix and framework reflection	Chapter 8

1.6.5 Validity, reliability, and ethical considerations

Construct validity is strengthened by grounding the six value categories in both empirical case evidence and the bodies of literature established in Chapter 3, including socio-technical renovation research, resident experience and comfort studies, and research on resident values. Because these sources demonstrate that renovation outcomes are shaped by lived experience, the values identified are treated as empirically and theoretically grounded constructs rather than ad-hoc categories (Bartiaux et al., 2014; Broers et al., 2022; Shove et al., 2012).

Internal validity is reinforced through methodological triangulation. Values are identified through literature, cross-case analysis, and documented resident participation studies (Broers et al., 2022; Soikkeli et al., 2023), ensuring that the framework builds on recurring themes across multiple forms of evidence. Framework claims are traced back to specific case references.

Ecological validity is addressed by applying the framework within a realistic case study and by evaluating design propositions against published performance envelopes and industry references. This aligns with findings from design-interpretation studies showing that residents interpret architectural intentions most accurately through visual scenarios and spatial representations (Boess, 2022; van Hoof & Boerenfijn, 2018).

Reliability is supported through transparent documentation of all analytical, diagrammatic, and design steps. Each scenario in Chapter 8 follows an identical reading structure, and each evaluation in Chapter 9 uses the same scored rubric, so that comparison is traceable and repeatable.

Ethical considerations. No primary human-subjects research was conducted. The thesis relies on published and anonymised case documentation. Care is taken not to speak on behalf of residents beyond what the source material supports; resident voices are used only when directly attributable to published case reports.

1.7 Scope and limitations

Scope:
This thesis focuses on modular façade refurbishment in post-war multi-family housing, with relevance to the Dutch social housing renovation context. While the study is positioned within the broader European debate on social housing refurbishment, its design application is developed through a Dutch case study of a post-war walk-up apartment block in Rotterdam.

- The selected case is used as a typological and technical application case for testing the framework, rather than as a one-to-one representation of Dutch social-housing governance.
- The research does not aim to produce a fully engineered façade product, but to develop and test a design approach through which resident values can be translated into façade-related design indicators, system logic, and modular façade configurations.
- The façade is treated as the primary object of study because it mediates between technical performance, industrialised construction logic, and resident experience.

Limitations:
The thesis operates within the following boundaries:
First, case studies are analytically rather than statistically representative.
Second, resident values are treated as situated and context-dependent, not as universal preferences.
Third, the thesis does not include detailed structural calculations, full energy simulations, life-cycle assessment, or cost optimisation; these are acknowledged as important but lie outside the scope of the design framework.
Fourth, the evaluation focuses on expert-analytical recognition of embedded values rather than longitudinal post-occupancy monitoring.
Fifth, no primary resident interviews are conducted. Resident values are identified through the systematic analysis of published participatory case documentation.

1.8 Relevance

Scientific relevance: The thesis contributes to the field of Building Technology by positioning modular façade refurbishment as a socio-technical design problem and by proposing a structured method for translating qualitative resident values into bounded modular façade configurations.
It extends the literature on Value Sensitive Design, socio-technical renovation, and industrialised refurbishment by operationalising the connection between them , a connection that each of these fields acknowledges but none has systematically bridged at the scale of the modular façade system.

Societal relevance: By making resident values explicit, designable, and traceable, the thesis supports a more inclusive and legitimate energy transition in the social housing sector. It responds to the growing recognition that deep renovation at scale requires not only technical acceleration but also socio-technical alignment, procedural fairness, and resident ownership.

1.9 Reading guide

The thesis is organised in five parts.

Part I (this chapter) introduces the problem, the research aim, the sub-questions, and the methodology.

Part II establishes the theoretical and empirical foundation: Chapter 2 reviews the literature on housing renovation, resident engagement, and value translation,

Chapter 3 grounds the value–design translation gap through cross-case analysis of eight European social-housing renovation cases (with the additional cases developed in Appendix A).

Part III builds the framework and the system: Chapter 4 develops the Value–Indicator Framework, Chapter 5 develops the Modular Façade System (with the component catalogue in Appendix B), and Chapter 6 develops the configuration logic that links them.

Part IV applies the configuration logic at the case study in Rotterdam-West (Chapter 7) and evaluates the four resulting design variants against the framework's value-based indicators (Chapter 8).

Part V closes the thesis with the discussion (Chapter 9), the answers to the sub-questions and the main research question, recommendations and reflection (Chapter 10) including the references, and the appendices.

Each chapter opens with a brief introduction stating what it does and how it is structured and closes with a chapter conclusion. Where a chapter is the principal answer to a sub-question, the conclusion states that answer explicitly so it can be read on its own to gain the knowledge needed to continue the research.

Chapter 2: Literature review

2.1 Introduction

Housing renovation is central to climate, housing-quality, and equity policy across Europe, and the challenge concentrates in social housing where large parts of the stock require substantial upgrading (Buildings Performance Institute Europe [BPIE], 2021; European Commission, 2020).

Policy and research mostly frame renovation as an energy and technical performance problem, yet a growing body of work shows that outcomes are equally shaped by social, institutional, and experiential factors (Bartiaux et al., 2014; Boess, 2022). The persistent shortfall between predicted and actual performance exposes the limits of purely technical approaches (Sunikka-Blank & Galvin, 2012).

This chapter sets out the conceptual foundation for studying how resident values can inform modular façade renovation design. It adopts a socio-technical perspective in which renovation is the product of interaction between technologies, institutional arrangements, and residents' everyday practices. Six themes structure the chapter and lead into the synthesis in §2.8, where a summary table consolidates the key insights and the gap the thesis addresses.

2.2 The renovation context: policy, social housing, and the performance gap

Renovation policy in Europe is ambitious, but its success depends on the social housing sector where outcomes are systematically constrained by occupant vulnerability, ageing stock, and a persistent gap between predicted and actual performance. This section establishes the scale, location, and nature of that constraint.

Housing renovation is central to Europe's strategy to achieve a climate-neutral built environment by 2050. Buildings account for around 40% of EU final energy consumption and 36% of energy-related greenhouse gas emissions (European Commission, 2020). Around 85% of EU buildings were built before 2001, and roughly 75% are considered energy inefficient (European Commission, 2020); since most will still be in use in 2050 (European Commission, 2020), renovation is unavoidable for climate mitigation.

European policy responds by introducing the Renovation Wave Strategy and the revised Energy Performance of Buildings Directive (EPBD, Directive (EU) 2024/1275). The Renovation Wave aims to at least double the annual renovation rate by 2030 and accelerate industrialisation, while the EPBD recast sets binding obligations to cut average residential primary energy use by 16% by 2030 and to make all new buildings zero-emission from 2030. Yet policy offers little guidance on how renovation should respond to resident values or daily practices (Morgan et al., 2024).

Social housing concentrates the challenge. In the Netherlands social housing makes up 28.2% of the stock (Centraal Bureau voor de Statistiek [CBS], 2025), the highest share in Europe. Where many post-war estates suffer from insufficient insulation, moisture problems, outdated systems, and inadequate thermal and acoustic comfort (Bouzarovski, 2015).
Their residents often face energy poverty, alongside limited authority over decisions about their homes, which are primarily made by housing associations, municipalities, and technical consultants.(Bouzarovski 2017; Furman et al., 2025; Ricci et al., 2025). Renovation in this context is therefore not only a technical intervention but a matter of equity, health, and well-being. (Femenías & Mjörnell, 2018)

Social housing is also characterized by strong place attachment and neighbourhood identity. Long-term residency fosters deep emotional connections to façade appearance, materials, and spatial rhythms. Façade transformations can either reinforce local identity and pride or trigger resistance when changes feel imposed or out of character. (Brown et al, 2015;Wise et al,2023). Renovation thus intersects with symbolic and cultural meanings that extend beyond energy performance. Renovation outcomes nevertheless fall short of predictions.

This widely documented consequence called 'the energy performance gap: the persistent difference between predicted and actual energy consumption after renovation (Sunikka-Blank & Galvin, 2012). This gap is driven by several interacting mechanisms:

The prebound effect occurs when low-income households restrict energy use prior to renovation due to economic constraints, meaning that actual pre-renovation consumption is lower than energy models predict, and post-renovation savings are therefore overestimated (Galvin & Sunikka-Blank, 2016).

The rebound effect occurs when occupants perceive less guilt about energy use in a renovated dwelling and operate heating and appliances more intensively, reducing anticipated savings (Zoonnekindt, 2019).

Occupant–technology interactions aggravate the problem: ventilation units are switched off, windows opened in winter, and ad-hoc privacy solutions introduced when perceived exposure increases (Galvin, 2014; van den Brom et al., 2017; Zoonnekindt, 2019). Recent Dutch evidence in zero-energy social housing confirms that occupant behaviour, satisfaction, and indoor environmental quality remain tightly interlinked (Guerra-Santin et al., 2025).

The performance gap is not a behavioural anomaly but a socio-technical misfit between the assumptions embedded in renovation technologies and residents' everyday practices (Boess, 2022; Charles et al., 2024). The next section turns to the theoretical framing that makes that misalignment legible.

2.3 Renovation as a socio-technical process

If the performance gap is a misalignment, then renovation cannot be understood through technical metrics alone. The socio-technical literature provides the conceptual frame in which technologies, institutions, and everyday practices co-produce outcomes.

The socio-technical perspective treats renovation as an interaction of technologies, institutions, practices, and meanings, not as the implementation of measures (Bartiaux et al., 2014; Lowe et al., 2017). Geels (2017) describes socio-technical systems as composed of interdependent elements within a wider innovation environment of markets, governance, and everyday practices, arguing that decarbonisation needs coordinated change across those dimensions rather than isolated technological gains.

In housing renovation this means energy performance depends on alignment between technical measures and the social and institutional contexts in which they are applied. Strategies fixated on end-point performance miss the conditions that determine how buildings are used (Tjørring & Gausset, 2018). Karvonen (2013) argues that retrofit policy still relies on a rational-choice consultation model that ignores how occupants live in their homes.

Bartiaux et al. (2014) and others show that sound technical measures can underperform when they conflict with routines or priorities. The literature describes this as socio-technical misfit: technically successful systems that fail to support lived experience (Boess, 2022; Charles et al., 2024).

Femenías et al. (2018) extend this further: post-renovation performance is co-produced through ongoing interaction between residents, building systems, and organisational practices, not fixed at handover.

If outcomes are co-produced, then resident knowledge of how buildings are inhabited becomes a design input, not an afterthought. The next section examines how that knowledge is currently collected, and why it rarely shapes design decisions.

2.4 Resident engagement and the value–design translation gap

Resident engagement matters in housing renovation because residents develop forms of knowledge through long-term inhabitation that are not captured by technical assessments alone. Haraway's (1988) concept of situated knowledge is useful here, as it frames knowledge as partial, contextual, and grounded in lived conditions rather than detached from them.

In housing contexts, this means that residents hold detailed knowledge about how buildings perform in practice, how social and spatial conditions are experienced, and how technical interventions affect daily routines, comfort, and wellbeing (Furman et al., 2025). In this thesis, the expression of this situated knowledge is conceptualised as resident values: the priorities, preferences, and concerns through which residents interpret their dwelling and living environment.

The literature suggests that these values are not limited to technical comfort alone. They include recurring dimensions such as comfort and wellbeing, control and agency, safety and security, identity and aesthetics, privacy, practical usability, and fairness and trust (Wise et al., 2021; Sunikka-Blank et al., 2018;Broers et al., 2022 Jafari et al 2016).

These values are particularly important in social housing renovation, where residents are strongly affected by refurbishment outcomes but often have limited influence over the decisions that shape them.

Resident engagement is therefore not only relevant as a matter of consultation or inclusion, but because it provides access to forms of experiential knowledge that can challenge and complement technical expertise.

A wide range of engagement methods exists, ranging from informative and consultative approaches to participatory design and co-creation (Arnstein, 1969; Awan et al., 2011; Sanders & Stappers, 2008; Boess, 2022). Research indicates that engagement becomes especially productive when it is linked to concrete building elements, such as façades, windows, thresholds, or shared interfaces, because residents can then respond to tangible spatial and technical conditions rather than to abstract policy or design language (Boess, 2022; Soikkeli et al., 2023). In such settings, residents more clearly articulate concerns related to control, comfort, identity, privacy, and usability.

At the same time, participation in renovation practice often remains limited in influence. Time pressure, budget constraints, and institutional routines frequently reduce resident involvement to consultation after key parameters have already been fixed (Soikkeli et al., 2023). Communication asymmetries further reinforce this problem: residents tend to describe their homes through experiential language, while professionals rely on technical abstractions such as U-values, ventilation rates, and cost metrics (Morgan et al., 2024). As a result, resident knowledge may be surfaced but still remain weakly embedded in design reasoning. This is reinforced by performance frameworks that focus on measurable technical criteria while giving less weight to experiential, social, and symbolic values (Thuvander et al,2012; Han et al., 2023).

These limitations become even more pronounced in modular and industrialised renovation, where design decisions are strongly shaped by production logic, standardisation, and system compatibility. In such contexts, participation may identify meaningful resident priorities yet still lack a methodological pathway through which these priorities can be translated into architectural design criteria, façade parameters, and bounded variation within the system (Femenías & Mjörnell, 2018; Jensen & Maslesa, 2015).

This persistent disconnect is conceptualised in this thesis as the value–design translation gap: the absence of a mechanisms that enable experiential knowledge and resident values to shape architectural decision-making in a traceable and operational manner.

Closing the gap requires a design element where resident knowledge can be made architecturally legible. The next section identifies the façade as that element.

2.5 The façade as sociotechnical mediator

The façade is the single building element where the technical and the experiential world meet on the same surface; it is therefore the natural locus for value-driven translation in renovation. This section establishes the façade's dual role and examines why design-driven approaches to that role remain marginal in industrialised practice.

Technically the façade shapes building performance through regulating heat loss, solar gain, daylight, ventilation, and acoustics. Experientially it forms the physical and symbolic interface between residents and their environment, mediating privacy, safety, identity, and daily routines (Knaack et al., 2007).

This mediating position of the facade is widely recognised but rarely treated as such in practice. Façade renovation is mostly approached as an envelope upgrade focused on energy and constructability, often without addressing how residents perceive or interact with façade changes (Bartiaux et al., 2014; Boess, 2022). Boess (2022) argues that renovation should be approached as a socio-technical design problem and shows that zero-energy projects often fail not for technical reasons but because the design insufficiently addresses how residents use the systems and spaces. Empirical work in social housing confirms that façade interventions shape sense of safety, comfort, and belonging, particularly where the exterior contributes to stigma or pride (van Hoof & Boerenfijn, 2018; Safarkhani,2025).

Design-driven and user-centred approaches suggest a way to integrate experiential knowledge into design reasoning. Rather than asking who is involved, they ask how lived experience enters the design process. Studies in housing renovation show that such approaches improve usability, support resident understanding of systems, and produce more inclusive outcomes (Lucchi & Delera, 2020; van Hoof & Boerenfijn, 2018; Awwal et al., 2022). The structural limitation is that they are rarely embedded within industrialised systems, where standardisation and cost dominate the renovation outcome, leaving the mediating potential of design unused.

If design-driven approaches lose ground precisely where industrialisation takes over, the question becomes whether industrialised systems themselves can be reconfigured to host them. The next section examines what modular façade renovation currently offers and where its limits lie.

2.6 Modular façade renovation: opportunities and limits

Modular façade renovation accelerates renovation, but its current logic typically reinforces standardisation rather than enabling resident influence. Two architectural theories, Brand's shearing layers (1994) and Durmisevic's hierarchy of dependencies and design for disassembly (2006) , together provide the conceptual basis for reorganising modular logic to host structured variation. This section develops both arguments and the dialogue between them.

Industrialised and modular façade renovation is increasingly promoted to accelerate deep renovation at scale (Mlecnik, 2012; Straub et al., 2025). Modular façade systems refer to industrialised renovation approaches in which façade elements are prefabricated and assembled on-site to improve speed, quality control, cost efficiency and reduced on-site disruption (Knaack et al., 2014).
Within such systems, the prefabricated standardised façade module functions as the physical unit of the renovation intervention, typically integrating insulation, airtightness, windows, and renewable technologies. into coordinated elements, allowing them to be produced under controlled conditions and installed rapidly (Rovers et al., 2016).
Field deployment confirms the operational gains: installation times reduced by 20 to 50% (BPIE, 2022; Hong et al., 2015), better quality control through factory production, and less disturbance for residents who remain in the dwelling during renovation.

These observations are not abstract. They have been tested in a sequence of different modular façade system or EU-funded research and demonstration programmes E2ReBuild, More-Connect, 4RinEU, and the Energiesprong / Nul-op-de-Meter programme, which have collectively proven deep retrofit completed within a few days of on-site work, with substantially reduced disturbance to occupied dwellings (Broers et al., 2022; Op 't Veld, 2015).

From a socio-technical perspective, however, modular systems are not neutral. They embed assumptions about standardisation, use, and control. Galvin and Sunikka-Blank (2014) show that retrofit technologies often presuppose ideal users, producing mismatches with actual practice. The dominant pattern across the deployed programmes is that the prefabricated cassette and the visible cladding are typically produced as a tightly coupled assembly, so the resident-facing side cannot easily vary without redesign of the technical side. Customisation potential is rarely realised; design priorities favour the technical and logistical, with few mechanisms for embedding resident values into modular logic (Boess, 2022). Modularity in current practice tends to reinforce standardisation rather than enable mediation. This is the field-level limitation the framework developed in this thesis addresses, but addressing it requires a different conceptual basis than the one that produced the limitation.

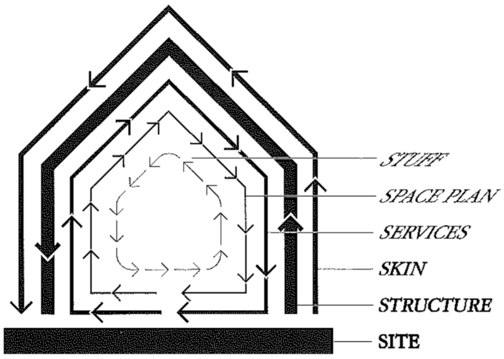
Two theories from the literature on building adaptability supply the basis of the façade as a socio-technical mediator.

The first is Brand's shearing layers (1994). Brand's argument is fundamentally temporal: a building is not a single object that ages uniformly, but a set of components that operate at distinct lifecycles and therefore have distinct logics of change. He proposes six layers: site, structure, skin, services, space plan, and stuff, each with its own pace of change. The site is effectively eternal. Structure changes on a scale of decades to centuries. Skin (the façade) and services change on a scale of decades. Space plan changes every few years, stuff changes constantly.

The architectural force of Brand's argument follows from the temporal hierarchy: a building works with time when its slow-changing layers and its fast-changing layers are not bound together. When a fast-changing layer is welded to a slow-changing one, change in the fast layer requires destructive intervention on the slow layer, and the building resists adaptation.

The skin sits at an intermediate position: longer life cycle than space plan or services, shorter life cycle than structure. This makes the façade strategically interesting in renovation, because the façade is precisely the layer where the longest-lived performance baseline (insulation, airtightness, structural integrity) and the shortest-lived experiential interface (cladding, shading, threshold articulation) co-exist.

Brand explains, at the level of architectural theory, why a façade designed as a single monolithic assembly resists adaptation, and why a façade that internally separates its slow and fast components becomes a candidate for both technical longevity and resident-driven change.



SHEARING LAYERS OF CHANGE. Because of the different rates of change of its components, a building is always tearing itself apart.

Figure 2: Shearing layers of Change (Brand, S. 1994) -How Buildings Learn: What Happens After They're Built

The second is Durmisevic's hierarchy of dependencies (2006). Where Brand provides the temporal argument, Durmisevic provides the engineering argument that converts the temporal claim into design practice. In her doctoral thesis on transformable building structures, Durmisevic proposes that buildings can be read as a hierarchy of building, system, component, and material levels, with explicit dependency relationships between them: each level depends on the levels below it for its physical realisation, and on the levels above it for its functional context.

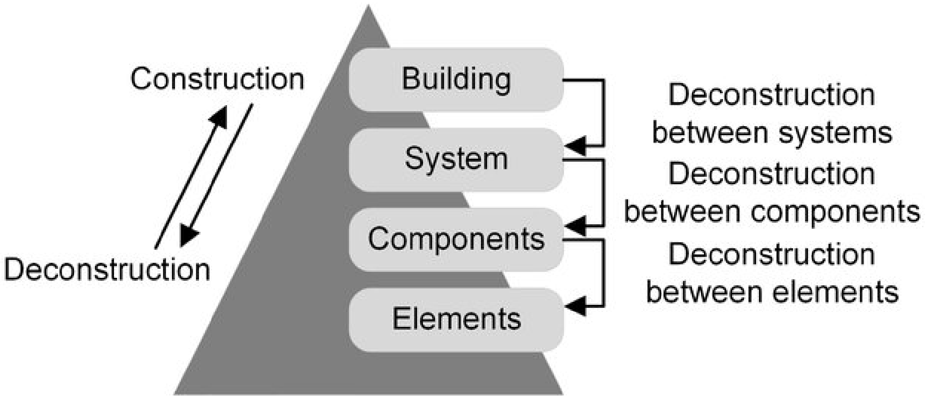


Figure 1.1:Hierarchy of Material Levels (Durmisevic, 2006)

Adaptability, in this hierarchy, depends on whether the connections between levels are designed to be reversible and demountable. A façade in which a cladding panel is mechanically fixed to a separate carrier frame, with a documented disassembly sequence, is transformable; a façade in which the panel is bonded directly to a structural element is not.

Durmisevic frames design for disassembly as the engineering principle that operationalises layered building: components and connections must be designed to come apart again so they can be replaced, recovered, or reconfigured without destroying their neighbours. The argument is technical in form but theoretical in implication.

A modular façade that is technically a shearing-layer system without reversible interfaces is, in Durmisevic's terms, only nominally layered: its components are arranged in layers, but its connections defeat the adaptability the layered arrangement was supposed to enable. Durmisevic (2006) develops this argument technically by introducing a hierarchy of building, system, component, and material levels with explicit dependencies, and by framing design for disassembly as the engineering principle that makes layered buildings sustainable: components and connections must be designed to come apart again so they can be replaced, recovered, or reconfigured without destroying surrounded elements. Buildings designed for transformability therefore separate slow-changing elements from faster-changing ones through controlled, reversible interfaces.
Together, the two frameworks supply the conceptual basis for designing modular façades in which a stable performance baseline can support an adaptive resident-facing layer without redesign of the support system; this is the basis of the two-layer system developed in Chapter 5.

Modular layering creates the architectural possibility of structured variation; what remains is the methodological question of how resident values can enter that variation. The next section examines the literature on indicators and architectural parameters that addresses exactly this question.

2.7 Translating resident values: design indicators and architectural parameters

Translation requires a mediating construct that holds qualitative resident values without collapsing them into performance metrics. The literature offers two constructs, boundary objects and indicators, and this section develops the position the thesis takes in relation to them.

Engagement effectively surfaces resident input but rarely translates it into architectural decisions, particularly in industrialised renovation where standardisation, performance metrics, and compliance dominate. Several literatures address how qualitative knowledge can become design relevant. Participatory design uses tools such as probes, personas, experience maps, and design scenarios to convert tacit knowledge into explicit representations (Mattelmäki, 2006; Sanders & Stappers, 2008).
Performance-based design operationalises qualitative goals through indicators, targets, and criteria (Han et al., 2023), but tends to focus on measurable aspects such as energy or daylight while leaving experiential and social values weakly represented (Thuvander et al, 2012).

Design research suggests treating indicators as boundary objects: shared constructs that let people from different fields use the same artefact while reading it from their own positions (Star & Griesemer, 1989; Bergman et al., 2007). Translating values in architectural design is interpretative and generative rather than representational; intermediary constructs reframe values in design-relevant terms while preserving their qualitative and contextual character (Boess, 2022).

Building on this, the thesis adopts architectural design indicators as constructs that translate resident values into design parameters within modular façade renovation.
Indicators do not represent values directly, and they are not performance metrics.

Examples illustrate the move: values about control may be translate into operability or user-adjustability; identity values into variation, articulation, or material expression; comfort values into daylight access, thermal buffering, or acoustic separation. Indicators support partial quantification through architectural parameters such as dimensions, ratios, ranges, or degrees of variation, supporting comparative exploration rather than optimisation (Hevner et al., 2007; Jensen & Maslesa, 2015). In this way, indicators provide a shared reference through which residents, designers, engineers, and housing providers can engage with design decisions without requiring a common disciplinary language.
The distinction matters because it keeps design indicators from being confused with key performance indicators (KPIs): KPIs measure and optimise outcomes, design indicators guide exploration while preserving qualitative intent (Attia et al., 2013). Chapter 8 of this thesis derives KPIs from the design indicators rather than substituting them.

With the conceptual foundation explained, values are situated, the façade is the design locus, modular logic can host structured variation, and indicators provide the translation mechanism, the next section consolidates these threads into the gap statement that is used throughout the rest of the thesis.

2.8 Synthesis: identifying the gap.

Six observations follow from the literature reviewed across §2.2–§2.7.
(1) The renovation challenge is not technical alone: predicted performance and actual performance diverge persistently, and the divergence concentrates in social housing where residents have limited authority over decisions.
(2) The socio-technical perspective explains that divergence by treating renovation as co-produced through technologies, institutions, and practices, not delivered by any one of them.
(3) Resident engagement reliably surfaces resident values but rarely translates them into design decisions; the disconnect, the value–design translation gap, is structural rather than methodological.
(4) The façade is the building element where this gap is most concentrated because it carries technical performance and social meaning at the same time.
(5) Modular façade renovation amplifies the standardisation pressure but read through layered building theory, also offers the architectural possibility of structured variation (adaptability) around a stable performance baseline (standardisation).
(6) Translation requires a mediating construct that holds qualitative values without collapsing them into performance metrics; the literature on boundary objects and on design indicators supplies the conceptual basis for such a construct.

Putting these six observations together identifies the gap. What is missing is a structured framework that translates resident values into architectural decisions inside modular renovation, one that can sit between resident experience and modular design logic, holding the qualitative intent of values while producing design-relevant parameters that an industrialised system can implement.

The chapter therefore contributes the literature half of the answer to sub-question 1: it establishes from the literature that resident values exist as situated knowledge in housing renovation, that they are persistently surfaced through engagement methods, and that they remain weakly translated into design decisions in industrialised renovation systems. The empirical half, which values recur across actual renovation cases, and how they are constrained in practice, is developed in Chapter 3.
Table 2.1 below synthesised the literature review into six themes mapped to the chapter sections.

Table 2.1: Literature themes summarised

Theme	Key insights consolidated from the literature	Implication for this thesis
1. The renovation challenge: policy, social housing, and the performance gap	European policy demands accelerated renovation, yet deep-renovation rates (~0.2%/yr) remain far below the required ~3%/yr (BPIE, 2021; EPBD 2024/1275). Predicted and actual energy consumption diverge through the prebound effect, the rebound effect, occupant–technology interactions, and modelling uncertainty (Sunikka-Blank & Galvin, 2012; Galvin, 2014; van den Brom et al., 2017). The largest renovation needs concentrates in post-war social housing, where energy poverty, affordability, place attachment, and identity converge and where residents have limited authority over decisions (Bouzarovski, 2017,2014; Femenías et al 2023; Wise et al., 2023; CBS, 2025).	Technical optimisation alone does not deliver renovation outcomes; the framework must address the human–system interface explicitly. The thesis context (post-war walk-up, Dutch social housing) concentrates the value–design translation gap in one typology.
2. Renovation as a socio-technical process	Outcomes are co-produced with practices, routines, and meanings. Comfort is socially constructed; "ideal-user" assumptions produce socio-technical misfit when technically well-performing systems fail to support lived experience (Shove et al., 2012; Gram-Hanssen, 2010,2012; Walker, 2014; Bartiaux et al., 2014; Karvonen, 2013; Boess, 2022; Charles et al., 2024).	The framework treats renovation as a practice–design interaction. Resident values are situated knowledge, not abstract preferences.
3. Resident engagement and the value–design translation gap	A broad methodological repertoire exists, from consultation to participatory design and co-creation (Arnstein, 1969; Sanoff, 2007; Puerari et al., 2018). Engagement consistently surfaces values but rarely shapes design decisions: late-stage entry, communication asymmetries, and tokenistic participation limit influence(Morgan et al., 2024; Voorberg et al., 2015; Soikkeli et al., 2023; Jensen & Maslesa, 2015).	The missing step between surfacing values and shaping design is the translation mechanism the thesis develops.
4. The façade as a socio-technical mediator	The façade governs technical performance and lived experience simultaneously: privacy, identity, control, neighbour interface, and recognisability are all decided at the façade scale (Knaack et al., 2007; Boess, 2022; Femenías et al., 2018; van Hoof & Boerenfijn, 2018; Lucchi & Delera, 2020). Design-driven approaches are rarely embedded in industrialised systems.	The façade is selected as the design locus because it concentrates the value-translation question at one architectural element.
5. Modular and industrialised façade renovation: structured variation potential	Prefabrication improves speed, cost, and quality but typically reinforces standardisation; the literature acknowledges a structured-variation potential that is rarely realised in practice (Mlecnik, 2012,2017; Konstantinou & Knaack, 2007; BPIE, 2022; Galvin & Sunikka-Blank, 2014). Layer theory provides a vocabulary for adaptable systems by separating slow-changing structure from faster-changing skin and services (Brand, 1994; Durmisevic, 2006).	The Modular Façade System uses two-layer logic to combine industrial standardisation with bounded resident-driven variation.
6. Translating values into design: boundary objects and indicators	Indicators function as boundary objects that translate qualitative values into design-relevant parameters without reducing them to performance metrics (Star & Griesemer, 1989; Bergman et al., 2007; Jensen & Maslesa, 2015; Attia et al., 2013). Architectural parameters operationalise indicators as controllable variables within modular façade systems, enabling partial quantification while preserving the qualitative intent of the values.	The Value–Indicator Framework operationalises this translation; the key performance indicators in Chapter 8 are derived from the indicators rather than substituted for them.

Chapter 3: Case analysis

3.1 Introduction

This chapter presents the empirical foundation of the thesis through the analysis of selected social housing renovation case studies. The purpose of the case analysis is to identify and synthesise resident values as they emerge in real renovation contexts, and to examine how these values are currently recognised, negotiated, and integrated within renovation processes. Rather than evaluating the technical performance of individual projects, the focus is on understanding the social and design-related dynamics that shape renovation outcomes from a resident perspective.

The chapter corresponds to Phase 1 (Analytical) of the methodology set out in Chapter 1 and addresses sub-question 1: which resident values recur across European social-housing renovation cases, and what currently prevents them from shaping design decisions? In line with the literature reviewed in Chapter 2, resident values are understood as situated and context-dependent, surfaced through interaction between residents, technical interventions, and institutional arrangements.

The chapter is organised in seven sections. Section 3.2 explains the case selection rationale and the analytical framework used across all cases. Section 3.3 outlines the programmatic frameworks within the cases are embedded. Section 3.4 presents one fully worked case observation (Reigersbos, Amsterdam) to understand how values are extracted from a renovation case. Section 3.5 synthesises the findings across all eight cases. Section 3.6 reads the implications of the synthesis for value-driven design translation, and Section 3.7 concludes the chapter. The full developments of the seven additional cases are documented in Appendix A. This chapter presents only the cross-case synthesis based on those developments.

3.2 Case selection rationale and analytical framework

Eight renovation cases were selected, representing a spectrum of European social housing renovation practices. Five cases originate from Dutch programmes: the four JustPrepare Living Lab cases , Amsterdam (Reigersbos), Rotterdam (Bospolder–Tussendijken), Gemert (NOM-woningen Gemert) and Nijmegen (Dukenburg), together with one institutionally distinct Dutch case in Utrecht (Overvecht-Noord).

Three cases are drawn from European pilot projects: Sutton Estate in London (United Kingdom), Križevci (Croatia), and Els Mestres in Sabadell (Spain). The cases reflect variation in governance structures, renovation strategies, and forms of resident involvement, while remaining comparable in their focus on social housing renovation and participatory processes.

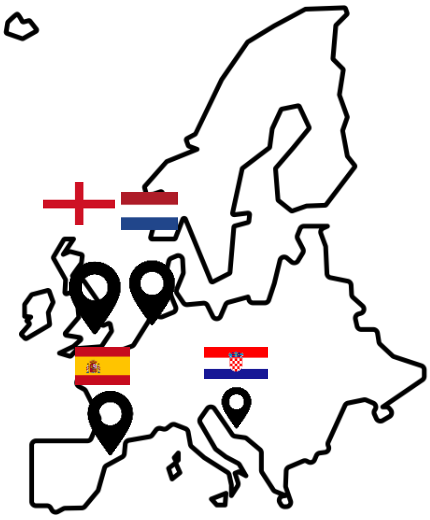


Figure 3: Locations of case study in Europe (own work)

Three criteria guided the case selection:

1. Each case had to include explicit forms of resident participation or co-design so that resident values would be articulated and documented within the renovation process.
2. Each case had to combine technical innovation with social or organisational innovation, since the analytical interest is in how participatory approaches interact with renovation strategies rather than in either dimension on its own.
3. Each case required sufficient public documentation or evaluation material to support systematic analysis and cross-case comparison.

Each case was analysed through the same analytical categories so that the eight cases remain comparable. The categories cover:

- **Project context**
  Building typology, renovation scope, energy-performance ambitions, and relevant socio-cultural background or neighbourhood characteristics.

- **Stakeholders and governance structure**
  Key actors involved in the renovation process, including housing providers, municipalities, designers, contractors, researchers, and residents, as well as their roles and decision-making responsibilities.

- **Renovation goals**
  Stated technical, environmental, social, and organisational objectives guiding the renovation project.

- **Resident engagement techniques**
  Methods used to involve residents, such as information sessions, consultations, co-design workshops, living lab activities, or participatory governance arrangements, including the timing and depth of engagement.

- **Resident values identified**
  Values articulated by residents during the renovation process.

- **Level of integration of resident values**
  The extent to which identified resident values are integrated in the renovation processes. Where each identified value is mapped to the renovation phase in which it was integrated (see table 3), identified through literature and case analysis, allowing the synthesis to distinguish strategic, design, and post-occupancy integration.

- **Challenges and constraints**
  Technical, institutional, economic, or organisational barriers that affected resident engagement or the integration of resident values.

- **Outcomes relevant to residents lived experience**
  Observed or reported effects of the renovation on residents' daily use, perception, and experience of their dwellings.

- **Key insights for value-driven renovation design**
  Cross-cutting observations relevant to translating resident values into architectural design logic and modular façade renovation strategies.

Table 2:Renovation phases used in the analytical framework.

Renovation phase	*Description*
Strategic planning	Goal setting, budget decisions, feasibility, policy alignment
Concept design	Early design choices, system selection, spatial and façade concepts
Design development	Technical detailing, modular configuration, material choices
Construction / implementation	Installation, phasing, disruption management
Post-occupancy / use	Everyday use, comfort experience, adaptation, feedback

The same categories are applied across all eight cases. They were selected to support a systematic understanding of how resident values are identified, communicated, and either integrated or ignored within renovation practice, rather than to assess project success or performance.

3.3 Programmatic context

The eight cases are embedded within broader programmatic frameworks that explicitly combine technical renovation strategies with resident engagement. These frameworks are not the object of evaluation in the thesis, but they provide the institutional and organisational contexts in which resident values are made visible and documented. Two programmatic groupings are particularly relevant.

Four of the Dutch cases (Amsterdam, Rotterdam, Gemert, Nijmegen) sit within the Just and Prepared Energy Transition Programme (JustPrepare, 2022–2026), an action-research programme led by the University of Amsterdam, HAN University of Applied Sciences, Hogeschool van Amsterdam, Radboud University, TU Delft, and TU Eindhoven, with around 40 practice partners (provinces, municipalities, housing corporations, energy companies, and consultancies) and €2.5M NWO-KIC funding under the programme "Energy Transition as Societal-Technical Challenge".

JustPrepare operates through four Living Labs in Amsterdam, Rotterdam, Nijmegen, and Gemert-Bakel, framed as action-research environments in which municipalities, housing associations, residents, and researchers test renovation strategies, governance arrangements, and engagement methods (Ricci et al., 2025).

The four Living Labs are deliberately diverse: the Amsterdam, Rotterdam, and Nijmegen labs centre on dense urban post-war neighbourhoods with rich participatory infrastructure, while the Gemert-Bakel lab studies a small-town renovation programme (NOM-woningen Gemert) in which engagement is primarily consultative, making it an analytically useful contrast within the same research network. The fifth Dutch case (Utrecht ,Overvecht-Noord) is institutionally distinct from JustPrepare but addresses similar renovation challenges with strong emphasis on participation and experimentation.

The three European cases extend the empirical scope. The Sutton Estate retrofit in London forms part of the United Kingdom's Social Housing Decarbonisation Fund and combines large-scale decarbonisation through ground-source heat-pump networks with architectural and heritage considerations.

The Križevci Co-operative Housing Project in Croatia represents a community-led approach to affordable and sustainable housing renovation embedded within the Affordable Housing Initiative European Initiative.

The Els Mestres retrofit in Sabadell is one of the demonstration sites of the EU Horizon 2020 HOUSEFUL project, which promotes circular and resource-efficient renovation in social housing. Although embedded in different national contexts, all three projects share the integration of technical renovation strategies with explicit forms of resident participation.

Figure 2.1: Programme logos extracted from their website (2026)-Just Prepare-Houseful- Affordable Housing Initiative European Initiative.

3.4 Worked case observation: Reigersbos, Amsterdam

This section develops one of the eight cases (Reigersbos, Amsterdam Zuidoost) at full depth it is clear how the analytical framework of §3.2 is applied. The full developments of the seven other cases are given in Appendix A; the analytical findings from those developments enter the cross-case synthesis in §3.5, and the comprehensive cross-case tables are presented in Appendix A §A.8.

3.4.1 Project context

Reigersbos is a residential neighbourhood in Amsterdam Zuidoost, developed between 1980 and 1984 as part of the Gaasperdam expansion of the Bijlmer area (Stadgenoot, n). The renovation case discussed here concerns the four- to five-storey housing blocks built above the Reigersbos shopping centre, containing approximately 280 apartments (Energie Lab Zuidoost). The blocks are organised in ten Verenigingen van Eigenaren (VvE, homeowner associations) that co-manage shared assets such as façades and roofs (Open research Amsterdam(2021); Stadgenoot,). Stadgenoot is one of the owners within several of the VvE in addition to private homeowners since part of the housing stock is social rental (Stadgenoot).

By 2020 the building performance was poor because of the (Open Research Amsterdam, 2022,2024):

- outdated, poorly insulated façades with air leaks, mould, and condensation
- deteriorated window frames
- minimal acoustic protection
- and energy performance certificates rated E–F with high gas consumption.

The sociocultural context is defined by a diverse and ageing population with strong community ties but socioeconomic vulnerability and language diversity. The Living Lab approach explicitly recognised that retrofit success depended on cultural and communicative inclusivity, not just engineering efficiency. (Ricci et al., 2025; AMS Institute,)

Reigersbos was selected in 2019 as the first façade project under the Energie Lab Zuidoost programme, co-funded with EU Climate-KIC, with the wider ambition of scaling the same retrofit approach to 10,000 homes in Amsterdam by 2040 (Energie Lab Zuidoost; AMS Institute).

Figure 3.2: Reigerbos front side and facade status apartments Reigerbos (Gemeente Amsterdam)

3.4.2 Stakeholders and governance

The Reigersbos retrofit illustrates a multi-stakeholder governance model with distributed decision-making.

- Ten VvE acted as initiators and key decision-makers.
- Stichting !WOON mediated resident support and participation.
- the Municipality of Amsterdam provided funding and technical oversight.
- Stadgenoot retained ownership of the social housing units.
- AMS Institute and TU Delft facilitated co-creation.
- EnergyLab Zuidoost connected technical and social pilots.
- and TNO provided energy simulation and monitoring.

A horizontal, participatory network shared decision-making among actors. The Co-Creation Roadmap Manual served as a governance tool defining roles, steps, and communication flows.(Open research Amsterdam, 2022,2024)

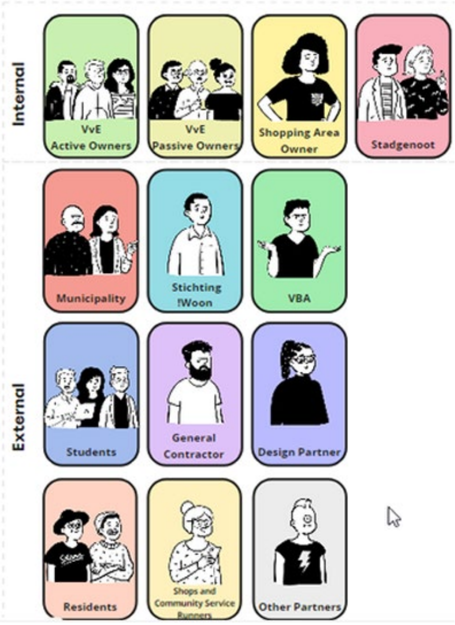


Figure 3.3:Stakeholder analysis visual (Open Research Amsterdam.report,*p.26)*

Figure 3.4: Reigerbos apartment complex backside

3.4.3 Renovation goals

The renovation goal was *to develop and demonstrate a circular, modular façade retrofit that improves comfort, energy efficiency, and affordability through co-creation and transparent governance.* (Ricci et al., 2025; Open Research Amsterdam, 2024).

Sub-goals included:

1. **Technical:** Improve thermal performance (high-performance insulation and triple-glazing) and lower energy consumption(reduce heating demand by 40–60%) prepare buildings for gas-free systems. (Open Research Amsterdam, 2021; Energie Lab Zuidoost, n.d.
2. **Social:** Strengthen resident participation and inclusivity across the renovation process to build trust between homeowners, municipality, and housing corporation and empower residents to co-decide on renovation priorities and costs. (JustPrepare, 2025)
3. **Economic:** Achieve a "budget-neutral" renovation, energy savings balancing renovation costs. Residents should not experience higher total housing expenses post-retrofit.(joint financing model) (Open Research Amsterdam, 2021)
4. **Environmental:** Test modular, demountable façades using circular principles to minimize disruption, labour time, and circularity (reusable modules, demountable fixtures, and traceable materials) (AMS Institute, n.d.)
5. **Governance:** Prototype decision models/tool to support transparent decision-making and experiment with participatory communication(Open Research Amsterdam, 2024)
6. **Learning:** Develop a replicable co-creation model for Amsterdam's just transition.- test decision-making frameworks, train public and private actors in co-creation and value-based retrofit evaluation, transfer knowledge into Amsterdam's Energy Transition Implementation Programme. (AMS Institute, n.d.; Energie Lab Zuidoost, n.d.)

3.4.4 Resident involvement technique

Resident involvement at Reigersbos was multi-channel and iterative, designed to combine technical, financial, and experiential perspectives within the same Living Lab (Open Research Amsterdam, 2024; Ricci et al., 2025). Six engagement techniques were used in combination, each targeting different sub-goals and surfacing different value dimensions (Table 3.1).

Table 3.1:Resident engagement techniques in the Reigersbos Living Lab and their effect.

Technique	Description	Effect
Co-creation sessions	Residents collaborated on visualising façade concepts (colour, daylight, materials) in working groups and made collective decisions	Strengthened trust and capacity; residents moved from consultation to co-decision
Semi-structured interviews	Collected lived experiences of discomfort, affordability concerns, and maintenance issues	Informed the budget-neutral principle and resident-defined comfort standards
Co-Creation Roadmap Manual	Visual tool documenting steps, responsibilities, and communication guidelines	Enabled transparent decision-making; shared understanding among stakeholders
Demowoning Reigersbos 70	Real flat used as prototype for insulation and material test scenarios (Open Research Amsterdam, 2021)	Tangible results fostered understanding of circular materials
Plain-language communication	B1-Dutch summaries, infographics, shared Miro boards	Increased inclusivity; reduced technical misunderstanding
Reflection sessions	Residents and partners reviewed what worked and what could be improved	Captured institutional learning; refined the process through feedback loops

3.4.5 Resident values identified.

Six recurring resident values were identified at Reigersbos. The six values are categorised by two coloumns. The first columns (Table 3.2) records how each value was surfaced during the engagement process: through which technique it became visible and the next columns describing what residents specifically expressed.

Table 3.2:Reigersbos:Resident values identified.

Resident value	Technique used	Description
Comfort	Door-to-door interviews; community workshops; on-site walkthroughs	Cold external walls; draughts at windows and balconies; condensation and mould complaints; uneven temperatures between rooms
Affordability	Resident finance working group; one-on-one tenant cost meetings; municipal-housing-association consultation rounds	Concern that renovation would raise rent above current housing-allowance limits; preference for cost-neutral refurbishment with energy savings offsetting investment
Fairness / transparency	Co-creation roadmap meetings; plenary feedback sessions; mailings with simplified summaries	Frustration with technical jargon, requests for clearer cost dashboards, and concerns that some VvE blocks would receive different treatment from others surfaced repeatedly. Fairness was articulated more as a procedural value ("how decisions are taken") than as a distributive one ("who gets what").
Empowerment / agency	Living Lab co-design sessions; three resident-led working groups (technical, finance, communication); on-site decision moments	Residents expressed a wish to be part of decisions rather than informed afterwards, willingness to take responsibility within VvE structures, and a preference for staged decisions with feedback at each stage. Empowerment was made operational through the three resident-led working groups (technical, finance, communication).
Identity / belonging	Façade preference workshops; visual reference sessions with material samples; site walk discussions	Attachment to the recognisable 1980s façade rhythm and colour palette; concern that a uniform retrofit would erase the block's identity in the neighbourhood
Sustainability / environmental awareness	Material-choice workshops; sustainability information sessions	Residents expressed interest in bio-based materials (timber cladding) and reduced operational energy use, with some questions about embodied impact and end-of-life. Sustainability was the value most strongly mediated by cost: it surfaced in workshops but rarely survived procurement

3.4.6 Level of integration

The next table (table 3.3) reads how each surfaced value is integrated into the renovation process. Showing the degree of integration, showing how far in the process the values were translated, some were translated fully into design and governance decisions; others were partially integrated; one (sustainability) was discussed but deferred to budget and policy constraints. The "type of decision" column records where in the project structure the value landed. The constraints that limited integration where values were not fully carried through are then read systematically in §3.4.7.

Table 3.3:Reigersbos: Level of integration

Resident value	**Degree of integration**	**How it was integrated**	**Type of decision**
Comfort	High	Insulation upgrade and mechanical ventilation prioritised in the technical brief; window replacement specified at $U \leq 1.0$ W/m²K; condensation and draught hot spots addressed at detail level	Technical design
Affordability	Medium–High	Budget-neutral renovation principle adopted: monthly energy savings projected to offset the increase in service charges; embedded in the financial model and tenant communications	Financial / policy
Fairness / transparency	Medium	Plain-language summaries, visual cost dashboards, and simplified meeting documentation introduced from mid-project; same renovation specification applied across all VvE blocks	Governance / communication
Empowerment / agency	High	Three formal VvE working groups (technical, finance, communication) embedded in the Co-Creation Roadmap Manual, with document-ed decision rights and feedback moments	Governance / organisational
Identity / belonging	Medium	Co-design workshops preserved the recognisable façade rhythm and colour palette of the original 1980s architecture; cladding strategy adjusted to retain the block's neighbourhood expression	Architectural design
Sustainability / environmental awareness	Medium–Low	Resident input on material choice (timber vs. polymer) discussed in workshops; some bio-based options included in the extensive list but few in the final selection	Material selection

3.4.7 Challenges

The Reigersbos retrofit encountered four categories of challenges that affected resident engagement and the integration of resident values. The challenges are summarised in Table 3.4.

Table 3.4: Reigersbos: challenges encountered.

Challenge category	Description
Existing-dwelling features (technical)	Existing concrete-frame structure introduced thermal-bridging risks at slab edges and balcony anchors; modular fit had to absorb dimensional irregularities of the 1980s façades; ventilation routing was constrained by tight floor plans and existing service shafts; window-reveal detailing was complicated by varying frame depths across blocks. These technical constraints forced standardisation of some component selections (cladding texture, sill depth) that residents had wanted differentiated
Complex multi-VvE governance coordination *(Institutional)*	Ten separate VvE with different decision rhythms slowed cross-block consensus; municipal procurement timelines did not align with the iterative Living Lab cadence; building-permit lead times pushed engagement decisions earlier than residents were ready for; split decision rights between VvE owners and Stadgenoot tenants created procedural ambiguity. Engagement moments were front-loaded into early phases, and later refinement decisions were made by professionals with limited resident review
Affordability under cost-ceiling pressure *(Economic)*	The project cost ceiling per dwelling tightened during 2022–2023 inflation, pushing back against bio-based cladding and triple-glazing preferences; the subsidy framework rewarded measurable energy savings ($kWh/m^2 \cdot yr$ reduction) more readily than qualitative resident gains (legibility, identity); service-charge calculations within each VvE varied, complicating the budget-neutral principle. Bio-based material preferences were noted but deferred; sustainability narrowed to operational-energy reduction
Participation depth and representation (Organisational)	Communication gaps in the early phase before plain-language tools were introduced; uneven participation between active VvE working-group members and less-engaged residents; coordination across seven institutional partners (TU Delft, AMS Institute, TNO, !WOON, Stadgenoot, the municipality, EnergyLab Zuidoost) introduced overhead; reflection sessions sometimes scheduled at times that excluded working residents. Active residents had disproportionate influence on decisions, and underrepresented voices (older non-Dutch-speaking residents, working renters) entered the process late or not at all

3.4.8 Outcomes

The renovation produced visible and reported effects on residents' daily use, perception, and experience of their dwellings. The outcomes are reported here as documented in JustPrepare reports, Living Lab reflection sessions, and the Stadgenoot post-renovation reviews; they are not framed as a definitive performance evaluation, but as a record of how the value translation in Tables 4.3 and 4.4 landed in lived experience.

On the comfort side, residents reported reduced draughts and a more consistent indoor temperature in renovated dwellings, with fewer condensation and mould complaints. Heating demand was reduced by 35–50% in the monitored sample, against a 40–60% design target. Triple glazing improved acoustic comfort, particularly on the busier street-facing elevations. Where solar control was under-specified on south- and west-facing rooms, residents reported episodes of summer overheating; this was logged as a refinement point for the next round of variants.

On the agency side, residents who participated in the three VvE working groups reported feeling "listened to" and that the documented decision-making process was a clear improvement over previous renovations they had experienced. Residents who were less involved reported feeling under-informed in the early phases, before the plain-language summaries and visual cost dashboards were introduced. The Co-Creation Roadmap Manual was retained as a governance instrument by Stadgenoot for use in subsequent projects.

On the identity side, the preservation of the 1980s façade rhythm and colour palette was reported as a positive outcome by long-term residents who had been concerned about the block's neighbourhood expression. Some standardisations of cladding texture across blocks (driven by procurement) were noted by a smaller subset of residents as a missed opportunity for per-block differentiation.

On the affordability side, the budget-neutral principle was achieved at portfolio level: the projected energy-cost savings offset the renovation-driven service-charge increase. A subset of lower-income households reported, however, that fixed-fee elements increased their monthly housing costs in the first year, before the energy savings became visible on their bills. This experience was logged as a financial-design refinement point: the timing of cost recovery matters for residents at the lower end of the income distribution.

On the sustainability side, the technical retrofit reduced operational-energy emissions, but residents reported that the embodied-carbon ambition had disappeared by the time material decisions were finalised. This was logged in the JustPrepare reflection sessions as a procedural-design lesson: embodied-carbon decisions need to be brought forward to early-stage workshops, not deferred to the procurement phase.

3.4.9 Key insights for framework development

Reigersbos shows that the most difficult barriers to a fair and effective retrofit were not technical but social and organisational. Although the project achieved progress in testing modular façades and co-creation tools, several interconnected challenges limited its overall impact. These challenges reveal the complexity of implementing participatory retrofit processes in mixed-ownership housing contexts.

- **Fragmented governance slowed progress.**
  With ten different homeowners' associations (VvEs), each having its own budget, leadership, and pace, decision-making became fragmented. No single actor had the authority to coordinate decisions across all buildings, resulting in delays and administrative complexity.
- **Communication gaps reduced inclusivity.**
  Project information was often too technical or too long, excluding residents with limited language or digital skills. This created frustration and a perception of unequal access to knowledge. Simplified summaries and visuals were only introduced later in the process.
- **Trust between residents and institutions was fragile.**
  Years of unclear maintenance responsibilities and financial uncertainty had eroded trust between residents, the housing corporation (*Stadgenoot*), and the municipality. This distrust initially prevented residents from engaging in collective decision-making.
- **Financing remained a persistent obstacle.**
  Many VvEs had small maintenance reserves and were hesitant to take out collective loans. Even with subsidies, not all homeowners could afford the retrofit. As a result, affordability became a precondition for participation rather than a shared goal.
- **Institutional procedures limited flexibility.**
  The municipality's formal approval processes and funding requirements did not fit the experimental, iterative rhythm of a Living Lab. This mismatch between policy timelines and participatory learning cycles slowed implementation.
- **Uneven participation created representation gaps.**
  Only a small group of highly engaged residents actively participated in workshops and meetings, while others remained passive or absent. As a result, certain voices and priorities were overrepresented in decisions.
- **Sustainability remained secondary.**
  Although circularity was part of the project's ambition, environmental considerations were often overshadowed by financial and technical priorities. Circular design choices were mostly policy-driven rather than co-decided with residents.

The case demonstrates that resident values must be treated as design parameters embedded in measurable indicators, that transparency tools are essential governance instruments, and that empowerment is more effectively delivered through formal subcommittees than through ad-hoc engagement.

These observations recur across the seven additional cases documented in Appendix A and feed into the cross-case synthesis below.

3.5 Cross-case synthesis

The cross-case synthesis is based on the application of the analytical framework (§3.2) to all eight cases. The synthesis is presented in three parts: the resident values that recur across the cases (§3.5.1); the engagement techniques and the stage at which they integrated values (§3.5.2); and the recurring constraints that limited integration (§3.5.3). A summary table is presented at the end of the section in table 3.5. The complete cross-case data, all ten analytical categories applied to all eight cases, is documented in Appendix A.8

3.5.1 Resident values identified.

Six recurring resident values were identified across the eight cases. They appeared consistently across contexts, although their relative importance varied between projects. The case-by-case evidence behind each value claim below is set out per case in Appendix A; the worked development of Reigersbos in §3.4 illustrates the same analytical logic for one of the eight.

- **Comfort and usability** (thermal stability, daylight, ease of use, control).
  Identified in all eight cases.
- **Affordability** (cost transparency, rent stability, total housing-cost neutrality)
  Identified in all eight cases as a precondition for acceptance.
- **Fairness and trust** (procedural justice, transparent communication, traceable decisions.
  Identified in five cases
- **Empowerment** (resident influence over outcomes, ownership, co-decision authority)
  Identified in four cases as a delivered outcome and in all eight as an aspiration.
- **Sustainability** (valued specifically when made visible and experiential rather than abstract)
  Identified in five cases.
- **Identity and belonging** (façade character, recognisability, continuity)
  Identified in four cases as a clear design driver, with implicit relevance across the others.

3.5.2 Engagement techniques and stages of integration

Across all eight cases, resident engagement was recognised as necessary yet implemented through varying methods that enabled diverse types of knowledge to emerge. Four recurring engagement formats were identified: walkthroughs and home visits; co-design workshops; information sessions; and living-lab arrangements. The methods were often combined, but their timing and depth significantly shaped their capacity to surface resident values and influence renovation decisions.

Walkthroughs and home visits were particularly effective in extracting values related to comfort, usability, and control. In Amsterdam (Reigersbos) and the Sutton Estate residents articulated preferences for operable windows, daylight access, and manual control only when discussing concrete spatial situations within their dwellings. These methods enabled residents to express tacit, experiential knowledge grounded in daily routines, which would not have emerged through abstract consultation formats. However, walkthroughs were typically conducted during diagnostic or evaluation phases, limiting their influence on early-stage design decisions.

Co-design workshops enabled a different type of engagement by allowing residents to interact with visualisations, models, or design scenarios. In Utrecht, Križevci, and Sabadell, workshops facilitated the articulation of values related to identity, empowerment, and sustainability. In Križevci, where co-design was embedded early and coupled with cooperative governance, residents influenced strategic decisions regarding renovation scope and spatial organisation.

In Amsterdam and Sabadell, workshops occurred after key technical and financial parameters had been established, constraining resident input to refinement rather than fundamental design choices.

Information sessions were the most widely applied engagement method and played a key role in procedural transparency. In Utrecht, Gemert, and Nijmegen these sessions revealed that affordability functioned as a threshold condition for acceptance: residents were willing to engage only when cost implications were clearly communicated. Nevertheless, these sessions primarily served a communicative function and rarely enabled residents to shape design decisions directly, as they were typically organised after major choices had been made.

Living-lab approaches, as in Amsterdam, Rotterdam, Nijmegen, and Sabadell, embedded engagement within longer-term experimental settings. These arrangements supported iterative feedback, learning, and trust-building. However, despite their participatory ambition, living labs often retained expert-led decision structures, and design outcomes remained constrained by institutional frameworks and technical systems.

A further pattern emerges from the cross-case material that is methodological rather than substantive but worth mentioning. The visual record of resident engagement across the eight cases is asymmetric. Public communications consistently document the technical deliverable ,the renovated building, the energy-performance figures, the oplevering ceremony ,while the participatory work that preceded it (klankbordgroepen, in-home consultations, bewonersbegeleiding, co-creation workshops, cooperative meetings) is rarely visually documented in publicly accessible form. This patern was found systematically across the cases reviewed in Appendix A: the building is photographed, the social process that should shape it is not. Three structural reasons account for this pattern: privacy and consent considerations under the Algemene Verordening Gegevensbescherming (AVG) make resident-facing photography institutionally cautious, communications budgets prioritise the photogenic completion moment over the slow work of trust-building; and the deliverable–process patern in housing-corporation media offices reproduces the same bias the thesis is critiquing.

The visibility gap in the case record therefore mirrors the value-translation gap identified in §3.6: the architectural object is documented and made legible, while the participatory process that should have shaped it remains invisible. This observation does not weaken the case evidence engagement activities are documented in the textual record of programme reports publicly available, but it does foreshadow the central argument that follows: resident values require an explicit translation step into design-relevant criteria, because neither the participatory work nor the values it surfaces are otherwise made visible at the moment of design decision.

The synthesis reveals that resident values were not only unevenly integrated across cases but also integrated at various stages of the renovation process, with substantial implications for their impact.

Values integrated during early strategic stages had significantly more influence than those introduced during design refinement or post-occupancy evaluation. In Utrecht, affordability concerns articulated during early engagement led to the suspension of an initially proposed renovation strategy, demonstrating that values can function as constricting conditions when acknowledged at the strategic level.

In Križevci, empowerment was embedded structurally through cooperative governance, enabling residents to influence both decision-making processes and outcomes. By contrast, in Nijmegen and Rotterdam, values such as learning and trust were primarily addressed during implementation and monitoring phases, limiting their influence on spatial and architectural decisions.

3.5.3 Recurring constraints on integration

Despite contextual differences, the cases exhibited a consistent set of constraints that limited the integration of resident values into refurbishment practice.

- **Technical constraints***.* Standardised systems prioritised efficiency and repeatability over adaptability and resident influence regarding façade articulation, operability, and appearance.
- **Institutional constraints.** Top-down governance structures prioritised efficiency and risk management over participatory flexibility, limiting residents' role in decision-making.
- **Economic constraints.** Affordability concerns frequently conflicted with ambitions for deep renovation, leading to scaled-back interventions or delayed implementation.
- **Organisational constraints.** Time pressure, engagement fatigue, and fragmented responsibilities reduced the continuity and depth of participation, especially in long-term projects.

These constraints help explain why resident engagement alone is insufficient to ensure value-driven renovation. While engagement methods effectively surface resident values, they rarely provide mechanisms for translating those values into design-relevant criteria that can operate within modular and industrialised renovation systems.

3.5.4 Cross-case summary table

Table 3.5 below presents a synthesis read of the cross-case analysis, organised by resident value. It is derived from the comprehensive cross-case data tables presented in Appendix A §A.8, which document all ten analytical categories applied to all eight cases. Table 3.5 shows for each of the six recurring values the dominant engagement techniques, the phase of integration, the cross-case pattern, and a representative example case.

Table 3.5: Cross-case synthesis of resident values, engagement techniques, integration stages, and frequency across the eight cases.

Resident value	Engagement techniques	Phase and degree of integration	Cross-case pattern (frequency)	Example case
Comfort	Walkthroughs, post-occupancy interviews, comfort diaries, demo houses	Design and post-occupancy	Comfort is associated with adaptability and user control, not automated optimisation (8/8)	Reigersbos: residents valued operable windows, daylight, and even temperatures over automated systems
Affordability	Information sessions, participatory budget reviews, surveys, klankbordgroepen	Strategic planning (early phase)	Affordability functions as a precondition for acceptance and as a gating condition for project continuation; unclear cost effects undermine trust (8/8)	Overvecht-Noord: affordability concerns (€4,000–€8,000 per dwelling, 7.5% Eneco return) led the municipality to halt the joint warmtenet project in April 2024
Fairness	Dialogue sessions, plain-language summaries, transparency tools, participatory monitoring dashboards	Governance and process design (continuous)	Creates trust when residents can trace how input affects decisions; fairness is most often addressed reactively rather than designed in (5/8)	Reigersbos : Co-Creation Roadmap Manual and visual cost dashboards introduced mid-project to address procedural-fairness concerns
Empowerment	Co-design workshops, cooperative governance, formal subcommittees, resident steering boards	Concept design and process design	Emerges only when residents influence tangible outcomes through formal decision rights, not only through ad-hoc engagement (4/8)	Križevci: cooperative governance with one-member-one-vote institutionalises empowerment through structural co-ownership rather than consultation
Sustainability	On-site reuse demonstrations, material tours, education, circularity-agent training	Design and construction	Valued when made visible and experiential rather than abstract; often constrained by cost ceilings during procurement (5/8)	Els Mestres: circular renovation with cork ETICS and reused materials, supported by HOUSEFUL circularity-agent training
Identity	Storytelling, façade-preference workshops, visual reference sessions, conservation reviews	Early design and aesthetic decisions	Residents value continuity and recognisability over stylistic novelty; identity is delivered most reliably when paired with a heritage or character requirement (4/8)	Sutton Estate: Edwardian Baroque character preserved within Chelsea Estates Conservation Area while delivering 75% energy demand reduction

3.6 Cross-case implications for value-driven design translation

The synthesis carries three implications.

1. Which is the clearest that resident values are consistently present and articulable across contexts. they are not exotic, unstable, or so context-bound that they cannot be transferred. The same six values appear across all eight cases, even when their relative priority shifts from one project to another.

2. The case studies show that engagement methods successfully surface values but rarely embed them structurally in design. The dominant pattern is that values are surfaced after the strategic decisions have already been made, which means the design space available to express them has already been narrowed before they enter the conversation.

3. Which points back to the façade specifically. Comfort, identity, control, and sustainability all converge on the façade scale: operable windows and shading carry comfort and control, threshold conditions carry identity and the relation with neighbours, cladding choices carry identity and sustainability, and the visible legibility of upgrade quality carries fairness and affordability. The façade is therefore where value translation has the most leverage.

The implications point in the same direction. They confirm the need for an explicit translation step between values and design decisions, and they confirm the strategic importance of the façade as the locus where this translation can be made operational.

They also indicate, by direct observation, that the framework needs to support not only the identification of values but their early-stage integration into design briefs and configuration choices, which is the methodological function of the Value–Indicator Framework introduced in the next chapter.

3.7 Chapter conclusion: answer to sub-question 1

Sub-question 1 asks *which resident values recur across European social-housing renovation cases, and what currently prevents them from shaping design decisions.*

The case analysis answers this question in two parts.

Six resident values recur across the eight European social-housing renovation cases analysed in this chapter: *comfort, affordability, fairness, empowerment, sustainability, and identity.* The values appear consistently across contexts, although their relative priority varies between projects.

Comfort and affordability are present in all eight cases; fairness and sustainability appear in five; empowerment and identity appear as clear design drivers in four cases and implicitly in the others. The case analysis of the other case studies and the large cross-case synthesis table is included in Appendix A.

The recurrence and articulation of these six values across diverse institutional, geographical, and socio-cultural contexts establishes their robustness as the empirical input for the framework developed in Chapter 4.

These values are currently constrained by four recurring patterns: Engagement methods successfully surface them, but four mechanisms prevent their translation into design decisions: late-stage entry of engagement into the renovation process, communication asymmetries between residents and professionals, fragmented governance across multiple decision-makers, and the standardisation logic of industrialised renovation systems.

Values introduced at strategic stages hace significantly more influence than values surfaced during design refinement, values that operate as governance properties (affordability, fairness) are weakly recognised in expressive design language; and the standardisation requirements of industrialised renovation are typically treated as competing with rather than coexisting with resident-driven differentiation.

Taken together, these two findings confirm the value–design translation gap identified in Chapter 2 and locate it precisely: the gap is the absence of a structured translation step between the surfacing of resident values and their integration into modular renovation design.

The framework developed in the following chapters is the methodological response to that absence. The six values identified here are the empirical input to Chapter 4, where they are translated into architectural design indicators and façade-related criteria.

Chapter 4 : Framework development

4.1 Introduction

The cross-case analysis presented in Chapter 3 demonstrates that resident values are consistently present in social housing refurbishment projects yet rarely translated into concrete architectural decisions. While engagement methods such as co-design workshops, walkthroughs, and living labs successfully surfaced values related to comfort, affordability, fairness, empowerment, sustainability, and identity. However, these values often remain descriptive or procedural rather than spatially operational.

In industrialised and modular refurbishment systems, façade solutions are typically shaped by technical performance targets, cost efficiency, and construction logistics.

As a result, resident values(although acknowledged through communication) , are rarely influence module configuration, materially articulation, or interface design.

This chapter addresses that translation gap; it represents the generative phase of the research. It operationalises the translation of resident values into:

- **Design indicators** (value-sensitive architectural parameters)
- **Modular façade design criteria** (operational conditions guiding configuration and articulation of the design)

The translation establishes the architecturalbdesign indicators that will guide the system development, configuration, and design explorations . The chapter does not yet propose final façade designs. Instead, it constructs a structured value–design matrix that mediates between lived experience and modular façade configuration.

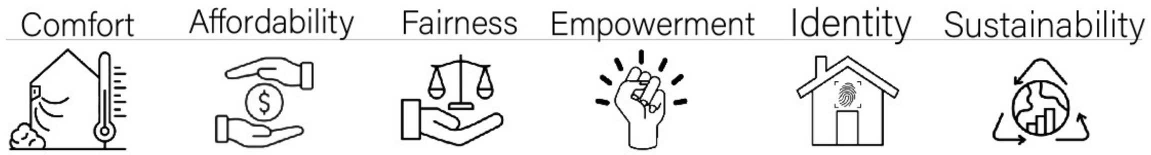
4.2 Identified resident values and key insights.

4.2.1 Recurring resident values across cases

The cross-case synthesis initially revealed a wider set of resident concerns and value dimensions related to façade-centred refurbishment. These included issues such as thermal comfort, daylight, ventilation, privacy, cost certainty, trust, decision transparency, control, empowerment and agency ,safety, material expression, environmental responsibility and belonging.

For the purpose of the framework, these dimensions were densified into six recurring resident values: *comfort, affordability, fairness, empowerment, sustainability, and identity.* This densification was necessary to make the framework usable for design.

Keeping every separate concern as an individual value would have produced too many categories to coordinate within a modular façade system. Reducing the material too far, however, would have made the framework too general to guide façade decisions. The six-value structure therefore balances analytical richness with design usability.



These values appeared across diverse socio-cultural and climatic contexts, although their articulation differed depending on governance structures, engagement depth, and refurbishment ambition.

The façade repeatedly emerged as the interface where these values converge. It mediates thermal comfort, daylight, material expression, visual identity, perceived safety, and user interaction, which is what makes the façade the right scale at which to develop a value-translation framework. The theoretical grounding of each value as a designable construct follows in the next sub-chapter §4.2.2

4.2.2 Theoretical grounding

The six resident values identified through the cross-case analysis: comfort, affordability, fairness, empowerment, sustainability, and identity, are not isolated empirical observations.

Rather, they resonate strongly with established theoretical perspectives in housing studies, socio-technical transition theory, and participatory design research. Situating these values within existing literature strengthens their conceptual legitimacy in this thesis and clarifies their relevance for façade refurbishment.
First, comfort has been widely problematised in building research as a socially constructed and practice-based phenomenon rather than a purely technical outcome. Studies grounded in social practice theory demonstrate that thermal comfort, ventilation behaviour, and daylight use are shaped by everyday routines, habits, and meanings attached to the home (Gram-Hanssen, 2010; Shove et al., 2012).

This challenges the assumption that improving envelope performance alone guarantees comfort satisfaction. The recurring emphasis on usability and operability across the analysed cases (§3.5.1; §3.4.5 Reigersbos; §A.1.5 Bospolder–Tussendijken) therefore aligns with broader critiques of performance-driven retrofit that neglect lived experience.

Second, affordability extends beyond investment cost to include perceptions of fairness, transparency, and long-term financial security. Research on energy poverty and energy justice highlights how low-income households often adapt their energy consumption prior to renovation due to economic constraints, the so-called prebound effect, leading to a difference between predicted and actual savings (Bouzarovski, 2017 Galvin & Sunikka-Blank, 2012).

In this context, affordability becomes not only an economic issue but a condition for trust and acceptance. The cross-case findings, where financial clarity directly influenced participation and approval (§3.5.1; Reigerbos §A.4 Overvecht-Noord; §A.3 NOM-woningen Gemert), reflect these structural dynamics.

Third, fairness and empowerment are closely linked to procedural justice and participatory governance. Arnstein's (1969) ladder of participation and subsequent literature on collaborative planning emphasise that meaningful influence over decision-making shapes legitimacy and trust.

In social housing refurbishment, where residents often lack formal ownership, perceptions of fairness depend on whether engagement is symbolic or genuinely influential (Voorberg et al,2015,Puerari et al., 2018). The analysed cases (§A.1 Bospolder–Tussendijken on procedural fairness through ABCD governance , §A.6 Križevci on cooperative empowerment) demonstrate that empowerment is not merely a normative aspiration but a condition for sustained engagement and reduced resistance.

Fourth, sustainability is increasingly understood within socio-technical transition theory as co-produced through interactions between technologies, institutions, and everyday practices (Bartiaux et al., 2014; Geels, 2017). Buildings are not neutral places but inhabited socio-technical systems: the success of any renovation depends not only on achieving energy-performance targets but also on aligning interventions with residents' routines, comfort strategies, privacy needs, and emotional attachments (Lowe et al., 2017).

Design therefore mediates how technical interventions are perceived, understood, and used in daily life. Design decisions influence whether renovation measures become legible, meaningful, and compatible with everyday routines, shaping long-term acceptance and use (Boess, 2022).

In several case studies (§A.7 Els Mestres on circular renovation; §A.6 Križevci on cooperative energy ownership), circularity and material reuse gained acceptance when residents could see and understand the sustainability logic, reinforcing the argument that environmental performance must be socially embedded.

Finally, identity reflects theories of place attachment and environmental meaning. Housing research demonstrates that residents develop emotional bonds with façade rhythm, materials, and neighbourhood character, which contribute to feelings of belonging and stability.Façade transformation can therefore either reinforce or disrupt local identity (Brown et al. 2003,2015 Wise et al., 2021).

The cross-case findings, where material continuity and recognisability influenced acceptance (§A.5 Sutton Estate on Edwardian Baroque heritage continuity, §3.4.5 Reigersbos on the 1980s façade rhythm), confirm the façade's symbolic as well as technical role.

Taken together, these theoretical perspectives reinforce the interpretation that resident values are not subjective preferences detached from technical concerns. They are structurally embedded in socio-technical systems of housing and refurbishment.

The task of this research is therefore not to add new values to the literature, but to operationalise established socio-technical insights into a design-relevant framework capable of informing modular façade configuration.

4.2.3 Cross-case key insights

Beyond identifying values, Chapter 3 surfaced six recurring dynamics in how those values shape acceptance and resistance comfort and usability drive acceptance; affordability defines perceived fairness; fairness builds trust; empowerment sustains long-term engagement; sustainability becomes credible when made visible; and identity carries belonging. Table 4.1 summarises the value-insight-design-implication relationship across all six.

These insights demonstrate that values are not abstract ethical statements; they influence whether refurbishment is accepted, resisted, or appropriated in everyday life. However, they remain experiential and qualitative and for influencing modular façade configuration, they require translation.

Table 3.1:summary of the value–insight–design-implication relationship

Value	**Key Insight**	**Design implication**
Comfort	Drive acceptance	Design for adaptability and control
Affordability	Defines fairness	Transparent and efficient retrofits
Fairness	Builds trust	Engage early, communicate decisions
Empowerment	Sustains engagement	Involve residents as co-designers
Sustainability	Builds trust via visibility	Make reuse and circularity visible
Identity	Creates belonging	Respect existing context and aesthetics

4.3 From resident values to design indicators

4.3.1 Why translation is necessary.

Resident values, as identified in the case studies, are experiential, contextual, and often expressed in qualitative terms. Documented qualitative research with social-housing residents during and after renovation reports four recurring patterns that illustrate how these values surface in practice:

- Comfort and operability are tied to perceived control: residents associate comfort with the ability to interact with their dwelling. for example, opening windows or adjusting heating, and report dissatisfaction when familiar means of control are removed by automated systems (Koops et al., 2023; Boess, 2022).
- Affordability becomes a precondition for acceptance: residents value transparent communication about renovation cost and the resulting service-charge or rent change; lack of information about cost is a leading source of renovation stress (Koops et al., 2023; Sovacool et al., 2019).
- Identity is read at the façade: residents' express attachment to the recognisable expression of their building and concern when uniform refurbishment risks erasing it (Femenías et al., 2018; Wise et al., 2021).
- Recognition is a value in itself: residents report that being acknowledged as participants in the process, not only as recipients of an upgraded dwelling, is itself a determinant of acceptance and perceived fairness (Koops et al, 2023).

These patterns are meaningful as design intent, but they cannot directly inform modular façade configuration such as geometry, connection detailing, or module dimensions without interpretive translation between resident experience and technical specification. (Boess, 2022; Friedman & Hendry, 2019).

Design indicators are introduced in this thesis as: '*mediating constructs that translate resident values into design-relevant parameters.*

The literature on Value Sensitive Design has established the need for such mediating constructs in technology development (Friedman & Hendry, 2019), and design research has framed them as boundary objects that allow people from different fields to use the same artefact while reading it from their own positions (Star & Griesemer, 1989; Bergman et al., 2007).

Unlike performance indicators, which quantify technical outcomes, design indicators operate at the interface between social meaning and architectural decision-making (Sanders & Stappers, 2008). They make values actionable without reducing them to purely technical metrics.

4.3.2 Defining design indicators.

In this thesis, design indicators are defined as:
'Design-relevant parameters that translate resident values into façade-related considerations capable of shaping configuration, articulation, and system behaviour within modular refurbishment systems.'

This definition extends the boundary-object framing introduced in §2.5 (Star & Griesemer, 1989; Bergman et al., 2007; Jensen & Maslesa, 2015) into the specific case of modular façade refurbishment.

They differ from technical performance metrics in three ways:

- They originate from resident experience.
- They operate at the architectural configuration level.
- They remain interpretable during design exploration. (Han et al., 2023; Thuvander et al,2012).

Design indicators therefore function as socio-technical mediators, enabling resident values to inform modular systems without abandoning industrial logic.

4.3.3 Value–indicator translation

Each resident value is translated into a limited set of design indicators grounded in empirical case insights and theoretical literature. This translation deliberately avoids one-to-one mapping.
A single value may inform multiple indicators, and a single indicator may respond to multiple values (for example, operable windows support both comfort and empowerment). This reflects the socio-technical nature of refurbishment rather than a linear optimisation logic.

Each indicator is justified by either a recurring observation in the case material of Chapter 3 or by a body of literature reviewed in Chapter 2. The aim is not to be exhaustive but to keep the indicator set small enough to be operational, and clear enough that two designers reading the same matrix would arrive at compatible interpretations. The six values and their indicators are summarised in Table 4.2 and developed in detail in Tables 4.3.1-4.3.6.

Table 4.2:Value-indicator translation matrix

Value dimension	**Design indicators**
Comfort	User control over indoor environment, daylight and visual comfort, ease of interaction,maintainability,minimised disruption
Affordability	Cost transparency, long-term cost stability, construction simplicity
Fairness	Decision transparency, traceability of input, equitable distribution
Empowerment	Configurability, degree of resident influence, adaptability over time
Sustainability	Recycled content, embodied carbon, environmental feedback, lifecycle awareness, material selection
Identity	Material continuity, façade articulation ,dwelling recognisability

Each value is now developed in turn, with the indicators stated as architectural qualities that the façade can be designed to provide.

Comfort: Comfort is defined as the everyday experience of being warm enough, cool enough, ventilated, daylight, and not exposed to noise or excessive solar gain. Following Gram-Hanssen (2010) and Walker (2014), comfort is treated as a practice-based phenomenon shaped by routines as well as by environmental conditions; the indicators therefore include both performance variables and adjustability. The cross-case material (§3.5.1; §3.4.5 Reigersbos; §A.1 Bospolder–Tussendijken) confirms that residents associate comfort with operability and daylight, not only with thermal performance. Documented qualitative evidence from Dutch social housing supports the same finding (Koops et al., 2023).

Table 4.3.1:Comfort indicators

Indicator	What the façade should make available
Thermal performance	Resistance to heat loss in the opaque wall and in the openings (Rc, Uw)
Operable openings and natural ventilation	At least one operable opening per habitable room, with ventilation provision in line with Dutch building regulations
Daylight access	Window-to-floor area ratio sufficient to maintain Bouwbesluit daylight requirements (≥ 1:7 of habitable floor area)
Solar control	Means of preventing overheating in summer without removing daylight in winter
Acoustic separation from outside noise	Façade buildup that meets the Bouwbesluit airborne-sound requirements for the dwelling type

Affordability: Affordability is defined here as the design-side conditions that keep a refurbishment industrially feasible at scale: a façade that can be procured, manufactured, transported, and installed without bespoke per-dwelling pricing (Mlecnik, 2012; Buildings Performance Institute Europe [BPIE], 2022). Affordability for the resident, expressed as housing-cost change after refurbishment, depends on financial arrangements that lie outside the scope of the design framework; the indicators therefore stay on the design side.

The cross-case material (§A.4 Overvecht-Noord; §A.3 NOM-woningen Gemert) shows that affordability functions as a precondition for participation rather than a desirable outcome, and where the affordability framing is unclear, projects can stall regardless of technical correctness. The literature on energy poverty and prebound effects supports the same structural reading (Bouzarovski, 2014,2017; Sunikka-Blank & Galvin, 2012).

Table 4.3.2: Affordability indicators.

Indicator	What the façade should make available
Component-family economy	A bounded number of distinct component families, so that procurement and assembly are not bespoke per dwelling
Repetition of the shared baseline	A high proportion of identical baseline modules across dwellings, supporting factory repetition
Per-square-metre cost	Façade cost per square metre within façade refurbishment industry benchmark

Fairness: Fairness is defined as the property that residents do not receive systematically different baseline performance depending on the position of their dwelling, the configuration they have selected, or the visibility of their façade to the street (Soikkeli et al., 2023). The framework treats fairness primarily as a design-side property of the system: every dwelling receives the same shared performance baseline, and every design decision is documented in a form that can be retraced. The cross-case material (§3.5.1–§3.5.2; §3.4.5 Reigersbos on plain-language documentation; §A.1 Bospolder–Tussendijken on ABCD governance principles) shows that procedural fairness, clarity about how decisions are made and traceability of input, is a stronger driver of perceived fairness than distributive equality alone. The literature on procedural justice in participatory planning supports this reading (Arnstein, 1969; Puerari et al., 2018).

Table 4.3.3:Fairness indicators.

Indicator	What the façade should make available
Baseline equality across dwellings	Every dwelling receives the same standardised performance baseline regardless of which configurable elements have been selected
Documented selection logic	Each configurable choice is traceable to a value priority and to a design indicator, so that the basis of the decision is recorded

Empowerment: Empowerment is defined as the resident's capacity to influence the indoor environment and the appearance of the dwelling through elements they can operate or recognise. The indicators draw on Boess (2022) on the importance of perceived control after renovation, and on the cross-case finding (§3.5.1; §3.4.5 Reigersbos on the three resident-led VvE working groups, §A.6 Križevci on cooperative governance with one-member-one-vote) that residents report dissatisfaction when familiar means of control are removed by automated systems and that empowerment is most durable when delivered through formal decision rights rather than ad-hoc consultation.

The literature on Value Sensitive Design and procedural participation supports this conception of empowerment as design-embedded rather than merely procedural (Friedman & Hendry, 2019; Sanders & Stappers, 2008).

Table 4.3.4 :Empowerment indicators.

Indicator	What the façade should make available
Resident-operable elements per dwelling	A minimum number of elements (windows, vents, shading) that the resident can operate by hand
Façade area under direct resident control	A proportion of the façade in which adjustable elements are located

Sustainability. Sustainability is defined as the capacity of the refurbishment to reduce environmental burden over the life of the façade and to keep its components available for future reuse. Following the literature on circular construction (Rovers, 2019; Durmisevic, 2006), the indicators address the materials in the façade, its embodied carbon, and the disassembly logic that determines whether components can be replaced or recovered. The cross-case material (§3.5.1; §A.7 Els Mestres on circular renovation with cork ETICS and reused materials; §3.4.5 Reigersbos on bio-based-material preferences expressed in workshops but largely deferred to procurement) shows that sustainability is most durably integrated when it is made visible and experiential to residents, and most fragile when it remains a policy-driven value that arrives at procurement stage.

Table 4.3.5:Sustainability indicators.

Indicator	What the façade should make available
Bio-based material share	A documented share of bio-based materials in the cladding and insulation by mass
Embodied carbon	Embodied carbon per square metre of façade within published Dutch EPD reference ranges
Reuse and disassembly	A façade in which components can be removed without destroying neighbouring components, scored using a Durmisevic-style index

Identity: Identity is defined as the recognisability of the dwelling and the building within the street and the neighbourhood. The cross-case analysis (§3.5.1; §3.4.5 Reigersbos on the 1980s façade rhythm; §A.5 Sutton Estate on Edwardian Baroque heritage continuity) showed that residents read façade rhythm, materials, and articulation as carriers of the building's standing in the street, and that uniform refurbishments tend to erase rather than reinforce that reading. The indicators therefore address how much the system allows variation between dwellings and across the elevation. The literature on place attachment and environmental meaning supports this conception of identity as a design-embedded rather than purely subjective concern (Wise et al., 2021,Brown et al., 2003,2015).

Table 4.3.6: Identity indicators.

Indicator	What the façade should make available
Distinct configurable combinations	A documented number of distinct combinations of configurable façade elements available within the system per dwelling type
Variation between dwellings	A proportion of façade elements that vary between dwellings, as opposed to elements that are uniform across the elevation

4.4 From design indicators to modular façade design criteria

4.4.1 Operationalising design indicators.

While design indicators articulate what matters from the perspective of resident values, design criteria specify how these indicators can be materially and spatially embedded within a modular façade refurbishment system. The shift from indicator to criterion represents a critical methodological step.

Design indicators remain interpretative and value-oriented; they express concerns such as operability, transparency, recognisability, or cost predictability. However, modular façade systems operate through defined geometries, structural grids, production constraints, and logistical sequences (Knaack et al., 2007; Konstantinou & Knaack, 2013; Lessing et al., 2015).

If value-driven considerations are not reformulated into system-compatible rules, they remain external to the design logic (Boess, 2022; Thuvander et al ,2012).

Design criteria therefore function as operational constructs. They translate value-based design indicators at the level of:

- **Module configuration**: how modules can vary.
- **Articulation principles:** how façade expression can adapt.
- **Interface design**: how residents interact with elements.
- **Connection principles:** how the façade is configured.

4.4.2 Compatibility with industrialised refurbishment logic

Industrialised and prefabricated façade refurbishment has been widely promoted as a necessary strategy to accelerate deep energy upgrades at scale (BPIE, 2022). Off-site manufacturing improves quality control, reduces construction time, and minimises resident disturbance. However, industrial logic also introduces constraints. To remain implementable, design criteria must operate within four structural characteristics of modular refurbishment systems.

1 **Prefabrication logic.** Industrialised refurbishment shifts construction from site to factory production, prioritising repeatability, and logistical efficiency (Lessing et al., 2015). Consequently, value-driven criteria must enable structured variation within standardised modules rather than bespoke fabrication. This aligns with the logic of mass customisation, where variation occurs within predefined production frameworks.

2 **Repetition with structured variation.** Modular systems rely on repetition for economic feasibility, yet repetition does not require uniformity. Stable structural systems can accommodate variation at the level of articulation, operability, or surface expression Konstantinou & Knaack, 2013). This is particularly relevant for identity and belonging, which are strongly influenced by façade rhythm and material continuity.

3 **Standardised structural interfaces.** Prefabricated façade systems depend on predictable anchoring, airtightness, and service-integration details (Knaack et al., 2007). Design criteria must therefore operate primarily at the level of configuration and articulation rather than altering core structural grids. This layered logic ensures compatibility between value translation and system integrity.

4 **Limited on-site intervention.** A central advantage of modular refurbishment is reduced resident disturbance (Mlecnik, 2012; Buildings Performance Institute Europe [BPIE], 2022). Since affordability and fairness are closely linked to installation duration and disruption, design criteria must also address construction sequencing and exterior-only installation strategies.

This translation must occur without undermining the industrial feasibility of modular refurbishment. It reframes modular façade systems not as fixed technical artefacts, but as configurable socio-technical assemblies.

Rather than asking how participation can be added to a prefabricated façade, this thesis reframes the question as: how can modular façade systems be configured so that resident values are structurally embedded within their industrial logic? In doing so, industrial logic does not determine the design principles; rather, it defines the boundary conditions within which resident-oriented principles are operationalized and the framework is designed to.

4.4.3 Value–Indicator matrix

The Value–Indicator Matrix in Table 4.4 collects the translation chain in a single artefact. Each resident value is read first into the resident-side design indicators that express what matters from the resident's perspective, then into the generalised modular façade indicators that name the design moves the façade must make, and finally into the specific design indicators that name the operational concerns the façade must address. The matrix stays at the indicator level throughout: it does not yet specify thresholds or measurable rules. Specifying the operational concerns as measurable criteria with documented provenance is a separate step, given in Table 4.5 (§4.4.4); that step supports the configuration logic of Chapter 6 and the evaluation of Chapter 8.

The matrix is read horizontally, value to resident-side indicator to generalised façade indicator to specific design indicator and is the conceptual core of the framework. The translation does not assign one indicator per value: some values decompose into several indicators because they cover multiple design concerns, and some indicators correspond to multiple façade design moves.

Reading Table 4.4: each row traces one value through the full translation chain. Comfort, for example, originates in resident-side concerns about user control, daylight, and ease of interaction, which the façade addresses through window-to-wall ratio, glazing, shading, and operability (the generalised façade indicators), which in turn are operationalised as thermal performance, operable openings, daylight access, solar control, and acoustic separation (the specific design indicators).

Table 4.4: Value–Indicator translation. Six recurring resident values translated into seventeen façade-related design indicators.

Resident value	Design indicators	Modular façade indicators (generalised)	Specific design indicators
Comfort	User control over indoor environment; daylight and visual comfort; ease of interaction; maintainability	Window-to-wall ratio; glazing type; insulation level; external shading integration; manual operability; intuitive use; high-performance insulated panels	Thermal performance · Operable openings and natural ventilation · Daylight access · Solar control · Acoustic separation
Affordability	Cost transparency; long-term robustness; construction simplicity	Prefabricated façade panels; standardised module dimensions; rapid installation strategy; durable, low-maintenance materials	Component-family economy · Repetition of the shared baseline · Per-square-metre cost
Fairness	Decision transparency; traceability of input; equitable distribution	Defined façade option catalogue; clear drawings, renders, mock-ups, documentation; consistent base performance across dwellings; transparent selection matrix	Baseline equality across dwellings · Documented selection logic
Empowerment	Configurability; degree of resident influence; adaptability over time	Modular variation within fixed structural grid; operable windows; adjustable shading; user-accessible façade elements	Resident-operable elements per dwelling · Façade area under direct resident control
Sustainability	Recycled content; embodied carbon; environmental feedback; lifecycle awareness; material selection	Recycled and bio-based materials; reversible connections; design for disassembly; material explanation	Bio-based material share · Embodied carbon · Reuse and disassembly
Identity	Material continuity; façade articulation; dwelling recognisability	Context-responsive façade articulation; customisable finishes; variation in rhythm, depth, or pattern to respond to existing building character	Distinct configurable combinations · Variation between dwellings

4.4.4 Value–Indicator–Criteria Matrix

Table 4.5 records the seventeen design indicators developed in §4.3, with each indicator paired to a façade-related criterion that states what the design must deliver to satisfy the indicator. The table reads horizontally: each resident value carries a set of design indicators, and each design indicator carries a façade-related criterion expressed at the design-criterion level including the grounding category of that criterion. The leftmost column groups the rows by resident value, with comfort carrying five indicators, affordability three, fairness two, empowerment two, sustainability three, and identity two.

The matrix supports a project-specific reading: a project with a particular value-priority profile picks up the rows attached to those values and treats them as a brief. As a worked example, a project whose value priorities are comfort and empowerment first and second, and sustainability third, picks up five comfort criteria (thermal performance, operable openings and natural ventilation, daylight access, solar control, acoustic separation), two empowerment criteria (resident-operable elements, resident-controlled façade area), and three sustainability criteria (bio-based material share, embodied carbon, reuse and disassembly). The result is a ten-criterion brief that the design must satisfy.

The 'Façade related-design criteria' column states the design-side concern in the form a façade designer can act on. For example, the Comfort value carries a Thermal-performance indicator whose criterion is that the façade buildup must minimise heat loss across both the opaque envelope and the glazing. The same indicator reappears in Chapter 8 with an external benchmark attached: opaque-wall thermal resistance and window thermal transmittance are read against the Dutch building regulation and the deep-retrofit benchmark of the product. The Chapter 4 statement is the design instruction; the Chapter 8 statement is the measurement instrument that lets the design instruction be evaluated.

The 'Source category' column groups each criterion by the kind of grounding it carries. Three categories are used. Regulatory grounding is used where a façade-design criterion derives from Dutch building regulation or its referenced standards; this category covers most Comfort indicators and some Affordability and Sustainability indicators.

Industry benchmark-and-research grounding is used where the criterion derives from established practice in industrialised renovation or from peer-reviewed research on resident-led design. Internal-framework grounding is used where the criterion is set by the rules in the V-I (Value-Indicator) Framework itself because no external benchmark exists for that dimension of resident experience. The full source documentation is recorded in Appendix C §C.3 when the indicators are operationalised into measurable performance indicators in Chapter 8.

A few notes apply to the matrix as a whole. First, the seventeen indicators in Table 4.5 form the full set of design-relevant criteria identified by the V-I Framework, Second, the matrix is reversible: a project that prioritises different resident values reads the matrix in a different order. Third, the matrix stays at the indicator-and-criterion level: the matrix does not specify thresholds, units, or measurement protocols. Specifying the operational concerns as measurable performance indicators is part of the evaluation chapter.

Table 4.5:The Value–Indicator–Criteria Matrix.

Indicator	Façade-related criterion	Source category:
Comfort		
Thermal performance	Façade buildup minimises heat loss across the opaque envelope and the glazing	Regulatory industry
Operable openings and natural ventilation	Each habitable room has at least one operable opening, with ventilation provision sufficient for the room's occupancy	Regulatory
Daylight access	Window-to-floor area sufficient to deliver the daylight provision required for habitable use	Regulatory
Solar control	Façade provides means to limit summer overheating without removing winter daylight	Industry/research + case observation
Acoustic separation	Façade buildup achieves airborne-sound performance appropriate to the dwelling type and location	Regulatory
Affordability		
Component-family economy	A bounded number of distinct configurable element types is used across the project	*Industry benchmark*
Repetition of the shared baseline	A high share of the façade is built from identical modular elements across all dwellings, supporting prefabrication	*Industry benchmark + research*
Per-square-metre cost	Façade unit cost remains within the deep-retrofit benchmark range for the building typology	*Industry benchmark + research*
Fairness		
Baseline equality across dwellings	All dwellings receive the same façade-performance commitment regardless of which configurable elements they receive	*Design rule internal framework*
Documented selection logic	Every configurable selection is recorded against a value priority and a design indicator, making the design route auditable	*Design rule internal framework*
Empowerment		
Resident-operable elements per dwelling	Each dwelling carries a meaningful set of resident-operable elements distributed across habitable rooms	*Case observation*
Façade area under direct resident control	A meaningful share of the façade carries adjustable elements (windows, vents, shading)	*Case observation*
Sustainability		
Bio-based material share	Cladding and insulation include a meaningful share of bio-based material where the variant targets sustainability	Industry benchmark+research
Embodied carbon	Façade buildup keeps embodied carbon within the deep-retrofit benchmark for the building typology	Regulatory + industry
Reuse and disassembly	Façade components are designed so they can be removed and replaced without damaging the underlying construction, following design-for-disassembly principles	*Research*
Identity		
Distinct configurable combinations	A meaningful number of distinct configurable combinations is available per dwelling type	*Design choice internal framework*
Variation between dwellings	A meaningful share of configurable elements varies between dwellings of the same building, supporting recognisability	*Design choice internal framework*

4.5 Chapter conclusion: answer to sub-question 2

Sub-question 2 asks *how resident values can be translated into architectural design indicators for façade renovation*. This chapter answers the question through the Value–Indicator Matrix and the Value–Indicator–Criteria Matrix.

The Value–Indicator Matrix translates the six resident values: comfort, affordability, fairness, empowerment, sustainability, and identity, into architectural design indicators. It does this through a documented translation chain: from the resident value to the resident-side concern, to the modular façade indicator, and finally to the specific design indicator that the façade must address. This matrix is the conceptual answer to sub-question 2, because it identifies what the design must respond to. The Value–Indicator–Criteria Matrix (Table 4.5) then makes this translation operational. It links each specific design indicator to a façade-related criterion that can guide later design decisions. This second matrix does not replace the conceptual translation; it prepares it for use in the following chapters. Chapter 5 uses the criteria to organise the modular façade system, Chapter 6 uses them to structure the configuration logic, Chapter 7 applies them to the case-study, and Chapter 8 uses them to evaluate the outcome.

Together, the two matrices form the framework developed in this chapter. The first matrix translates resident values into design indicators; the second matrix turns those indicators into criteria that can be used by the façade design process.
This chapter establishes what the design must address; the following chapters test how those requirements can be organised, configured, and evaluated within a modular façade system.

Chapter 5:Modular Façade System Development

5.1 Introduction

This chapter answers sub-question 3: how can the architectural design indicators developed in Chapter 4 be operationalised into a modular façade system suitable for industrialised refurbishment?

The chapter is organised in nine sections. §5.2 reads the existing modular façade systems against the Value–Indicator criteria to identify the field-level gap. §5.3 sets out the design ambition and the system principles. §5.4 establishes the theoretical basis for a layered system, drawing on Brand and Durmisevic theory. §5.5 specifies the two-layer logic of the Value-Integrated Modular Façade System (VIMFS). §5.6 develops Layer 1, the standardised performance layer; §5.7 develops Layer 2, the adaptive socio-technical interface. §5.8 explains how values are distributed across the two layers. §5.9 develops the operational form of Layer 2, the value-affinity clusters and the component catalogue documented in full in Appendix B. §5.10 closes with the answer to sub-question 3.

5.2 State of the art of modular façade systems

Chapter 2 (§2.6) established the field of industrialised modular façade refurbishment as the EU-funded demonstration landscape.
This section reads selected systems from the literature review against the criteria of the Value–Indicator Framework (Table 4.5) to identify what they offer and what they leave unaddressed.

5.2.1 Basis of the comparison: from V–I criteria to system-reading criteria

The seven comparisons are derived directly from the Value–Indicator–Criteria Matrix in Chapter 4 (Table 4.5). Each criterion in that matrix demands a particular capability from any modular façade system that wants to satisfy it. Reading down the matrix and grouping the criteria by the kind of system capability they require produces the seven system-reading criteria used in this chapter. Table 5.0 records this derivation explicitly so the basis of the comparison is auditable.

Table 4. Derivation of the system-reading criteria from the V–I Framework (own work)

System-reading criterion	**Derived from these V–I Framework criteria (Ch. 4, Table 4.5)**	**Why this matters for the modular system**
Deep-retrofit performance	Comfort: thermal performance; operable openings and natural ventilation; daylight access; solar control; acoustic separation.	The system must deliver a deep-retrofit envelope baseline regardless of which design variant is configured
Prefabrication and installation	Affordability: component-family economy; repetition of the shared baseline; per-square-meter cost. Comfort: acoustic separation and minimized construction disturbance where relevant to installation quality.	The system must be industrially producible at scale and installed externally with minimal disruption
Structural interface	Fairness: baseline equality across dwellings. Affordability: repetition of the shared baseline. Sustainability: reuse and disassembly.	The system needs a shared anchoring and carrier convention that does not vary per dwelling
Dwelling-level configurability	Identity: distinct configurable combinations; variation between dwellings. Empowerment: façade area under direct resident control.	The system must support recognisable, dwelling-level differentiation without redesigning the support
Resident-facing adaptability	Empowerment: resident-operable elements per dwelling; façade area under direct resident control. Comfort: operable openings and natural ventilation; solar control.	Resident-facing components must be selectable, operable, and replaceable as a separate logic from the technical envelope
Value-led selection logic	Fairness: documented selection logic. All resident values: each configurable selection must be traceable to a value priority and design indicator.	The system must provide a documented route from resident value → criterion → component selection
Transparency and fairness of variation	Fairness: baseline equality across dwellings; documented selection logic. Affordability: component-family economy; repetition of the shared baseline. Sustainability: reuse and disassembly.	Variation across dwellings must be visible as a bounded, equal option set rather than as bespoke per-project decisions

5.2.2 The reference systems

Five reference systems are read against these criteria. They are anchored to actual built work rather than to abstract "system families", each system is illustrated through a specific deployed project or documented manufacturer build-up:

2ndSkin:TU Delft pilot on Dutch post-war row housing. Prefabricated insulated cassette mounted onto existing brickwork, with the technical section published in Konstantinou & Knaack (2013). Documented build-up in Figure 5.2.

Before *After*

Figure 5.2:2ndSkin façade project: prefabricated insulated cassette mounted onto existing brickwork, applied to a Dutch post-war porch-apartment block (Soendalaan Vlaardingen case study, TU Delft 2ndSkin project- https://www.2ndskin.nl/index.php?view=article&id=28

4RINEU: a timber based multifunctional façade-4RinEU developed robust and reliable deep-renovation technology packages for residential buildings, including prefabricated multifunctional timber-frame façade elements that are attached externally to the existing envelope. The façade elements can integrate insulation and building-service components, allowing much of the work to be shifted off-site and reducing works inside occupied dwellings. The system is relevant for this thesis because it combines the industrial logic of prefabricated deep retrofit with a timber-based, service-integrating envelope. At the same time, its documented logic remains primarily performance- and package-driven rather than resident-value-driven: resident-facing variation, co-choice, and identity expression are not formalised as a separate adaptive layer. Documented concept in Figure 5.3.

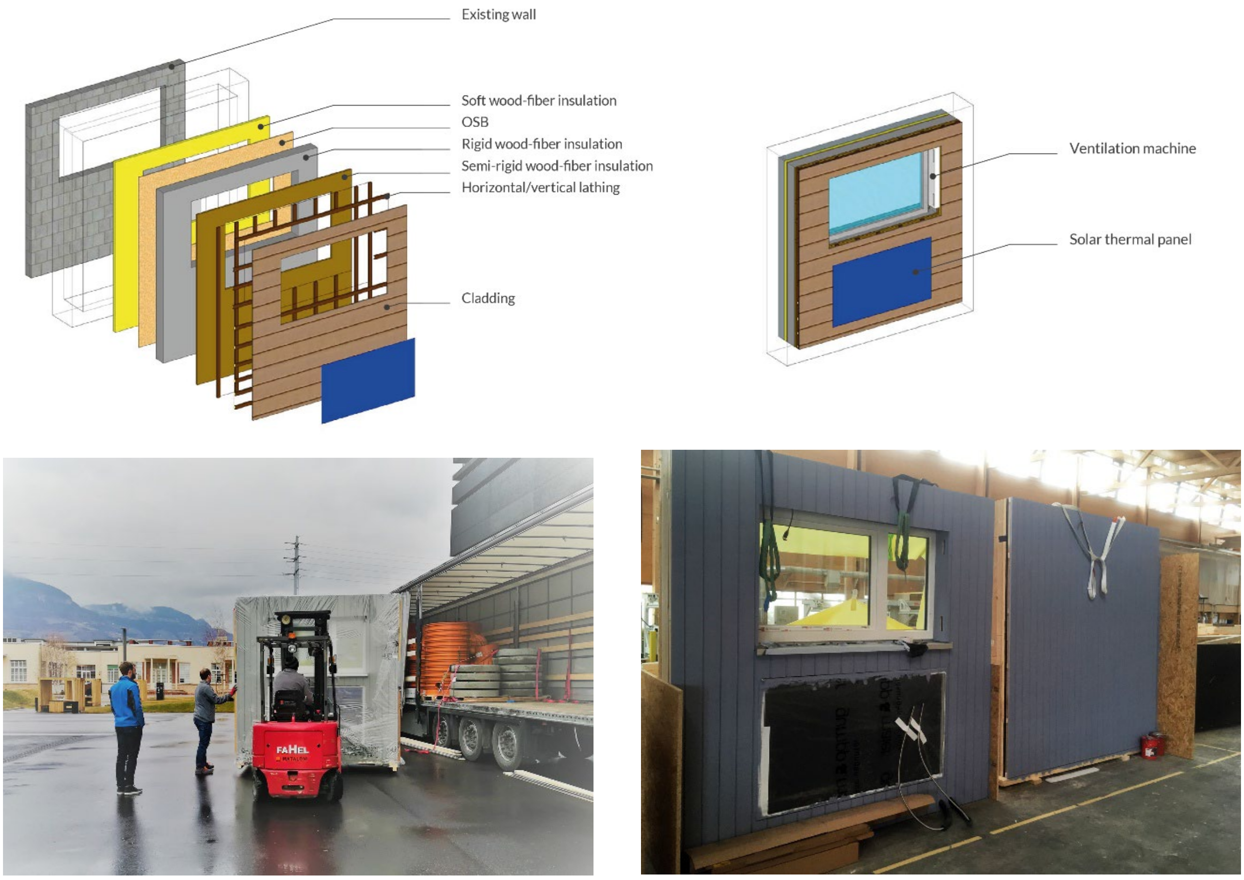


Figure 5.3: 4RinEU facade concept, transportation, and real-life prototype (4rineu.eu.nl)

TES Energy Façade: timber-frame prefabricated retrofit (TES EnergyFacade EU research project). Timber-based element system developed for energy-efficient retrofit of building envelopes, with CNC-fabricated timber-frame modules dimensioned to the existing façade geometry and integrated insulation, weather membrane, windows, and outer cladding (Cronhjort et al., 2009). The timber base distinguishes this system from the predominantly aluminium-cassette family and makes it directly relevant to the bio-based material and disassembly indicators of the V–I Framework.

Figure 5.3: TES-envelope concept (left), TES energy facade on-site (middle), TES-energy facade applied on projectGrüntenstraße in Augsburg 2016 (sdg21) (Rigth)(Technische Universität München Fakultät für Architektur, (Cronhjort et al., 2014)

MeeFS: (Multifunctional Energy Efficient Facade System for Building Retrofitting)(EU MeeFS project). A multifunctional façade-retrofit concept that integrates insulation, ventilation, solar control, and energy-generation functions into a single prefabricated module (MeeFS Retrofitting, n.d.). The system is relevant for this comparison because it tests the constructional limit of integrating multiple performance functions into one assembly, which is precisely the integration that the layered approach in this thesis decouples. Documented build-up in Figure 5.4.

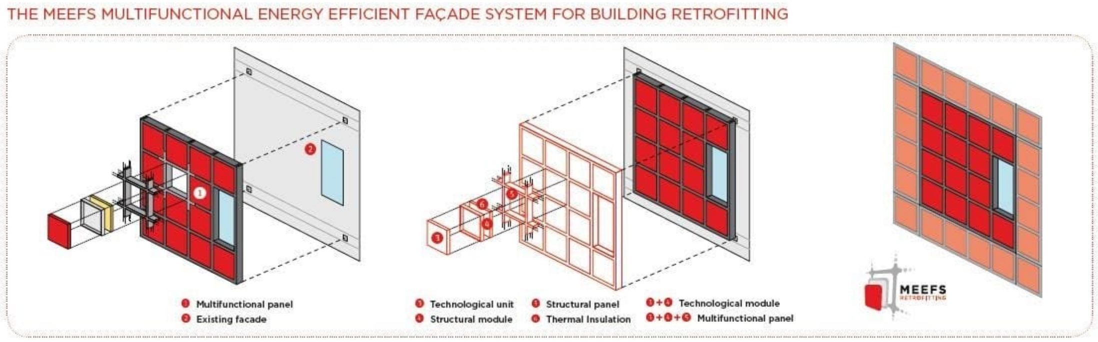


Figure 5.4: MeeFS multifunctional retrofitting façade concept: base structural frame + interchangeable infill modules (insulation, ventilation, solar control, energy generation).(Greenovate-Europe.eu)

Unitised façade tradition: manufacturer reference systems (Schüco AF UDC 80; Knaack et al., 2007). The constructional family from which VIMFS inherits its industrial logic. Exploded axonometric of the Schüco AF UDC 80 build-up Figure 5.5, or alternatively the assembly sequence and other relevant information of a unitized façade in Knaack et al. (2007) *Facades: Principles of Construction*,(Figure 5.6) To understand the system's configurational potential and limitations, it is necessary to decompose it into its constituent components and analyse their functional roles, lifespans, and interdependencies. These analyses can be found in appendix C.

5.2.3 Reading the reference systems against the V–I criteria.

Table 5.1 reads the six reference systems against the seven system-reading criteria derived in §5.2.1. The columns describe what the reference systems collectively deliver, and what remains underdeveloped. The full system-by-system assessment, with cells per system and cited sources, is given in Appendix C, Table C.1.

Table 5.1:Comparative system reading of five modular façade refurbishment references (own work)

Criterion category	Existing reference systems	Capability still missing in the dominant pattern
Deep-retrofit performance	Achieved across the reference set, including 2ndSkin, TES, 4RinEU, MeeFS, and unitised façade systems (Rc, Uw, airtightness, weather-tightness; BENG-compatible buildups).	Performance baseline is delivered, but in most systems its delivery is tied to a fixed cassette and therefore not separated from resident-facing design variation.
Prefabrication and installation	Achieved through factory production, dry external installation and reduced on-site disturbance, 4RinEU adds a service-integrating timber-frame renovation package.	Industrial efficiency is delivered through factory-integrated cassettes; the degree to which resident-facing elements can be exchanged after installation remains limited.
Structural interface	Standardised in most systems: slab-edge anchoring, thermally broken brackets, timber-frame support logic, or unitised carrier frames.	Anchoring is solved technically per system, but a shared anchoring convention that deliberately separates support, performance, and resident-facing components is uncommon.
Dwelling-level configurability	Limited in most cases; cassette or façade package tends to be uniform across dwellings, with variation at project level.	Most systems produce a uniform cassette across dwellings; dwelling-level variation is not usually structured as a repeatable design method.
Resident-facing adaptability	Partly present in some systems through sub-modules, cladding options, or service integration, but not framed as resident agency.	The resident-facing side is rarely organised as a separately replaceable, configurable layer with its own value logic.
Value-led selection logic	Not formalised in the reviewed systems. Technical criteria, cost, production, and performance dominate the system descriptions.	There is no explicit chain from resident value to design indicator to façade component selection.
Transparency and fairness of variation	Variation is usually project-specific or procurement-specific rather than visible as an equal option set for residents.	Existing systems do not document how all dwellings receive an equal baseline while allowing bounded variation in visible or usable components.

5.2.4 The gap that follows from the reading.

Three observations follow.

First, the existing systems reliably deliver the deep-retrofit performance envelope, prefabrication efficiency, and structural-interface coordination. The industrial logic of modular refurbishment is well established and does not need to be reinvented.

Second, configurability and resident-facing adaptability are partly present in some systems l sub-modules in MeeFS, timber-jointing in TES, service integration in 4RinEU, but in the dominant pattern, the performance cassette and the visible cladding remain tightly coupled.

Third, no reference system formalises a documented chain from resident value to design indicator to component selection, and no reference system presents bounded variation as a fair, documented option set rather than as bespoke per-project decisions.

The bottom four rows of Table 5.1 , dwelling-level configurability, resident-facing adaptability, value-led selection logic, and transparency of variation, describe the field-level gap that the V–I Framework foregrounds and that Chapter 5 sets out to close. The next sections develop the design ambition (§5.3), the theoretical basis for a layered organisation (§5.4), and the system architecture that responds to this gap (§§5.5 onward).

5.3 Design ambition and system principles

Before specifying what, the modular façade system must do, this section names what it is trying to be. The design ambition is set out as four reconciliation points (§5.3.1), and the system principles that follow from those points are organised in two sets: system-oriented principles that govern the industrial and performance side of the façade (§5.3.2), and resident-interface principles that govern the configurable and value-carrying side (§5.3.3). The two sets are not in competition; they are the two sides of the design problem, and the layered organisation introduced in §5.5 is the architectural answer that holds them together.

5.3.1 Design ambition

In short, the proposed Value-Integrated Modular Façade System (VIMFS) seeks to reconcile four orientations in industrialised refurbishment practice:

- **Industrial prefabrication logic**. Repeatability, manufacturability, and construction efficiency at the scale and pace that deep-renovation programmes require.
- **Structural and environmental stability**. Robust performance continuity across dwellings: a thermal, airtight, and weather-tight envelope that does not depend on per-dwelling redesign to perform.
- **Configurational flexibility.** Controlled variation and replacement capacity, so that components can be selected, exchanged, and reconfigured over time without disturbing the performance baseline.
- **Resident value integration**. Meaningful resident-oriented outcomes carried through the design itself, not added as decoration after the technical decisions have been made.

These four orientations point toward a system in which industrial logic and resident-oriented design are decoupled at the level of the system architecture so that they can be coordinated at the level of the design variant. The principles in §5.3.2 and §5.3.3 specify each side.

5.3.2 System-oriented principles

System-oriented principles govern what the industrial side of the façade must guarantee in every project, regardless of which resident values are foregrounded. They define the non-negotiable performance, prefabrication, and structural-interface conditions that protect the industrial feasibility of the system at scale.(Table 5.2)

Table 5.2:System-orientated principles modular facade system

System-oriented principle	What the system must provide
Industrial standardisation	Repeatable module dimensions; dry, external installation; bounded number of component families; transportable panel sizes; standard slab-edge anchoring; a stable performance envelope across dwellings
Performance baseline	Thermal performance compatible with deep retrofit ($Rc \geq 4.7$ m²K/W per BBL 2024; $Uw \leq 0.9$ W/m²K where triple glazing is targeted); airtightness and weather-tightness coordinated at one interface; ventilation provision integrated
Structural interface continuity	Standardised mechanical interfaces between the façade module and the existing building; documented anchoring system shared across all design variants; coordination of load transfer with building tolerances

5.3.3 Resident-interface principles

Resident-interface principles govern what the resident-oriented side of the façade must enable. Unlike the system-oriented principles, these are activated differently in each design variant according to the value priorities established in the configuration logic of Chapter 6.

Table 5.3: Resident-interface principles modular facade system

Resident-interface principle	What the system must enable
Resident-facing adaptability	Operability of openings; adjustability of shading; configurable threshold use; recognisable dwelling expression; accessible controls that the resident can use without technical mediation
Maintainability and reversibility	Outer adaptive components replaceable without modification of the supporting performance cassette; mechanical (rather than chemical) connections wherever possible; documented option set so future replacement is bounded and predictable
Traceability	Every façade element traceable back to a value, an indicator, and a criterion in the Value–Indicator Framework (Chapter 4), so the basis of each design decision can be retraced

Together, the two sets of principles describe a design problem with a clear architectural shape: the system-oriented side calls for a stable, standardised, repetitive baseline, the resident-interface side calls for bounded variation that respects but does not depend on that baseline.
The next section turns to the building theory that supports this kind of split, and §5.5 develops it into the Value-Integrated Modular Façade System.

5.4 Theoretical basis: layered system logic

The layered organisation of the modular façade system follows from a body of open-building theory that conceives buildings as layered systems whose components change at different rates. Two references are central here: Brand's shearing-layers model and Durmisevic's hierarchy of building materials. A third move, specific to this thesis, extends those references to make the realm of daily inhabitation explicit at the top of the layer stack.

5.4.1 Brand's shearing layers

To transform the design ambition and guiding principles into a coherent system logic, this thesis adopts Stewart Brand’s ‘Shearing Layers of Change’ (1994)as an analytical starting point .Brand (1994) conceives a building as an assembly of layers that change at different speeds, Site and Structure change very slowly, while Services, Space plan, and especially Stuff are subject to much faster adaptation. As illustrated in Figure 5.5: the original shearing-layers diagram distinguishes the building according to both function and temporal rhythm.

The argument is that buildings should be designed and modified in ways that respect this temporal hierarchy rather than fuse layers together: when slow-changing structure and fast-changing fittings are locked into the same assembly, the building becomes harder to adapt over time and tends to be replaced rather than transformed. Within Brand's stack, the façade belongs to the skin layer: the environmental envelope that changes more frequently than the structure but less frequently than the services, the spatial layout, or daily occupation.

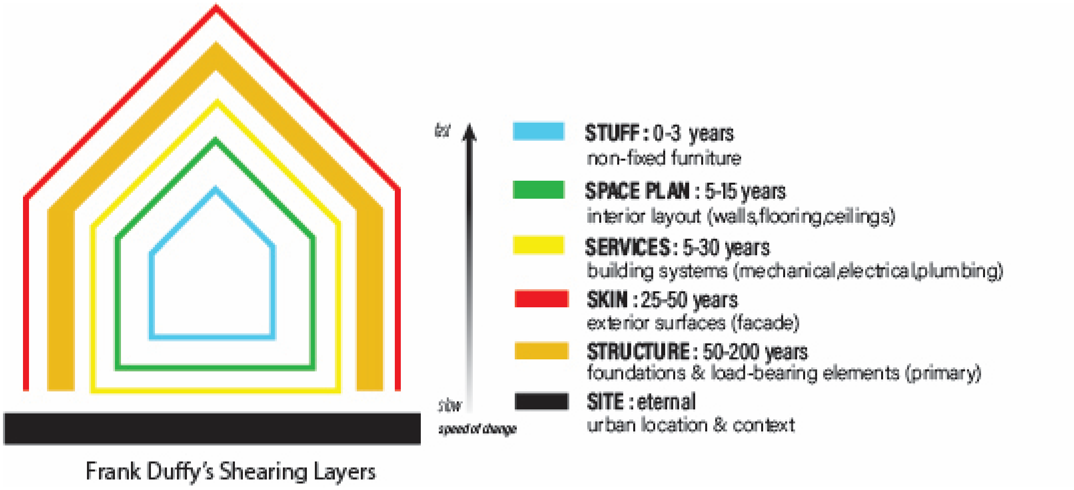


Figure 5.5:Own diagram from Shearing layers of Change (Brand, S. 1994) -How Buildings Learn: What Happens After They're Built

5.4.2 Durmisevic's hierarchy of building materials

Durmisevic's (2006) doctoral work “Transformable building structures: Design for disassembly as a way to introduce sustainable engineering to building design and construction” refines the layered argument of Brand by introducing a hierarchy of building, system, component, and element levels with explicit technical and physical dependencies between them. Its central engineering claim is that “design for disassembly” is the principle that makes a layered building (or a layered building system) sustainable over time: a building or system can only be transformed without destruction connections, components, and material relationships are designed to come apart again.

Buildings designed for transformability are therefore separated through a hierarchical system slow-changing structure from faster-changing skin and services through controlled, reversible interfaces. (see figure 5.6)

From this principle, two consequences for façade design follow directly.

First, a façade that is technically and physically independent from the structural shell can be replaced without altering the building.

Second, an outer-facing component that is mechanically rather than chemically connected to its support can be replaced without altering that support.

Disassembly is therefore not a side benefit of layered organisation; it is the operational test of whether the layered organisation has been designed properly. Durmisevic's framework is what allows the conceptual move from "layered building" to "layered façade product" that this thesis makes: the same logic of decoupled lifecycles, and the same disassembly criterion, are applied at the scale of the modular façade itself. Durmisevic's framework is what allows the conceptual move from "layered building" to "layered façade product" that this thesis makes: the same logic of decoupled lifecycles is applied at the scale of the modular façade itself.

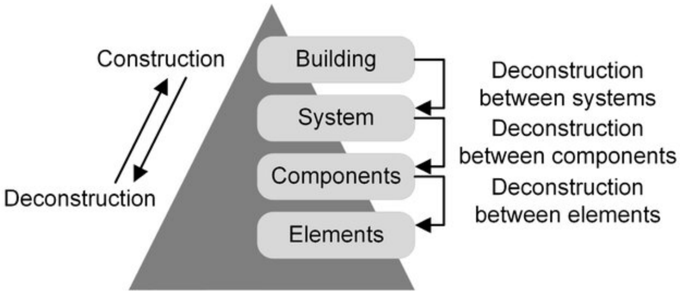
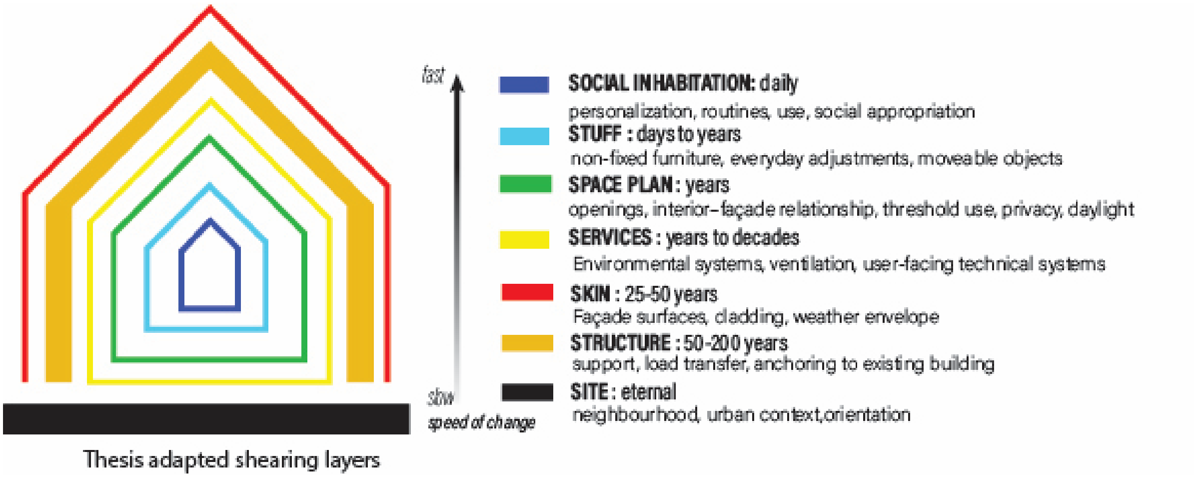


Figure 5.3:Hierarchy of Material Levels (Durmisevic, 2006)

5.4.3 An extension: the daily-inhabitation layer

Brand's fastest-changing layer ‘Stuff’ already points toward the realm of everyday use and occupation, but it does so from the perspective of the building rather than the resident. Because this thesis is centred on the resident and on the façade as a socio-technical interface, it adds a further reading at the top of the stack: a daily-inhabitation layer in which residents act on the façade through the openings they operate, the shading they adjust, the usability: windowsills they sit on, the personalisation and appearance of the dwelling they recognise as theirs or their daily routines.

This layer is not a new physical layer of the building. It is an analytical layer that names what the lower layers must make available so that daily inhabitation can take place.
Adding this layer matters for how the resident-facing part of the modular façade is conceived. If the daily-inhabitation layer is left implicit, the resident-facing components are read as outer finishes attached to a thermal shell.



Thesis adapted shearing layers

Figure 5.7: Facade specific diagram of Brands Shearing Layers of Change including extra layer (Own work)

If it is made explicit, the resident-facing layer has a function of its own: it is the layer through which the daily-inhabitation layer is materialised. The components of the resident-facing layer are then no longer secondary to the technical envelope; they are the part of the façade that the resident interacts with and that gives the lower layers their socio-technical presence. The façade specific interpretation of Brands shearing layers is shown in Figure 5.7

Within industrial façade construction, the proposal sits in the unitised tradition rather than the stick-built one: prefabricated storey-high modules installed as complete units, as distinct from on-site assembly of mullions, transoms, and infill (Knaack et al., 2007). This is the constructional family in which the layered façade organisation can be realised without losing factory efficiency. The layered façade strategy including the structural attachment, environmental control, fixed service integration, and resident-facing interaction will be introduced in the next chapter.

5.5 The Value-Integrated Modular Façade System (VIMFS)

The Value-Integrated Modular Façade System (VIMFS) is the synthesis of the previous three sections: the gap left by existing systems (§5.2), the design ambition and principles that follow from it (§5.3), and the layered building theory that supports a decoupled organisation (§5.4). VIMFS is organised as two layers, named Layer 1 and Layer 2 to signal their separate roles and rates of change.

This section establishes the **architectural shape** of VIMFS — two layers, decoupled, with documented mechanical interfaces between them. The next section develops Layer 1 in detail; §5.7 then explains how resident values are distributed across the two layers, which is the conceptual move that organises the rest of the chapter.

Layer 1 is the standardised performance layer: a slow-changing technical platform that consolidates the structural, environmental, and fixed service-related functions of the façade.

Layer 2 is the adaptive socio-technical interface: a faster-changing layer of resident-facing and expressive elements mounted onto Layer 1.

The two layers are physically and technically independent: every Layer 2 component is mechanically connected to an interface on Layer 1 and can be added, replaced, or reconfigured over time without altering Layer 1. An axonometric reading of the layered system is given in Figure 5.8 and shown in appendix D.

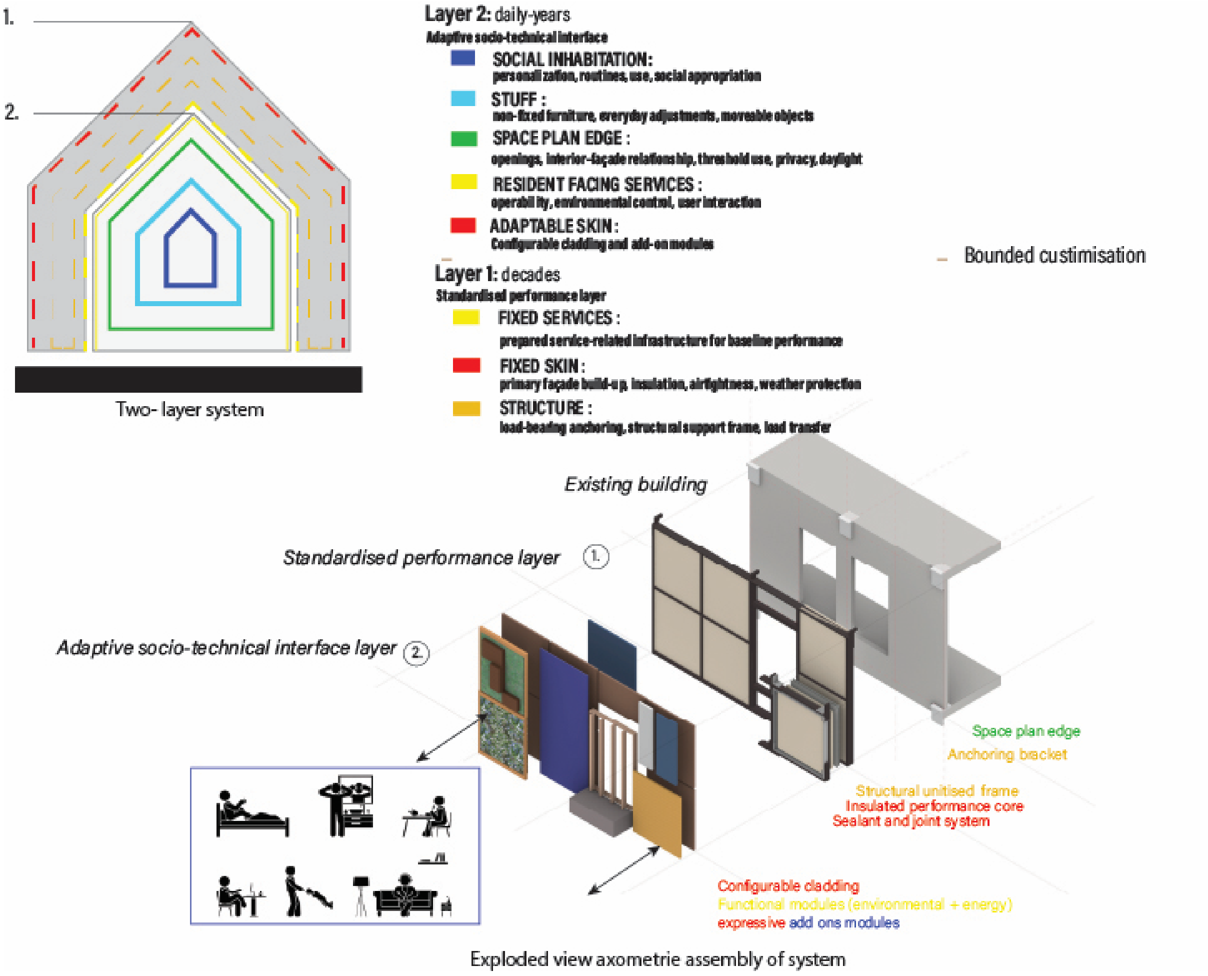


Figure 5.8: The value integrated facade system (VIMFS) in relation to the Shearing layers of change (Own work)

This organisation operationalises the four industrial characteristics named in §4.4.2.
Prefabrication logic and standardised structural interfaces are absorbed into Layer 1, which carries the deep-retrofit performance envelope, the dimensional grid, and the anchoring details that allow factory production.
Repetition with structured variation is absorbed into Layer 2, where bounded variation among resident-facing components occurs without altering the structural baseline.
Limited on-site intervention is achieved by the system since Layer 1 is delivered as prefabricated units and Layer 2 components are mechanically connected to Layer 1 from outside. VIMFS is therefore not an alternative to industrial logic; it is a configuration of industrial logic that reserves space for resident-driven variation.

This organisation extends rather than rejects the unitised façade tradition. Conventional unitised systems prefabricate framing, insulation, glazing, membranes, and external cladding into a single cassette, achieving manufacturing efficiency at the cost of locking long-life and short-life components into the same assembly.

VIMFS retains the unitised system's industrial advantages: prefabrication, dimensional coordination, repeatability, controlled installation, but separates the long-life performance functions (kept in Layer 1) from the shorter-life resident-facing functions (released into Layer 2). The result is a façade that remains industrially feasible and resident-responsive at the same time.

5.6 Layer 1: the standardised performance layer

Layer 1 is the long-life support and performance platform of the system. It consolidates the structural, environmental, and fixed service-related functions of the façade, and it is the layer that secures the deep-retrofit performance envelope.
Layer 1 is project-specific in the sense that its dimensions are derived from the building condition, but it stays the same across all design variants developed for one project. The Layer 1 buildup is documented in Appendix D through the design variants.

5.6.1 The four component groups

Layer 1 is built up from four component groups.

1. **Anchoring system.** The connection between the new façade and the existing building. It transfers the loads of the modular package back to the existing structure through stainless-steel A4 brackets and post-installed anchors with a thermal break, and it allows the system to be installed as an external refurbishment layer with minimal disturbance to occupied dwellings. The approach is consistent with established slab-edge anchoring solutions in unitised practice, including HALFEN cast-in channels and Hilti post-installed anchor systems where cast-in channels are not available.

2. **Structural unitised frame.** The load-bearing chassis of the façade module. A thermally broken aluminium carrier frame with primary verticals (typically 75 × 160 mm; reinforced bays 75 × 180 mm) and secondary verticals (50 × 160 mm) provides dimensional stability, carries the self-weight of the assembly, and supports the attachment of both the inner performance core and the outer adaptive elements. One fixed point per panel with sliding points absorbs thermal movement. The chosen profile family aligns with mainstream unitised façade systems such as Schüco AF UDC 80, Reynaers Element Façade 7, Lindner ECO_N Hybrid, and Stabalux H/SR.

3. **Inner performance core.** The environmental core of the system, consisting of insulation and weather-tight / airtight control layers. It provides the primary thermal, moisture, and airtightness performance of the façade. The detailed buildup and the achieved performance envelope are given in §5.6.2.

4. **Sealant and joint system.** The continuity layer of the system. It absorbs tolerances, seals the connection between modules and between the new façade and the existing structure, and protects the integrity of the performance core. EPDM gaskets at the module-to-module joints and silicone-based sealants at the module-to-existing-building joints maintain airtightness and watertightness across the assembled façade.

Together, these four component groups make Layer 1 the long-life support and performance platform of the system. They guarantee structural integrity, airtightness, thermal continuity, and a shared baseline of technical performance across all dwellings of the project.

Figure5.9: Schematic visualisation of base layer 1, applied on existing wall on site (own work)

5.6.2 Performance envelope

The Layer 1 buildup secures the thermal, airtightness, and weather-tightness performance of the façade in one coordinated package.

Going from the existing wall outward, the buildup adds five components:

- a compressible mineral-wool strip (40 mm, λ = 0.040 W/mK) that takes up tolerance and decouples the modular element from the irregular existing brick surface
- a wooden substrate sheet (18 mm, λ = 0.13 W/mK) providing a flat anchorage surface
- a 160 mm structural-frame zone filled with high-density mineral wool (λ = 0.035 W/mK
- a continuous 60 mm wood-fibre external sheathing (λ = 0.040 W/mK) that reduces the thermal-bridge effect at the carrier verticals and a wind-tight membrane.
- A ventilated cavity of approximately 30 mm sits between the membrane and the Layer 2 cladding.

On a typical post-war existing wall (210 mm solid clay brick + 20 mm cement plaster + drywall installation cavity + vapour retarder + 15 mm gypsum fibre board), this Layer 1 addition produces a post-retrofit Rc ≈ 7.7 m²K/W and U ≈ 0.13 W/m²K (calculation per NEN and BBL 2024)

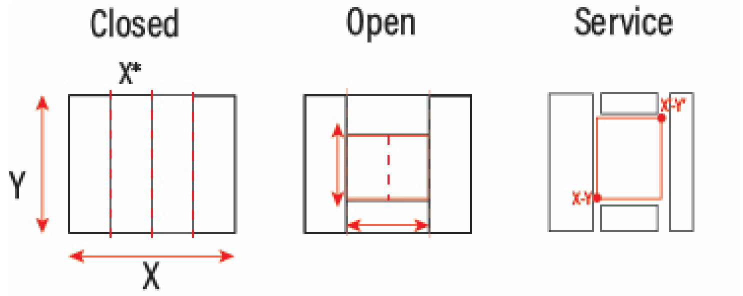
The achieved Rc exceeds the Dutch new-construction minimum for façade walls (Rc ≥ 4.7 m²K/W per Bouwbesluit 2024) by approximately 64% and meets the Passive House Standard reference for external walls.

5.6.3 Three Layer 1 base platforms

Although Layer 1 stays the same across the variants of one project, it is configured internally as three base platforms to match the differentiated façade conditions of the post-war walk-up typology: more closed and robust fields, more open and dwelling-oriented fields, and more service-prepared fields.

The three platforms belong to the same standardised technical platform but differ in the way the façade field is configured within the modular envelope.

Table 5.6 The three Layer 1 base platforms, their provision, and their typical placement in a post-war walk-up.



Base platform	What it provides	Where it is used
Closed	A continuous insulated cladding-ready surface with hidden mounting rails for outer cladding; supports thermal continuity, acoustic buffering, and weather protection	Opaque wall zones (e.g. stair-side walls, side of building walls)
Open	A frame-and-rail system with prepared field positions for windows, threshold elements, and operable façade modules; supports daylight access, view, and the relation between interior and exterior	Window and daylight zones (e.g. living room and bedroom façades)
Service-ready	Layer 1 with pre-routed conduits, drainage gutters, and electrical provisions for systems mounted on the outside; supports ventilation, service routing, and maintenance access	Technically loaded façade zones (kitchens, bathrooms, mechanical rooms)

5.7 Layer 2 the adaptive socio-technical interface

Layer 2 is the adaptive socio-technical interface of the system. It is the locus of value-driven variation and the part of the façade that residents perceive and interact with most directly.

Unlike Layer 1, Layer 2 is not specified once for a project; it varies by design variant according to the value priorities established in Step 1 of the configuration logic (Chapter 6). Layer 2 is structured to absorb this variation in a bounded way, through two component families and four value-affinity clusters explained in this chapter.

5.7.1 Two component families

Layer 2 is not merely an outer finish. Although it is mounted externally, it acts as an interface across the inside–outside boundary. In this sense, Layer 2 is the façade’s negotiable zone: the part of the system through which resident needs, preferences, and forms of use can become materially expressed.

In the axonometric (figure 5.10), Layer 2 is built up from two main families of attachable component families:

Functional and expressive add-on modules. The resident-facing and use-related elements that directly shape comfort, control, and façade expression. They include operable insulated window units (available in timber, aluminium, steel, or timber–aluminium composite frames depending on the variant's material strategy), ventilation modules, solar-control elements (textile screens, outdoor blinds, manual movable louvres), threshold elements (deep windowsills, façade-integrated bench seating, exterior storage units, Juliet rail extensions), and ecological inserts (vertical greening cassettes, biodiversity inserts, BIPV panels). They are mounted to the prepared interface positions of Layer 1.

Configurable cladding modules. The outer visual and tactile components of the façade. They include cladding panels in stones, woods, metals, colours, and bio-based materials, mounted on a ventilated rainscreen detail to the cladding rails of Layer 1.

All Layer 2 elements are mechanically connected to the standardised interface of Layer 1 and remain physically independent from the primary thermal shell. This means they can be added, replaced, maintained, or reconfigured over time without undermining the technical integrity of the base system.

These two component families are what of Layer 2. The how , how a designer navigates from a value priority to a component selection without falling into bespoke customization, is the subject of the next section.

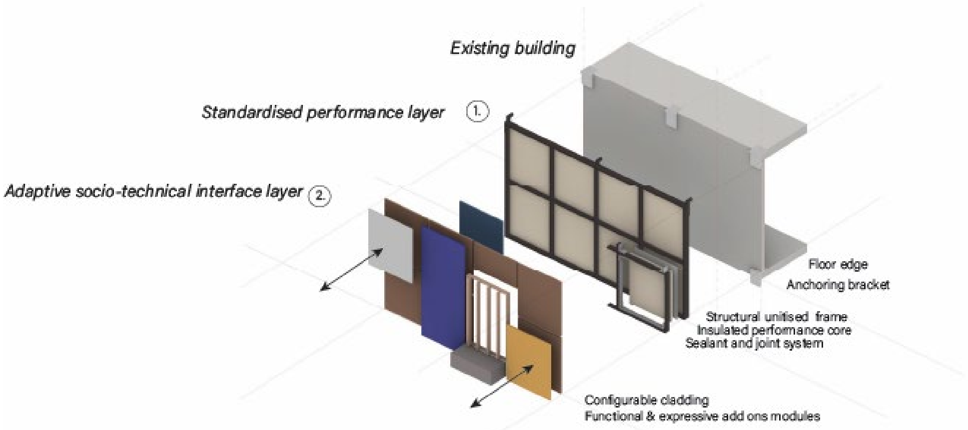


Figure 5.10: Exploded view of two layered system of VIMFS including the components.

5.8 Value translation across the two layers

The two-layer architecture of VIMFS only becomes meaningful when it is read as a value-translation structure, not only as a technical separation. Resident values are not all located in the same place in the façade. Some values require a stable and equal baseline; some values require visible and adjustable variation; comfort requires both. The two-layer organisation lets each value type be anchored where it is technically and socially most appropriate.
Three roles can be distinguished:

Stability values : anchored in Layer 1. Affordability and fairness depend on repetition, equal baseline performance, equal thermal upgrading, and a bounded number of component families. They are therefore primarily expressed through Layer 1: every dwelling receives the same Layer 1 specification regardless of which Layer 2 components are selected, and the baseline thermal performance is the same everywhere. Affordability and fairness also constrain Layer 2: the catalogue offers variation, but bounded variation. The catalogue is therefore deliberately structured as controlled choice, not as open-ended customisation. This is where the V–I criteria fairness and affordability criteria live.

Adaptability values: anchored in Layer 2. Empowerment, sustainability, and identity depend on selection, visible difference, material expression, user control, and recognisability. These values cannot be anchored in Layer 1 because Layer 1 is constant across variants. They are expressed through Layer 2, which is the layer that varies between design variants of the same project. Empowerment is most visible through the Climate Agency and Social Threshold component groups; sustainability through Ecological Regenerator components; identity through Neighbourhood Face, Ecological Regenerator, and Social Threshold components. The clusters that organise these components are introduced in §5.9.

Mediating values: across both layers. Comfort does not sit cleanly on either side. Thermal continuity, airtightness, acoustic separation, and moisture safety belong to Layer 1; usable control, operable openings, shading, ventilation, threshold occupation, and privacy adjustment belong to Layer 2.
Comfort is therefore produced by the interaction of the two layers, and the V–I criteria for comfort (C1–C5) are split between them: , thermal performance and acoustic separation are delivered by Layer 1, the standardised performance baseline; operable openings and natural ventilation, daylight access and solar control are delivered through their resident-facing operation and shading carried by Layer 2.

Table 5.7:Value translation across Layer 1, Layer 2, and the catalogue route (own work)

Value	*Role*	*Where anchored*	*Layer 2 cluster(s) most responsive*	*Indicative component types*
Comfort	Mediating	Layer 1 + Layer 2	Climate Agency	Layer 1: thermal envelope, airtightness, acoustic separation. Layer 2: operable window units, ventilation modules, solar-control elements
Affordability	Stability	Layer 1	—	Standardised performance baseline; bounded number of component families; repeated Layer 1 specification across dwellings
Fairness	Stability	Layer 1	—	Equality of the performance baseline across dwellings; documented selection logic from the V–I Framework
Empowerment	Adaptability	Layer 2	Climate Agency, Social Threshold	Operable window units; ventilation modules with resident-accessible controls; threshold elements (deep windowsills, exterior storage, Juliet rail extensions)
Sustainability	Adaptability	Layer 2 (with Layer 1 disassembly logic)	Ecological Regenerator	Bio-based cladding; vertical greening modules; biodiversity inserts; BIPV panels; mechanical (reversible) Layer 2-to-Layer 1 connections
Identity	Adaptability	Layer 2	Neighbourhood Face, Ecological Regenerator, Social Threshold	Configurable cladding panels: threshold elements that vary between dwellings; visible bio-based and ecological elements

5.9 Operational form of Layer 2: clusters and component catalogue

Layer 2 needs an organisational structure for two reasons.
First, the catalogue of components is large enough that an unstructured list would force the designer back to ad-hoc choice, undermining the traceability that fairness requires.
Second, the value-translation chain set out in §5.8 has to remain visible at the point of component selection, otherwise the framework collapses into a parts list.
the operational answer is a two-stage organisation: value-affinity clusters for navigation, and a bounded component catalogue for selection.

5.9.1 The component catalogue as a design document

The component catalogue (full version in Appendix B) is the operational form of Layer 2. It is not an appendix added after the system was designed, it is the document through which Layer 2 becomes usable. Without the catalogue, Layer 2 would remain an abstract idea of adaptability. With the catalogue, adaptability becomes structured: values lead to clusters, clusters lead to component families, component families are checked against Layer 1, and the selected component codes define the design variant.(figure 5.10.2)

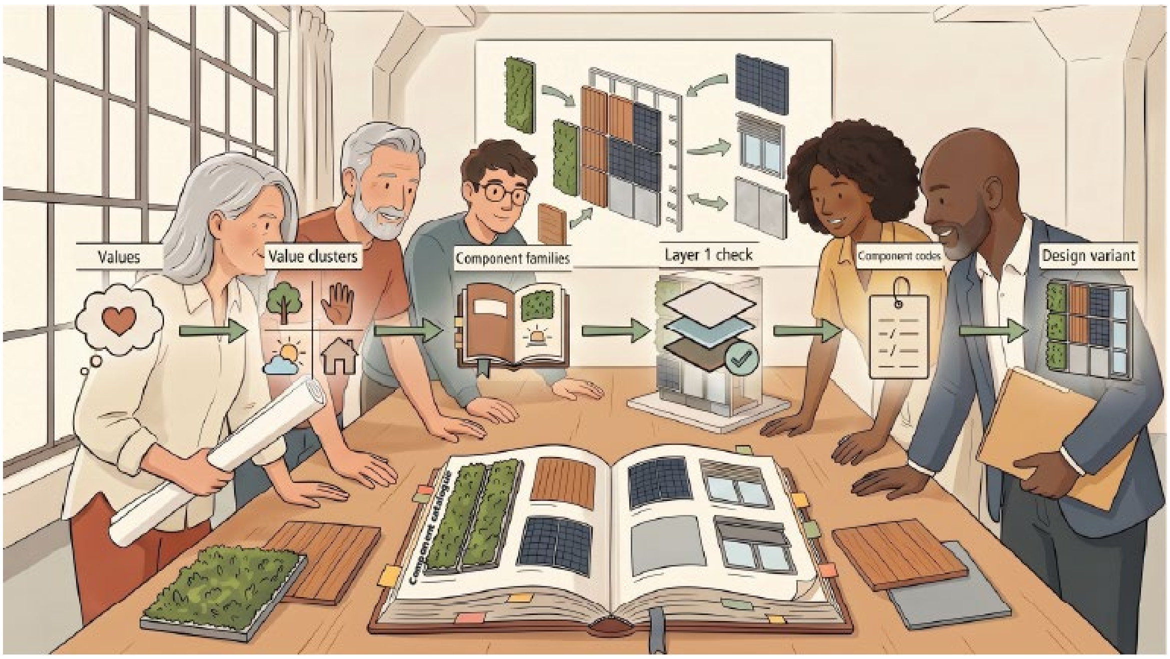


Figure 5.10.2:The component catalogue as the operational form of Layer 2. The open catalogue (centre) is the document through which resident values are translated into a built design variant, via a structured chain: values → clusters → component families → Layer 1 baseline check → component codes → design variant. (Conceptual illustration.)

5.9.2 Value clusters as navigation structure

The catalogue is organised internally through four value-affinity clusters. The clusters are a navigation index for the catalogue, not a configuration mechanism. A cluster does not "decide" the design; it groups Layer 2 components that respond to recurring combinations of V–I criteria, so that a designer reading from a value priority to a component family can move along the framework's translation chain in a single step.

The four clusters are derived from §5.8. Each cluster collects components whose criteria respond to a recurring combination of the adaptability values and the resident-control side of comfort:

Ecological Regenerator (ER). Components that respond primarily to sustainability and identity, with comfort as a secondary effect. The façade as an active contributor to the local ecosystem: bio-based cladding, vertical greening cassettes, biodiversity inserts, BIPV panels.

Social Threshold (ST). Components that respond to comfort, identity, and empowerment. The façade as an inhabitable edge between dwelling and exterior: deep windowsills, exterior storage, Juliet rail extensions, integrated façade seating.

Climate Agency (CA). Components that respond to comfort and empowerment. The façade as an instrument residents can adjust operable insulated window units, decentralised ventilation modules, textile screens, outdoor blinds, manual movable louvres.

Neighbourhood Face (NF). Components that respond primarily to identity, with fairness through coherence. The façade as the public face of the building: configurable cladding panels in mineral, timber, metal, colour.

Table 5.8: Layer 2 component index (cluster summary)

Cluster	*Code range*	*Component families*	*Primary value role*
Ecological Regenerator	ER01–ER04	Bio-based cladding; biodiversity insert; vertical greening module; BIPV façade panel	Makes ecological transition visible and supports sustainability-oriented identity
Social Threshold	ST01–ST04	Deep windowsill; exterior storage; Juliet rail extension; integrated façade seating	Turns the façade into an inhabitable edge and supports everyday use, recognition, and social connection
Climate Agency	CA01–CA06	Operable window module; decentralised ventilation unit; textile screen; outdoor blind; movable louvre; service-ready environmental module	Gives residents usable control over air, daylight, glare, privacy, and overheating
Neighbourhood Face	NF01–NF04	Configurable mineral, timber, metal, colour, and bio-based cladding panels	Creates recognisable façade expression while preserving collective coherence

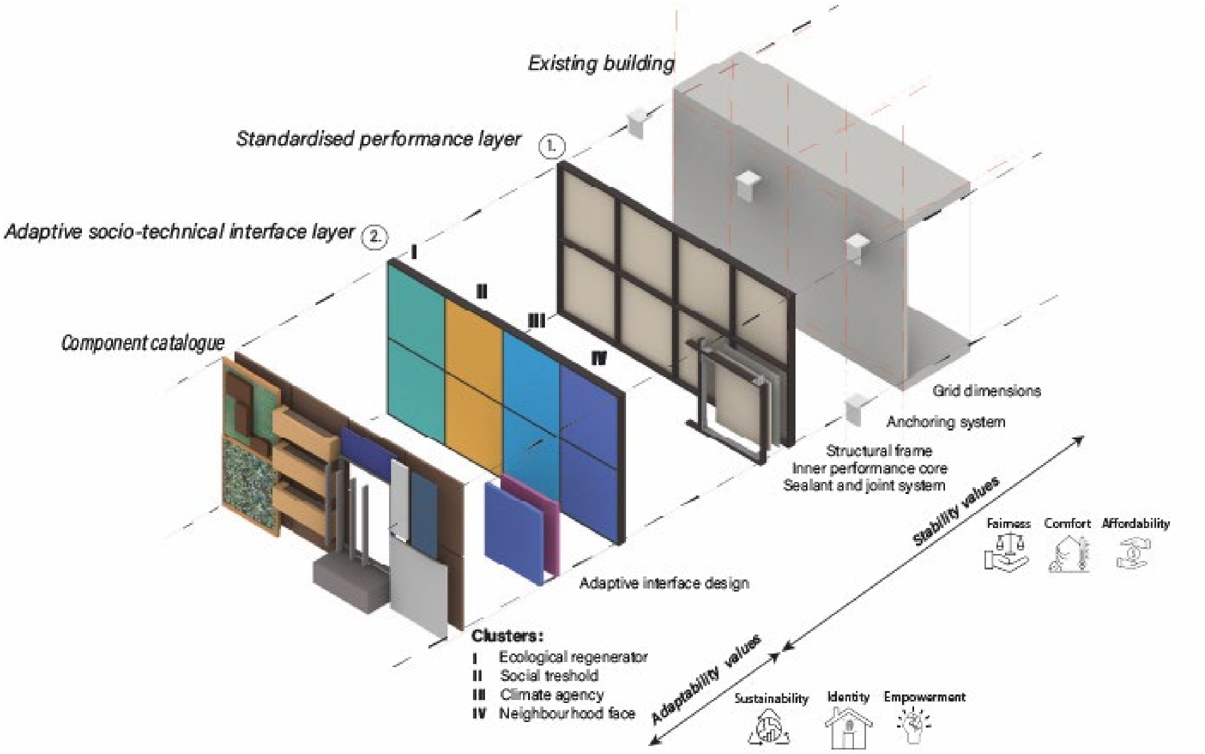


Figure 5.11:Value integrated façade system (VIMFS) _+ value translation clusters

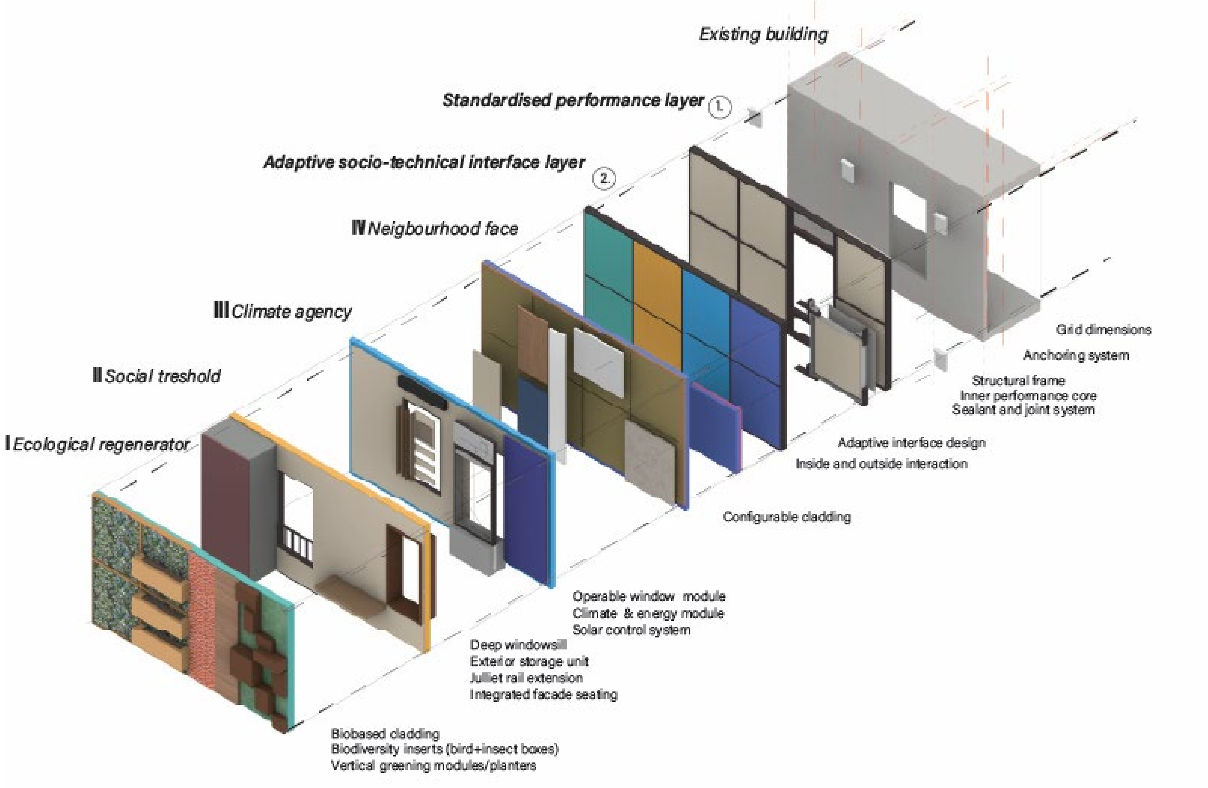


Figure 4.12: Value clusters and components overview component catalogue layer 2.

5.9.3 Component catalogue overview

The full component catalogue is documented in Appendix B as a designed visual artefact. This section presents the catalogue at the overview level and gives the codes through which components are referenced in the rest of the thesis.

Table 5.9:Component catalogue overview

Code	Component	Cluster	Primary value output
ER01	Bio-based cladding	I.Ecological Regenerator	Visible carbon-storage surface
ER02	Biodiversity inserts	I.Ecological Regenerator	Habitat for birds and insects
ER03	Vertical greening module	I.Ecological Regenerator	Living surface, cooling, air quality
ST01	Deep windowsill	II.Social Threshold	Inhabitable edge — sit, place, lean
ST02	Exterior storage unit	II.Social Threshold	Reclaimed interior floor space
ST03	Juliet rail extension	II.Social Threshold	Safe interior–exterior continuity
ST04	Integrated façade seating	II.Social Threshold	Place to pause at the building edge
CA01	Operable window module	III.Climate Agency	Resident-operable fresh air and view
CA02	Decentralised ventilation unit	III. Climate Agency	Room-based ventilation with heat recovery
CA03	BIPV façade panel	III.Climate Agency	Visible renewable energy generation
CA04	Solar control — textile screens	III.Climate Agency	Glare and heat control with view intact
CA05	Solar control — outdoor blinds	III.Climate Agency	Adjustable daylight, glare, and privacy
CA06	Solar control — manual movable louvres	III.Climate Agency	Tactile sun and visual control
NF01	Configurable cladding options	IV.Neighbourhood Face	Identity, texture, rhythm

5.10 Chapter conclusion: answer to sub-question 3

Sub-question 3 asks how the architectural design indicators developed in Chapter 4 can be operationalised into a modular façade system suitable for industrialised refurbishment. The answer is the Value-Integrated Modular Façade System (VIMFS), which operationalises the Value–Indicator Framework by separating the façade into two coordinated layers with different tasks, lifespans, and degrees of variation, and by organising the resident-facing layer through a bounded, value-affinity-structured component catalogue.

Layer 1 is the standardised performance layer. It contains the anchoring system, the unitised carrier frame, the inner performance core, and the sealant and joint system, configured internally as three base platforms (closed, open, service-ready). It is specified once per project and stays the same across all design variants of that project. Layer 1 carries the stability values (affordability, fairness) and the Layer 1 side of comfort.

Layer 2 is the adaptive socio-technical interface. It is structured through the bounded component catalogue (Appendix B), navigated through four value-affinity clusters (ER, ST, CA, NF), and connected to Layer 1 through reversible mechanical interfaces.

It carries the adaptability values (empowerment, sustainability, identity) and the Layer 2 side of comfort (C3, C4 via shading). Variation between design variants of the same project happens in Layer 2 only.

The chapter therefore answers sub-question 3 as follows: design indicators can be operationalised into a modular façade system by separating stable performance requirements from adaptable resident-facing components, distributing the six values across the two layers according to whether they require stability or admit adaptability, and structuring the adaptable layer through a coded component catalogue navigated by value-affinity clusters. This makes VIMFS technically compatible with industrialised refurbishment while leaving room for value-led façade variation. Chapter 6 turns this system into a configuration logic, and Chapter 7 applies it to a case-study building in Rotterdam-West.

Chapter 6: Configuration logic

6.1 Introduction

Chapters 4 and 5 established the two analytical instruments of this thesis: the Value-Indicator Framework, which translates resident values into architectural design indicators and facade criteria, and the Value-Integrated Modular Facade System (VIMFS), which gives those criteria a two-layer system logic. Chapter 6 explains how these instruments are used to configure design variants.

The chapter does not introduce a new framework. It reorganises the analytical work of the previous chapters into a configuration logic: a sequence of steps through which a designer, housing association and tenant group can move from a project condition to traceable facade variants. The purpose is to make the route from value priorities to component selection explicit enough that it can be applied, compared, and evaluated.

The chapter contributes to sub-question 4 by developing the methodological side of the answer: how value priorities can become traceable design variants within the modular facade system. Chapter 7 then applies this logic to the Gijsingstraat case study, while Chapter 8 evaluates the extent to which the values are visible and measurable across the resulting variants.

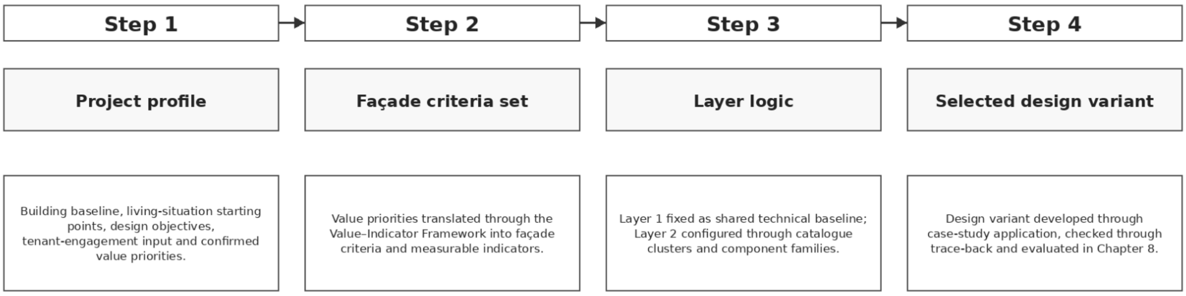
6.2 Overview of the configuration logic

The configuration logic consists of four steps. Each step combines a guiding question, the instrument used to answer it, and a defined outcome. The steps are sequential: each outcome becomes the input for the next step. The purpose of the sequence is not to automate design, but to make design reasoning traceable.

Table 6.1:The four design steps of the configuration logic. Each step has one question, one instrument, and one outcome.

Step	Design question	Instrument used	Outcome
1. Project requirements and principles	What is the project being asked to solve, and which values are foregrounded?	Existing condition analysis, design objectives, living situation analysis and tenant engagement protocol	Project profile: building baseline, design objectives, living situation, tenant engagement output and confirmed value-priority brief
2. Translation through the Value–Indicator Framework	How do the prioritised values become design intentions?	Value–Indicator–Criteria Matrix (Chapter 4)	Façade criteria set
3. Layer logic of the design variant	Which façade response does the criteria set produce within the modular façade system?	Two-layer logic with value-led selection from Layer 2 clusters and component catalogue(Chapter 5)	Layer logic per variant: fixed Layer 1, selected Layer 2 components organised by cluster
4. Comparison of design variants	How do different value priorities applied to the same building produce different but compatible variants?	Comparative reading across variants	Selected variant for further development and evaluation

The data flow between steps is shown in Figure 6.0. The diagram reads from left to right and traces how the project profile from Step 1 moves through the V–I Framework (Step 2), the modular façade system (Step 3), and the comparative reading (Step 4) to produce one selected design variant ready for evaluation.



Building baseline, living-situation starting points, design objectives, tenant-engagement input and confirmed value priorities.

Value priorities translated through the Value–Indicator Framework into façade criteria and measurable indicators.

Layer 1 fixed as shared technical baseline; Layer 2 configured through catalogue clusters and component families.

Design variant developed through case-study application, checked through trace-back and evaluated in Chapter 8.

Figure 6.0: . Data flow across the four steps of the configuration logic.

Two principles underlie the sequence. First, the design process starts from the project condition and the resident value priorities, not from the catalogue. Second, variation between variants is produced through Layer 2 while Layer 1 remains the equal technical baseline. This keeps the system compatible with industrialised refurbishment while allowing value-led differentiation.

6.3 Step 1 : Project requirements and principles

Step 1 compiles everything the design needs to know about the project before any value translation begins. The step has four components: building conditions, design objectives, living situation, and value priorities. They are consolidated into a single project profile.

Together they answer one client-facing question: what must this façade design respond to, and for whom?

6.3.1 Building conditions

The building is the fixed starting point of any modular façade design. The architect records typology, structural rhythm, façade rhythm, balcony logic, technical condition, and renovation boundary conditions. These do not represent design ambitions; they define what cannot or should not be changed. They establish the dimensional and structural envelope within which Layer 1 must fit and within which Layer 2 variation can take place.

6.3.2 Design objectives

The design objectives translate the recorded building condition into a list of design problems. Where the building condition records what is there, the design objectives record what the façade needs to address. Objectives may be environmental (poor insulation, overheating, glare), agency-related (limited operability, no shading control), spatial (weakly inhabitable threshold), social (privacy, neighbour interface), or architectural (weak identity, monotony, ageing material). Naming the objectives makes the façade legible as a lived interface, not only as a technical envelope.

6.3.3 Living situation

Living situation/resident context captures who is being designed for and how they use the dwelling. It records a plausible recurring dwelling condition rather than an individual household profile. Examples include an elderly couple oriented toward rest and a sheltered threshold; a family apartment with active everyday use of windows and balcony; ground-floor households facing the courtyard with a stronger relation to neighbours; or a working couple oriented toward affordability and clarity. Living situation is therefore not biographical detail. It is a typological reading of how the dwelling is inhabited within the building. It includes orientation-specific use (street side vs. courtyard side) and the daily routines that touch the façade (ventilation, shading, threshold occupation, privacy adjustment).

Living situation matters at this stage for two reasons.

It grounds the value priorities in a recognisable everyday context, so that values such as comfort or empowerment do not remain abstract but attach to specific dwelling conditions and façade interactions. An elderly-couple living situation with comfort and empowerment as priorities asks for a different Layer 2 expression than a family-apartment living situation with the same priorities, even when the value list is identical. When more than one variant is developed for the same building, varying the living situation is also one of the two main ways the framework generates difference between variants.

The other is varying value priorities. Without an explicit living situation in the project profile, scenario differentiation tends to collapse back onto value priorities alone, which weakens the architectural specificity of each variant.

In the case study (Chapter 7), the four developed variants each name a different living situation in their Step 1 project profile. The differences in Layer 2 selection across the four variants are visibly driven by the combination of living situation and value priority. The configuration logic therefore treats living situation as a first-class component of the project profile, on equal footing with building conditions, design objectives, and value priorities.

6.3.4 Engaging the tenant.

This section defines how tenants enter the configuration logic. Engagement is not treated as a separate participation process beside the design work, but as the first input layer of the design method. Its purpose is to translate residents' everyday concerns into value priorities, then into design indicators, and finally into Layer 2 component choices. In this way, engagement becomes part of the facade configuration process rather than a consultation exercise after the main decisions have already been made.

The engagement protocol responds directly to the cross-case analysis in Chapter 3. That analysis showed that engagement methods such as walkthroughs, home visits, co-design workshops, information sessions, and living-lab arrangements can surface resident values, but often do so after technical, financial and organisational decisions have already narrowed the design direction (§3.5.2-§3.5.3). The purpose of the engagement protocol is therefore not to add more consultation, but to move resident input earlier into the configuration logic.

The engagement protocol is designed around three improvements.

First, it expands reach through door-to-door visits, so that participation does not depend only on residents who attend public meetings.

Second, it creates continuity through a representative *Resident Design Council* that follows the configuration process across multiple steps.

Third, it makes the effect of resident input traceable through a decision log, so that tenant concerns can be followed from initial statement to value priority, design indicator, component choice, and evaluation criterion. With the goal that resident input will not be treated as general feedback, but as the starting point for a traceable design route from value priority to indicator, component direction, and later evaluation.

6.3.4.1 What is fixed and what remains open.

The engagement process does not ask tenants to redesign the entire facade system. Some aspects are fixed by regulation, ownership, budget, and technical performance requirements. Other aspects remain open within the component catalogue. Making this distinction explicit prevents unrealistic expectations and clarifies where resident influence can meaningfully shape the design.

Layer 1 therefore remains the shared technical baseline. It provides insulation, airtightness, weather protection, structural support, and equal performance. Tenant influence is concentrated in Layer 2, where resident-facing components can vary within a bounded catalogue. This allows the system to combine industrialised repetition with meaningful resident-oriented differentiation.

Table 6.2. Fixed project constraints and open tenant-influence points.

Already fixed by project constraints	**Open to tenant influence**
Need for facade renovation	Value priorities
Layer 1 technical performance baseline	Layer 2 component selection
Regulatory and safety requirements	Relative weighting of comfort, identity, sustainability, and control
Industrialised construction logic	Bounded variation within the component catalogue
Overall affordability range	Preferences for shading, privacy, threshold use, material expression, and facade articulation
Equal baseline performance for all dwellings	Selection and combination of resident-facing components

6.3.4.2 Engagement structure

The engagement structure is organised as a sequence of seven moments, grouped by phases that describe their role in the configuration logic.

- SET BASELINE establishes the shared project frame: what is technically, financially, and legally fixed, and what remains open to tenant influence.
- REACH ALL prevents the process from depending only on residents who attend meetings by collecting household-level input through door-to-door visits.
- FORM REPRESENTATION creates a smaller Resident Design Council that can follow the process continuously.
- CO-DESIGN:
    - Workshop 1: value priorities: translates individual concerns into collective value priorities.
    - Workshop 2:design translation: checks whether those values have been correctly reformulated into design indicators and early Layer 2 directions.
- REVIEW COMPONENTS connects the confirmed values to catalogue options.
- CLOSE FEEDBACK LOOP communicates the final design logic back to all tenants.

The process is coordinated by a bewonersbegeleider / tenant liaison. This refers to the tenant liaison officer appointed by the housing association for the renovation process. This person is not the architect and not the contractor, but the continuity figure between tenants, the housing association, and the design team. Their role is to organise communication, conduct door-to-door visits, coordinate interpreters where needed, record tenant input, maintain the trace-back log and make sure updates reach all households.

The Resident Design Council is the smaller resident group that follows the configuration process after the household-level engagement has taken place. It is formed after the plenary meeting and door-to-door visits, using a representative selection across dwelling type, household composition, age band, and length of tenancy.
The Council does not replace the legal decision-making authority of the housing association. Its role is procedural: it reviews whether the values collected from tenants are translated recognisably into value priorities, design indicators, Layer 2 component directions and final variant feedback. For the case-study scale, the Resident Design Council consists of a small representative group of tenants. Representation is based on dwelling type, household composition, age band, and length of tenancy rather than open self-nomination alone. This reduces the risk that only already engaged or institutionally confident residents shape the process.
Together, these two roles make the engagement process operational. The tenant liaison ensures reach and continuity across all households, while the Resident Design Council provides a stable resident body for reviewing the translation of tenant input into the configuration logic. Table 6.3 sets out the seven engagement moments through which this process unfolds.

Table 6.3 :Tenant engagement structure within Step 1.

Phase	Engagement moment	Who is involved	Tenant experience	Technique	Output to Step 1
1.SET BASELINE	**Plenary information evening** Single evening, 2 hours; community-room venue.	All tenants invited. Housing association, architect, and tenant liaison attend. Invitation delivered two weeks in advance in all building languages.	Tenants hear what will change, what is fixed, what can still be influenced, how the process works and who to contact.	Cost band, programme, and fixed/open decision space are presented. Open Q&A. Council recruitment introduced.	Affordability baseline established. Initial Council interest expressed.
2.REACH ALL	**Door-to-door visits** Two to three weeks. One in-home visit per household, 30-45 minutes.	Tenant liaison with each household; interpreter present where needed.	Tenants discuss dwelling conditions, routines, concerns, and priorities in their own home.	In-home conversation using six value cards. Living-situation observation. Initial Council recruitment checked against representativeness.	Living-situation patterns per dwelling type. Household-level value concerns collected.
3.FORM REPRESENTATION	**Resident Design Council selection** Finalised after door-to-door visits.	Tenant liaison, tenants, and housing association.	Tenants understand how representatives are selected and how different household types are included.	Selection across dwelling type, household composition, age band, and length of tenancy. Replacement process defined if a member withdraws.	Resident Design Council formed. Representation documented.
4. CO-DESIGN	**Co-design workshop 1: value priorities** Two hours, before Layer 2 component selection is fixed.	Resident Design Council. Architect and tenant liaison facilitate. Housing association observes.	Council members compare everyday concerns and discuss which values should guide the facade configuration using value cards and scenario boards	Six-value card weighting. A3 scenario boards based on door-to-door observations. Tensions between values identified.	Draft value priorities. First articulation of design objectives.
5.CO-DESIGN	**Co-design workshop 2:Design translation** Two hours, after first translation into indicators and criteria.	Resident Design Council, architect, project lead, and tenant liaison.	Council members review whether tenant concerns have been translated correctly into indicators and early Layer 2 directions.	Review of draft criteria. Iteration on weighting. Procedural confirmation of value priorities.	Confirmed value priorities. Agreed criteria language entering Step 2.
6.REVIEW COMPONENTS	**Layer 2 component review** After draft component selection.	Resident Design Council, architect, tenant liaison, and housing association.	Council members compare tangible facade options and see how components respond to comfort, control, identity, sustainability, and affordability.	Component catalogue boards, material samples, facade scenario comparison, and discussion of trade-offs.	Reviewed Layer 2 component direction. Component preferences entered into trace-back log diagram
7.CLOSE FEEDBACK LOOP	**Design variant feedback and communication update.** After variant comparison and before final communication.	All tenants informed. Resident Design Council reviews. Tenant liaison communicates.	Tenants see which variant was selected, why it was selected, and how earlier input affected the final facade proposal.	Final variant explanation, trace-back log, website update, newsletter, and entrance-hall board.	Traceable design decision recorded and communicated.

Door-to-door visits are placed before workshops because Chapter 3 showed that workshop-based participation can overrepresent already active residents and miss quieter, older, working or less institutionally confident tenants. Home visits allow these residents to enter the process without first attending a public meeting. They also connect values to concrete living situations: overheating, draught, lack of privacy, noise, storage shortage, maintenance concerns, or attachment to the existing facade rhythm.

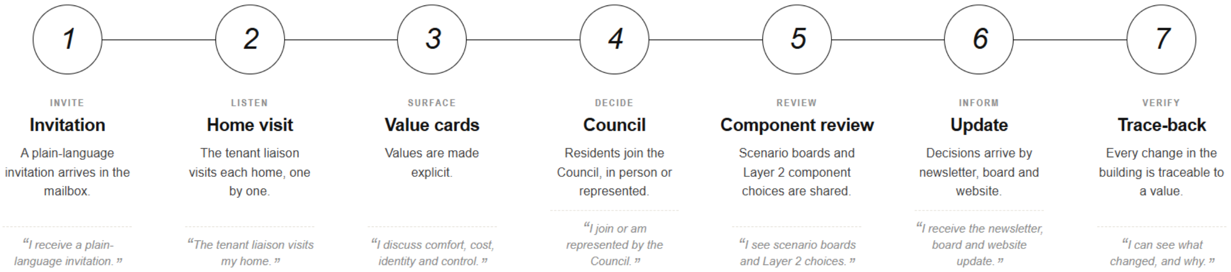


Figure 6.1: Tenant journey diagram throughout the engagement protocol (own work)

Figure 6.2-6.5: illustrative engagement scenarios developed for visualisation of the proposed configuration process. and how the protocol could operate in my imaginary world. Plenary information evening, door-to-door value-card visit, Resident Design Council workshop, Entrance-hall information board (ownwork)*

6.3.4.3: From tenant input to facade decisions

The engagement process does not directly produce final façade components. Its immediate output is a confirmed value-priority brief for Step 1. The actual translation of these values into design indicators and façade criteria takes place in Step 2, and the selection of Layer 2 components takes place in Step 3. Table 6.4 therefore shows an illustrative translation route: it demonstrates how a tenant concern collected during engagement can later move through the configuration logic from resident value to design indicator and Layer 2 response.

Table 6.4: Example translation route from tenant input to Layer 2 response

Tenant input from engagement	**Step 1: resident value priority**	**Step 2: design indicator**	**Step 3: possible Layer 2 response**
“My living room overheats in summer.”	Comfort / empowerment	Solar control, resident operability	Textile screen, outdoor blind, movable louver
“People can look directly inside.”	Privacy / comfort / control	Adjustable visual screening	Louvers, textile screens, deeper reveal
“I want the building to still feel like ours.”	Identity	Material continuity, recognisable façade rhythm	Cladding rhythm, colour variation, articulated outer layer
“I need more usable space near the entrance.”	Social threshold / comfort	Inhabitable edge, storage, threshold use	Exterior storage, integrated façade seating, deep windowsill
“I want sustainable materials I can actually see.”	Sustainability / identity	Visible ecological value, material legibility	Bio-based cladding, vertical greening, biodiversity inserts
“I am worried the renovation will become too expensive.”	Affordability / fairness	Cost transparency, bounded variation	Component-family limit, baseline package, clear cost update

6.3.4.4:Continuous tenant communication: three-channel system

Engagement does not only happen during workshops. Tenants also need to know what has been decided, what is still open, and how earlier input has affected the design. A single communication channel would repeat the access problems identified in Chapter 3. A project website alone excludes residents who are not digitally connected; a newsletter alone does not provide a searchable archive; a workshop alone reaches only those who attend.

The framework therefore uses a three-channel communication system.

Table 6.5:Three-channel communication system.

Communication channel	**What it contains**	**Frequency**	**Purpose**
Project website	Searchable archive: trace-back tables, Council minutes, sketches, decision log, schedule, FAQ and contact details.	Updated within five working days after a Council decision or design change.	Transparency and audit trail.
Printed monthly newsletter	Two-page plain-language summary delivered to every mailbox, with one image or sketch and no technical jargon.	Monthly, with extra issues for major milestones.	Reach residents who do not use digital channels.
Entrance-hall information board	Two-week schedule, current FAQ, latest decision, contact card and QR/link to the website.	Updated every Monday with date stamp.	Shared visibility in the building.

6.3.4.5: Limits of the engagement protocol

- No design decision is locked until it has appeared on all three communication channels for two weeks. During this period residents can flag misunderstandings or raise concerns through the Resident Design Council.
- Every Council decision, design-team response and housing-association override is entered into the trace-back log which is always published online.
- The Resident Design Council has procedural authority within the proposed design method, but it does not have statutory veto power. The housing association remains legally responsible for the renovation. The Council’s role is to confirm whether tenant values have been translated recognisably and to make any deviation from resident input visible in the trace-back log.
- The process still cannot fully solve distrust or non-participation. The door-to-door visits and three-channel communication system reduce this risk, but they do not remove it entirely. The framework responds by making communication failures and design overrides visible rather than silent. The value of the protocol is therefore not that it guarantees consensus. Its value is that it makes the route from tenant input to facade configuration explicit, repeatable, and reviewable.

6.3.5 Value priorities

Value priorities select which of the six resident values established in Chapter 4 are foregrounded in a particular project: comfort, affordability, fairness, empowerment, sustainability, and identity. In the revised Step 1 sequence, these priorities are confirmed after the building conditions, design objectives, living situation and tenant-engagement process have been read together. This order is important: the priorities are not imposed before engagement but are refined through the tenant-facing protocol described above.

The priority set is not expected to include all six values at the same intensity. Each variant foregrounds two or three dominant values, while the remaining values operate as background requirements. For example, a “control and comfort” variant may foreground comfort and empowerment while still meeting the fairness requirement of an equal Layer 1 baseline.

The output of this sub-step is a value-priority brief. These brief records the dominant values, the living situation they respond to, the tenant input that supports them, and the first design consequences expected for Layer 2. The brief becomes the input for Step 2, where the Value-Indicator Framework translates the priorities into facade-related criteria.

6.3.6 The consolidated project profile

The outputs of Step 1 are consolidated into a single project profile. This profile is the only client-side deliverable needed before the design process continues into Step 2. Everything beyond the profile belongs to the design translation and configuration process.

Component	What it records	Outcome for the design process
Building conditions	Typology, structural and façade rhythm, balcony and threshold logic, technical condition, renovation boundary conditions	Defines what cannot change and frames the dimensional envelope of Layer 1
Design objectives	Environmental, agency, spatial, social, and architectural problems that the façade must address	Defines the design problem in lived and architectural terms, not only in performance terms
Living situation	Recurring dwelling condition the variant addresses orientation-specific use; daily routines that touch the façade	Grounds the variant socially and spatially; turns abstract value priorities into a recognisable everyday context that drives differentiation between variants
Tenant engagement output	Value-card results, Council confirmation, trace-back log, and communication record	Documents how resident input entered the design process and supports later evaluation
Value priorities	Selected primary, secondary and background values from the six resident values (Chapter 4)	Sets the value emphasis that the V–I Framework will translate in Step 2

Table 6.6 : The consolidated project profile produced in Step 1.

When multiple variants are developed for the same building, the building conditions stay constant across variants. The components that change most directly between variants are living situation, tenant engagement emphasis, and value priorities. This is what allows the same case-study building to produce different but comparable facade variants in Chapter 7.

6.4 Step 2 : Translating criteria into design indicators

Step 2 takes the value-priority brief from Step 1 and translates it into facade-related design indicators and criteria. The Value-Indicator Framework developed in Chapter 4 is the instrument. The framework prevents values from remaining abstract by translating them into operational design concerns such as operability, daylight, solar control, component-family economy, material expression, disassembly, and documented selection logic.

The translation reads from resident value to design indicator to facade criterion. Comfort, for example, decomposes into thermal performance, operable openings, daylight, solar control, and acoustic separation. Identity decomposes into material continuity, facade articulation, and dwelling recognisability. Affordability does not simply mean low cost; it is translated into bounded component-family economy, repetition, and construction simplicity.

The criteria set is the bridge between the value framework and the facade system. Up to this point, the language is values and indicators. From the criteria set onwards, the language becomes facade design: openings, components, dimensions, material families, adjustable elements, and interfaces.

6.5 Step 3:Layer logic of the design variant

Step 3 is where a design variant is configured. The criteria set produced in Step 2 is assigned to the modular facade system defined in Chapter 5. Layer 1 is the standardised performance layer; Layer 2 is the adaptive socio-technical interface.

This step specifies which Layer 2 components are selected to satisfy the criteria set, organised by value-affinity cluster, and how Layer 1 supports them. The component-level selection is worked out in detail in the component catalogue in Appendix B.

6.5.1 Layer 1 stays the same across variants.

Across all design variants developed for the same project, Layer 1 remains the same. It is derived from the building condition recorded in Step 1 and is therefore project-specific, but it is independent of the value priorities. Keeping Layer 1 fixed across variants is essential to the argument of the thesis: bounded variation in Layer 2 should not require redesign of the support system. This is what makes the system industrially feasible, and it is also what makes the variants directly comparable in Step 4. Layer 1 carries the stability values established in §5.7. Every dwelling receives the same baseline performance and the same component-family economy regardless of the variant under development.

6.5.2 Layer 2 organisation by clusters

Layer 2 is organised into four clusters that group components by value affinity. The clusters are a navigation index for the catalogue, not a configuration mechanism: an architect uses the cluster labels to find components that respond to the project's value priorities and selects components from the catalogue. The four clusters were introduced in §4.6.2 and are recalled here:

- **Ecological Regenerator.** Sustainability + identity (with comfort as a secondary effect). Bio-based cladding, vertical greening cassettes, biodiversity inserts, building-integrated photovoltaic panels.
- **Social Threshold.** Comfort + identity + empowerment. Deep windowsills, exterior storage units, Juliet rail extensions, integrated façade seating.
- **Climate Agency.** Comfort + empowerment. Operable insulated window units, decentralised ventilation modules, textile screens, outdoor blinds, manual movable louvres.
- **Neighbourhood Face.** Identity (with fairness through coherence). Configurable cladding panels in stones, woods, metals, and colours.

6.5.3 Component selection guided by value affinity.

A design variant is configured by reading the value priorities from Step 1 against the value-affinity column of the catalogue. Each value tends to express itself in the façade through a particular cluster, although the mapping is a guide rather than a rigid rule: a single value can be expressed through more than one cluster depending on the criteria set produced in Step 2. The general pattern of value affinity is the following.

Table 6.7:Value-affinity reading: how value priorities guide component selection across Layer 2 clusters and Layer 1.

Value priority	Components most likely to be selected	Type of expression in the façade
Comfort	Climate Agency components (operable windows, ventilation, solar control); Layer 1 thermal performance	Operable openings, integrated ventilation, glazing performance, shading
Empowerment	Climate Agency components plus Social Threshold elements	Resident-adjustable elements, configurable threshold use, accessible controls
Identity	Neighbourhood Face cladding plus Social Threshold articulation	Cladding strategy, dwelling articulation, recognisable threshold expression
Sustainability	Ecological Regenerator components (bio-based cladding, greening, biodiversity inserts, BIPV)	Bio-based cladding, vertical greening, biodiversity, building-integrated renewables
Affordability	Discipline of repetition; restraint in Layer 2 variation	Fewer component families per variant; high Layer 1 repetition
Fairness	Layer 1 (not Layer 2)	Equality of baseline across dwellings; documented selection logic

Two features of this table explain how the configuration logic works.

Affordability does not select components from a cluster; it constrains the total number of component families used in the variant. Fairness does not operate at Layer 2 at all but at Layer 1: it is expressed by giving every dwelling the same baseline and by documenting every selection. Comfort, empowerment, identity, and sustainability are the four values that drive Layer 2 selection; affordability and fairness operate at the level of the system. The architect retains design judgement throughout: the table indicates selections, but the actual variant is composed by reading the criteria set from Step 2 and choosing the components that satisfy it.

6.5.4 Configuring a single design variant.

Configuring a single variant is a short sequence. Read the value priorities and living situation from Step 1. Consult the criteria set from Step 2. Identify the components that satisfy those criteria within that lived context, using the cluster labels of the catalogue to navigate. Then write the layer logic of the variant as a short statement:

"Layer 1 fixed (closed/open/service-ready platforms as needed); Layer 2 selects components A, B, C, in response to criteria X, Y, Z, derived from values V_1 *and* V_2*."*

The statement is short, traceable to Steps 1 and 2, and compatible with the comparative reading in Step 4. The detailed component options are bounded by the component catalogue established in Chapter 5 and documented in detail in Appendix B.

6.5.5 Configuring multiple variants for the same project.

When more than one variant is developed for the same project, each variant follows the same configuration logic from Step 1 to Step 3. The same building, the same Value-Indicator Framework, the same Layer 1 baseline and the same component catalogue are used. What changes is the living situation and the value-priority emphasis.

Bounded variation means exactly this: the framework does not generate unlimited customisation, but a small number of recognisably distinctive design responses to the same project condition, each traceable back to a different priority set.

6.6 Step 4 : Comparison of design variants

Step 4 places the design variants produced in Step 3 side by side. It reads how different living situations and value priorities applied to the same project produce different but system-compatible design outcomes. This is the step that turns a set of variants into a design-decision tool. The comparison shows which trade-offs each variant accepts. It supports the selection of the variant that will be developed in further detail or evaluated.

Variants are compared on the same axes used to construct them. The comparison therefore stays internally consistent with the configuration logic. The minimum comparison reads each variant against five axes: dominant values; living situation addressed; selected Layer 2 components; character of the north and south façade response; and main façade ambition.

Table 6.8:Reading axes for the comparative reading of design variants in Step 4.

Reading axis	**What the comparison shows**
Dominant values	Which two or three values are foregrounded; the comparison shows that the framework can carry different value emphases without losing coherence
Living situation addressed	Which recurring dwelling condition the variant responds to. The comparison shows how the same building admits multiple lived readings under different priority sets.
Selected Layer 2 components	Which components are present and from which clusters they come; the comparison shows that variation operates within the same component catalogue, not by inventing new components
North / south façade character	How the same orientation logic is read differently under different value priorities (e.g. protected vs. ecological vs. inhabited threshold)
Main façade ambition	One-sentence statement of what the variant is trying to do; provides the design principle the variant expresses

The comparative reading produces two things. It singles out the variant that will be developed at component-level detail in the case study chapter and evaluated in Chapter 8, and it produces a design-level overview of the alternative variants that demonstrates the range of the framework without requiring all variants to be developed at the same depth.

6.7 Bridge to evaluation

The final task of Chapter 6 is to set up the evaluation that follows. The configuration logic produces design variants in which values are present by construction, but their presence still needs to be demonstrable, plausible, and feasible. Chapter 8 makes this measurable by linking a small number of key performance indicators (KPIs) to each value dimension.

The KPIs are derived directly from the design indicators of the V–I Framework, so the evaluation does not introduce new criteria; it makes the existing translation measurable in the resulting façade. This bridge is what allows Chapter 8 to evaluate value translation without becoming a separate framework.

6.8 Chapter conclusion: contribution to sub-question 4

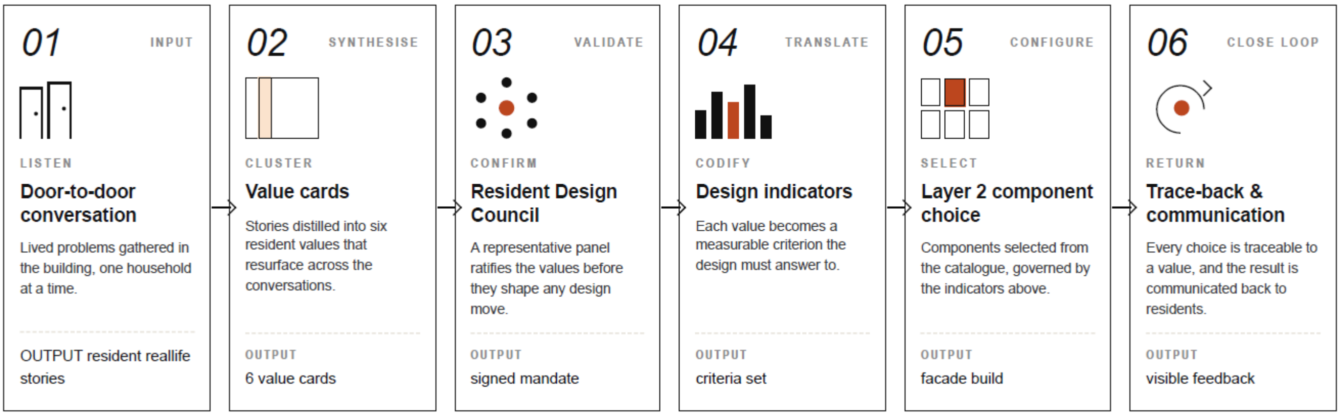
Sub-question 4 asks *how a configuration logic can translate value priorities into traceable design variants within the modular facade system.* This chapter develops the methodological answer.

Step 1 produces a project profile consisting of building conditions, design objectives, living situation, tenant engagement output and confirmed value priorities. Step 2 translates the prioritised values through the Value-Indicator Framework into facade criteria. Step 3 assigns those criteria to the two-layer facade system, keeping Layer 1 equal and using Layer 2 for value-led variation. Step 4 compares the resulting variants on the same axes used to construct them.

The revised tenant-engagement protocol strengthens the configuration logic by clarifying how resident input enters Step 1. Tenants are approached through plenary information, door-to-door visits, value cards, a Resident Design Council, and three-channel communication. Their input is not treated as separate consultation data, but as the first layer of the design chain: resident statement -> resident value -> indicator -> layer 2 component -> façade drawing location -> KPI. This trace-back logic connects Chapter 6 directly to the fairness and documentation criteria evaluated in Chapter 8.

The chapter therefore shows that VIMFS is not only a system of facade components. It is a design-decision structure in which the same Layer 1 can support different Layer 2 compositions without losing traceability. Value priorities become design variants because each step records what is fixed, what is open to variation, which values are foregrounded, which components are selected and how the final variant can be compared with others.

Figure 6.6: From resident voice to façade component summary diagram



Door-to-door conversation

Lived problems gathered in the building, one household at a time.

OUTPUT resident reallife stories

Value cards

Stories distilled into six resident values that resurface across the conversations.

OUTPUT
6 value cards

Resident Design Council

A representative panel ratifies the values before they shape any design move.

OUTPUT
signed mandate

Design indicators

Each value becomes a measurable criterion the design must answer to.

OUTPUT
criteria set

Layer 2 component choice

Components selected from the catalogue, governed by the indicators above.

OUTPUT
facade build

Trace-back & communication

Every choice is traceable to a value, and the result is communicated back to residents.

OUTPUT
visible feedback

Chapter 7 :Case study application

7.1 Introduction

This chapter applies the configuration logic of Chapter 6 to a representative post-war walk-up apartment block: the row at Gijsingstraat 76–112 in Tussendijken, Rotterdam West, with the building unit 92 A/D–94 A/D used as the design test case.

The chapter follows the four-step structure introduced in Chapter 6 (project requirements, value translation, layer logic, comparison). One design variant is developed in full so that the reader can follow the configuration logic from project profile to component selection. Three additional variants are introduced briefly to demonstrate the range of the framework; their full development is given in the appendices.

The chapter therefore has two intentions. It tests whether the configuration logic produces a coherent and traceable design when applied to a real building, and it produces the design variants that Chapter 8 evaluates.

7.2 Case selection and selected building

The case study was selected on four criteria: it had to represent a building type relevant to modular façade intervention; it had to provide enough technical and architectural information to support a grounded design application; it had to be representative of a common housing condition rather than an exceptional project; and it had to sit in an urban context where housing transition, energy upgrading and resident experience are already active themes.

A post-war walk-up apartment block in Rotterdam West meets all four. The Gijsingstraat row in Bospolder–Tussendijken is the case-study site of Ricci's PhD research on just energy renovation in vulnerable Dutch neighbourhoods (Ricci et al., 2024, 2025); the present chapter draws on that research record for the neighbourhood-scale context, governance structure, and resident-experience dimension of the case.

The technical baseline of the selected building unit is taken from the case-study report by Lalyko (2024) and my own site visit, which served as the technical reference for this thesis.

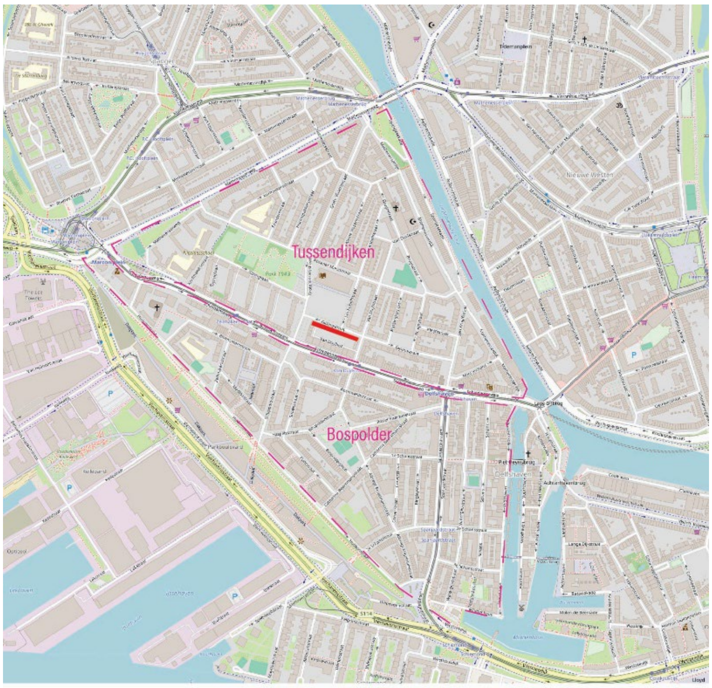


Figure 7.0: Map of district in Rotterdam-West (OpenStreetMap)

The selected building is a four-storey walk-up block from 1952 in the Bospolder–Tussendijken (BoTu) area, with an unconditioned attic under a pitched roof, repetitive porch-access organisation, and a clear façade rhythm. Within the larger row, the unit 92 A/D–94 A/D is used as the design test case. It contains the structural rhythm, dwelling organisation and north–south façade conditions of the wider block while remaining manageable as a detailed application. The street façade faces north-east, the courtyard façade faces south-west, and the resulting environmental and social asymmetry is exactly what makes the case useful for façade comparison.

The case is privately owned and managed through a VvE rather than a single housing association . The building is therefore used here as a typological and technical application case, not as a one-to-one representation of Dutch social-housing governance. Its relevance lies in its architectural and refurbishment characteristics.

Figure 5.1: Selected building unit Gijsingsstraat 92 A/D–94 A/D

Figure 7.2: Gijsingstraat building unit + street picture (Funda.nl)

7.3 Baseline building conditions

The building functions as the fixed reference condition for all design variants developed in this chapter. Before any value translation begins, its architectural, technical, and contextual properties are recorded.

The baseline conditions are summarised in Table 7.1, with the wider neighbourhood and governance context drawn from the JustPrepare programme and own research (Ricci et al., 2025). The repetitive structural and dwelling logic supports modular intervention, while the weak environmental performance and uneven envelope condition create a clear need for upgrading. Energy labels collected for fifteen apartments in the row range from C–E for the lower floors and D–G for the third floor, with an average heating demand of 205.33 kWh/m²·yr (Rijksoverheid). The case is therefore representative of an energy-inefficient post-war building type in which the façade remains a major performance problem.

The case is thus selected because it combines three useful qualities: it is a recognisable post-war walk-up type, it contains a sufficiently regular façade and dwelling logic for modular intervention, and it is embedded in a wider urban context where building upgrading is tied to broader questions of housing quality and neighbourhood transition

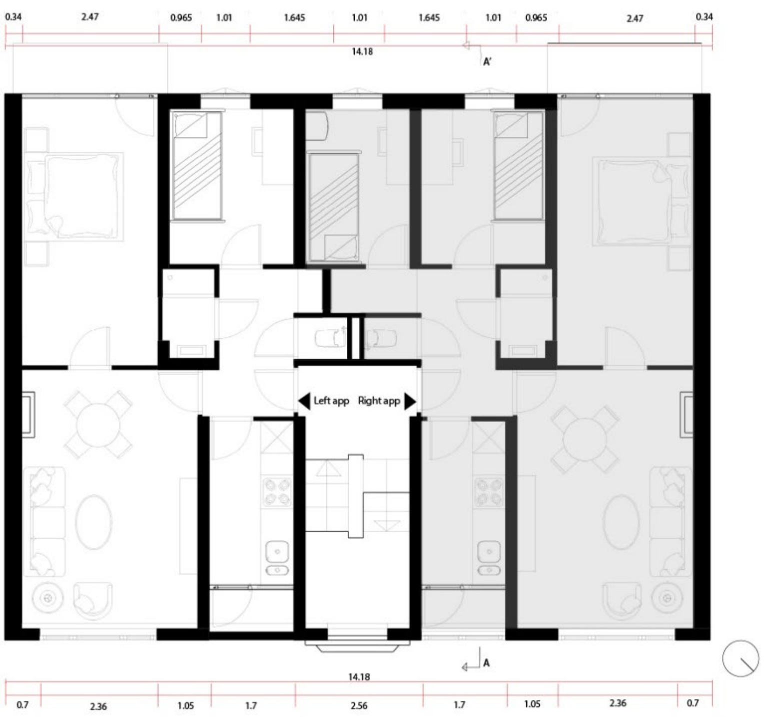


Figure 7.3: Standard floorplan app 1 and 2 (own work)

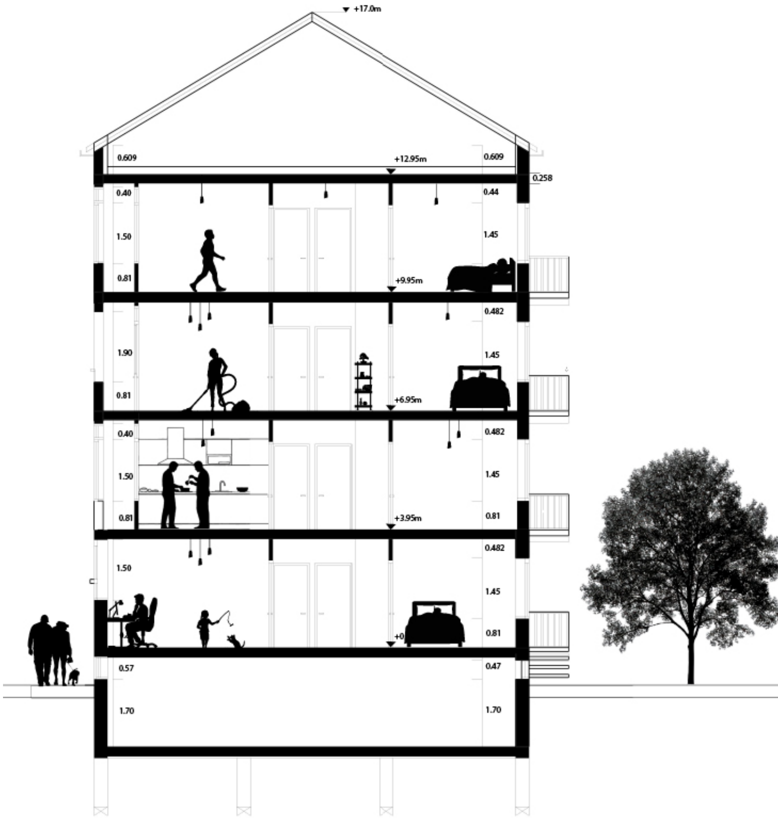


Figure 7.4:Cross section AA' app unit

Figure 7.5: Elevation Street North-East Side (Left): Elevation Courtyard South-West Side (Right)

Category	*Baseline condition*
Case building	Unit 92 A/D–94 A/D within the wider Gijsingstraat 76–112 row, Tussendijken, Rotterdam-West
Typology	Post-war walk-up apartment block / porch-access housing
Construction period	1952
Urban context	Dense inner-urban residential area in BoTu; street parallel to a main shopping/tram corridor; marketplace across the street; similar four-storey blocks nearby; some 8-storey gallery flats to the north-west
Ownership	Privately owned apartments managed by a VvE; owner-occupied or private rental
Building height	4 storeys + unconditioned attic under pitched roof
Access logic	Central staircase with two apartments per floor in each unit
Dwelling repetition	Left apartment: 2 bedrooms, approx. 54.8 m². Right apartment: 3 bedrooms, approx. 62.3 m²
Orientation	Entrance façade street oriented north-east; courtyard façade-oriented south-west
Outdoor relation	Each unit has access to a courtyard with approximately 20 m deep gardens and some trees: rear alley behind gardens
Plan organisation	Kitchen adjacent to staircase on street side; bedrooms toward courtyard; larger rooms span façade depth; some flexibility between living/sleeping use
Balcony logic	Small loggia balconies above ground floor; larger room has balcony access
Wall construction	Solid Dutch standard brick masonry **Exterior wall.** • Ground floor+Basement: 340 mm (triple layer brick (32cm)+ 2cm cement plaster), • Upper storeys . 230 mm north side (double leaf wall)(21 cm brick+2 cm cement plaster) • 300 mm south side (21 cm brick+75 mm drywall installation+0.5 mm vapor retarder+15 mm gypsum fibre board) **Interior wall**: 90 mm lightweight drywall
Floor construction	Timber-joist lightweight floor construction, approx. 250 mm
Window condition	Timber-framed windows; largely single glazing; some later double-glazed replacements with operable ventilation slits
Balcony window/door condition	Many balcony windows and doors only half glazed; some north-side loggias already closed with windows
Ventilation condition	Mechanical exhaust penetrations through façade in some kitchens; indications of ventilation gaps above south bedroom windows; leaky envelope assumed
Existing shading	No exterior shading on either façade
Envelope condition	Ageing façade, poor environmental performance, limited resident control, limited façade articulation
Energy label	Available energy label: Labels found for 15 apartments in the row (rijksoverheid) Ground to second floors: C to E; third floor: D to G
Heating	Average 205.33 kWh/m²·yr; natural gas via individual or central condensing boilers
Main constraints	Fixed structural rhythm, repeated opening order, balcony positions, dimensional limits, modular production logic
Main opportunities	Repetitive façade fields, room for add-on layer, clear threshold zones, component-based intervention potential

Table 7.0 Baseline conditions case study

7.4 Layer 1 specification for the project

Layer 1 is specified once for the Gijsingstraat project and remains identical across all four design variants developed in §7.5–§7.7. This is what makes the configuration logic of Chapter 6 operational: by fixing Layer 1 at the project level, the system guarantees the same deep-retrofit performance baseline (Rc ≈ 7.7 m²K/W; Uw ≤ 0.9 W/m²K where triple glazing is targeted) and the same fairness baseline (every dwelling receives the same Layer 1 specification regardless of which Layer 2 components are selected) for all variants. Variation between variants therefore happens entirely in Layer 2.

Table 7.1: Layer 1 specification for the Gijsingstraat project.

Layer 1 component group	Specification for the Gijsingstraat project
Anchoring system	Stainless-steel A4 brackets with thermal break; post-installed anchors into solid masonry; one fixed point per panel + sliding points to absorb thermal movement
Structural unitised frame	Thermally broken aluminium carrier frame; primary verticals 75 × 160 mm (reinforced bays 75 × 180 mm); secondary verticals 50 × 160 mm; aligned with Schüco AF UDC 80 / Reynaers Element Façade 7 family. North-East street façade: 3500x3000 (2x) and 2500x3000mm (2x) Staircase: 2800x3000mm (1x) South-West courtyard façade: 3340x3000 (2x) mm and 2500x 3000mm (3x)
Inner performance core	40 mm compressible mineral-wool tolerance strip + 18 mm wooden substrate sheet + 160 mm carrier zone with high-density mineral wool (λ = 0.035) + 60 mm continuous wood-fibre external sheathing + wind-tight membrane + 30 mm ventilated cavity
Sealant and joint system	EPDM gaskets at module-to-module joints; silicone-based sealants at module-to-existing-building joints
Achieved performance	Post-retrofit Rc ≈ 7.7 m²K/W; installed U ≈ 0.13 W/m²K (NTA 8800; λ per EN ISO 10456; cavity convention per EN ISO 6946); exceeds BBL 2024 minimum (Rc ≥ 4.7) by ~64%
Base platforms mix for the building	Closed platform on stair-side walls and end gables; open platform on living-room and bedroom façades; service-ready platform at kitchen and ventilation zones

Three Layer 1 base platforms are deployed across the building (Chapter 5, §5.6.3): the closed platform on stair-side walls and end gables, the open platform on living-room and bedroom façades where windows and threshold elements need preparation, and the service-ready platform at kitchen and ventilation zones where decentralised systems and routed services are anticipated.

The mix of platforms is fixed; what varies between variants is which Layer 2 components are mounted onto them.

7.5 The four design variants quick overview.

Four design variants are developed for the same Gijsingstraat building.
Each variant follows the four-step configuration logic of Chapter 6, with building conditions and Layer 1 fixed across all four (§7.3 and §7.4 above). What changes between variants is the combination of living situation and value priorities recorded in Step 1 of the configuration logic (Chapter 6, §6.3.3 and §6.3.4). Different living situations and value priorities lead to different Layer 2 cluster activations and component selections, and therefore to visibly different façade outcomes, while the underlying building, the V–I Framework, and the Layer 1 baseline remain the same.

Table 7.2:The four design variants briefly. P = primary value priority; S = secondary.

Variant	Living situation	Value priorities	Active Layer 2 clusters	Main façade ambition
V01-Control and comfort	Elderly couple in left apartment + family apartment on the right; mixed sheltered and active everyday use	Comfort (P), Empowerment (P), Identity (S)	CA + ST + NF	Improve resident control over climate, privacy, and threshold use
V02-Clear and affordable upgrade	Working couple / budget-sensitive household across both apartments; minimal personalisation	Affordability (P), Fairness (P), Comfort (S)	CA + NF	Deliver a robust, fair, and repeatable façade upgrade
V03-Future orientated ecological renewal	Climate-aware household oriented toward visible ecological renewal and long-term lifecycle awareness	Sustainability (P), Identity (P), Comfort (S)	ER + CA + NF	Make ecological transition spatially and materially legible
V04-Community threshold	Ground-floor households facing the courtyard; valuing neighbour contact and active threshold use	Empowerment (P), Comfort (P), Identity (S)	ST + CA + NF	Strengthen neighbour contact and threshold use at ground-floor level

V01 is developed in full in §7.6 below. V02–V04 are read comparatively in §7.7; their full developments are documented in Appendix D, alongside technical drawings and renders that support the variant work.

7.6 Variant 01:Control and comfort

Variant 01 is developed in full to demonstrate the configuration logic operating end-to-end on a real building. The sections below follow the nine-section reading template that all four variants share: living situation, façade tensions identified, value priorities, façade criteria set, Layer 1 confirmation, Layer 2 cluster activation, component selection by cluster, resulting façade response, and a trace-back table that records the full chain from value to component code.

The same template is applied to V02–V04 in Appendix D.

7.6.1 Living situation

Variant 01 addresses two recurring living situations within the unit.

The left apartment is occupied by an elderly couple oriented toward rest and a sheltered threshold; the right apartment is a family apartment with active everyday use of windows, ventilation, balcony, and storage.

Both households face the same north–south asymmetry, but they make different demands on the façade.

The elderly couple values privacy on the street side, calm shading on the courtyard side, and quiet, intuitive interaction with façade controls.

The family apartment values practical operability, windows that open easily for ventilation, deep sills that support everyday use, accessible exterior storage, and sun control on the balcony side.

The combined living situation therefore foregrounds the façade as the place where daily comfort and environmental control are directly experienced, by households that occupy the building in diverse ways.

7.6.2 Façade tensions identified.

The combination of building condition and living situation surfaces five tensions that the design must address. The existing building has poor envelope performance, mixed window quality (largely single-glazed), no exterior shading, and weak ventilation provision. Read through the elderly-couple-and-family-apartment living situation, this baseline produces:

- **Weak environmental performance:** draughts, condensation risk, overheating in summer on the south side, and uneven temperatures between rooms.
- **Limited resident control :**windows that are difficult to operate, no shading control, no privacy adjustment on the street side.
- **Underused threshold :**balconies present but weakly inhabitable, no storage at the façade edge, sills too shallow for everyday use.
- **Privacy on the street side:** direct exposure to the street with no façade-level filter.
- **Weak dwelling articulation:** the two apartments of the unit are not visibly distinguishable from outside, despite housing different living situations.

7.6.3 Value priorities

Comfort and empowerment are foregrounded as primary values because the dominant tensions surface as control deficits ,over climate, privacy, and threshold use , which affect both households in their daily lives. Identity is secondary because improved performance should also become spatially legible, particularly through dwelling-level differentiation between the two apartments.

Value dimension	**Priority level**	**Why it matters in this scenario**	**Typical design direction**
Comfort	Primary	indoor environmental quality and ease of use are weak	operability, shading, glazing quality, ventilation, insulated modules
Empowerment	Primary	residents need more agency over openings and shading	operable elements, user-accessible systems, adjustable shading
Identity	Secondary	façade should become more recognisable as a domestic interface	threshold articulation, dwelling legibility, façade accents

Table 7.3Variant 01, value priority in relation to facade tension and design direction

7.6.4 Façade criteria set.

Translating comfort, empowerment, and identity through the V–I Framework (Chapter 4, Table 4.5) produces the criteria set for the variant. Each prioritised value is decomposed into its specific design indicators, and each indicator is operationalised as a façade criterion.

- **comfort** → user control, daylight quality, maintainability, ease of interaction.
- **empowerment** → configurability, user influence, operability, accessible façade elements
- **identity** → domestic threshold articulation and dwelling recognisability

Table 7.4:Variant 01 façade criteria set. P = primary, S = secondary.

Value (priority)	**Specific design indicators activated**	**Façade criteria for the variant**
Comfort (P)	C1 thermal performance · C2 opaque-wall Rc · C3 operable openings · C4 daylight · C5 acoustic separation (design stage)	Uw ≤ 0.9 W/m²K (triple glazing); Rc ≥ 4.7 (achieved 7.7 by Layer 1); ≥ 1 operable opening per habitable room; window-to-floor ≥ 1:7; airborne-sound performance per dwelling-type table
Empowerment (P)	E1 resident-operable elements per dwelling · E2 façade area under direct resident control	≥ 4 resident-operable elements distributed across habitable rooms; ≥ 30% of façade area carries adjustable elements (windows, vents, shading)
Identity (S)	I1 distinct configurable combinations per dwelling type · I2 variation between dwellings	≥ 4 distinct combinations available; ≥ 20% of configurable elements vary between left and right apartment of the unit

7.6.5 Layer 1 confirmation

Layer 1 stays as specified in §7.4 (Table 7.2).
The carrier frame, the inner performance core (Rc ≈ 7.7), the sealant and joint system, and the mix of three base platforms across the building are all identical to those used in V02–V04. C2 (opaque-wall Rc) and C5 (acoustic separation) are therefore satisfied at the Layer 1 level for this variant by construction.

7.6.6 Layer 2 cluster activation

Three of the four Layer 2 clusters are activated for V01:

- Climate Agency (CA) for the resident-control side of comfort and for empowerment
- Social Threshold (ST) for the threshold-use side of comfort and identity
- Neighbourhood Face (NF) for differentiated dwelling expression on the street and courtyard façades.

The activation pattern (CA + ST + NF) is the architectural translation of the value-priority set: comfort + empowerment + identity, with comfort and empowerment carried by CA and ST and identity carried by NF and the ST articulation differential between the two apartments. The resulting Layer 2 cluster activation for Variant 01 is shown in Figure 7.6.

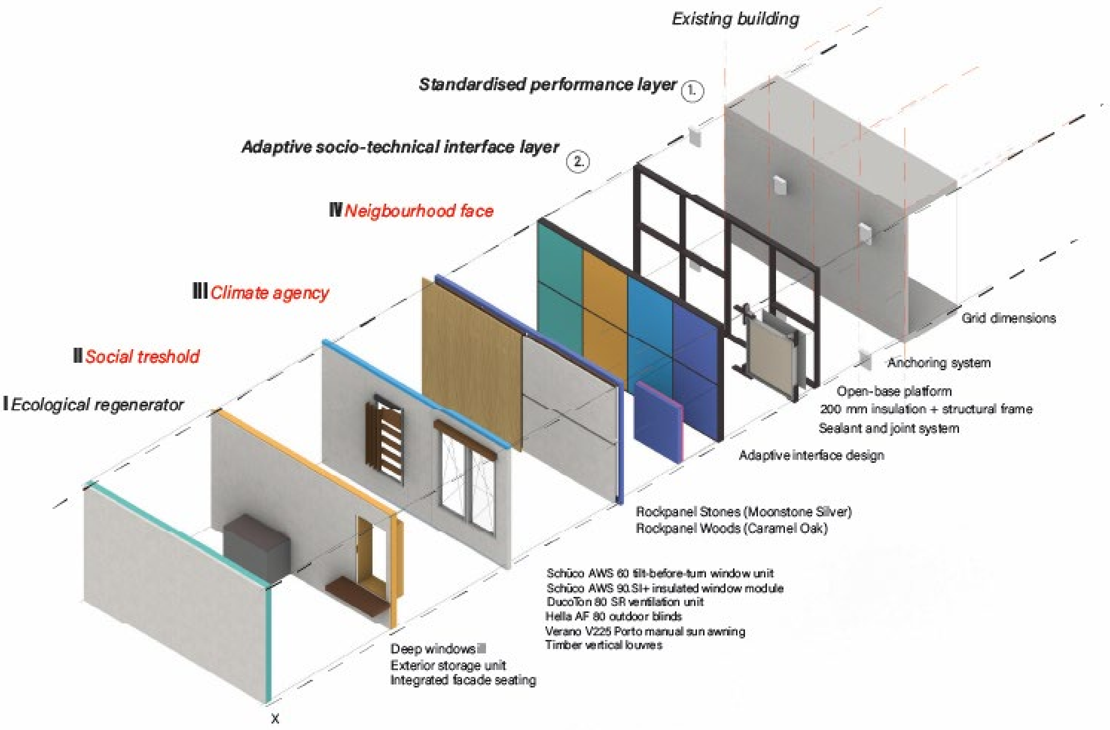


Figure 7.6: Layer 2 cluster activation design variation 01 (systematic and technically rendered)

7.6.7 Component selection by cluster

Within each active cluster, components are selected from the component catalogue (Appendix B) to satisfy the criteria set of §7.6.4. Each component is recorded with its catalogue code so that the selection is traceable across variants and auditable against the V–I Framework.See figure 7.6 for visualisation.

Table 7.5: Component selection for Variant 01 by cluster. Component codes refer to the component catalogues in Appendix B).

Cluster	Component code	Component specification	Located on
Climate Agency	CA01 -operable insulated window, Schüco AWS 90.SI+	Triple glazing Ug ≈ 0.6 W/m²K; tilt-and-turn operability; Uw ≈ 0.8 W/m²K; thermally broken aluminium frame	North-east street and south-west courtyard façades, both apartments
Climate Agency	CA02-secondary operable window, Schüco AWS 60	Tilt-before-turn opening for kitchen and bathroom locations; reduced section depth	Kitchen window of the family apartment; bathroom-side openings
Climate Agency	CA03 -decentralised ventilation, DucoTon 80 SR	Self-regulating window-mounted ventilation; integrated below window head	Below window heads on both façades, both apartments
Climate Agency	CA04 -outdoor blind, Hella AF 80	External roller blind with manual adjustment	South-west courtyard façade, balcony-side window of both apartments
Climate Agency	CA05- manual sun awning, Verano V225 Porto	Manual cassette awning at balcony level for full balcony shading	South-west courtyard balcony of the family apartment
Climate Agency	CA06 -vertical privacy louvres	External vertical louvres 89 × 200 × 2000 mm with manual rotation	North-east street façade, ground-floor, and first-floor street-side openings
Social Threshold	ST01 -deep windowsill	Inhabitable sill 2350 × 200 × 50 mm in solid timber finish	North-east kitchen window of the family apartment
Social Threshold	ST02 -exterior balcony storage	Weatherproof storage unit 1340 × 620 × 670 mm	South-west balcony of the family apartment
Social Threshold	ST03- integrated façade bench seating	Built-in bench seat at balcony level, fixed to Layer 1 carrier	South-west balcony of the elderly-couple apartment
Neighbourhood Face	NF01 -Rockpanel Stones, Moonstone Silver	Mineral-bound facade panel; calmer, more public-facing tone; 9 mm	North-east street façade across the unit
Neighbourhood Face	NF02 -Rockpanel Woods, Caramel Oak	Mineral-bound facade panel with timber-look finish; warmer, more domestic tone; 9 mm	South-west courtyard façade across the unit

7.6.8 Resulting façade response

The climate agency components respond to the dominant tensions of weak control, poor ventilation, overheating risk, and privacy problems. Operable window systems and integrated ventilation improve comfort through better climate control. Outdoor blinds and manual awnings address solar exposure and glare. The vertical louvres moderate visibility and create a calmer street relation.

The social threshold components respond to the dominant façade tension of weak threshold use and everyday appropriation of the façade edge. The bench seating supports resting and quiet occupation for the elderly couple, while the storage unit supports family routines without reducing interior floor area. The deep sill gives the family apartment a more inhabitable north façade edge.

The cladding strategy of the neighbourhood face cluster is selected as part of the value translation, not as a decorative finish. Rockpanel Stones on the north façade support a calmer, more robust, and more public-facing street expression. Rockpanel Woods on the south façade support a warmer, softer, and more domestic courtyard-facing threshold.(see figure

Figure 7.7:Façade tension responds in design by tenant from before to after situation, based on step 1 of configuration logic (own work).*

Figure 7.8: Facade design response design variant 01- north-street façade (only rockpanel and cariant 2 cladding south and noth combined, picture below south-courtyard facade including different variants (own work)*

7.6.9 Trace-back from value to component

Table 7.6 records the full chain from each value priority to the criterion it activates, the cluster in which the criterion is satisfied, and the specific components selected. This is the methodological deliverable of the variant: every Layer 2 selection is traceable back to a value priority and a documented criterion.

Table 7.6:Trace-back table for Variant 01.

Value priority	Indicator	Criterion satisfied	Cluster	Component(s) selected
Comfort	C1 Uw	≤ 0.9 W/m²K	CA	CA01 (AWS 90.SI+, triple-glazed)
Comfort	C2 Rc	≥ 4.7 m²K/W (achieved 7.7)	Layer 1	Layer 1 carrier and insulation core
Comfort	C3 operable openings and natural ventillation	≥ 1 per habitable room +>25m3/h	CA	CA01 plus CA02 across all habitable openings
Comfort	C4 daylight 1:7	Maintained at upgraded openings	CA	Existing window openings preserved by CA01 / CA02
Comfort	C5 acoustic separation (design stage)	Per Bouwbesluit dwelling-type table	Layer 1 + CA	Layer 1 buildup plus CA03 acoustically rated vent Ducoton 80 SR
Empowerment	E1 ≥ 4 operable elements	Achieved (window, vent, blind, awning, louvres)	CA	CA01 + CA02 + CA03 + CA04 + CA05 + CA06
Empowerment	E2 ≥ 30% controllable area	Achieved (~35%)	CA + ST	Active CA components plus ST01 / ST03 threshold use
Identity	I1 ≥ 4 combinations	Achieved	NF + ST	NF01 / NF02 cladding pair × ST01 / ST02 / ST03 mix
Identity	I2 ≥ 20% variation between dwellings	Achieved (~22%)	ST + NF	ST01 (family apt) vs. ST03 (elderly apt); balcony differentiation

7.7 Comparative reading of the four variants

With V01 developed in full and V02, V03, V04 documented in Appendix D, the four variants can be read side by side. The comparison uses the five reading axes introduced in Chapter 6, Table 6.4: dominant values, living situation addressed, selected Layer 2 components, north and south façade character, and main façade ambition. The comparison is not a ranking. It shows that the same building, the same V–I Framework, and the same Layer 1 admit four recognisably distinctive design responses when the living situation and value priorities of the project profile are changed.

Table 7.7: Comparative reading of the four design variants on the five axes of Chapter 6

Reading axis	***V01: Control and comfort***	***V02:Affordable and fair upgrade***	***V03:Ecological renewal***	***V04:Community threshold***
Living situation	Elderly couple + family apartment	Working couple / budget-sensitive	Climate-aware household	Ground-floor courtyard household
Dominant values	Comfort, Empowerment, Identity	Affordability, Fairness, Comfort	Sustainability, Identity, Comfort	Empowerment, Comfort, Identity
Active L2 clusters	CA + ST + NF	CA + NF (restrained)	ER + CA + NF	ST + CA + NF
North façade character	Protected, controllable street edge with operable windows + privacy louvres	Calm, repeated street façade with one shared window logic	Public ecological façade with bio-based cladding, low-carbon windows, biodiversity inserts	Protected but active street plinth with operable windows, deep sill, and bike racks
South façade character	Domestic courtyard with seating, storage, resident-controlled shading	Standardised courtyard with one repeated shading + ventilation package	Productive courtyard with planting, BIPV, climate-responsive shading	Social courtyard edge with seating, planters, Juliet rails, shading
Main façade ambition	Improve resident control over climate, privacy, and threshold use	Deliver a robust, fair, repeatable façade upgrade	Make ecological transition spatially and materially legible	Strengthen neighbour contact and threshold use at ground-floor level

Three readings follow from the comparison.

First, no two variants select the same combination of components in the same way. The framework therefore produces variation that is system-internal rather than ad hoc, it does not invent new components per variant; it reorganises the catalogue around different priority sets.

Second, the variants show that affordability and fairness operate as background conditions across all four: every variant uses the same Layer 1, every variant respects the bounded catalogue, every variant documents its selections, regardless of which adaptability values are foregrounded.

Third, the comparison shows that façade variation can have social as well as technical consequences. This is most visible in V04, where the proposed ground-floor cross-section turns the façade into a social threshold. The technical adjustment of adding depth, seating, shading, planting, and controlled openings creates a safer and more usable transition between inside and outside.

Instead of treating the façade as a flat boundary, V04 uses it as an intermediate zone that can support informal encounters, everyday surveillance, neighbour recognition, and a stronger connection to the courtyard. In this sense, the societal outcome is not added after the technical design; it is produced through the spatial and material organisation of the façade itself.

This is illustrated through the new cross section of the building unit, visualizing design variant four.(figure 7.9). The north-street façade designs for variants V02–V04 are shown in Figure 7.11 (full development in Appendix D)

The comparative reading also demonstrates the design-process intent of Chapter 6. The four variants are not alternatives chosen by a designer in isolation. They are a structured exploration of the design space opened by the framework. A housing association reading the four variants together can see how different value emphases lead to different façade outcomes, and can decide which variant, or which combination of features, should be developed further.
This is the configuration logic working as a design-decision tool, not just as a generative method.

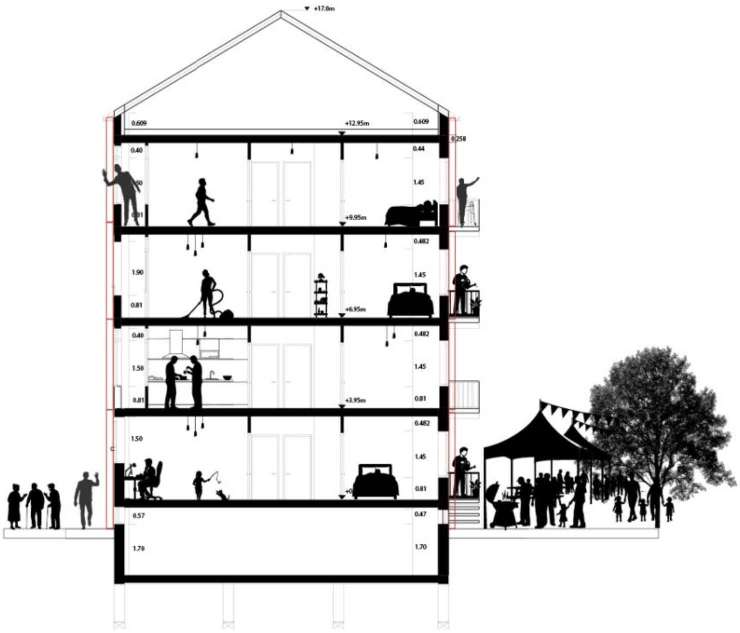


Figure 7.9:Community threshold section: connecting dwelling, façade, and courtyard (own work)

Figure 7.10: First row front façade design including different designs per level and visualisation community threshold section, lower row future perspective applying different design variants on the facade to align values(own work)*

Figure 7.11: Design variant 02-04 north-street facade design rendered (see appendix D for more info, own work*)

7.8 Chapter conclusion: completion of sub-question 4

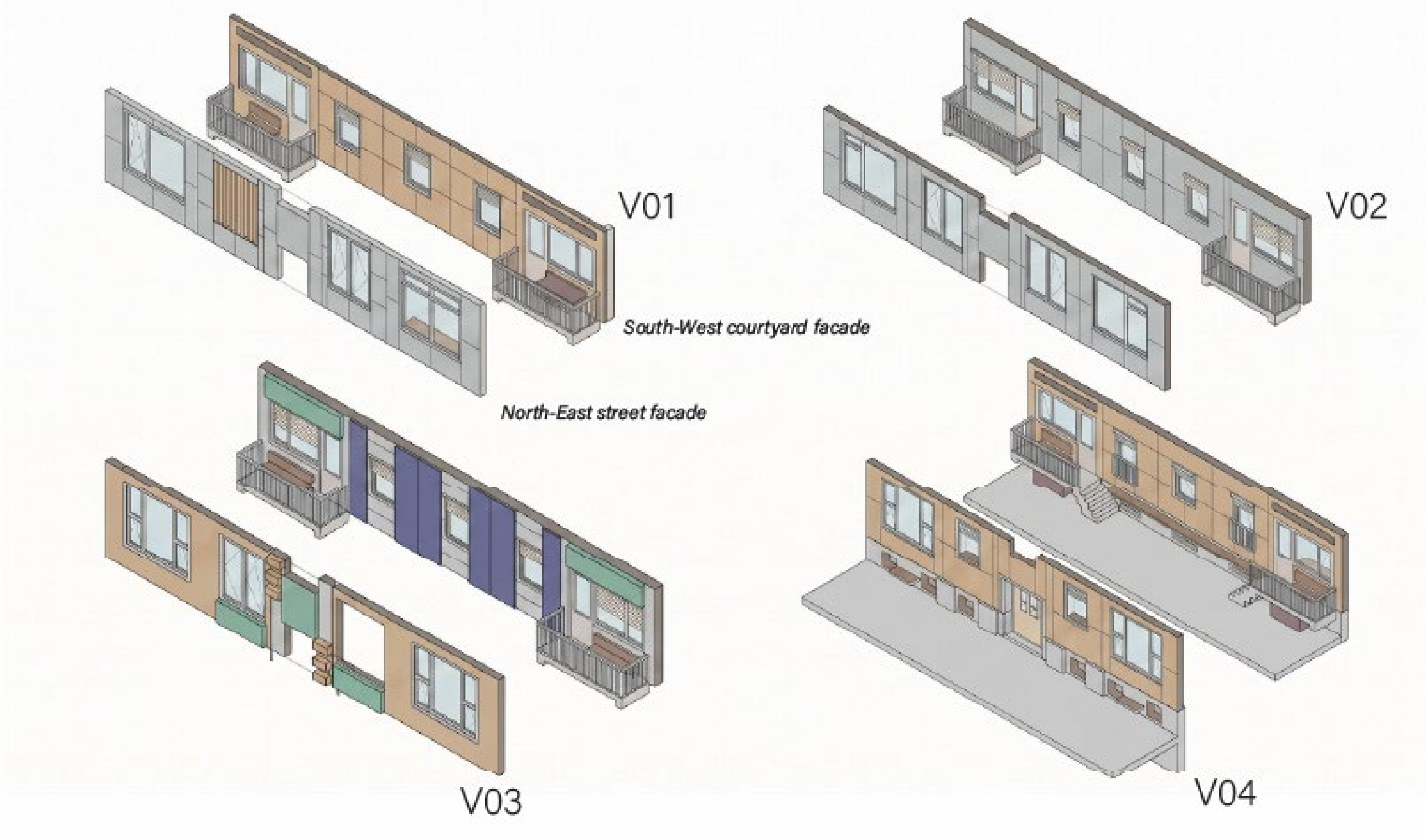
Sub-question 4 asks how a configuration logic can translate value priorities into traceable design variants within the modular façade system. Chapter 6 answered the methodological side. This chapter completes the answer by applying that logic to a real building.

The case study has shown that the configuration logic of Chapter 6 produces traceable, coherent, and comparable design variants when applied to a representative post-war walk-up apartment block. The same building, the same V–I Framework, the same Layer 1 specification, and the same Layer 2 component catalogue produce four distinct design variants when the living situation and value priorities of the project profile are changed. V01 has been developed in full of project profile to component-level selection (§7.6); V02–V04 have been read comparatively in §7.7 and are developed in full in Appendix D. The trace-back table in §7.6.9 demonstrates that every Layer 2 selection in V01 is traceable back to a value priority and a documented criterion.

Together, Chapter 6 (method) and this chapter (application) therefore answer sub-question 4: a configuration logic translates value priorities into traceable design variants by changing only the living situation and value priorities of Step 1, while keeping the building, the V–I Framework, Layer 1, and the component catalogue constant.

The four variants produced in this chapter and Appendix D are the input to the evaluation in Chapter 8, which measures the translation of resident values into each variant through key performance indicators.

Figure 7.12: Four design variants case study application



Chapter 8 : Evaluation

8.1 Introduction

This chapter evaluates the four design variants developed in Chapter 7 by measuring the extent to which each of the six resident values is translated into the resulting façade design. It addresses the fifth research sub-question:

SQ5: To what extent are the resident values visible, measurable, and differentiated across the resulting design variants?

The evaluation is conducted entirely based on design data. No human-participation methods are used: there are no resident interviews, surveys, post-occupancy questionnaires, focus groups, or expert review panels in this evaluation. . The evaluation is therefore a design-stage value-translation assessment.

The assessment uses only the evidence available at this design stage: the Value-Indicator Framework, the two-layer facade logic, the Layer 2 component catalogue, the design drawings and variant descriptions, and published benchmark or published reference data, together with the baseline building conditions of the Gijsingstraat case-study unit recorded in Chapter 7, Table 7.1.

The evaluation should therefore not be read as a ranking of final solutions. A higher total score means that more value indicators are visible in the design-stage evidence, not that the variant is objectively better for every project or resident group.

The chapter is structured in seven sections. §8.2 shows the translation from framework to KPI, . §8.3 records the source of each KPI , Dutch building regulation, the Value–Indicator Framework, or published industry benchmarks, so that the basis of every threshold is auditable. §8.4 defines the seventeen KPIs by value dimension, each with its unit, threshold, source, and method of measurement, the thermal and ventilation

KPIs (Key Performance Indicators) are calculated against the baseline conditions recorded in Chapter 7. §8.5 sets out the scoring method and §8.6 aggregates the per-value scores into a value-translation profile for variant 1 focussing and list the scoring of each KPI in a table. §8.7 applies the KPIs to each of the four design variants developed in Chapter 7, organised value by value so the comparison stays inside one value at a time including the explanation and evaluation of the shared design choices and scoring that emerged across the four variants..§8.8 closes the chapter with the answer to sub-question 5.

8.2 From framework to KPIs

The KPIs are derived from the same translation chain that structures the thesis:

resident value -> design indicator -> facade criterion -> KPI -> variant score.

This keeps the evaluation traceable. The KPI set does not introduce a new design agenda; it tests whether the values already embedded in the framework have become legible in the variants.

Resident value	Resident-side concern	Facade design indicator	KPI translation
Comfort	Warmth, daylight, fresh air, acoustic comfort, and ease of use	Thermal performance, daylight, operability, ventilation, and solar control	Uw, Rc, operable openings, daylight proxy, ventilation capacity
Affordability	Cost clarity, long-term robustness, and feasible renovation	Standardisation, repetition, limited component families, and simple construction	Cost per m2, component-family count, Layer 1 repetition
Fairness	Equal treatment, transparent decisions, and traceable choices	Equal baseline, clear option logic, and documented selection route	Layer 1 equality, documented selection logic
Empowerment	Resident control and influence over the dwelling interface	Operable facade elements, adjustable shading, and configurable facade zones	Operable element count, facade area under resident control
Sustainability	Low-carbon materials, circularity, and visible ecological value	Bio-based materials, embodied carbon reduction, disassembly, and reuse	Bio-based share, embodied carbon, disassembly index
Identity	Recognisability, belonging, facade character and dwelling expression	Material rhythm, articulation, variation, and customisable outer layer	Distinct combinations, variation between dwellings

8.3 KPI sources

Each KPI in this chapter is derived from one of three sources.

Dutch building regulation. C2, C3, C4, and C5 derive their thresholds from the Besluit Bouwwerken Leefomgeving (BBL 2024) and the underlying NEN standards.

Value–Indicator Framework. E1, E2, I1, I2, F1, and F2 are derived directly from the design indicators developed in Chapter 4 and the criteria column of Table 4.5. They are design-side indicators: the criterion is set by the framework itself, not by an external regulation. The cross-case grounding for these criteria is given in §4.3.3 with back-references to §3.5.1 and Appendix A sections.

Industry benchmarks and published reference data. C1, S1, S2, S3, A1, A2, and A3 take their thresholds from published industry sources/industry performance targets: BPIE retrofit cost data (A1), Dutch EPD reference values (S2), Durmisevic-style disassembly scoring (S3), and the bounded-component-family conventions of unitised façade systems (A2, A3, S1).

8.4 Key performance indicators per value dimension

8.4.1 Comfort indicators (C1–C5)

Comfort is measured through five indicators that quantify thermal performance, ventilation provision, daylight access, and operability of openings. The comfort KPIs operationalise the Table 4.5 comfort indicators: thermal performance as C1 (window Uw) and C2 (opaque Rc); operable openings and natural ventilation as C3 (operable openings) and C5 (ventilation capacity); and daylight access as C4.

Solar control and acoustic separation are verified at design stage, through the variant's adjustable external shading and the Layer 1 build-up respectively, rather than as separate numeric KPIs. All the thresholds are anchored in sources referenced in appendix C. The thermal indicators (C1, C2) are calculated against the baseline wall and window conditions of the Gijsingstraat case-study unit recorded in appendix C.2 , pre-renovation Rc ≈ 0.5 m^2K/W in the opaque wall and Ug ≈ 5.2 W/m^2K in the existing single-glazed timber-framed windows , so that the post-retrofit scores reflect what each variant achieves in this specific case rather than abstract performance numbers.

Table 8.1: Comfort KPIs.

KPI	Indicator	How it is calculated	Unit	Threshold	Source
C1	*Window thermal performance Uw*	Uw value of selected window system in W/m2K	*W/m^2K*	*≤ 0.9 (where triple glazing targeted)*	*Industry benchmark*
C2	*Opaque wall thermal resistance Rc*	Rc value of Layer 1 opaque wall build-up in m2K/W	*m^2K/W*	*≥ 4.7*	*BBL 2024*
C3	*Operable openings per habitable room*	Number of resident-operable windows, purge openings, or controllable ventilation openings per habitable room	*count*	*≥ 1 per room*	*BBL/Bouwbesluit*
C4	*Daylight access (window-to-floor area)*	Window-to-floor area = total window area (glazing)/total floor area Ratio as a design-stage daylight proxy	*ratio*	*≥ 1:7 (10-15%)of habitable floor area or equivalent check against BBL / NEN 2057*	*BBL/Bouwbesluit*
C5	*Ventilation rate per habitable room*	Facade-integrated natural or mechanical ventilation capacity per habitable room	*m^3/h*	*≥ 25 m^3/h*	*NEN 1087*

8.4.2 Affordability indicators (A1–A3)

Affordability is measured through three design-side indicators.

Table 8.5: Affordability KPI's

KPI	Indicator	How it is calculated	Unit	Threshold	Source
A1	*Cost-efficiency :façade cost per square metre,*	A1 = (layer 1 baseline)€380/m² + total Layer 2 component cost ÷ evaluated façade area Layer1 : Aluminium cassette frame, Rockwool insulation, standard openings, airtight / watertight interfaces +	*€/m²* *Afacade can be per façade segment, dwelling type, and full building*	*≤ €450/m² for retrofit envelope* *Met <= EUR 450/m2; partial EUR 451-600/m2; not met > EUR 600/m2.*	*BPIE retrofit cost data (Excludes VAT, subsidies, tenant communication, internal renovation, financing structure, rent adjustment, maintenance, or lifecycle cost))*
A2	*Count of bounded variety of configurable elements across the variant*	Number of distinct component families used in one design variant	*count*	*≤ 12 distinct Layer 2 families*	*Design choice supporting industrial feasibility*
A3	*Module repetition*	identical Layer 1 module area / total Layer 1 façade area × 100%.	*% identical Layer 1 modules across dwellings*	*≥ 90%*	*Industry benchmark for prefabricated unitised systems*

8.4.3 Fairness indicators (F1–F2)

Fairness is measured through two design-side indicators on the equality of the Layer 1 baseline and on the documented basis of every selection.

Table 8.6:Fairness KPIs.

KPI	Indicator	How it is calculated	Unit	Threshold	Source
F1	*Layer 1 performance equality across dwellings*	Share of dwellings receiving the same Layer 1 performance specification	*% of dwellings sharing the same Layer 1 specification*	*100%* , Layer 2 choices may vary, but the technical baseline must remain equal.	*V–I Framework §4.4.4 (design rule)*
F2	*Documented selection logic F2*	*Documented selections ÷ total configurable selections × 100*	*yes/no per design decision*	*100% documented* *is met only when every selected Layer 2 component can be traced through the chain: resident value → design indicator → façade criterion → component code → drawing location.*	*V–I Framework §4.4.4(design rule)*

8.4.4 Empowerment indicators (E1–E2)

Empowerment is measured through two indicators that quantify resident-controllable presence in the façade. The thresholds derive from cross-case observations in Chapter 3: residents reported dissatisfaction in cases where operable elements were below these levels.

Table 8.2:Empowerment KPIs

KPI	Indicator	How it is calculated	Unit	Threshold	Source
E1	*Resident-operable elements per dwelling*	Count of elements directly adjustable or usable by the resident without professional intervention	*count*	≥ 4 elements (windows, vents, shading) . Static cladding and fixed ecological inserts are not counted.	*V–I Framework §4.4.4 (case observation)*
E2	*Façade area under direct resident control*	adjustable façade area ÷ total façade area of dwelling × 100	*% of total façade*	≥ 30% Count operable windows, adjustable shading, movable louvers, and controllable ventilation zones.	*V–I Framework §4.4.4 (case observation)*

8.4.5 Sustainability indicators (S1–S3)

Sustainability is measured through three indicators on the materials in the façade, embodied carbon, and disassembly. The thresholds derive from published Dutch and European reference data.

Table 8.4:Sustainability KPIs.

KPI	Indicator	How it is calculated	Unit	Threshold	Source
S1	*Bio-based material share (cladding + insulation by mass)*	bio-based material mass ÷ total relevant façade material mass × 100	*%*	*Met >= 50%; partial 25-49%; not met < 25%. Scope: cladding, insulation, and selected Layer 2 finish materials. Exclude glazing, PV cells, ventilation units, and fixings.*	*Industry benchmark; literature on bio-based retrofit*
S2	*Embodied carbon per square metre of façade*	Indicative A1-A3 embodied carbon per m2 facade area for Layer 1 plus selected Layer 2 components	*$kgCO_2eq/m^2$*	*≤ 200 kgCO2eq/m2. Use benchmark bands rather than exact claims at this design stage.*	*Dutch EPD reference values*
S3	*Reuse / disassembly index for Layer 2 components*	Weighted disassembly index averaged across selected Layer 2 components	*0–1 score*	*Met ≥ 0.70; Partial = 0.50–0.69; Not met < 0.50* *See Table 8.4.1*	*Durmisevic (2006) disassembly scoring*

Table 8.4.1: Sub-criterion threshold S3

S3 sub-criterion	Weight	Score logic
Reversible mechanical fixing	30%	1 = bolted / clipped / screwed; 0.5 = partly reversible; 0 = bonded or destructive
Independent removal without damaging neighbouring elements	25%	1 = removable without removing neighbouring components; 0.5 = partly dependent; 0 = dependent
Connection accessibility	20%	1 = accessible from outside or service zone; 0.5 = partly accessible; 0 = hidden or inaccessible
Reuse potential after removal	15%	1 = reusable after removal; 0.5 = recyclable but not reusable; 0 = waste after removal
Documentation / material passport	10%	1 = component and fixing logic documented; 0.5 = partly documented; 0 = undocumented

S3 = weighted average of the five sub-criteria across the selected Layer 2 components.
Met ≥ 0.70; Partial = 0.50–0.69; Not met < 0.50

8.4.6 Identity indicators (I1–I2)

Identity is measured through two indicators that quantify how much the modular system makes the façade variable rather than uniform. The first KPI counts what the catalogue makes available for one dwelling type: the second measures actual variation between dwellings of the same building.

Table 8.3:Identity KPIs.

KPI	Indicator	How it is calculated	Unit	Threshold	Source
I1	*Distinct Layer 2 component combinations available per dwelling type*	Number of distinct Layer 2 combinations available per dwelling type within the selected variant logic	*count*	*≥ 4 combinations*	*V–I Framework §4.4.4(design choice)*
I2	*Variation between dwellings (Layer 2 elements differing)* *differing Layer 2 elements ÷ total Layer 2 elements × 100*	differing Layer 2 elements ÷ total Layer 2 elements × 100	*% of Layer 2 elements that vary*	*≥ 20%* *Calculated per elevation because identity is read visually from the facade.*	*V–I Framework §4.4.4(design choice)*

8.5 Scoring method

Each KPI is scored on a three-level scale: met (1), partial (0.5), not met (0) (Table 8.10). A KPI is met when it reaches the threshold or fully satisfies the design rule, partial when it addresses the value, but the threshold, boundary, or documentation is incomplete, and not met when it falls clearly short. Partial captures the maturity of design-stage evidence: at this stage, many KPIs are argued from drawings, datasheets, and reference bands rather than measured performance, and a binary scale would force those cases into false precision.

Table 8.10: Scoring scale

Score	Meaning	Use in this evaluation
1	Met	The design reaches the stated threshold or fully satisfies the design rule.
0.5	Partial	The design addresses the value, but the threshold, boundary or documentation is incomplete.
0	Not met	The design does not address the value or is clearly below the threshold.

The KPIs are scored in three ways. Most use a quantitative band with an explicit partial range (Table 8.11). Three are binary threshold checks, where a partial score would be artificial because the criterion is either met or not , operable openings (C3), ventilation (C5), and the component-family cap (A2). The two fairness KPIs (F1, F2) are design-rule checks, scored on whether the baseline equality and the selection logic are fully documented.

The thresholds are drawn from external sources , BBL 2024 ,product datasheets , the deep-retrofit benchmark and the system's own standardisation logic. Each partial band reflects how much tolerance its value can absorb. Some KPIs are therefore binary: daylight, ventilation, and operable openings either meet the requirement or fail it, because a room that is ventilated is not partially comfortable, it is simply inadequate. Others carry a partial band, because the value degrades gradually rather than falling out the threshold: a façade slightly over the cost benchmark, an embodied-carbon figure modestly above target, or a repetition rate a few points below ninety per cent still delivers most of the intended value. The bands are thus calibrated to each KPI rather than applied uniformly.

Table 8.11:KPI thresholds and scoring bands.

KPI	Met (1)	Partial (0.5)	Not met (0)
C1 Glazing thermal performance (Uw)	≤ 0.9	0.91–1.30	> 1.30 (W/m^2K)
C2 Opaque-wall thermal performance (Rc)	≥ 4.7	4.0–4.69	< 4.0 (m^2K/W)
C3 Operable openings	≥ 1 per habitable room	binary	0 rooms
C4 Daylight access	window-to-floor ≥ 1:7	1:7–1:8	< 1:7
C5 Ventilation capacity	≥ 25 m^3/h per room	binary	< 25
A1 Per-square-metre cost	≤ €450	€451–550	> €550
A2 Component-family economy	≤ 12 families	binary	> 12
A3 Repetition of the shared baseline	≥ 90%	80–89%	< 80%
F1 Baseline equality across dwellings	identical Layer 1	partly documented	not equal
F2 Documented selection logic	100% traceable	incomplete	undocumented
E1 Resident-operable elements	≥ 4	2–3	< 2
E2 Façade area under resident control	≥ 30%	20–29%	< 20%
S1 Bio-based material share	≥ 50%	25–49%	< 25%
S2 Embodied carbon	≤ 200	201–250	> 250 ($kgCO_2eq/m^2$)
S3 Reuse / disassembly index	≥ 0.70	0.50–0.69	< 0.50
I1 Distinct configurable combinations	≥ 4	2–3	< 2
I2 Variation between dwellings	≥ 20%	10–19%	< 10%

8.6 Worked evaluation-variant 01 (Control and Comfort)

V01 is scored in full below: V02–V04 are read comparatively in §8.7 and developed scoring-calculation per KPI in Appendix C.4.

Table 8.5:Calculation per KPI for V01 Control and comfort.

KPI	Criterion / threshold	V01 design input	V01 calculation	Score
C1	Uw <= 0.9 W/m^{2}K for the selected window system.	CA01 uses Schüco AWS 90.SI+ / equivalent triple-glazed operable window family.	V01 selects Schüco AWS 90.SI+. Datasheet Uw = 0.8 W/m^{2}K (triple glazing).	Met=1
C2	Rc >= 4.7 m^{2}K/W for the opaque Layer 1 wall build-up.	Shared Layer 1 build-up with (used case study)	Calculated Layer 1 Rc ≈ 7.70 m^{2}K/W. Calculation: 7.70 / 4.70 = 1.64 times the target, therefore the opaque-wall target is met.(table 7.2)	Met=1
C3	At least one resident-operable opening per habitable room.	CA01 and CA02 operable windows are distributed across the representative habitable rooms.	Drawing check: 4 representative habitable rooms checked; 4 rooms have at least one operable opening. Calculation: 4 / 4 = 1.00 operable opening provision per room.	Met=1
C4	Daylight access: window-to-floor ratio >= 1:7, or equivalent design-stage daylight check.	V01 preserves the existing large opening fields; solar control is adjustable rather than permanently blocking daylight. FloorA rooms with window approx.= 120m 2 (2 app) Awindow 2 facades= 32m2	Threshold calculation: 1 / 7 = 0.143=14.4The V01 drawing is checked as compliant at design stage because the existing opening fields are retained and no fixed daylight obstruction is introduced. Awindow glazing south+north 32/ A floor area 2 app)120= 32/120=0,266= 26.7%, i.e. 1:3.75.	Met=1
C5	Ventilation capacity >= 25 m^3/h per habitable room.	Climate Agency ventilation provision is integrated through façade/window-mounted ventilation and operable openings.	Catalogue capacity check: the selected façade ventilation family covers approx. 30–200 m^3/h. Minimum check: 44,3 m^3/h >= 25 m^3/h, therefore the ventilation target is met. Ducoton 80 sr airflow=44,3 m^3/h/m @ 2 Pa	Met=1
A1	Cost efficiency façade per square meter <= EUR 450/m^2;	V01 uses the shared cladding-free Layer 1 baseline plus Rockpanel cladding, solar control, awning, privacy louvres, deep sill, storage, seating, and fixings.	A1_variant = Baseline price layer 1 (380/m2) + total Layer 2 component cost ÷ evaluated façade area = EUR 380/m^2 + EUR 14,250 / 85.08 m^2 = EUR 380 + EUR 167.5 = EUR 547.5/m^2, rounded to approx. EUR 548/m^2. Partial:451–600	Partial 0.5
A2	Maximum 12 different component families per variant.	V01 uses component families from Climate Agency, Social Threshold and Neighbourhood Face.	Catalogue family count: CA01, CA02, CA03, CA04, CA05, CA06, ST01, ST02, ST03, NF01, NF02 = 11 component families. Calculation: 11 <= 12.	Met-1
A3	Layer 1 module repetition >= 90% of the evaluated Layer 1 façade area.	V01 uses the same repeated aluminium Layer 1 technical baseline across the evaluated level.	Repetition calculation: identical Layer 1 area / total Layer 1 façade area x 100 = 85.08 / 85.08 x 100 = 100%. met (1)>= 90% of the Layer 1 façade area is built from identical repeated modules; partial (0.5) 80 -89%; and not met (0) <80%.	Met=1
F1	Layer 1 performance equality across dwellings	The V01 Layer 2 choices do not change the underlying Layer 1 performance layer.	Dwelling check: 2 out of 2 evaluated dwellings receive the same Layer 1 specification. Calculation: 2 / 2 x 100 = 100%.	Met=1
F2	100% documented selection logic.	All V01 component families are traceable to value priorities, design indicators, and component codes.	Traceability check: 11 selected Layer 2 component families documented through value -> design indicator -> façade criterion -> component code -> drawing location. Calculation: 11 / 11 x 100 = 100%.	Met=1
E1	≥ 4 resident-operable façade elements per dwelling.	V01 includes operable windows, controllable ventilation, outdoor blinds, sun awning, and manual privacy louvres.	Count directly resident-operable component families: CA01 + CA02 + CA03 + CA04 + CA05 + CA06 = 6. Calculation: 6 >= 4.	Met=1
E2	≥ 30% façade area under c direct resident control.	Adjustable area comes from operable openings, controllable ventilation, solar control, and louvres. sum of (window opening area	V01 drawing estimate: controllable area ≈ 35% of the evaluated façade area. ~21.6% windows + ~8% shading (blinds and awning) + ~5% threshold use ≈ 35%.(NF=8.878m2,SF=11,44m2)+ shading area + adjustable threshold area × 0.5) divided by total façade area of the unit. (14,18x3=42,54m2))The 0.5 weighting on threshold treats partial controllability conservatively.	Met=1
S1	Bio-based material share	V01 is dominated by non-biobased cladding	Selection of no biobased materials. >= 50%; partial = 25–49%; not met < 25% w So 0%	Not met=0
S2	Indicative embodied carbon <= 200 kgCO$_2$eq/m^2 façade area; partial where close to or slightly above the target.	Compute embodied carbon as sum of (mass per m^2 of each material × kgCO$_2$eq per kg from NMD Category 3 cradle-to-gate, EN 15804 modules A1 to A3).	Reference-band estimate for V01: approx. 200–290 kgCO$_2$eq/m^2 façade. The lower bound touches the 200 targets, but the upper bound exceeds it; therefore, V01 is scored as partial rather than met. Layer 1 ~140 plus rockpanel cladding (NF) ~85 ≈ 225 kgCO$_2$eq/m^2.	Partial= 0.5
S3	Layer 2 disassembly / reuse index >= 0.70.	V01 Layer 2 components are mechanically fixed catalogue elements with replaceable interfaces.	S3 sub= reversible fixing 1.0 x 0.30 = 0.30; independent removal 0.8 x 0.25 = 0.20; connection accessibility 0.8 x 0.20 = 0.16; reuse potential 0.8 x 0.15 = 0.12; documentation 1.0 x 0.10 = 0.10. Total = 0.88;	Met=1
I1	≥ 4 distinct Layer 2 combinations available per dwelling type.	V01 combines Climate Agency, Social Threshold and Neighbourhood Face components.	Combination check: two cladding expressions (NF01/NF02) combined with three threshold components (ST01/ST02/ST03). Calculation: 2 x 3 = 6 combinations; 6 >= 4.	Met=1
I2	≥ 20% variation between dwellings	Variation is created through different threshold components and balcony/street-side articulation between the two apartments.	Drawing count: 2 differing Layer 2 positions out of 9 configurable positions. Calculation: 2 / 9 x 100 = 22.2%, which is above the 20% threshold.	Met=1
			Score:	15/17

8.6.1 Worked calculation: affordability A1 (V01-V04)

A1 is calculated as a design-stage direct facade cost, not as a tender price. The KPI separates the shared Layer 1 baseline from the scenario-specific component catalogue selection. The calculation used in this chapter is:

A1_variant = Baseline price layer 1 (380/m2) + total Layer 2 component cost ÷ evaluated façade area

Layer 1 is treated as the standardised technical performance platform build up from : aluminium prefabricated cassette, ROCKWOOL insulation, airtight and weather-tight foils, secondary fixing rails, standard opening integration, and installation. Where the next component selection including cladding belongs to Layer 2 because it is part of the component catalogue and carries identity, sustainability, and neighbourhood expression.

The case-study geometry defines the calculated façade area for the deign variants: one facade face is 14.18 m x 3.00 m = 42.54 m2. V01, V02 and V03 use two facade faces, therefore 85.08 m2. V04 includes the same two facade faces plus an additional 25.00 m2 plinth / threshold zone, therefore 110.08 m2.

Table 8.9 : Shared Layer 1 baseline cost build-up used for A1, calculated per evaluated level.

Layer 1 cost category	Specific material / system reference	Estimated cost
Aluminium prefabricated carrier frame	Schuco AF UDC 80 aluminium unitised facade platform used as reference for the cassette: scalable prefabricated aluminium units, tested assemblies, and adjustable brackets.	€170/m²
ROCKWOOL insulation layer	ROCKWOOL Rockfit Duo stone-wool facade / cavity insulation, approx. 160 mm; RD approx. 4.70 m2K/W; lambda=0.034 W/mK	€45/m²
Airtight and weather-tight membranes	Airtight layer, water-resistant layer, tapes, seals, cavity/weather protection	€35/m²
Secondary fixing rails and thermal-break interfaces	Aluminium/steel rails, brackets, anchors, tolerance zones, thermal-brake pads	€45/m²
Standard opening / window integration allowance	Reveal, sill, head, frame interface, standard connection detailing	€55/m²
Installation, logistics and small fixings	Lifting, handling, standard assembly, minor fixings, tolerances	€30/m²
Total Layer 1 baseline	Shared technical façade package, excluding layer 2	**€380/m²**

The Layer 1 baseline is kept at EUR 380/m2. The layer 1 baseline price is an indicative design-stage estimate, not a tender price. It excludes VAT, subsidies, financing, long-term maintenance, and contractor-specific procurement conditions.

(partial 451–600)

For layer 2 cost estimate, the supplier source is taken from the component catalogue wherever possible. When the catalogue supplier publishes a retail or material price, that value is used directly. When the catalogue supplier works with project quotations only, the table records this and uses a conservative market allowance or public benchmark for design-stage comparison. A1 therefore estimates the order affordability; final values must be replaced by contractor quotations during technical development.

Table 8.10 :Layer 2 supplier and unit-price assumptions used for the A1 calculation.

Component catalogue code / supplier	**Supplier price basis used**	**A1 input value**	**Variation**
NF01 Rockpanel A2 cladding options - Rockpanel	Public Dutch retail references for Rockpanel Colours A2 are around EUR 90-95/m2 material-only; final installed price is project-specific.	EUR 93/m2 material reference; used for selected Rockpanel cladding areas.	Counted as Layer 2 cladding cost for V01, V02 and V04. Not included in the Layer 1 baseline.
ER01 MOSO Bamboo X-treme - MOSO / Gevelhout	Gevelhout lists MOSO Bamboo X-treme facade profiles from about EUR 94.74 to EUR 160.50/m2 depending on profile.	EUR 107/m2 representative material price plus clips / battens allowance.	Used in V03 as bio-based cladding premium.
ER03 Cloud Garden EFIX green facade - Cloudgarden	Cloud Garden states EFIX green facade systems at about EUR 600-1,200/m2.	EUR 900/m2 installed design-stage allowance.	Used in V03 where vertical greening is a main ecological component.
ER02 biodiversity insert - Vivara Pro / Schwegler	Vivara Pro products are quote-based; Schwegler 25A is a comparable built-in nest block. Public prices vary by distributor.	EUR 125/unit allowance.	Used in V03 as biodiversity premium.
CA03 BIPV facade panel - Solarix / Kameleon Solar	Solarix and Kameleon Solar are project/quote based. Published BIPV facade references commonly range about EUR 200-625/m2.	EUR 500/m2 installed design-stage allowance.	Used in V03 as productive facade surface.
CA04 textile screens - Renson Fixscreen GO / Verano V550	Verano V550 public retail examples start around EUR 499/unit; Verano solar zip screens are about EUR 900-1,300 for 3000 x 2000 mm.	EUR 499/unit for standard screen; EUR 250/m2 allowance for larger solar-control zones.	Used in V01, V02 and V04 as glare and overheating control.
CA05 outdoor blind / awning - HELLA AF 80 / Verano V225 Porto	HELLA AF 80 is quotation-based. Verano V225 Porto fixed size/manual public prices start about EUR 1,027/unit and other retailers show about EUR 1,299/unit.	EUR 1,027/unit for manual awning; HELLA blind zones treated by area allowance.	Used in V01 and V04 for balcony and courtyard shading.
ST01 deep windowsill - Dorpelshop / Hellopal / natural-stone or composite suppliers	Catalogue supplier prices vary by length, depth, and material.	EUR 250/unit installed allowance.	Used in V01 and V04 as inhabitable threshold edge.
ST02 exterior storage unit - Biohort / Lutrabox	Biohort HobbyBox 130 public retail price about EUR 389/unit; size 1340 x 620 x 710 mm.	EUR 389/unit.	Used in V01 as exterior balcony storage.
ST03 / ST04 seating and Juliet rail - MaximaVida / Vista Architectural	MaximaVida foldable facade bench public price about EUR 349/unit. Juliet rail systems are usually quotation-based; comparable railing references range widely.	EUR 349/unit for seating; EUR 600/unit allowance for Juliet rail.	Used in V01 and V04 as social-threshold components.

A1 calculation per scenario

Scenario	Layer 2 package counted in A1	A_facade	Total L2 cost	L2 premium	A1 result
V01 Control and comfort	Rockpanel cladding; solar control; awning; privacy louvres; deep sills; storage; bench; secondary fixings.	85.08 m2	EUR 14,250	14,250 / 85.08 = EUR 168/m2	380 + 168 = approx. EUR 548/m2; partial
V02 Affordable baseline	Repeated Rockpanel cladding; restrained screens; ventilation / opening allowance; minor fixing and opening contingency.	85.08 m2	EUR 9,600	9,600 / 85.08 = EUR 113/m2	380 + 113 = approx. EUR 493/m2; partial
V03 Ecological renewal	MOSO bamboo cladding; Cloudgarden greening; BIPV; biodiversity inserts; bio-composite zones; irrigation / electrical / access and secondary fixing premium.	85.08 m2	EUR 33,115	33,115 / 85.08 = EUR 389/m2	380 + 389 = approx. EUR 769/m2; not met
V04 Community threshold	Rockpanel plinth / threshold cladding; seating; Juliet rails; deep sills; screens; planter / carrier allowance; small fixings.	110.08 m2	EUR 14,710	14,710 / 110.08 = EUR 134/m2	380 + 134 = approx. EUR 514/m2; partial

A1, per-square-metre cost, is met (1) when the façade cost is at or below the deep-retrofit benchmark of €450/m²; partial (0.5) when it falls between €451 and €600/m², that is, up to roughly a third above the benchmark; and not met (0) above €600/m².

8.6.2 Worked calculation: embodied carbon (S2) for V01 and V03

S2 requires a non-trivial calculation chain: a bill of materials, an emission factor, and a system-boundary convention. This sub-section documents the full calculation explicitly so that the basis of the S2 scores is auditable.

Method. Embodied carbon is calculated as the sum, across each material in 1 m² of façade, of (mass per m² of façade) multiplied by (kgCO_2eq per kg of material). Mass per m² is derived from the build-up specifications in Chapter 5 (Layer 1, identical across all four variants) and Chapter 7, §7.6.7 (Layer 2 per variant), using standard material densities (mineral wool 30–40 kg/m³, wood-fibre 140 kg/m³, aluminium 2700 kg/m³, bamboo composite 1080 kg/m³, mineral cladding 1100 kg/m³). Emission factors are taken from Nationale Milieu database Category 3 reference values for cradle-to-gate (EN 15804 modules A1 to A3). The system boundary is the new façade only (Layer 1 plus Layer 2). The existing wall is excluded because it is pre-existing.

Reporting convention. Results are reported as a band reflecting variation in NMD Category 3 ranges. Tightening the band to a point estimate would require Category 1 product-specific EPDs from the manufacturers of the selected components. The reported band is conservative: each variant's score takes the worst-case end of the band as the reference for the threshold check.

V01 with its rockpanel cladding and aluminium-window combination produces a total of approximately 200 to 290 kgCO_2eq/m², reported as a band of approximately 200 to 250. The variant lands at or just over the 200 thresholds.

V03 selection of MOSO bamboo plus recycled-aluminium window frames combination produces approximately 137 to 197 kgCO_2eq/m², reported as a band of approximately 140 to 200. V03 lands well under the threshold. The architectural difference between mineral cladding and bamboo cladding is responsible for roughly 50 to 70 kgCO_2eq/m² of the spread. The aluminium recycled-content difference (verified through Schuco website: GWP 1.99 kgCO_2eq/kg for AWS 90.SI+ Green, compared to approximately 9 to 11 kgCO_2eq/kg for standard alloy) is responsible for roughly 80 to 110 kgCO_2eq/m².

S2, embodied carbon, is met (1) when the indicative A1–A3 embodied carbon is at or below the deep-retrofit benchmark of 200 kgCO_2eq/m² of façade; partial (0.5) between 201 and 250 kgCO_2eq/m², that is, up to roughly a quarter above the benchmark; and not met (0) above 250 kgCO_2eq/

Table 8.9:Embodied-carbon (S2) worked calculation for V01 (Comfort and Empowerment) and V03 (Ecological Renewal) using NMD Category 3 cradle-to-gate factors.

Material / component	Density (kg/m^3)	Thickness (m) or kg/m^2	Mass per m^2 façade (kg/m^2)	kgCO$_2$eq/kg (NMD Cat. 3, A1–A3)	kgCO$_2$eq/m^2 façade
LAYER 1 (constant across all four variants)	x	x	x	x	x
Mineral wool insulation, 160 mm	40	0.160	6.4	1.20–1.50	8–10
Wood-fibre sheathing, 60 mm	140	0.060	8.4	0.30–0.50	3–4
Aluminium carrier frame	x	8.0 kg/m^2	8.0	9.00–13.00 (recycled to primary source)	72–104
Wooden substrate sheet, 18 mm	550	0.018	9.9	0.40–0.60	4–6
Tolerance strip plus sealants plus fixings	x	x	1.5	1.00–2.00	2–3
Membrane plus accessories	x	x	0.5	2.00–3.00	1–2
Layer 1 sub-total (constant)					≈ 90–130 kgCO$_2$eq/m^2
LAYER 2 — V01 (mineral cladding + aluminium windows)	x	x	x	x	x
Rockpanel mineral cladding, 9 mm	1100	0.009	9.9	1.20–1.50	12–15
AWS 90.SI+ window unit (per m^2 façade share)	x	~12 kg/m^2 façade share	12	8.00–11.00 (incl. glass)	96–132
Threshold and shading components (allocated)	x	x	2.5	2.00–4.00	5–10
Layer 2 sub-total V01					≈ 113–157 kgCO$_2$eq/m^2
V01 total (L1 + L2)					≈ 200–290 kgCO$_2$eq/m^2. Reported band ~200–250
LAYER 2 — V03 (bamboo cladding + low-carbon Al)	x	x	x	x	x
MOSO Bamboo X-treme, 20 mm	1080	0.020	21.6	0.60–0.90 (incl. carbonisation)	13–19
AWS 90.SI+ Green (75% recycled Al, GWP 1.99 kgCO$_2$eq/kg)	x	~12 kg/m^2	12	1.99	~24
Cloudgarden plus planter substructure (allocated)	x	x	5	2.00–4.00	10–20
Solarix BIPV (allocated where applied)	x	x	8	5.00–8.00	40–64 (PV zones)
Layer 2 sub-total V03 (cladding-zone average)					≈ 47–67 kgCO$_2$eq/m^2
V03 total (L1 + L2)					≈ 137–197 kgCO$_2$eq/m^2. Reported band ~140–200

8.7 Total value-translation and comparative reading

Summarizing the KPI scores per value gives the value-translation profile of each variant. The profiles read as follows. See appendix C for the full calculations per KPI.

Table 8.11:Summary of KPI scoring value-translation profiles for the four design variants.

Value	Maximum	V01	V02	V03	V04
Comfort	*C1–C5 (5)*	*5/5*	*4.5/5*	*5/5*	*5/5*
Affordability	*A1–A3 (3)*	*2.5/3*	*2.5/3*	*2/3*	*2.5/3*
Fairness	*F1–F2 (2)*	*2/2*	*2/2*	*2/2*	*2/2*
Empowerment	*E1–E2 (2)*	*2/2*	*1/2*	*2/2*	*2/2*
Sustainability	*S1–S3 (3)*	*1.5/3*	*1.5/3*	*3/3*	*2/3*
Identity	*I1–I2 (2)*	*2/2*	*1/2*	*2/2*	*2/2*
Total	*17*	**15/17**	**12.5/17**	**16/17**	**15.5/17**

V01 performs strongest on comfort, empowerment, and fairness. The variant translates resident values into operable windows, controllable ventilation, solar control, privacy elements, and inhabitable threshold components. It is therefore strongest where residents need direct control over indoor climate, daylight, privacy, and the dwelling edge. Its limitation is that additional Layer 2 components increase system complexity, cost, and embodied carbon. V01 should therefore be read as a successful control-and-comfort facade, not as the cheapest or most ecological option.

V02 performs strongest on affordability related to the repetition in the design. It demonstrates that the system can keep a shared technical baseline and a limited component-family count. The trade-off is that resident control, identity expression, and social threshold qualities are less developed. V02 is useful as a reference variant because it shows what is gained and lost when the system prioritises industrial simplicity.

V03 performs strongest on sustainability while also maintaining comfort, empowerment, and identity. It uses the ecological regenerator logic most explicitly through bio-based materials, visible greening, and disassembly-oriented component choices. It receives the highest total value-translation score, but this should not be read as a universal ranking. It scores highly because the value priorities selected for V03 align strongly with the KPI set for sustainability, identity, and comfort.

V04 performs strongly on comfort, empowerment, identity, and fairness. Its main contribution is the translation of the facade into an inhabitable edge through seating, storage, Juliet rail extensions, cladding rhythm, and threshold articulation. It is less strong than V03 on sustainability, but more explicit in social and neighbourhood-facing value translation. The façade design is meant to not only perform as a thermal and material envelope, but a social edge where residents can pause, see, meet, and feel connected to the courtyard.

No variant scores 17/17. Each variant foregrounds particular value priorities and accepts trade-offs on the values it does not foreground. The four variants score predictably differently across the six values. The evaluation therefore confirms that the same framework can support different value priorities without losing the shared Layer 1 baseline. This logic is important for fairness. If a component changes during design development, procurement or construction, the trace-back record makes the value at risk visible. A substitute component can then be judged against the same value and indicator, rather than being selected only because it is cheaper or easier to source. The detailed trace-back tables and supporting calculations are placed in Appendix C.4 and D.

8.8 Chapter conclusion: answer to sub-question 5

Sub-question 5 asks *to what extent the resident values are visible, measurable, and differentiated across the resulting design variants*.

The evaluation shows that the resident values are visible because they appear in façade drawings and component catalogue-readable decisions.
They are measurable because each value is linked to a defined KPI, calculation boundary and scoring rule. Defined by units, thresholds, counts, area ratios, or traceability checks.
They are differentiated because the four variants produce different value profiles rather than one generic facade upgrade.
The answer to SQ5 is therefore positive, with a defined boundary.
The framework makes resident values legible and comparable in design-stage facade variants. The evaluation does not prove final building performance: final cost, embodied carbon, daylight, overheating risk, or resident satisfaction. Those claims require simulation, tendering, EPD-based LCA and post-occupancy validation. The implications of this result are discussed in Chapter 9.Instead it demonstrates that the Value-Indicator Framework, the two-layer system and the component catalogue together form a method for comparing how different resident values become design decisions within industrialised facade renovation.

Chapter 9: Discussion

9.1 Introduction

Chapter 8 demonstrated that the framework can produce different value profiles. This chapter discusses what that means for the method, the facade system, and the wider renovation context. The discussion focuses on five points: what the evaluation reveals about the framework, which trade-offs become visible, why the two-layer system matters, how sensitive the method is to changed input priorities, and where the limits of the KPI-based assessment remain.

9.2 What the evaluation reveals about the framework.

The framework operates as a translation method rather than as a product selector, where the framework carries a priority structure. If every variant had scored equally, the method would have produced only a generic good-practice facade. Instead, the scores show that different value priorities lead to different component selections, different facade characters, and different evaluation outcomes.

The intermediate steps are essential. Resident values cannot be moved directly into component choices. Comfort, identity, sustainability, fairness, and empowerment are too broad to specify a facade component on their own. Instead the framework produces a structured route from a resident value to a position on the façade, and back.

The route runs through the V-I Framework (value → indicator → criterion), through the modular system (criterion → Layer 1 + Layer 2 component selection), through the four-step configuration logic, and into the trace-back tables of Chapter 7 and the KPIs of Chapter 8. Every selected component on the façade can be retraced to a value that justifies it, through an indicator that operationalised it, into a KPI that tests whether the value remains visible.

This matters because Chapter 2 (§2.4) and Chapter 3 (§3.5) identified the value-design translation gap as the field-level problem the thesis sets out to address. Engagement methods surface resident values reliably across the European cases. What was missing in every case was the connection between what residents said and what the design did. Values appeared in consultation but disappeared from architectural decisions. The framework's response is to insert intermediate steps, so the chain does not break between Step 1 and the step where the modular façade gets built.

The four variants demonstrate that the framework does not produce arbitrary variation. The same project profile produces different variants because the value priorities are different. V01 prioritises comfort and empowerment; V02 prioritises affordability and fairness; V03 prioritises sustainability and identity; V04 prioritises empowerment, comfort, and identity. Each variant uses the same Layer 1, the same V-I Framework, and the same component catalogue. The variants differ in which Layer 2 components are selected and which value-affinity clusters are activated.

The result is not a universal facade recipe. It is a decision structure. That distinction is important. The framework does not say that every social housing renovation should use the same cladding, shading or threshold elements. It says that the route from resident value to facade decision should be explicit, bounded, and reviewable.

9.3 Trade-offs between resident values

The evaluation makes several trade-offs visible. These trade-offs are not failures of the method. They are the reason a value-led evaluation is useful. A facade that improves every value without cost, complexity or governance consequences would not be a realistic renovation system.

Table 9.1:Recurring trade-offs across the four variants.

Trade-off	What the evaluation shows	Implication
Comfort and empowerment vs affordability	More operable shading, screens, windows, and user-control elements improve comfort and agency, but they increase component count and cost. (V01 & V03)	Resident control has a cost. Comfort and empowerment must be designed within a bounded component catalogue, not added on top of a fixed system.
Sustainability vs affordability	Bio-based cladding, greening and BIPV improve ecological visibility and performance, but they create a high Layer 2 cost and the clearest affordability tension.	Ecological visibility requires early budget positioning, not late material preference. The affordability conversation must happen at Step 1, not at procurement.
Identity vs standardisation	Visible variation makes the facade recognisable and resident-facing (I1 and I2), but excessive variation weakens repetition and simplicity important for rapid and affordable standardisation.(V02)	Identity needs controlled variation, not unlimited customisation. The bounded option set is the mechanism through which identity becomes legible without each dwelling becoming a unique product.
Fairness vs differentiation	Layer 1 protects baseline equality, while Layer 2 allows difference.	Fairness is secured at Layer 1 and the trace-back logic, not at Layer 2. The framework separates fair-baseline-performance from resident-led-differentiation.

The trade-offs are not weaknesses. They are the point at which value translation becomes architectural. A value-led façade system that hides its trade-offs is not value-led; it is value-claiming. The framework's job is to make the trade-offs legible so that residents, the housing association, the architect, and the contractor can see what each variant costs and gains.

V04 is especially important for this discussion. The community-threshold variant shows that a technical adjustment can create a social outcome. By thickening the ground-floor facade zone, adding seating, planters, Juliet rails, shading and bicycle-related elements, the façade design becomes more than a thermal envelope. It becomes an intermediate space between the dwelling and the courtyard. This supports informal encounter, everyday surveillance, a safer edge, and a clearer connection between inside and outside. The social effect is not added after the technical design; it is carried by the spatial and material organisation of the facade.

9.4 The role of the two-layer façade logic

The two-layer logic is the central technical move that makes the value framework designable.

Layer 1 carries the slow-changing, equal technical baseline performance: insulation, airtightness, weather protection, anchoring, installation logic, and technical repetition.

Layer 2 contains the faster-changing resident-facing decisions: cladding, shading, greening, threshold elements, storage and other visible or operable components that form the adaptable interface residents can touch and interact with.

The separation does two things.

First, it protects fairness. Without a shared Layer 1, resident-facing variation could produce unequal technical performance between dwellings. By holding Layer 1 equal, Layer 2 can vary without turning resident preference into technical inequality. The F1 fairness criterion highlights the importance of this point.

Second, the two-layer model makes industrialisation and adaptability possible. The component catalogue does not maximise choice; it bounds it. Layer 2 can be updated, repaired, or reconfigured without redesigning the performance layer. This Layer 1 base platform is used across all variants, which lets the same factory line, anchoring strategy, and prefabrication tolerances support different design outcomes. This is the difference between customisation, which requires bespoke engineering for each dwelling, and structured variation, which works within an industrial discipline. The current industrialised façade systems can do customisation at project level, but they do not formalise structured variation at dwelling level.

This gives the two layered system a longer useful life than a monolithic facade assembly in which cladding, insulation, structure and resident-facing choices are coupled too tightly.

9.5 Sensitivity of the framework

The framework is sensitive to changing input conditions by design. It does not produce one fixed façade answer, but a different traceable configuration when resident priorities, affordability limits, catalogue options or engagement conditions change. This sensitivity is not a weakness; it is what allows the method to respond to situated project conditions.

Table9.2:Sensitivity of the framework to its main input variables.

Input variable	What changes in the framework	Why it matters
Resident priority brief (step 1)	Different Layer 2 components become relevant. A comfort-led profile activates shading and operability; an ecological profile activates greening, bio-based cladding, and BIPV; a community-threshold profile activates seating, planters, and facade depth.	The method is responsive rather than fixed. It produces different variants because value priorities change, not because the designer invents unrelated options.
Affordability threshold	A stricter threshold reduces component families and favours repetition. A looser threshold allows more resident-facing components and greater differentiation.	Cost is not a late procurement issue. It is a design boundary that shapes how much variation can be offered fairly.
Component catalogue size	A smaller catalogue protects repetition and maintenance simplicity. A larger catalogue increases resident choice but adds procurement complexity and risk of unequal outcomes.	Choice must remain bounded. The catalogue should not maximise options; it should define a manageable set of meaningful variations.
Engagement timing and representation	If engagement starts late, value priorities enter after criteria, and component directions are already fixed. If the Resident Design Council is too small or self-selected, the priority brief becomes biased.	The quality of participation affects the design output. The framework only works if resident input enters before Step 2 and if the Council represents more than the most active residents.

Other variable inputs could be Layer 1 baseline performance specifications and building regulations which are less flexible. If future regulatory thresholds become stricter, the Layer 1 specification would need to be adjusted before Layer 2 configuration begins. That would change the technical floor of the system, but not the translation logic itself. The resident-facing decisions would still be organised through Layer 2, the catalogue, and the trace-back chain.

The sensitivity analysis shows that the framework depends on bounded variation. If the catalogue is too small, the facade becomes technically efficient but socially unresponsive. If the catalogue is too large, the system risks procurement complexity, unequal outcomes, and loss of industrial repeatability. The critical design task is therefore not to maximise choice, but to define the level of variation that is meaningful for residents and still manageable for the housing association, supplier, and contractor.

9.6 Limits of the KPI-based evaluation

The KPI evaluation gives the framework methodological discipline, but it has limits. Several KPIs are design-stage proxies: A1 uses supplier assumptions rather than tender prices, S2 reports indicative cradle-to-gate embodied carbon rather than a full life-cycle assessment, E2 measures resident-controlled area but not actual use; F2 measures traceability in design documentation but not whether tenants experience the process as fair. The evaluation tests visibility, measurability, and differentiation in the design output. It does not test final building performance, occupant satisfaction, or procedural justice.

This limit matters because the thesis works from secondary case evidence and a design-stage application. The evaluation shows that values are embedded in the design logic; it does not show that the built renovation would produce resident satisfaction, energy savings, or institutional trust. Those outcomes require resident engagement or post-occupancy monitoring, formal simulation, and longitudinal evaluation, which are out of scope for design-stage evaluation. These indicators can be categorized into three groups:

Subjective indicators that need resident input, examples such as perceived thermal stability, sense of agency, façade recognisability, visible nature, carbon-storage visibility, actual energy use, resident satisfaction, full life-cycle assessment, maintenance performance, governance quality and real disassembly testing.

Resident-side financial indicators, examples such as housing-cost change, payback period, total housing-cost neutrality.

Governance and process indicators, examples such as procedural justice, consultation depth, transparency of decision-making. These are relevant points for post-occupancy work.

None of these can be generated through design-stage analysis. Future work combining the framework with post-occupancy research would be able to evaluate them.

9.7 Transferability of the method

The method is transferable as a process, not as a fixed component set. What transfers is the structure: resident values → design indicators → façade criteria → layer 2 component catalogue → design application → KPI evaluation.

Another housing block, another city, another housing association would require a different project profile, different priorities, different costs, and different components. The structure remains, the contents change.

Transferability is strongest to post-war multi-family housing in the Netherlands or comparable European contexts where deep renovation is due and an industrialised approach is desired.

It is weaker where the building carries heritage constraints, where geometry is highly irregular, where project scale is too small to justify prefabrication, or where governance prevents tenant engagement from influencing strategic priorities. The Resident Design Council and the three-channel hybrid communication system documented in §6.3.5 are determined for Dutch social-housing practice and would need reconsidering elsewhere.

The framework can also work as a communication tool independently of the technical system. Instead of presenting residents with a finished design, housing associations can show which decisions are fixed (Layer 1), which are open (Layer 2 within the catalogue), and how value priorities influence the selection. This does not remove conflict. It makes the design reasoning visible, which is a precondition for the trust the cross-case material in Chapter 3 shows is often absent. It is relevant for designers because it turns resident values into design indicators and drawing decisions. It is relevant for manufacturers because it suggests where product platforms could support bounded variation rather than one-size-fits-all repetition.

Transferability has limits. The method is most suitable where the facade is a major renovation object, where the housing provider can define a shared baseline, and where a component catalogue can be negotiated before procurement. It is less suitable for emergency repairs, highly fragmented ownership situations, or projects where resident engagement is only allowed after technical decisions are closed.

9.8 Discussion conclusion

The framework reads most convincingly as a traceable design method that makes trade-offs legible rather than resolving them. The two-layer separation is what gives the framework its analytical clarity: by holding Layer 1 constant, it forces the trade-offs into Layer 2 where they can be named, scored, and reviewed. The framework does not claim to resolve the conflict between technical performance, affordability, and lived experience, it gives that conflict a defined place in the design process.

Chapter 10 closes the thesis by answering the sub-questions, naming the contributions, formulating recommendations, and reflecting on what the project did and what it could not yet do.

Chapter 10: Conclusion, recommendations and reflection

10.1 Introduction

This chapter answers the sub-questions and the main research question, names the contributions, formulates recommendations for further research and practice, and reflects on the research and design project.

10.2 Answers to the sub-questions

The five sub-questions break into three parts, following the structure of the thesis itself: identifying the problem (SQ1), building the framework (SQ2 to SQ4), and testing whether it works (SQ5).

Problem identification

SQ1: Which resident values recur across European social-housing renovation cases, and what currently prevents them from shaping design decisions?

Six resident values recur across the eight European social-housing renovation cases analysed in Chapter 3 (Reigersbos worked case in §3.4, seven additional cases in Appendix A): comfort and usability, affordability, fairness and trust, empowerment and agency, sustainability, and identity and belonging. The values appeared across diverse socio-cultural and climatic contexts, although their articulation differed depending on governance structure, engagement depth, and refurbishment ambition . They fail to shape design for four recurring reasons:

First, engagement happens too late, after the technical and financial decisions that narrow the design space have already been made.

Second, residents speak in everyday language, and designers speak in architectural language, and translating between the two is not done systematically.

Third, when resident input does enter the process, it is not consistently traced into the resulting design decisions, so the influence of engagement becomes invisible.

Fourth, the residents most affected by renovation (older residents, residents with a different language, residents who do not attend public meetings) are systematically missed by participation processes that depend on people signing up to attend workshops.

The result is that values are visible in consultation but disappear from architectural outcomes, the value-design translation gap this thesis sets out to close.

Framework structure

SQ2:How can these resident values be translated into architectural design indicators for façade renovation?

Resident values are translated by treating indicators as intermediate constructs between the participatory conversation and the technical specification. Or in other words as an intermediate for what residents express and what the façade is asked to perform.
The Value-Indicator Framework developed in Chapter 4 breaks each of the six values down into a small set of architectural indicators: comfort into thermal performance (C1, C2), operable openings and natural ventilation (C3, C5), daylight access (C4), and solar control; affordability into the number of distinct component families (A2), repetition of the shared baseline (A3), and per-m² cost (A1); fairness into baseline equality across dwellings (F1) and a documented selection logic (F2); empowerment into the number of resident-operable elements per dwelling (E1) and the share of façade area under direct resident control (E2); sustainability into bio-based material share (S1), embodied carbon (S2), and reuse and disassembly potential (S3); identity into the number of distinct configurable combinations (I1) and the degree of variation between dwellings (I2).
The full value → indicator → criterion matrix is recorded in Table 4.5 and developed value-by-value in Tables 4.3.1 to 4.3.6. The indicators are specific enough to guide design while keeping the qualitative meaning of each value intact. This is what distinguishes the framework from engagement methods that surface resident values without binding them to architectural decisions.

SQ3:How can these design indicators be operationalised into a modular façade system suitable for industrialised refurbishment?

The indicators are operationalised through the Value-Integrated Modular Façade System (VIMFS) developed in Chapter 5, which separates the façade into two layers that perform distinct roles.

Layer 1 is the standardised performance layer (§5.6): it brings together four component groups (anchoring, structural frame, performance core, sealant and joint system) and delivers the deep-retrofit baseline equally to every dwelling. Layer 1 inherits its construction logic from the unitised façade tradition (reviewed in Appendix C.1) and uses three design versions called base platforms: closed, open, and service-ready, to match the different conditions found in the post-war walk-up typology (§5.6.3).

Layer 2 is the adaptive resident-facing layer (§5.7): it carries the parts of the façade that residents see and interact with, including cladding, shading, greening, threshold elements, and operable controls. Layer 2 is organised into four clusters that group components by which values they support (value-affinity clusters): Ecological Regenerator, Social Threshold, Climate Agency, and Neighbourhood Face, and uses a bounded component catalogue documented in full in Appendix B.

Reversibility of Layer 2 is treated as a working principle of the system rather than as a worked-out connection detail, the design-for-disassembly principles of Durmisevic (2006) and Brand's shearing-layers logic (§5.4) underpin this assumption, but the specific reversible fixings, demounting sequences, and component-replacement scenarios are identified as further research in §10.5.1.

The two-layer separation is the design move that lets industrialised standardisation (Layer 1) and resident-led variation (Layer 2) coexist within one façade system.

SQ4: How can a configuration logic translate value priorities into traceable design variants within this system?

Chapter 6 develops a four-step configuration logic (Table 6.1) that translates value priorities into traceable design variants.

Step 1:builds the project profile from four parts: building conditions, design objectives, living situation, and value priorities, and organises tenant engagement as a seven-step process, supported by the Resident Design Council, a three-channel communication system (project website, monthly newsletter, entrance-hall information board), and the bewonersbegeleider (tenant liaison) as the person who keeps continuity across phases.
Step 2:translates the value priorities into façade criteria through the V-I Framework.
Step 3:assigns those criteria to the two-layer system, keeping Layer 1 identical across all variants and choosing Layer 2 components from the catalogue by matching the value priorities to the four cluster types (Table 6.7).
Step 4: compares the resulting variants on five criteria (Table 6.8): dominant values, living situation addressed, selected Layer 2 components, character of the north and south façade response, and main façade ambition. This makes the variants comparable without reducing them to a single ranking.

The trace-back chain documented in Chapter 7 and Appendix D records how each value priority moves through the design process:
resident value → design indicator → façade criterion → Layer 2 component → design application → KPI

In this way, the configuration logic translates value priorities into design variants by making every step of the design route explicit. A value priority is first reformulated as a design indicator and façade criterion, then linked to a Layer 2 component, applied in the façade design, and finally evaluated through a KPI. The result is a set of variants that are not arbitrary alternatives, but traceable design responses to different value priorities within the same modular façade system.

Framework evaluation

SQ5: To what extent are the resident values visible, measurable, and differentiated across the resulting design variants?

The evaluation in Chapter 8 confirms that the values are visible, measurable, and differentiated across the four design variants developed for the case study in Rotterdam-West.
Visibility is established because each value appears through design decisions that can be read directly from the façade drawings or the component catalogue (§8.4).
Measurability is established through seventeen KPIs (C1 to C5, A1 to A3, F1 to F2 E1 to E2, S1 to S3 I1 to I2,)drawn from three source categories: Dutch building regulation, published industry references and product standards, and the V-I Framework itself for the indicators that have no external benchmark.
Differentiation is established by the four variants' distinct value profiles: V01 (Control and Comfort) scores 15/17, V02 (Clear and Affordable Upgrade) scores 12.5/17, V03 (Ecological Renewal) scores 16/17, and V04 (Community Threshold) scores 15.5/17.
Each variant emphasises different value priorities while sharing the same Layer 1 baseline, which keeps the F1 fairness reading equal across all dwellings.

10.3 Answer to the main research-question

The main research question asks: *how can resident values be systematically integrated into modular façade renovation design in social housing?*

Resident values can be systematically integrated by treating them as the starting point of a traceable design chain, rather than as late-stage consultation input. In this thesis, that chain moves from resident values to design indicators, from indicators to façade criteria, from indicators to façade criteria, and (via the configuration logic)from criteria to Layer 2 component selections, scenario applications, and KPI-based evaluation.
The systematic contribution lies in this sequence. Resident values are not only identified or described; they are translated, operationalised, configured, and evaluated. Three linked artefacts make this possible:

- The Value–Indicator Framework structures the six recurring values : comfort, affordability, fairness, empowerment, sustainability, and identity, into seventeen design indicators and corresponding façade criteria.
- The Value-Integrated Modular Façade System (VIMFS) gives those values a technical structure: Layer 1 secures the shared performance baseline, while Layer 2 carries resident-facing variation through a bounded component catalogue.
- The configuration logic is the operator that turns a project's value priorities into a specific façade by activating value-affinity clusters, selecting components, and producing a trace-back table that records why each choice was made.

The four design variants demonstrate the result of testing these artefacts to a case study, resulting in: the same building, the same Layer 1 baseline, and the same component catalogue producing four recognisably different value profiles, each evaluated through the same seventeen KPIs.

The answer is therefore not one final façade design. It is a method for producing value-responsive façade variants within a modular renovation logic. Its strength is that it makes the route from resident concern to design decision visible enough to be discussed, checked, adjusted and evaluated. In this way, resident values become more than participation outcomes; they become design inputs that can be traced through the façade system itself.

10.4 Main contribution

The thesis makes six contributions that together reframe modular façade renovation from a primarily technical question: “which façade system delivers the energy target?”, into a value-translation question: “*how do resident values become visible in the built outcome?*” Together, these contributions define a method for translating resident values into modular façade renovation design.

The contributions are not separate outputs but connected parts of one design chain. The engagement protocol produces value priorities; the Value–Indicator Framework translates these priorities into design indicators; the two-layer façade system gives them a technical structure; the component catalogue makes variation selectable; the configuration logic turns this selection process into design variants; and the KPI framework evaluates whether the values remain visible, measurable and differentiated.

Table 10.1: Contribution of the thesis categorised in six themes

Contribution	**What it adds**
Value-translation method	The thesis gives resident values an operational route into façade design. It connects case-derived values to design indicators, façade criteria, Layer 2 component choices, design application and KPI-based evaluation.
Two-layer façade logic	The separation of Layer 1 and Layer 2 turns a technical system principle into a fairness argument. Layer 1 secures equal baseline performance across dwellings, while Layer 2 allows resident-facing variation without re-engineering the shared technical envelope.
Component-catalogue approach	The catalogue structures choice without allowing unlimited customisation. It makes bounded variation possible within an industrialised renovation system by organising Layer 2 components into selectable value-affinity clusters.
Configuration logic	The four-step configuration logic makes the design process readable from project profile to selected design variant. It translates the value-priority brief into façade criteria, component selection and design variant comparison, so that the design process is traceable rather than intuitive only.
Engagement structure	The proposed tenant-engagement structure connects familiar Dutch renovation participatory practices, such as the bewonersbegeleider / tenant liaison, door-to-door visits, information evenings and Resident Design Council workshops, to the configuration logic. Its novelty lies in binding engagement outputs to value priorities, design indicators, component directions and the trace-back log.
Evaluation framework	The KPI system tests whether values are visible, measurable and differentiated across the design variants. It shifts the assessment from selecting a single “best” option to comparing value profiles, trade-offs and design-stage evidence.

The engagement structure is not an additional participation layer beside the design method. It is the input mechanism of the configuration logic. Its techniques are familiar within Dutch renovation practice, but the thesis changes their role: tenant input is not only collected, but translated into value priorities, carried through the component catalogue, documented in the trace-back log and tested through the KPI framework. The deeper contribution is therefore the auditability of value translation. Each major design decision can be traced back to the resident value that justified it and forward to the evaluation criterion through which it is assessed.

10.5 Future recommendations

10.5.1 For further research

The evaluation and reflection show that the framework is sufficiently structured to be tested, but not yet complete as an implementation tool. This thesis demonstrates the value-translation logic at design stage. Further research should therefore focus on moving the framework from a thesis-based design method toward a tested renovation process.

- **Test the tenant-engagement protocol with actual tenants in a real-life renovation project.**
  The Resident Design Council should be tested as a procedural body within a real housing-association process before the protocol is used as a project decision tool. A real-life test would show whether the value-priority brief reflects tenant concerns, whether the trace-back log supports trust, and whether the three communication channels reach residents who do not engage through one channel alone.
- **Develop a contractor-reviewed cost plan for Layer 1 and the main Layer 2 component families.**
  The A1 affordability indicator should move from supplier-based design estimates to project-specific cost planning. This would make the cost evidence more reliable and clarify which forms of Layer 2 variation remain feasible within social-housing budgets.
- **Develop the S2 embodied-carbon assessment into a full EPD-based life-cycle assessment.**
  A complete A1–C4 life-cycle assessment (LCA) would extend the current assessment boundary to manufacturing, transport, installation, use, maintenance and end-of-life. This should follow EN 15804+A2 and Dutch NMD conventions so that embodied-carbon comparison becomes more robust.
- **Run overheating, ventilation, daylight and acoustic simulations for the selected design variant.**
  In this thesis, C4 is currently scored against the Dutch building regulation (Bbl 2024 and NEN.)A full calculation would extend the verification beyond the area-based check and reveal per-room daylight quality across the building unit.

- **Develop the reversibility of Layer 2 as a worked-out connection design.**
  The thesis treats reversibility as a system principle, following Durmisevic's design-for-disassembly logic and Brand's shearing-layer theory. The next step is to specify the actual reversible fixings, joint details, demounting sequences and component-replacement scenarios, and to verify them through physical prototyping. This would move reversibility from a design-stage assumption to a detailed technical specification.
- **Test the social-threshold assumption through spatial simulation, resident review or a small mock-up.**
  Currently design variant 4 assumes that increased threshold usability support perceived safety, informal contact and social cohesion. This claim should be tested through resident feedback, behavioural observation, spatial simulation or a full-scale façade fragment.
- **Apply the framework to additional post-war housing typologies.**
  The framework should be tested on gallery flats, point blocks and larger housing complexes to understand whether the method remains usable beyond the Gijsingstraat walk-up case, and where its boundary conditions appear.

10.5.2 For design practice

For architects and façade designers, the main recommendation is to use the framework at the beginning of the renovation process, before the façade system, component directions and cost boundaries have already been fixed. Five recommendations follow.

- **Begin tenant engagement before façade criteria and Layer 2 component directions are fixed.**
  The framework's central commitment is to reverse the late-engagement pattern identified in the cross-case analysis. Resident input only has design impact if it enters before the design criteria are stabilised.
- **Separate fixed technical requirements from open resident-facing choices in tenant communication.**
  The Layer 1 / Layer 2 distinction should be used as both a technical and communicative tool. Layer 1 can be explained as the equal performance baseline; Layer 2 as the zone where bounded resident-facing variation is possible.
- **Use a bounded component catalogue rather than unlimited customisation.**
  Structured variation can produce recognizable differences between the value-clusters while keeping the system industrially feasible and accessibility manageable.
- **Document every selected component through the trace-back chain.**
  Each major component should be linked to the chain:
  resident value → design indicator → façade criterion → component code → design application → KPI.
  This trace-back is the mechanism through which value translation becomes traceable.
- **Treat affordability and fairness as process conditions, not only as design outcomes.**
  Affordability should be introduced transparently at the plenary stage, before residents are asked to discuss preferences. Fairness is protected by holding Layer 1 equal across dwellings and documenting how Layer 2 choices are selected.

10.5.3 For housing associations and suppliers

For housing associations and façade suppliers, the framework is most useful when it is treated as a shared decision-support structure rather than only as an architectural design method. Four recommendations follow.

- **Maintain a continuity figure throughout the renovation process.**
  A bewonersbegeleider, tenant liaison or equivalent role should stay involved across design, procurement, construction and delivery. This role is essential for continuity between tenant input, design decisions and communication.
- **Publish key design decisions through multiple communication channels.**
  The project website, printed newsletter and entrance-hall information board should be used together. Multi-channel communication should be treated as a procedural condition of the renovation, not as an optional communication layer.
- **Develop modular façade products with a clear long-life / short-life separation.**
  Suppliers should distinguish between durable technical support layers, equivalent to Layer 1, and replaceable resident-facing components, equivalent to Layer 2. This would make adaptability easier to implement in real projects.
- **Publish transparent product data for value-based comparison.**
  Product information should include cost range, embodied carbon, maintenance requirements, expected service life, replacement logic and disassembly method. Without this information, architects and housing associations cannot compare components according to resident values, circularity and long-term use.

10.6 Reflection

10.6.1 Positioning the thesis within Building Technology Graduation studio.

The thesis is positioned between two worlds that are often separated in modular façade renovation. The first is the technical world of regulation, thermal performance, prefabrication, material systems, cost control, tolerances and construction logic. The second is the societal world of residents, everyday routines, comfort expectations, affordability concerns, identity, trust, safety and control.

The reason I chose this topic is that façade renovation is often described through performance language, while residents experience it through daily life. A new façade is not only a new thermal layer or technical skin. It changes how people open a window, look outside, feel privacy, recognise their building, understand costs, experience safety and trust the organisation carrying out the work. This difference between professional performance language and resident experience became the motivation for the thesis.

As a Building Technology graduation project, the aim was not to reject technical precision. A façade still must insulate, carry loads, keep water out, be buildable, remain affordable and comply with regulation. The aim was to test whether this technical precision could be directed by resident values rather than separated from them. Building Technology is therefore used as the medium through which resident values become designable. Without this translation, resident values risk remaining stuck at the level of consultation.

The thesis also responds directly to the research gap defined in Chapter 1: the absence of a structured framework that connects resident values to architectural design indicators, façade criteria, system logic and modular façade configurations in a traceable way.
In that sense, the project is not only about designing a façade system; it is about designing a method through which resident values can enter industrialised refurbishment without losing technical accountability.

10.6.2 Reflection on the research approach

The thesis combines Design Science Research, Research by Design and diagrammatic reasoning. This combination was necessary because the project had to develop both a method and a design application. Design Science Research helped structure the analytical artefacts: the Value–Indicator Framework, the Value-Integrated Modular Façade System and the configuration logic. Research by Design then tested whether those artefacts could produce actual façade variants rather than remain conceptual models. Diagrammatic reasoning connected the two by making the translation from values to indicators, criteria, components and evaluation visible.

The approach worked because the research and design were not separate phases. The framework shaped the design variants, but the variants also tested the framework. Drawing, selecting components and comparing variants revealed tensions that theory alone did not show. For example, the trade-offs between comfort and affordability, sustainability and cost, identity and standardisation, or fairness and variation only became clear once the values were pushed through a component catalogue and applied to a real façade case.

At the same time, the method had limits. The project shifted during its development from designing a façade product toward designing a traceable method for façade configuration. This was a productive shift, but it also meant that the four design variants should not be read as final proposals ready for construction. They are design-stage tests of the method. Their role is to show whether value priorities can produce distinct, traceable and comparable façade outcomes within one modular system.

This is the main strength and weakness of the research approach. Its strength is that it makes the value–design translation process explicit. Its weakness is that the framework is tested through design-stage evidence rather than through implementation, resident feedback, tender pricing, post-occupancy monitoring or physical prototyping. The approach led to the intended result, a structured value-translation method, but not yet to a validated renovation process.

10.6.3 Reflection on standard values and resident values

A central methodological tension in the thesis is that it questions renovation processes dominated by standard technical values, while the evaluation itself also uses regulations, thresholds and KPIs. Chapter 8 evaluates the variants through Dutch building regulation (Bbl 2024)benchmarks, cost assumptions, façade-area calculations, component counts and material indicators. These are standardised forms of assessment, while the thesis argues that resident values should become more central.

This is not a contradiction, but it is a tension that needs to be acknowledged.

The thesis does not argue that technical standards should disappear. In social housing renovation, standards protect minimum quality, safety, fairness and technical accountability.

The problem is not the existence of standards; the problem is the moment at which they dominate the design process. In many renovation processes, technical standards define the problem before resident values have been translated. In this thesis, the order is reversed: resident values are structured through the Value–Indicator Framework first, and only then evaluated through measurable criteria.

Still, the approach has limits. Because the thesis had to remain verifiable within the time and scope of graduation, several indicators were evaluated through design-stage proxies rather than resident-defined thresholds. Comfort, for example, was assessed through thermal performance, operability, shading and daylight-related criteria.

Yet the meaning of comfort is not universal. An elderly resident may value stable temperature, low draught and simple operation. A younger household may accept more temperature variation but prioritize daylight, exterior use or identity. A high comfort setting might increase insulation thickness, improve window performance, add exterior shading or increase operable area. A high affordability setting might reduce the number of component families and favour repeated solutions.

A high identity setting might allow more variation in colour, rhythm or material expression. A higher-income ownership context might allow more expensive Layer 2 options, while a social housing context requires stricter affordability boundaries.

A stronger future version of the framework would therefore contain value-level sliders that allow residents, housing associations and designers to adjust the intensity of each value throughout layer 1 and 2 before component selection begins. The framework would not only ask which values matter, but also how strongly they matter and what level residents consider acceptable. Such a tool would make trade-offs visible. It could show, for example, how increasing comfort affects façade thickness and cost, or how increasing identity affects repetition and maintenance.

This would combine regulatory benchmarks with engagement-based thresholds. The thesis demonstrates the structure for that translation, but it does not yet prove that the chosen thresholds are the correct ones for the actual residents of the selected case study.

10.6.4 Reflection on the engagement structure

The engagement structure was not the starting point of the thesis. My initial focus was on the translation from resident values into design indicators, system logic, component choices and KPI evaluation. During the development of the project, however, it became clear that this translation could not be convincing without a proposed implementation context. If resident values are to become design inputs, the thesis also must explain how those values would be collected, prioritised, communicated and reviewed in practice. The engagement protocol in Chapter 6 was therefore developed as a methodological scenario: not as completed fieldwork, but as the procedural setting in which the value-translation framework could realistically operate.

The engagement structure responds to the cross-case finding that resident values are often surfaced through engagement but enter too late to shape architectural decisions. The thesis therefore tries to move engagement to the beginning of the configuration logic, before façade criteria and layer 2 component direction are fixed.

The thesis does not claim to know what Gijsingstraat residents want. It proposes a method through which their values could be collected, translated, reviewed and evaluated if the protocol were applied in a real housing-association renovation project.

The Resident Design Council should also be understood carefully. It is not presented as a legal decision-making body and does not replace the authority of the housing association. Its role is procedural: it checks whether resident values remain recognizable as they move into value priorities, design indicators, component directions and trace-back documentation. This is important because claiming legal power for the Council would be unrealistic. A more defensible claim is that the Council makes translation visible and reviewable.

The engagement structure is therefore both necessary and incomplete. It is necessary because without it, the framework risks speaking about residents rather than with them. It is incomplete because its actual reachability, trust-building capacity and representativeness remain untested. The next step is to test the Resident Design Council, value cards, tenant liaison role and three communication channels with actual tenants in a live renovation process.

10.6.5 Reflection on the two-layer system and component catalogue

The Layer 1 / Layer 2 separation became more than a technical ordering principle. It became the ethical and organisational structure of the proposal.
Layer 1 secures the equal technical baseline: insulation, airtightness, weather protection, structural support and performance reliability.
Layer 2 carries the resident-facing variation: cladding, shading, greening, storage, seating, privacy elements and threshold components.

This separation matters because it allows fairness and variation to coexist. If every dwelling receives the same Layer 1, the technical baseline remains equal. If Layer 2 can vary, residents or resident groups can still influence the façade elements that shape comfort, identity, control, sustainability and threshold use. The thesis therefore does not treat standardisation and resident responsiveness as opposites. It uses the two-layer system to organise their relationship.

The component catalogue supports this relationship, but it also raises a critical question: how much choice should be offered?

A larger catalogue can support more resident choice and more identity expression, but it can also create procurement complexity, higher maintenance demand, increased cost and unequal outcomes. A smaller catalogue protects repetition and affordability but may become too narrow to reflect real resident priorities.

The purpose of the catalogue is therefore not to maximise choice. Its purpose is to structure bounded variation: enough options to express meaningful value differences, but not too many that the industrialized renovation logic becomes unmanageable.

This is one of the main lessons of the project. Value-led design does not mean unlimited customisation. It means controlled variation with a traceable reason.

10.6.6 Testing the framework against change.

A method for façade renovation must be able to respond to future change. Especially a relevant question for this thesis positioning itself between the societal and technical world. The façade developed in this thesis is situated in a specific case-study context, but the social world around a building change: tenants move, household structures shift, residents age, work patterns change and the use of the dwelling may be different in twenty or fifty years.

A façade that responds well to one resident group may not respond equally well to another.

The technical world also changes resources become limited, material prices rise, embodied-carbon regulation tightens, suppliers may no longer deliver the same products, and climate conditions will continue to change.

A façade designed for today’s heating-dominated renovation targets may need to perform differently under future conditions of overheating, heavier rainfall, changing ventilation needs and increased cooling demand.

The two-layer logic is the thesis response to this uncertainty. Layer 1 protects the long-term technical baseline, while Layer 2 carries the adaptable resident-facing interface. This means that future changes in privacy, shading, threshold use, identity or climate response can, in principle, be addressed through Layer 2 without replacing the entire envelope.

Under changing technical conditions, the component catalogue would also need to operate as a value-aware substitution tool. If a specific cladding material, insulation type or shading component becomes unavailable, the design team should not only ask which replacement is cheapest or easiest to procure. It should ask which available component still supports the same resident value and design indicator.

This is where the trace-back logic becomes essential. If each component is linked to a resident value, design indicator, façade criterion, design application and KPI, then substitution can remain value aware. Without that record, material replacement risks becoming purely technical or financial. With it, the team can test whether the alternative still supports comfort, sustainability, identity, control or affordability in the same way.

The technological context may also change. AI-supported design and manufacturing could make modular façade configuration faster and more precise, for example by generating module layouts, coordinating factory production or testing component combinations. However, if optimisation is driven by cost, carbon or production efficiency, resident values may again become secondary. In that context, the trace-back logic becomes more important, not less, because it keeps configuration decisions explainable in value terms.

Finally, the framework is transferable as a method, but not as a universal product. A modular façade system cannot simply be applied to every building without reconsidering the anchoring strategy, structural grid, slab edges, tolerances and load paths. The Layer 1 carrier must remain project-specific, even if the value-translation logic can travel to other contexts.

Figure 10.1 Speculative future scenario testing the framework against change (§10.6.6). The Layer 1 baseline and module grid remain fixed, while the resident-facing Layer 2 adapts to a changed social and technical world: added balconies, more greenery responding to resident needs, additional shading and BIPV to a warmer climate, and value-aware component substitution to rising material costs and supply constraints. An added rooftop storey, built in the same modular system, and taller neighbouring blocks reflect densification under housing shortage. The illustration shows adaptability achieved through Layer 2 reconfiguration rather than replacement of the whole envelope. (Conceptual illustration.)

10.6.7 Lifetime, circularity and end-of-life

The evaluation in Chapter 8 focuses on design-stage performance. It assesses whether values are visible, measurable and differentiated across the variants.

Modular façade design, however, is temporal by nature. A component may perform well at installation but become less suitable after twenty years if resident needs change, maintenance becomes difficult or the component cannot be reused at end-of-life.

The current disassembly logic begins to address this through reversible fixing, independent removal, accessibility, reuse potential and documentation.

However, the connection details that would make Layer 2 demountable are not fully worked out in this thesis. A full lifetime evaluation would need to ask how often Layer 2 components are expected to change, whether they can be repaired without replacing Layer 1, whether removed components can be reused in another project, and whether materials can be recycled without losing value.

In hindsight, the end-of-life perspective could have been introduced earlier in the component catalogue. Each component could have been described not only through cost, value relation and technical function, but also through expected service life, disassembly sequence, reuse potential and compatibility with future projects. This would strengthen the sustainability claim of the system and connect the social adaptability of Layer 2 to a stronger circularity logic.

10.6.8 Ethical and methodological limitations

The strongest ethical limitation of the project is that it designs a resident-value framework without directly engaging the residents of the case-study building. Resident values were derived from literature and documented participatory renovation cases. This was appropriate within the scope of the thesis and avoided the ethical and data-management complexity of primary human-subject research. However, it also means that the framework was not validated through actual tenant conversations at the case-study of the Gijsingstraat building in Rotterdam-West.

This matters because the thesis argues that residents should not be reduced to standard assumptions. Yet the design process still had to use scenario households, assumed resident profiles and living situation and regulatory benchmarks. The project therefore does not claim to speak for the residents of the case-study building. It shows how their values could be collected, translated and evaluated if the engagement process were carried out. I dealt with this ethical issue by keeping the claims limited.

The same care applies to visual material. Engagement diagrams or scenarios can help explain how the process would work, but they should not suggest that engagement has already taken place. A thesis about resident values must avoid creating the impression of participation where participation has not happened.

10.6.9 Societal impact and practical applicability

The societal impact of the thesis lies in making resident values part of the design process of modular façade renovation. The project does not only propose a technical system for improving the energy performance of existing housing; it proposes a method for making renovation decisions more transparent, reviewable and connected to everyday living conditions.

This is relevant in the wider social context of the energy transition, where large numbers of social-housing dwellings must be upgraded, but where residents often have limited influence over the decisions that affect their homes.

The results are applicable in practice as an early-stage decision-support method, not yet as a ready-to-build façade product. The Value–Indicator Framework, two-layer façade logic, component catalogue, configuration logic and trace-back system could be used by housing associations, architects and façade suppliers before the façade system is fixed. Their practical function would be to clarify which decisions are fixed by regulation, budget and technical feasibility, which decisions remain open to resident influence, and how selected components can be traced back to resident values and forward to evaluation.

The projected innovation has therefore been achieved at the level of a design-stage method. The thesis demonstrates how resident values can be identified, translated into design indicators, operationalised through a modular façade system, configured through Layer 2 component choices and evaluated through KPIs. What has not yet been achieved is implementation: the Resident Design Council has not been assembled, the value cards have not been tested with tenants, the cost model is not contractor-validated, and the system has not been prototyped. The framework is structured enough to be tested but not yet proven in practice.

The project contributes to sustainable development (people, planet, profit/prosperity) by linking environmental upgrading to social and procedural quality. For people, the framework treats comfort, affordability, fairness, control, identity and trust as design inputs rather than late-stage feedback.

For the planet, the modular façade system supports energy upgrading, material comparison, reversibility and future reuse, although full environmental performance still requires life-cycle validation.

For profit and prosperity, the bounded component catalogue and Layer 1 / Layer 2 logic help keep resident-facing variation compatible with cost control, repetition and procurement.

The socio-cultural impact is that the façade is reframed as more than a technical envelope. In social housing, façade renovation affects privacy, identity, perceived safety, belonging, threshold use and the relation between dwelling and neighbourhood.
The ethical impact lies in the trace-back logic: residents should be able to see how values were translated, which choices were made, which choices were not made and why. This does not remove conflict, but it makes the design reasoning more accountable.
And regarding the influence of the effect of the project on architecture and the built environment, is related to the suggestion that industrialised renovation does not have to mean one uniform solution for every dwelling. If variation is bounded, documented and technically coordinated, modular façade systems can support both standardisation and resident responsiveness. The façade becomes a socio-technical interface: a building layer where performance, construction logic, resident agency and architectural expression meet.

10.6.10 Positioning the contribution and its limits.

Reflecting on the completed project, the question could be raised: what is truly new?
Engagement methods already exist; modular façade systems already exist and KPIs already exist. The novelty lies in structurally connecting fields that are often treated separately. The thesis connects resident values, design indicators, façade criteria, two-layer system logic, component selection, trace-back and evaluation into one method. The innovation is not that tenants are consulted or that façades are modular. It is that resident values are given a traceable route into modular façade configuration.

This also clarifies why the thesis belongs within Building Technology. The project is not a participation study with a façade added to it. The social values are translated into façade related indicators. Building Technology is the medium through which the values become designable, testable and technically accountable.

The KPI scores should also be read within this boundary. A higher score does not automatically mean that one variant is universally better. The scores show how strongly each variant expresses the selected value indicators within the assumptions of the framework. The appropriate variant still depends on the project profile, resident priorities, affordability limits, technical constraints and housing-association objectives.

10.6.11 Personal motivation and future professional position

My motivation for this thesis came from the feeling that façade renovation is often discussed as a technical upgrade, while the people living behind the façade are discussed later, separately or indirectly. As a future Building Technology graduate, I do not see the role of the façade designer only as optimising U-values, joints, modules and production tolerances, although these remain essential. I see the role as translating between different forms of knowledge: the measurable knowledge of building physics and construction, the organisational knowledge of housing associations and suppliers, and the situated knowledge of residents.

In practice, I imagine the framework being used at the beginning of a housing-association renovation project. Before the façade system is fixed, residents would be approached through plain-language communication, home visits and value cards. Their input would be translated into value priorities and design indicators. The architect and façade designer would then use the component catalogue to configure Layer 2 options within the shared Layer 1 baseline. The housing association would still make final legal and financial decisions, but those decisions would be traceable. Residents could see what was selected, what was not selected and why.

This is where I see the academic and practical strength of the project. Academically, the thesis contributes to the value–design translation gap. Practically, it suggests that industrialised renovation does not have to mean one uniform solution for every dwelling. If variation is bounded, documented and technically coordinated, standardisation and resident responsiveness can support each other rather than cancel each other out.

10.6.12 What I would do differently

If I were to continue the project, I would change three aspects of the process.
First, I would test the Value–Indicator Framework and value cards with actual tenants earlier. This would make it possible to adjust the value definitions, value levels and engagement tools before design variants are developed.
Second, I would develop the component catalogue with suppliers, contractors and housing-association maintenance teams. The feasibility of Layer 2 variation depends not only on design ambition, but also on procurement, installation, maintenance, replacement and warranty.
Third, I would expand the evaluation from design-stage KPIs to lifetime scenarios. This would include maintenance, reuse, disassembly, changing occupancy, transport logistics and end-of-life routes.
Besides that, I thought about the potential of modular façade renovation beyond this case because it can upgrade existing buildings throughout the entire world toward sustainability targets while improving the exterior quality and tenant–façade interaction.
A new façade layer can do more than insulate it can renew ageing housing blocks, support shading and privacy, improve threshold use and make the energy transition visible in everyday life.

These steps would not replace the framework developed in the thesis. They would test its robustness. The main learning from the project is that value-driven façade design cannot be solved by adding more options or asking residents for preferences at the end. It requires a structured translation process that can negotiate between technical limits and social change. The thesis provides a first version of that process. Its next development should test how it behaves when real residents, real supply chains and real long-term use conditions begin to push back.

10.7 Final conclusion

This thesis set out to close a gap that recurs across European social-housing renovation: residents are asked thoughtful questions in engagement sessions, and then the façade arrives looking very much like every other one. Industrialised modular façades accelerate retrofit, but they reinforce one-size-fits-all solutions, even though a new façade changes how people open a window, feel privacy, and recognise their home.

Resident values are currently surfaced through engagement but then lost before the design process starts. That disconnect is not a failure of intention; it is a failure of method, and Building Technology is where the method must be built. Treating a façade as only a thermal layer makes its social dimension invisible by design. Treating it as a social-technical interface makes the everyday experience of opening a window, seeing a neighbour, recognising your own home, into something the discipline can engineer for.

The contribution is therefore not another façade product but a method: a traceable route that carries resident values through indicators, criteria, a two-layer system, a bounded catalogue and a KPI evaluation, so that every design decision can be traced back to the value that justifies it.

The innovation of this thesis lies in the link itself, it shows how social criteria can drive design parameters and modular configuration, not as a parallel concern but as the operator that decides what the façade becomes.

The Value–Indicator Framework and the Value-Integrated Modular Façade System (VIMFS), together with its configuration logic, make the route from value to component visible, traceable, and auditable, so that every component on the wall is answerable to a value behind it.

The central finding is demonstrated by the four case-study design variants: the same building, the same Layer 1 baseline and the same component catalogue produce four recognisably different value profiles.

Modular façade renovation therefore does not have to choose between industrialised standardisation and resident responsiveness. Layer 1 secures the shared, equal technical baseline, while Layer 2 lets the resident-facing façade vary through documented, bounded choices. Standardisation protects fairness and technical reliability; bounded variation carries comfort, identity, control, sustainability, and social use.

The thesis is deliberate about what it does not claim. It does not complete a renovation, engage the actual residents of the case-study building, or prove resident satisfaction, energy savings or institutional trust. The variants are design-stage tests of a method, not construction-ready proposals. The contribution is more precise than a built result: it makes the route from resident value to façade decision explicit enough to be reviewed, questioned, adjusted, and tested.

That precision is also the starting point for what comes next.

The method now needs to meet reality, to test the configuration logic with residents, validate the cost model with contractors, develop the reversible connections, and study the lived outcome after delivery. If that step is taken, the framework can move from a thesis-based design method toward a renovation process.

The broader claim is modest but consequential: modular façade design can do more than optimise technical performance. It can build the structures through which social values become technically designable. Translation, not consultation. Standardised, but human. Industrialised, but answerable to the people who live behind the wall. That is the façade this thesis builds the method for and the way modular façade design should now be built around the values of the people who live with it.

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Artificial intelligence in this thesis:

In the preparation and writing of this thesis, ChatGPT (OpenAI) and Claude (Anthropic) were used solely as language-editing aids, limited to checking grammar, spelling, and punctuation and improving the clarity and fluency of the author's own text. No substantive content, such as research, analysis, design work, results, or conclusions , was generated by AI. All AI-assisted edits were reviewed by the author. All figures and tables are my own work unless a source is stated in the caption. The façade-design renders were produced with the AI tool Artlist (AI toolkit), used only to process my own design inputs already presented in this thesis, concisting of the author's own detailed Rhino model applied onto a base-layer photograph of the building. The AI tool was not used to generate the design itself, which is the author's own work. Referring to the renders marked with an asterisk (*) are the author's own work, visualised using the Artlist AI toolkit applied to the author's own Rhino model and a base-layer site photograph.Using: Artlist. (2026). Artlist AI [AI image-generation tool]. https://artlist.io

Glossary of key terms

- **Resident value**: A recurring concern, preference or aspiration expressed by residents in social-housing renovation that affects how they live with the façade. Six are identified in this thesis: comfort, affordability, fairness, empowerment, sustainability, and identity (Chapter 4).
- **Design indicator**. An architectural or experiential property of the façade through which a resident value can be expressed in design.
- **Façade design criterion**. A measurable or specifiable façade-level requirement derived from a design indicator, used to direct the selection of Layer 2 components (Chapter 4).
- **Value–Indicator Framework (V–I Framework).** The analytical artefact linking the six resident values to seventeen design indicators and their corresponding façade criteria (Chapter 4).
- **Value-Integrated Modular Façade System (VIMFS)**. The two-layer modular façade system developed in Chapter 5 that operationalises the V–I Framework into a buildable system logic.
- **Layer 1**. The standardised performance layer of VIMFS: insulation, airtightness, weather protection and structural support, shared across all dwellings to secure an equal technical baseline (Chapter 5).
- **Layer 2**. The adaptive socio-technical interface of VIMFS: the resident-facing components — cladding, shading, threshold elements, greening and operable parts — selected from the component catalogue (Chapter 5).
- **Component catalogue**. The bounded set of Layer 2 components, grouped by value-affinity cluster, from which façade variants are configured (Appendix B).
- **Value-affinity cluster**. A grouping of catalogue components by the resident value they primarily serve ,the operational form of Layer 2 (§5.9).
- **Configuration logic.** The four-step procedure developed in Chapter 6 that translates a project's value priorities into a specific façade variant by activating clusters and selecting components.
- **Design variant.** A complete value-driven façade configuration produced by the configuration logic on a specific project profile; in this thesis, V01–V04 on the Gijsingstraat case (Chapter 7; Appendix D).
- **Trace-back table.** A table mapping each selected Layer 2 component back to the value, indicator and criterion that justifies it; the auditability instrument of the configuration logic (Chapter 7; Appendix D).
- **Key Performance Indicator (KPI).** A measurable design-stage check on whether a design indicator is satisfied in a variant; seventeen KPIs in total, one per indicator (Chapter 8).
- Value–design translation gap. The methodological gap, identified in Chapters 2 and 3, between identifying what residents value and integrating those values into architectural and technical façade decisions — the gap that the V–I Framework, VIMFS, and configuration logic together set out to close.

Appendices

This section gathers the supporting work behind the thesis.
Appendix A : Cross-case analysis develops the seven renovation cases that, with the worked Reigersbos observation (§3.4), form the empirical basis of Chapter 3, each following the nine-part structure of §3.2 so the eight cases stay comparable in the synthesis (§3.5).

Appendix B: Component catalogue presents the full Layer 2 catalogue from Chapter 5 (§5.9), documenting the four value-affinity clusters and the component codes used in Chapters 6–8.

Appendix C: Additional tables and information record the technical and regulatory reference base behind Chapter 5 (§5.2) and the Chapter 8 evaluation: the unitised façade tradition, the system-by-system comparison, the Layer 1 thermal calculation, and the sources and calculation tables behind the seventeen KPIs.

Appendix D: Additional design variants develops V02, V03, and V04 in full, following the §7.6 template, with their project profiles, criteria sets, component selections, trace-back tables, and supporting drawings.

Appendix A-Cross-case analysis: seven additional cases

This appendix develops the seven additional renovation cases that, together with the worked Reigerbos case in §3.4, form the empirical basis of the cross-case analysis in Chapter 3. Each case is developed through the same nine-subsection structure used for Reigersbos, so the eight cases remain directly comparable in the cross-case synthesis (§3.5).

The cases are presented in three groups. The first group consists of the three additional JustPrepare Living Lab cases (alongside Reigersbos in Ch. 3): Bospolder-Tussendijken in Rotterdam (A.1), the NOM-woningen programme in Gemert (A.2),Dukenburg in Nijmegen (A.3).
The second group is a single Dutch case institutionally distinct from JustPrepare: Overvecht-Noord in Utrecht (A.4).
The third group consists of three European pilots within other programmatic frameworks: Sutton Estate in London (A.5; UK Social Housing Decarbonisation Fund and Kensa Retrofit Programme), the Križevci co-operative housing project in Croatia (A.6) Affordable Housing Initiative and SHAPE), and Els Mestres in Sabadell (A.7; EU Horizon 2020 HOUSEFUL project).

Each case is structured following the analytical framework defined in §3.2: project context; stakeholders and governance; renovation goals; engagement techniques; resident values identified; degree of integration of values in decisions; challenges; outcomes; and key insights for framework development.

The case studies are based on desk research using publicly accessible online sources: programme documentation, government publications, organisational press releases, and journalism. No primary research (interviews, internal documents, private communications) was conducted; this is a secondary-source review of European social-housing renovation cases.

A.1 Bospolder-Tussendijken (BoTu), Rotterdam

1.1 Project context

Bospolder-Tussendijken (BoTu) is a historically working-class, densely populated inner-city neighbourhood in the borough of Delfshaven, Rotterdam, characterised by low socioeconomic indicators and a diverse population with high cultural plurality. It was built primarily in the early to mid-20th century with compact mixed housing and local amenities and has a legacy of strong local initiative and community organising.

The Resilient BoTu 2028 programme (Veerkrachtig BoTu 2028) is a long-term area transition initiative launched in 2019 with the explicit goal of making BoTu the first "resilient neighbourhood" in Rotterdam by 2028 (Resilient BoTu 2028, 2019.). This resilience framing integrates energy transition goals (e.g., neighbourhood-wide decarbonisation and gas-free retrofit) with improvements in social cohesion, participatory capacity, safety, and quality of life, measured through instruments like the Social Index, which benchmarks improvements relative to Rotterdam's urban average (Gemeente Rotterdam,Doff, 2021).

The most extensively documented JustPrepare focus within BoTu has been the renovation of the Gijsinglaan flats ,a complex of five galerijflats containing 360 apartments, originally built in 1959 by housing corporation Havensteder (Bouw en Uitvoering, 2020). The renovation was carried out from November 2020 to March 2022 by BAM Wonen as construction partner and Havensteder as housing corporation, with Eneco as warmtenet (district-heat) provider; the dwellings moved from energy label F/G to label A and residents rated the project 8.2/10 on completion (BAM Wonen et al., 2022; Havensteder, 2020).
The wider Resilient BoTu 2028 programme aspires to transition around 1,600 BoTu homes off gas across the broader neighbourhood transformation (Rebel Group, 2023), of which the 360 Gijsinglaan apartments are the first major delivered phase.

Figure A1.1: BoTu website meeting the neighbour’s website page.

1.2 Stakeholder and governance structure

The BoTu retrofit illustrates a multi-stakeholder governance model with two housing associations as primary owners, a programme office coordinating cross-actor activity, and structured resident participation channels. The stakeholders are:

- **Municipality of Rotterdam:** local government driving policy, coordination, and funding channels within Resilient BoTu 2028.
- **Havensteder:** housing corporation that owns the Gijsinglaan flats and is the lead retrofit client. Active partner in the resilience programme.
- **BAM Wonen:** construction partner for the Gijsinglaan retrofit (November 2020–March 2022), responsible for executing the works in occupied dwellings and providing dedicated bewonersbegeleiding (resident-support staff) on site.
- **Eneco:** warmtenet (district-heat) provider; the Gijsinglaan flats moved from individual gas heating to Eneco's stadsverwarming network, with Havensteder providing each dwelling with a warmte-afleverset and an inductiekookplaat.
- **Residents and community organisations:** including local initiatives, neighbourhood councils, and informal networks; bewonersraad BoTu12 (12 residents advising the kernteam) (Doff,2021.).
- **Social entrepreneurs and NGOs:** De Verbindingskamer, Rebel Group, Delfshaven Coöperatie, and the dedicated sociaal team "Team Gijsingflats" assembled for the Gijsinglaan project (including a resident, Havensteder staff, Frontlijn, WMO Radar, Zorgvrijstaat, and De Verbindingskamer) (BAM Wonen et al., 2022, Havensteder, 2020).
- **Researchers and monitoring partners:** Veldacademie, Erasmus University, TU Delft, and Hogeschool Rotterdam support monitoring, evaluation, and knowledge production (Veldacademie, 2021, Doff, 2021); JustPrepare is the action-research framing (JustPrepare, 2025).

Governance structure. The formal governance of BoTu 2028 is designed around collaborative decision-making and Asset-Based Community Development (ABCD) principles, aiming to build community capacity and enable residents through living to take an increasingly active role in co-producing neighbourhood resilience, rather than purely following top-down planning directives. In a way that he housing associations retain formal authority on the building stock, while the Living Lab provides a structured channel for resident input into design and programme decisions.

Figure A1.2: Veerkrachtig BOTU ‘praatplaat’ (Gemeente rotterdam)

Figure A1.3: Bird view Bospolder tussendijken Rotterdam West (trek.zone.nl)

1.3 Renovation goal

The core renovation goal was to:
Develop and demonstrate a deep-retrofit refurbishment of the existing housing stock that meets the climate-neutral 2050 target, demonstrably improves comfort and indoor air quality, and respects the neighbourhood's architectural identity and resident affordability, within a multicultural and multilingual neighbourhood context.

While Resilient BoTu 2028 is broader than a narrow renovation project, the JustPrepare component frames renovation goals around effective and just energy retrofit that integrates technical decarbonisation with social-justice outcomes. In practice, JustPrepare researchers focused on how the Gijsinglaan flats renovation met both effectiveness (realising targets) and justice (fair distribution of benefits and inclusion in decisions). Key reported outcomes included on-schedule renovation, stable cost burdens for residents, and active resident involvement in project decisions.
Sub-goals are structured here in six categories, each grounded in JustPrepare and Veerkrachtig BoTu 2028 documentation:

- **Technical**. Decarbonisation and gas-free housing infrastructure through district heating and insulation upgrades; on-schedule delivery of renovation works.

- **Social**. Active resident involvement in project decisions; fair inclusion in participation; recognition of resident experience and knowledge as part of the planning process.

- **Economic.** Cost-burden protection: no increased financial burdens for residents; stable housing costs through and after renovation.

- **Environmental.** Gas-free housing trajectory contributing to Rotterdam's wider decarbonisation target.

- **Governance.** Multi-actor governance constellation (municipality, housing corporations, residents, NGOs, researchers); collaborative decision-making organised around Asset-Based Community Development (ABCD) principles.

- **Learning.** Documenting the BoTu approach as a transferable model; the Resilient District Toolkit captures collective learning on just, climate-resilient approaches for cities; participatory monitoring is treated as an ongoing learning practice.

Figure A1.3:BoTU Gijsinglaan buildings (BAMwonen.nl)

1.4. Resident involvement techniques

Resident involvement in BoTu has been documented through a variety of participatory and community-engaged techniques, summarised in Table 1.1

Table A.1.1 : Resident engagement techniques in Bospolder–Tussendijken.

Technique	Description	Effect
Interviews	With residents, municipal staff, housing-corporation representatives, and local entrepreneurs about lived experiences of social and retrofit processes	Surfaced lived-experience narratives across actor groups
Collaborative and community forums	Story cafés and storytelling walks to map local networks and narratives about neighbourhood resilience	Made the social texture of the neighbourhood visible to retrofit actors
Social-network mapping and monitoring	Tracking how local organisations and informal groups connect and grow over time	Documented growth of resident influence in governance
Open calls and grassroots initiatives	Social Impact by Design invited residents and creative entrepreneurs to propose and develop resilience-oriented ideas	Broadened the range of actors contributing to resilience outcomes
Participatory research and co-monitoring	Students and academics collaborated directly with residents to document neighbourhood development and governance shifts	Embedded ongoing reflection into the programme rather than reserving evaluation to end-of-project

These techniques reflect a mix of qualitative engagement, community organising, and participatory monitoring, not solely technical workshops. They align with ABCD principles prioritising local agency and strengths.

Figure A1.4: BOTU neighbourhood initiatives through openoproep (Bospoldertussendijken.nl)

1.5 Resident values identified.

While systematic tabulated resident values specific to energy renovation are less directly re-ported in current programme documentation, multiple sources indicate key values emerging in BoTu:

- **Fairness and justice in transition**. Residents emphasised that renovation should not increase financial burden and should be inclusive in decision-making. JustPrepare research emphasised fairness in costs and participation in renovation decisions.

- **Recognition and respect.** Residents expressed the importance of their experiences and needs being acknowledged by planners and institutions. This value is implicit in the JustPrepare focus on recognition justice (balancing effectiveness with resident acknowledgement).

- **Community resilience and social cohesion**. The BoTu 2028 programme frames resilience as built through local networks, mutual support, skills, and collective action.

- **Capacity for self-organisation.** Residents value the ability to organise, act together, and participate in shaping their neighbourhood's energy and social futures, as evidenced by community-led post-2019 governance shifts.

While these are less granular than interview quotes, they remain consistently cited across monitoring and programme narratives as core resident-oriented values feeding into the design of participatory techniques and governance reforms.

1.6. Level of Integration of values in decisions

Table A.1.2 : Bospolder–Tussendijken: integration of values in decisions.

Resident value	Degree of integration	How it was integrated
Fairness / Justice	Conditional / High	Renovation completed and residents involved; JustPrepare finds that costs did not rise for residents, indicating fairness integrated into planning and execution
Recognition	Medium	JustPrepare highlighted resident concerns in evaluation and reflection on process, suggesting residents were recognised as knowledge holders
Social cohesion / capacity building	High	Monitoring and network mapping explicitly track community connections; programmes designed to strengthen these networks
Self-organisation	Evolving	Governance shifts documented show increasing influence of informal and resident-led groups in decisions over time

Overall, resident values are embedded more procedurally and relationally than through formal design parameters (unlike comfort metrics in building retrofits). They feed into governance, process fairness, and participatory culture rather than narrow technical specifications.

1.7. Challenges

Table A.1.3 : Bospolder–Tussendijken: challenges encountered.

Challenge category	***Description***
Complex socio-economic vulnerabilities	A neighbourhood with persistent poverty and subjective wellbeing measures showing divergence from objective improvements, complicating straightforward retrofit enthusiasm and participation
Integrating technical and social priorities	Many residents prioritise daily livelihood needs (education, jobs, health, safety) over energy transition per se, making it difficult to align traditional energy-retrofit narratives with community priorities
Governance coordination	Evolving from institutional leadership to co-governance with residents reveals tensions and the need to balance formal decision authority and community autonomy
Monitoring subjective experience	While objective improvements are measurable, subjective perceptions of progress have declined in recent Social Index measurements, highlighting the challenge of perceived impact versus measured impact

1.8 Outcomes

BoTu’s transition produced several outcomes:

- **Energy and retrofit progress.** The 360 Gijsinglaan apartments across five galerijflats moved from energy label F/G to label A; gas heating replaced by Eneco's warmtenet; geysers/boilers replaced by warmte-afleverset; each dwelling received an induction cooktop; estimated 125,000 m^3/year gas saved and ~225,000 kg/year CO_2 reduction. The Gijsinglaan delivery is the first major phase of a wider Rotterdam transition that targets gas-free retrofitting of approximately 1,600 BoTu homes.(Rebel Group, 2023).

- **Resident reception**. Residents rated the project 8.2/10 on completion. Despite COVID-19 conditions during the works, BAM Wonen reported full resident cooperation; the bewonersbegeleider model and the sociaal team "Team Gijsingflats" were credited as central to that result. (BAM Wonen et al., 2022).

- **Strengthened community networks**. Social-network analysis shows increased connections and cohesion among formal and informal actors over time. (Veldacademie, 2021)

- **Greater resident agency.** Residents and informal groups hold increasing influence in governance and resilience actions, shifting from institutional control toward community empowerment. (Veldacademie, 2021)

- **Integrated neighbourhood learning.** The BoTu experience has fed into toolkits (e.g., Resilient District Toolkit) capturing collective learning on just, climate-resilient approaches for cities. (Rebel Group, 2023)

1.9 Key Insights for framework development

From the BoTu case, you can derive the following framework insights:

- **Justice beyond technical results.** Retrofit effectiveness must be evaluated alongside procedural fairness and recognition, not only outcomes such as energy savings.

- **Governance and value integration**. Resident empowerment and network strength are crucial indicators, measurable through participation trajectories and network analysis, not just design outputs.

- **Subjective vs. objective impact.** The framework should incorporate both objective performance indicators and subjective perceptions (e.g. Social Index versus lived experience).

- **Holistic participation techniques.** Values appear most integrated when participatory methods are diverse (interviews, story cafés, network mapping), capturing the social texture of community life.

- **Resilience as a composite indicator.** BoTu suggests that resilience (social, economic, environmental) can be treated as a composite framework dimension tied to community capability, network density, and adaptive agency.

A.2 NOM-woningen, Gemert

2.1 Project context

The NOM-woningen Gemert programme is a phased, long-running renovation initiative run by Goed Wonen Gemert, the social-housing corporation in Gemert-Bakel, Noord-Brabant. The programme targets the corporation's existing post-war and mid-century social-housing stock across Gemert and the surrounding kerkdorpen of Bakel, De Mortel, De Rips, Elsendorp, Handel, and Milheeze. Goed Wonen Gemert manages approximately 2,850 dwellings in total.

The programme started in 2018 with a two-dwelling pilot and has scaled to roughly 50–60 dwellings per year. Its design objective is to convert existing social-rental dwellings to gasloos (gas-free) and nul-op-de-meter (NOM, net-zero) performance, in collaboration with Huybregts-Relou (construction and prefab elements) and Nathan Systems (energy modules and ground-source heat pumps). Sociocuturally, residents include families and long-term tenants with strong attachment to place and modest population turnover; local identity ("ons-kent-ons" feeling) remains strong, reflecting small-town community dynamics.

A specific named subset of the programme is Renovatie Den Elding, where 55 dwellings in Gemert are scheduled for gas-free renovation in 2026, including façade and roof insulation upgrades, new windows, heat-pump installation, CO_2-controlled mechanical ventilation, and façade impregnation.

2.2 Stakeholders and governance structure

Table A.2.1: NOM-woningen Gemert: stakeholders and roles.

Stakeholder	Role and contribution
Goed Wonen Gemert	Local housing corporation; programme owner; responsible for tenant engagement, dwelling selection, and overall implementation
Residents / Tenants	Recipients of housing improvements; involved through individual communication, briefings, and door-to-door discussions
Huybregts-Relou	Construction partner since 2018; co-develops the NOM renovation approach including prefab and biobased elements (e.g., biobased roof plates)
Nathan Systems	Energy-module and heat-pump partner; supplies the ground-source heat pumps (alpha innotec) and the integrated energy module developed for social-housing renovation
Municipality of Gemert-Bakel	Provides local-policy framework for sustainable neighbourhood renewal and housing quality

Governance structure: led by Goed Wonen Gemert, in coordination with the municipality and technical partners (e.g., Nathan Systems) to implement energy-efficient retrofits. Resident involvement occurs through informal consultations, communication materials, and meetings rather than formal co-governance structures.

Figure A.2.0: Example homes throughout Gemert part of phased renovation -40 homes(Goed Wonen Gemert en Huybregts Relou)

2.3 Renovation goal

The core goal of the NOM-woningen Gemert programme is to bring existing social-rental dwellings to gasloos en nul-op-de-meter (gas-free and net-zero) performance through a combined envelope-and-services upgrade. The goal is both technical (deep energy reduction) and social (affordable comfort), aligned with broader municipal ambitions for a sustainable and socially inclusive built environment, and with the national 2050 housing-decarbonisation commitment. Sub-goals are structured here in six categories, each grounded in Goed Wonen Gemert reporting, the Nathan Systems and Huybregts-Relou project documentation, and Den Elding renovation communications:

- **Technical.** Improve energy performance to NOM (net-zero) level through external insulation of façades and roofs, new windows and doors, ground-source heat-pump installation (alpha innotec, supplied through Nathan Systems' integrated energy module), and CO_2-controlled mechanical ventilation; use prefab and biobased components where feasible (e.g., Huybregts-Relou biobased roof plates).
- **Social.** Affordable comfort for tenants; tenant trust through visibility ,Goed Wonen emphasises being zichtbaar en benaderbaar (visible and approachable); recognition of small-town community attachment ("ons-kent-ons").
- **Economic.** Maintain or improve housing affordability; the NOM model converts gas + electricity costs into a fixed energiebesparingsvergoeding (energy-saving fee) paid to the corporation, with documented monthly costs typically lower than pre-renovation gas-and-electricity bills; PV income at the dwelling level can further offset annual cost.
- **Environmental.** Reduce CO_2 emissions in line with the national 2050 housing-decarbonisation commitment; remove the dwellings from the gas grid; deploy biobased materials where feasible; progress toward energieneutrale woningen across the corporation's portfolio.
- **Governance.** Single-corporation programme led by Goed Wonen Gemert with stable two-partner technical delivery (Huybregts-Relou, Nathan Systems); coordination with the municipality on planning frameworks; informal consultative tenant engagement rather than formal co-governance.
- **Learning.** Phased rollout with iterative learning between phases — the first block trialled different installation systems per dwelling and was evaluated jointly to select the optimal NOM configuration for subsequent phases; use of biobased prefab components contributes to the staged industrial integration of these materials.

FigureA.2.1:: Gemert-Bakel Goed wonen- 259 homes(Goed Wonen Gemert en Huybregts Relou)

2.4 Resident involvement techniques

Resident involvement in the NOM-woningen Gemert programme is less formally documented compared to larger Living Labs, but engagement has included three principal techniques:

- **Direct communication and briefings**. By Goed Wonen Gemert to tenants about retrofit strategies and new installations such as heat pumps, mechanical ventilation, and the energy-fee model.
- **Door-to-door and in-home discussions.** Project staff visit dwellings individually to discuss the ren-ovation, address concerns about specific dwelling features (e.g., rear extensions, attached struc-tures that complicate the new envelope), and explain the timeline for that resident.
- **Informal listening** sessions and tenant communication. Via newsletters, social media (the corporation maintains active Facebook and LinkedIn channels), and personal contact between corporation staff and tenants.

These techniques are primarily communicative and consultative, rather than systematic co-design workshops.

2.5 Resident values identified.

Table A.2.2: NOM-woningen Gemert: resident values identified.

Resident value	Technique used	Description
Affordability	Tenant briefings; corporate communications	Residents value sustainable upgrades only if affordable and not increasing total housing cost — supported by the NOM energy-fee model that is documented to reduce monthly outlay relative to pre-renovation gas-and-electricity bills
Comfort and energy savings	Individual communication on heat-pump rollouts and post-renovation feedback	Heat-pump installations and improved insulation reflect resident interest in lower energy bills and improved comfort; documented post-renovation performance has tended to exceed pre-calculated savings
Trust and communication	Direct discussions; newsletters/social events	Goed Wonen emphasises being zichtbaar en benaderbaar (visible and approachable) to build trust with residents
Attachment to dwelling and dwelling features	Door-to-door discussions; in-home visits	Friction surfaces around dwelling features residents value (e.g., rear extensions or attached structures that the new external envelope cannot accommodate); recognition of these attachments is part of the engagement
Sustainability and environmental responsibility	Corporate annual report and retrofit discussions	Long-term vision to achieve energieneutrale woningen reflects resident and organisational value alignment

These values are drawn from Goed Wonen Gemert progress communication, the documented Nathan Systems and Huybregts-Relou project descriptions, and Den Elding renovation communications.

2.6 Level of integration of values in decisions

Table A.2.3 — NOM-woningen Gemert: integration of values in decisions.

Resident value	Degree of integration	Description
Affordability	High	The NOM energy-fee model directly addresses cost burden; documented monthly costs are typically lower than pre-renovation; PV income can further offset annual cost
Comfort and energy savings	High	Technical measures (insulation, heat pumps, mechanical ventilation, new windows) are explicitly intended to improve comfort and reduce energy bills; documented performance tends to exceed predicted savings
Trust and communication	Medium	Corporate efforts to be visible and engage reflect integration of trust as a value, but no formal participatory governance structures are documented
Attachment to dwelling features	Medium	Some friction in cases where the external retrofit envelope cannot accommodate existing rear extensions or attachments; resolved case-by-case rather than systemically
Sustainability	Medium	Long-term organisational commitments and biobased material choices influence strategy, though direct resident involvement in material decisions is limited

2.7 Challenges

Table A.2.4 :NOM-woningen Gemert: challenges encountered.

Challenge category	Description
Balancing affordability with NOM ambition	Net-zero upgrades require substantial upfront investment that must be recoverable within social-housing rent and energy-fee structures; the energy-fee model addresses this but depends on documented cost reduction holding over time
Resident-engagement depth	Engagement tends to be communicative rather than co-design-oriented, limiting resident influence on technical choices
Existing-dwelling features	External envelope retrofit conflicts with rear extensions, attached structures, or owner-installed features that residents value; these conflicts surface in door-to-door discussions and require case-by-case resolution
Scaling of biobased and prefab components	Biobased and prefab components (e.g., Huybregts-Relou roof plates) are nascent at industrial scale and require continued supply-chain development

2.8 Outcomes

- **Technical.** Phased rollout from a 2018 pilot to ~50–60 dwellings per year; ground-source heat pumps installed across the renovated stock; documented multi-year stable operation; planned 2026 renovation of 55 dwellings at Den Elding.

- **Economic.** NOM energy-fee model produces typical monthly cost slightly below pre-renovation; PV income at dwelling level provides additional annual offset for many residents.

- **Social**. Increased tenant awareness of energy use and retrofit benefits through communication channels; positive resident reception reported once technical concerns are addressed.

- **Governance.** Stable single-corporation governance with two long-term technical partners enables iterative learning between phases.

- **Environmental.** Progressive removal of dwellings from the gas grid; deployment of biobased prefab elements; CO_2-neutral target for 2050 across the corporation's portfolio.

2.9 Key insights for framework development

- **Affordability as core metric**. Retrofit frameworks must explicitly measure total monthly housing cost (rent + energy fee + service charges), not only technical energy savings; the NOM energy-fee model is one operational form of this principle.

- **Trust requires ongoing visibility.** Corporate presence and communication (visits, newsletters, social media, approachable staff) supports trust — a key social metric rarely captured in quantitative retrofit analysis.

- **Comfort as quantifiable and qualitative value.** Energy-bill reductions and subjective comfort improvements (temperature stability, perceived indoor quality) both matter; documented post-renovation performance can exceed predicted savings.

- **Existing-dwelling attachment is a design constrain**t. External retrofit envelopes conflict with rear extensions and owner-installed features that residents value; recognising these attachments is part of value-driven retrofit design.

- **Iterative learning between phases**. The Gemert programme demonstrates that phased rollout with explicit between-phase evaluation lets the technical configuration adapt to lessons from earlier phases, a useful pattern for scaling NOM retrofit nationally.

A.3 Dukenburg, Nijmegen

3.1 Project context

Dukenburg is a large post-war residential suburb of Nijmegen (predominantly 1960s–1970s housing stock) with a mix of multifamily apartment blocks, social rental properties, and family homes. It was allocated as a pilot area for the national Aardgasvrije Wijken (Gas-Free Neighbourhoods) programme, aiming to transition housing off natural-gas connections by developing collective thermal networks and deep retrofit measures. The selected buildings for renovation are shown in the included pictures.

The neighbourhood includes diverse populations with a range of incomes and has historically faced sustainability challenges (energy efficiency, ageing building stock) alongside everyday socioeconomic concerns. Dukenburg was designatie in 2018 as a national Aardgasvrije Wijken proeftuin, with a rijksbijdrage of €480,000 (Nationaal Programma Lokale Warmtetransitie [NPLW], 2025,Gemeente Nijmegen, 2018).
The proeftuin scope covers approximately 2,425 dwellings (around 700 owner-occupied and 1,725 housing corporation/private rental) (NPLW, 2025). The first phases of the warmtenet rollout target 642 dwellings in Zwanenveld and Lankforst-Noord, with later expansion planned to De Kamp and Kerkenbos (Firan, 2024; Gemeente Nijmegen. 2022).

Aardgasvrij delivery for Zwanenveld and Lankforst-Noord is currently targeted for 2035 (revised from earlier 2030 ambitions) (De Dukenburger, 2023). The official proeftuin description records bewonersinitiatief as 'No' , the project is municipally led rather than resident-initiated, although structured participation channels run alongside it (NPLW, 2025).
A new publicly owned warmtebedrijf, Nijmegen Warmte B.V., was established on 9 July 2025 to take operational responsibility for the warmtenet (Gemeente Nijmegen, 2026).

Figure A3.1:De grote zwaan renovation, Dukenburg, Nijmegen (Kleissen.nl)- Figure A.3.3 (below) Building Lankforst,Dukenburg (opzoomarchitecten)

3.2 Stakeholders and governance structure

Table A.3.1: Dukenburg: stakeholders and roles.

Stakeholder	Role
Municipality of Nijmegen	Lead on strategic planning, enabling warmtenet and spatial transitions under the city's climate and housing policies
Housing Corporations (Portaal, Woonwaarts, Talis)	Owners/managers of a large share of dwellings; key implementers of retrofit and warmtenet connection
Energy/Warmte Partners (Firan, In-Warmte, ARN)	Technical and delivery partners for warmtenet infrastructure and heat supply
Residents and community actors	Participants in workshops, participatory planning, and informational events shaping transition visions
Researchers and practitioners (Just-Prepare, TNO Urban Energy)	Facilitate and document participatory engagement focused on comfort and retrofitting practices

Governance structure: is multi-actor and networked, combining municipal leadership with housing corporations, technical companies, and community interaction. Layers of resident involvement include workshops, information sessions, and public meetings specifically on warmtenet development.

3.3 Renovation goal

While not a single building retrofit project, Dukenburg's Living Lab is part of a broader neighbourhood transition that combines technical decarbonisation with embedded participatory processes. The Living Lab is also embedded in Nijmegen's Ontwikkelagenda and Destination Plan 2021, which sets out leefbaarheid (liveability), sustainability, and housing-diversification objectives. Sub-goals are structured here in six categories, each grounded in JustPrepare and Wijkaanpak Dukenburg documentation. Including the renovation goals categorisation:

- **Technical.** Achieve gas-free living for large shares of the housing stock via a collective warmtenet (rest heat from ARN); reduce energy demand through insulation and efficiency upgrades to existing buildings.

- **Social.** Strengthen social resilience and community agency amid energy transitions; design retrofit pathways within a participatory context; integrate liveability and housing-diversification objectives.

- **Economic**. Design retrofit pathways that are affordable and technically feasible; address resident concerns about cost, reliability, and transparency of future heating systems.

- **Environmental**. Decarbonisation through gas-free living using rest heat from ARN; reduction in energy demand.

- **Governance.** Multi-actor governance: Municipality of Nijmegen, three housing corporations (Portaal, Woonwaarts, Talis), and energy/warmte partners (Firan, InWarmte, ARN); structured resident channels through bewonerscommissies, public meetings, zienswijze processes, and the Duurzaam Wonen drop-in centre.

- **Learning.** JustPrepare-facilitated participatory workshops generate resident-led knowledge artefacts on home comfort and incremental sustainability solutions, treated as community expertise that feeds back into the broader transition.

Figure A3.2 Renovation building Zwanenveld (Dedukenburger.nl)

3.4 Resident involvement techniques

Table A.3.2: Dukenburg: resident involvement techniques.

Technique	**Method**
Participatory workshops (JustPrepare)	Residents shared lived experiences of comfort and sustainability, using a physical modular house model to map home-level solutions and knowledge exchange
Public meetings on warmtenet	Inform and collect questions on roles, costs, and future participation (e.g., warmtenet company roles)
Information and engagement points (Duurzaam Wonen locus)	Drop-in location for direct advice, energy tools, and sustainability info located in the local shopping centre
Zienswijze / planning consultations	Formal land-use/planning feedback processes through the bestemmingsplan, allowing resident submissions
Neighbourhood-centre dialogues	Broader dialogues about neighbourhood wellbeing, green space, mobility, and housing futures

The range spans deep qualitative engagement (workshops) to formal planning participation and ongoing public information exchange.

3.5 Resident values identified.

Table A.3.3: Dukenburg: resident values identified.

Resident value	Technique used	Description
Comfort and practical solutions	Participatory workshops	Residents shared micro-level insights about what works for them in their homes (draughts, cooling, self-solutions) and sustainability tips, indicating lived comfort priorities
Affordability and reliability	Public workshops and warmtenet sessions	Participants and warmtenet attendees raised concerns about costs, reliability, and transparency of future heating systems
Learning and shared knowledge	Workshops	Residents valued peer knowledge exchange, demonstrating capacity to contribute context-specific solutions for comfort and sustainability
Participation and influence	Zienswijze and public meetings	Engagement mechanisms revealed that residents expect meaningful influence, not just information, especially in long-term energy-infrastructure decisions

Resident values here come through dialogue-based and deliberative techniques rather than metrics, highlighting practical and experiential knowledge about homes and collective services.

3.6 Level of integration of values in decisions

Table A.3.4 : Dukenburg: integration of values in decisions.

Resident value	Degree of integration	Description
Comfort and practical solutions	Medium–High	Workshop insights influence understanding of what matters to residents in retrofit decisions, feeding into technical dialogue and project framing
Affordability and reliability	Medium	Public warmtenet meetings foreground cost concerns; concrete decision shifts (e.g., price guarantees) are still evolving
Learning and shared knowledge	Medium	Workshops embed resident knowledge into ongoing discussions, but systematic integration into formal planning instruments remains emerging
Participation and influence	Medium	Formal planning (zienswijzen) and meetings enable voice, but influence on key technical outcomes (routing of warmtenet, retrofit sequencing) is still mediated through institutional actors

Integration is procedural and deliberative rather than embedded as formal technical criteria.

3.7 Challenges

Table A.3.5:Dukenburg: challenges encountered.

Challenge category	Description
Complex multi-scale governance	Multiple actors and layers (city spatial plan, energy companies, housing corporations) make clarity of decision paths challenging
Technical uncertainty vs. resident expectations	Balancing innovative infrastructure (warmtenet) with lived expectations of comfort and cost transparency is ongoing
Participation vs. impact	Engagement channels exist but translating resident inputs into binding decisions remains limited
Long time horizons	Deep retrofit and energy transition are projected to 2030/2035, making sustained engagement harder

3.8 Outcomes

- **Neighbourhood-wide energy-transition pathway**. The city is progressing warmtenet development in phases (Zwanenveld, Lankforst-Noord) connecting hundreds of homes and planning broader integration.

- **Resident-led knowledge artefacts.** JustPrepare-facilitated workshops generated rich resident insights on home comfort and incremental sustainability solutions, showing community expertise.

- **Participatory planning structures.** Formal planning (bestemmingsplan, public meetings) continues to engage residents alongside institutional oversight, embedding social input into spatial and energy decisions.

- **Ongoing community dialogue**. Initiatives like the Duurzaam Wonen centre and community events broaden access to sustainability support.

3.9 Key insights for framework development

- **Comfort must be interpreted broadly.** Combining lived home practices with neighbourhood energy-infrastructure implications rather than only technical indoor-temperature data.

- **Participatory techniques reveal tacit knowledge.** Standard surveys may miss creative adjustments resident’s use; bottom-up strategies for comfort and sustainability deserve attention.

- **Affordability and reliability are core justice criteria.** They shape both acceptance and design of heating infrastructures.

- **Deliberative engagement complements formal consultation.** Workshops that engage residents as co-learners deepen value integration beyond token participation.

- **Procedure and transparency shape trust**. Long project horizons and complex governance risk disconnects unless residents see their inputs reflected in policy and technical decisions.

A.4 Overvecht-Noord, Utrecht

4.1 Project context

Overvecht is a post-war residential district in Utrecht, constructed in the 1960s, characterised by high-rise apartment complexes and social housing with surrounding green spaces. Its development was part of broader urban expansion aimed at alleviating housing shortages. As of 2024, Overvecht is one of the largest districts in Utrecht with a multicultural population, significant proportions of renters (especially social housing), a high share of low-income households, older residents, and diverse cultural backgrounds.

Within Overvecht, Overvecht-Noord has been a focus for energy-transition ambitions, especially linked to the Programma Aardgasvrije Wijken (PAW). The municipality declared in 2016 that Overvecht-Noord would be the first existing Utrecht neighbourhood to go aardgasvrij (gas-free) by 2030 (Gemeente Utrecht, 2024; DUIC, 2025). The plan covered approximately 8,000 dwellings, of which around 2,000 were owner-occupied (koopwoningen) and the rest social rental (NOS, 2025,RTV Utrecht, 2025).
The intended pathway combined connection to Eneco's warmtenet (district heat) with insulation upgrades and individual heat pumps in selected sub-areas. In April 2024, the municipality of Utrecht, Eneco, and the housing corporations decided that warmtenet aansluiting was too expensive for residents and discontinued the joint project (Gemeente Utrecht, 2024,Echt Overvecht, 2024); the gemeente has since been working on an alternative plan for the wider district.

Figure A4.1: Overvecht-Noord complex bird view (inductie.nu)

Figure A4.2: *Post-war Camera Obscura housing typology, Overvecht-Noord, Utrecht in 2030. Source: Building Types Online (BDT_27_021)*

4.2 Stakeholders and governance structure

Primary stakeholders include:

- **Municipality of Utrecht:** planning, policy, and programme oversight for district housing and energy-transition strategies (Omgevingsprogramma and Omgevingsvisie Overvecht).

- **Residents of Overvecht-Noord:** a diverse, multicultural population invited into dialogue processes around heating transition, affordability, and communal outcomes.

- **Housing corporations** (Woonin, Portaal, Bo-Ex): owners and managers of the social-housing stock; according to the Rekenkamer audit, the corporations were positioned more as 'passengers' in the project than as proactive partners (Rekenkamer Utrecht, 2025; Echt Overvecht, 2024).

- **Eneco:** intended warmtenet provider; withdrew from the joint project in April 2024 after a 7.5% return requirement made aansluiting onaffordable for residents (€4,000–€8,000 per dwelling on the warmtenet, with some homeowners facing €30,000–€80,000 for individual conversions) (RTV Utrecht, 2025; DUIC, 2025).

- **Stedin**: netbeheerder; began replacing the gas distribution network in the area despite the project halt (RTV Utrecht, 2025).

- **Energie-U:** local citizen energy cooperative (bewonerscoöperatie) involved in dialogue and informed by the audit (Rekenkamer Utrecht, 2025).

- Resident core groups: two organised groups, "Klopvaart Aardgasvrij" and "Nieuwe Energie voor Vechtstroom" , formed during the project to develop alternative collective-heat-pump proposals (RTV Utrecht, 2024).
- **Rekenkamer Utrecht** (Municipal Audit Committee): produced the 2025 audit "Gas terugnemen , Een kroniek van het verloop en de voorspelbare beëindiging van het project Overvecht-Noord aardgasvrij", concluding that the project's failure was foreseeable and that the gemeente lacked sufficient resources, knowledge, and decision authority (Rekenkamer Utrecht, 2025-NOS, 2025).

- **Voorbeeldwoning Jouwhuisslimmer** (Costa Ricadreef 183): demonstration dwelling for residents to view energy-saving measures; remains a public information venue (Echt Overvecht, 2024).

Governance for energy transition in Overvecht-Noord developed through formal municipal planning processes and resident-engagement channels including workshop series, klankbordgroepen (sounding-board groups), and resident surveys incorporated into strategy documents. Participation was supported but not legally binding, making governance hybrid and consultative.

4.3 Renovation goal

The central goal articulated through the Omgevingsprogramma Overvecht, and subsequent plans was to transform Overvecht into a sustainable, inclusive, and resilient urban district by 2040, with Overvecht-Noord specifically targeted for a gas-free transition by 2030.
Due to technical and affordability barriers in the heat-network option, the original aardgasvrij plan was discontinued in 2024, and authorities began formulating alternative approaches better aligned with resident needs and economic viability.

Sub-goals are structured here in six categories, each grounded in Omgevingsprogramma Overvecht documentation and the Rekenkamer Utrecht audit:

- **Technical**. Gas-free transition by 2030; replacement of natural-gas heating with alternative heat sources; heating retrofit at district scale.
- **Social.** Maintain or improve comfort for current occupants; integrate heating retrofit with broader neighbourhood renewal (housing quality, green space, mobility, community wellbeing); inclusion of multicultural population through dialogue.
- **Economic.** Maintain or improve affordability; transition pathways must not raise living costs (this requirement directly drove the abandonment of the heat-network plan in 2024).
- **Environmental**. Reduce CO_2 emissions from residential heating by moving away from natural gas.
- **Governance**. Hybrid municipal-corporation governance combining formal planning processes with consultative resident channels.
- **Learning**. Pilot and learn how to co-design energy-transition pathways with residents; Rekenkamer evaluation produced governance reflections feeding into future participatory and technical planning.

4.4 Resident involvement techniques

Resident involvement for energy and housing transition in Overvecht-Noord took place through:

- **Public dialogues and neighbourhood surveys** exploring resident perspectives on heating alternatives and priorities for affordability.
- **Focus conversations and panels (klankbordgroepen)** established from 2017 onward to discuss ongoing plans with structured resident input.
- **Local participation in planning phases** integrated into the Omgevingsvisie Overvecht process, involving in-person meetings and online consultations where residents could provide input on spatial and environmental plans.

These techniques were consultative and deliberative rather than co-design workshops, reflecting the broader governance scope of the Omgevingsvisie and energy-planning dialogues.

4.5 Resident values identified.

Table A 4.1: Overvecht-Noord: resident values identified.

Resident value	How it was surfaced	Description
Affordability	Resident surveys; neighbourhood dialogues	Residents prioritised affordability repeatedly emphasising that any transition away from gas must not raise living costs. This led directly to ruling out the district-heat plan in 2024
Fairness / equity	Klankbordgroep discussions; audit interviews	Residents expressed that vulnerable households should not bear higher costs; fairness framed as equal benefit distribution
Comfort and continuity	Surveys; feedback sessions with housing corporations	Tenants expressed concern that new heating systems should maintain warmth and reliability equal to current gas systems
Trust and procedural clarity	Public information sessions; Rekenkamer interviews	Many residents indicated confusion and mistrust due to unclear communication and changing timelines; transparency viewed as a core value
Participation and voice	Klankbordgroep and dialogues	Residents valued being heard in planning discussions but noted that consultation did not always translate to influence on final decisions

4.6 Level of integration of values in decisions

Table A4.2: Overvecht-Noord: integration of values in decisions.

Resident value	Degree of integration	Example of integration
Affordability	High	Affordability concerns directly factored into the decision to halt the heat-network plan when it proved too expensive for the community
Fairness / equity	Medium	Equity concerns acknowledged in planning documents and public debates, though specific mechanisms to guarantee equitable outcomes remain under development
Comfort and continuity	Medium	While not explicitly documented in technical criteria, comfort considerations informed the shift in heating-technology planning
Participation and voice	Medium	Surveys and klankbordgroepen provided avenues for resident input, but final decisions remained with municipal and policy authorities
Trust and procedural clarity	Low–Medium	Audit findings highlight that residents perceived weaknesses in transparency and procedural communication, indicating incomplete integration

4.7 Challenges

Table A4.3: Overvecht-Noord: challenges encountered.

Challenge category	Description
Affordability and feasibility	Collective heat-network options were deemed too expensive given local building types (many low-rise homes) and distribution costs, leading to plan abandonment
Complex governance coordination	Involvement of multiple corporations, energy companies, and municipal actors led to unclear roles and decision authority, a point reinforced by the Rekenkamer audit
Mismatch between ambition and capacity	Early gas-free goals (2030) were aspirational but lacked adequate instruments to enforce or financially support uptake at scale
Resident uncertainty	Long timelines, evolving plans, and discontinuity (e.g., withdrawal of partners like Eneco) contributed to resident confusion and lack of clear project milestones

4.8 Outcomes

- **Revised planning approach.** The original aardgasvrij strategy was discontinued in favour of new planning alternatives better aligned with affordability and resident constraints.

- **Enhanced resident-dialogue infrastructure.** Networks of engagement, klankbordgroepen, and survey tools have been established and maintained for future transition planning.

- **Municipal learning and accountability.** The Rekenkamer's evaluation provided clear governance reflections that can inform future participatory and technical planning.

- **Spatial and policy inclusion.** Overvecht's longer-term Omgevingsvisie incorporates resident input into spatial and sustainability priorities through iterative consultation processes.

4.9 Key insights for framework development

- **Affordability as a gating value.** Effective retrofit or transition strategies must prioritise affordability as a core metric , if residents face increased costs, technical goals are unlikely to succeed.

- **Participation mechanisms shape legitimacy.** Even consultative participation (surveys, klankbordgroepen) affects perceived fairness and acceptance; integration into formal planning documents strengthens legitimacy.

- **Governance clarity matters.** The Rekenkamer audit highlights that unambiguous roles, timelines, and communication protocols are essential to uphold resident trust and effective co-creation.

- **Tension between ambition and feasibility.** Aspirational goals (2030 gas-free) need realistic assessment of technical and economic constraints, and resident values help ground these in lived priorities.

- **Iterative planning over fixed pathways.** The shift from a heat-network plan to new alternatives reflects that transition frameworks must remain adaptive to resident feedback and changing conditions.

A.5 Sutton Estate, London

5.1 Project context

Sutton Dwellings is a historic Edwardian-era social-housing estate in London Borough of Chelsea, originally built between 1912 and 1914 by the Sutton Model Dwellings Trust (now Clarion Housing Group), as one of the earliest examples of affordable housing in the UK (RE-DWELL, 2023; Clarion Housing Group, 2023). The estate was designed in Edwardian Baroque style by E.C.P. Monson and comprises fifteen mid-rise red-brick blocks arranged around courtyards (HTA Design, 2024). The estate sits within the Chelsea Estates Conservation Area (HTA Design, 2024). Over time, the buildings became outdated in terms of energy efficiency, comfort, and technical systems.

Following resident campaigning around earlier demolition proposals (the 2018 "Save our Sutton" campaign) (RE-DWELL, 2023), Clarion Housing Group initiated a regeneration project in 2019 that combined refurbishment with deep retrofit, aiming to preserve the estate's historical fabric while improving thermal performance and reducing carbon emissions (Kensa Heat Pumps, 2024a).

The completed phase covers four of the fifteen blocks, where the original 159 small flats and bedsits were remodelled into 81 modern one- to four-bedroom flats accessible by new lifts, with ground-floor flats made wheelchair accessible (HTA Design, 2024; RE-DWELL, 2023).
The refurbishment also re-opened previously closed balconies as private outdoor spaces. The estate has become one of the first examples of a networked ground-source heat-pump system in historic urban social housing ,challenging assumptions about the use of modern renewable technologies in dense, heritage contexts (Kensa Heat Pumps, 2024a, 2024b).

Figure A5.1:Chelsea Sutton-Estate -Flamstead House -original facade (chelseasuttonestate.com)

Figure A5.2:Chelsea Sutton-Estate redesign of HTA design LLP (hta.co.uk)

Aldbury House **Bedmond House** **Chipperfield House** **Delmerend House**

Figure A 5.3: four of the 15 estate blocks of Sutton Estate process (Suttonchelseaalive.com)

5.2 Stakeholders and governance structure

Table A5.1: Sutton Estate: stakeholders and roles

Stakeholder	Role in the project
Clarion Housing Group	Housing-association owner and lead developer; led the regeneration and financing of the retrofit
Kensa Group	Technical partner responsible for designing and installing the networked ground-source heat-pump system
Residents / Tenant Steering Board	Engaged in pre-application design feedback and ongoing consultation via newsletters, workshops, and steering-group sessions
Royal Borough of Kensington and Chelsea (RBKC)	Planning authority; previously engaged with residents in early demolition vs. refurbishment debates
Architectural and regeneration design team (HTA Design LLP)	Led design and energy-retrofit coordination, ensuring integration of heritage and performance improvements.

Governance structure: is blended top-down organisational leadership (Clarion and designers) with formal resident-participation mechanisms (Steering Board, surveys, public consultations) to align retrofit decisions with social values.

5.3 Renovation goal

The overarching aim was to modernise and decarbonise the Sutton Estate while preserving its social and architectural heritage. The project also aimed to debunk myths that heat pumps are unsuitable for old buildings or dense urban settings.

Sub-goals are structured here in six categories, each grounded in Clarion Housing Group, Kensa Group, and HTA Design project documentation:

- **Technical.** Replace legacy gas-heating systems with low-carbon networked ground-source heat pumps providing heating and hot water with minimal on-site emissions; energy-efficiency upgrades to the existing fabric; demonstrating that deep retrofit is feasible in dense urban historic buildings.
- **Social.** Retain existing affordable social-housing stock and community character; integrate retrofit with broader estate regeneration including new communal spaces, improved landscaping, and accessibility upgrades; preserve the social and architectural heritage of the estate.
- **Economic.** Reduce energy costs for residents (modelled annual heating costs ~£301–£712 depending on flat size); affordability for social tenants aligned with long-term housing-affordability goals.
- **Environmental.** Decarbonisation through replacement of legacy gas heating with networked GSHP delivering zero carbon emissions at point of use; HTA Design report a 75% reduction in energy demand and a 39% biodiversity net gain (London's first Building with Nature accreditation).
- **Governance**. Public–private partnership: Clarion Housing Group as lead developer and owner, Kensa Group as technical partner, HTA Design LLP as design lead, RBKC as planning authority; resident participation through the Tenant Steering Board, public consultations, and design-update newsletters.
- **Learning.** Myth-busting demonstrator showing that ground-source heat pumps are suitable for historic, dense urban housing; project recognised through multiple awards (e.g., Green Heat Project of the Year, Energy Efficiency Awards), validating both technical and social impact and contributing to wider sector learning.

5.4 Resident involvement techniques

Table A5.2 :Sutton Estate: resident involvement techniques.

Technique	Method
Resident Steering Board	A core group of residents engaged early in the design phase to comment on plans and influence decisions
Public consultations	Online and in-person sessions to discuss draft designs and gather feedback
Design-update newsletters	Distributed estate-wide to update on design evolution, gather input, and keep the community informed
Interactive workshops and exhibitions	Hosted to allow detailed dialogue about retrofit choices and understand resident priorities

These mechanisms combined formal participatory planning with community forums and written communication to ensure residents had multiple avenues to influence retrofit outcomes.

Figure A 5.4: Communication and engagement Clarion Housing Group webpage -engagement stories and September 2020, a socially distanced outdoor cinema part of the six key events and right the monthly Resident's Steering Group exploring design ideas (

5.5 Resident values identified.

Table A5.3:Sutton Estate: resident values identified.

Resident value	Technique used	Description
Comfort	Interactive workshops; Steering Board	Residents emphasised the need for reliable, warm homes with effective heating that feels familiar and functional within their flats. Work in this case emphasised user-level satisfaction with ground-source heat-pump systems sized to mimic gas-boiler comfort
Affordability	Newsletters; consultations	A core concern was ensuring low running costs. The heat-pump system is designed to give annual energy bills similar or lower than previous systems (~£301–£712 per year depending on flat size)
Heritage continuity	Steering Board; public consultation	Residents and stakeholders valued maintaining historic architecture and community character rather than demolition and redevelopment
Trust and inclusion	Ongoing engagement; newsletters	Engagement over years (since pre-2019 redesign debates) reflected a value placed on being heard and part of decision phases, particularly regarding heritage and energy-system choices

While not all participatory techniques are documented as formal surveys, the Steering Board and newsletters demonstrate active efforts to capture resident concerns and embed them in planning.

5.6 Level of integration of values in decisions

Table A5.4: Sutton Estate: integration of values in decisions.

Resident value	Integration level	Example of integration in decision
Comfort	High	Ground-source heat-pump systems sized to mimic gas-boiler performance were installed to match resident expectations of comfort
Affordability	High	Annual operating costs were modelled to remain affordable for social tenants, aligning with long-term housing-affordability goals
Heritage continuity	High	Retrofit preserved the estate's historic fabric and avoided demolition amid earlier resident campaigns ("Save our Sutton")
Trust and inclusion	Medium	Formal participatory structures ensured involvement, but governance remained with Clarion and designers; resident input shaped design but did not control technical decisions

Integration of comfort, affordability, and heritage values is visible in retrofit choices; participation values are embedded via structured engagement rather than co-decision in technical-governance documents.

5.7 Challenges

Table A 5.5:Sutton Estate: challenges encountered.

Challenge category	Description

Balancing heritage and retrofit	Preserving historic architecture while installing modern heating infrastructure required careful planning and space-limited technology (e.g., heat-pump units inside cupboards)
Urban logistics	Space constraints in dense Chelsea necessitated creative installation of 27 boreholes and coordination of drilling in restricted street spaces
Resident trust	Prior proposed demolitions and redevelopment plans (e.g., early-2010s schemes) had eroded trust, requiring sustained engagement to ensure the refurbished vision was accepted
Technical unfamiliarity	Myth-busting was necessary to reassure residents that heat pumps could work effectively in old, urban flats

5.8 Outcomes

- **Decarbonised heating.** 81 flats across four blocks now receive heat and hot water via networked ground-source heat pumps, delivering zero carbon emissions at point of use and (HTA Design) a 75% reduction in energy demand compared to pre-retrofit (HTA Design, 2024; Kensa Heat Pumps, 2024a). The system uses 27 boreholes drilled to 200m depth feeding individual Kensa Shoebox heat pumps housed inside cupboards (HTA Design, 2024; RE-DWELL, 2023).
- **Preserved social-housing stock**. The retrofit protected and upgraded historic social housing, securing affordable homes for existing and new tenants.
- **Affordability benefits.** Estimated annual heating costs (~£301–£712) demonstrate potential for affordable low-carbon living.
- **Awards and recognition.** Project has won multiple awards (e.g., Green Heat Project of the Year and Energy Efficiency Awards) validating technical and social impact.
- **Myth-busting demonstrator.** Demonstrates that ground-source heat pumps are suitable for historic, dense urban housing.

5.9 Key insights for framework development

- **Historic urban retrofit is feasible**. The Sutton retrofit shows that heritage preservation and decarbonisation can coexist, which is relevant for cities with old housing stocks.

- **Comfort and affordability are interlinked**. Technologies must meet resident-comfort expectations while keeping energy costs stable or lower , a central equity metric across cases.

- **Participation structures enhance legitimacy.** Formal resident forums (Steering Boards, newsletters) helped embed social values into design decisions.

- **Visible performance indicators matter.** Adoption and awards highlight the importance of measurable performance outcomes (emissions reduction, cost savings).

- **Myth-busting as value integration.** Demonstrating technology viability in lived conditions is itself a value-confirming process.

A.6 Križevci Co-operative Housing Project, Croatia

6.1 Project context

Križevci is a small town in northern Croatia (under 50,000 inhabitants), transitioning from a historically industrial economy toward a renewable, community-based model (Energy Cities, 2025a).

The Križevci Co-operative Housing Project converts a four-storey former military dormitory into Croatia's first community-owned cooperative housing pilot, combining energy-efficient retrofit, renewable on-site generation, and collective ownership (Affordable Housing Initiative [SHAPE], 2023; RE-DWELL, 2024).

The dormitory sits within a 77,000 m² former military base; the Croatian Army left the site in 2003, and the City of Križevci began converting the area for civilian use in 2007 (SHAPE, 2023).

Most existing barracks have already been renovated and repurposed (development centre and technology park, kindergarten and polyclinic, retirement home), with several new public buildings (high school, city library, observatory) added (SHAPE, 2023).

In 2018, the Croatian government formally transferred ownership of the area to the City of Križevci with the condition that it be used only for social-development and non-profit purposes (SHAPE, 2023).

The four-storey dormitory targeted for cooperative housing has its ground floor occupied by a polyclinic and kindergarten; the upper floors are reserved for non-profit residential use (SHAPE, 2023). The cooperative-housing pilot started in 2021 and is the final phase of the wider district renovation (RE-DWELL, 2024). A 50-kW photovoltaic array is planned for the building's roof, and recycled materials will be prioritised for interior fit-out (Energy Cities, 2025b).

The pilot was awarded a New European Bauhaus Prize in 2025 for transforming the former military dormitory into a housing cooperative (Energy Cities, 2025b). Križevci's wider energy-democracy context is anchored in the 2018 Sunčani krovovi ("Solar Roofs") crowdfunding campaign , the first energy-themed crowdfunding in Croatia — initiated jointly by the City of Križevci and the Green Energy Cooperative (Zelena Energetska Zadruga, ZEZ) (Osservatorio Balcani Caucaso Transeuropa, 2025; Energy Cities, 2025a).

A separate climate-energy cooperative, KLIK (Križevci Climate Innovation Laboratory), was founded in 2020 by twelve local citizens (mostly women) and operates as a community climate-energy hub running a Climate Energy Office, advisory services, and educational programmes (Osservatorio Balcani Caucaso Transeuropa, 2025; Energy Cities, 2025a).

Figure A6.2 Visualization of the reconstructed former barracks building in Križevci, which will house 36 apartments for Križevci Co-operative Housing Project /Photo: Zadruga Otvorena arhitektura. https://forbes.dnevnik.hr/aktualno/u-europi-je-hit-a-uskoro-ce-biti-moguce-i-u-hrvatskoj-novi-model-gradnje-priustivih-stanova/

Figure A 6.1: The four-storey dormitory of the JNA-kazerne(energy-cities.eu)

6.2 Stakeholders and governance structure

Table A5.1:Križevci: stakeholders and roles.

Stakeholder	*Responsibility*
City of Križevci	Lead public authority; provides the building (former military dormitory) and the regulatory framework via long-term building-rights agreements; co-initiator of the pilot
Open Architecture cooperative	Architectural design partner for the cooperative housing pilot
ZEF -Cooperative for Ethical Financing (Zadruga za etično financiranje)	Financial-cooperative partner; develops the cooperative financing model
MOBA Housing SCE (European Cooperative Society)	Transnational housing-cooperative network supporting the pilot; partner in mapping land, architectural and financial models, and advocating for enabling legal frameworks
Future cooperative residents / members	Once the pilot is operational, residents become members of the housing cooperative, sharing ownership and decisions democratically
European partners (Energy Cities, SHAPE, RE-DWELL, Climate-KIC)	Provide transnational expertise, dissemination, replication frameworks, and Future Cities of Southeast Europe alignment
Wider energy-transition context (KLIK, ZEZ)	Operate in parallel rather than as direct housing-cooperative partners. ZEF (financial), ZEZ (energy/solar), and KLIK (climate-innovation hub) together form Križevci's broader cooperative-transition ecosystem; the housing pilot benefits from this culture without being directly delivered by KLIK or ZEZ

Governance structure: for the housing pilot is co-operative and participatory: members of the housing cooperative will share ownership and management decisions democratically, a first in Croatia's housing history (RE-DWELL, 2024). Housing cooperatives are not yet explicitly regulated under Croatian law; the Križevci pilot operates under the general Co-operative Law (Zakon o zadrugama) of 2011, originally written for agricultural and consumer cooperatives, using municipal land leases and voluntary financial models within what Cooperative Housing International describes as a legal grey area (Cooperative Housing International, 2024)

6.3 Renovation goal

The pilot's goal is to create Croatia's first community-owned, energy-efficient cooperative housing model, demonstrating that affordable housing, renewable energy, and citizen participation can be integrated within one retrofit framework. Sub-goals are structured here in six categories, each grounded in Affordable Housing Initiative (SHAPE), RE-DWELL, Energy Cities, and Cooperative Housing International project documentation:

- **Technical**. Retrofit a four-storey former military dormitory for non-profit residential use; install a 50 kW PV array on the roof; prioritise recycled and reused materials for interior fit-out; passive-design strategies.

- **Social.** Empower residents through co-ownership and democratic self-management following European cooperative-housing principles; promote social inclusion through secure, affordable housing alternatives beyond speculative markets; foster community and belonging through shared spaces and co-design.

- **Economic.** Below-market rents through cooperative financing developed with ZEF; reinvestment of revenues; long-term affordability built into the cooperative ownership model rather than dependent on market dynamics; municipal land contributed under building-rights agreements to reduce cost.

- **Environmental.** On-site PV generation; passive design; alignment with Križevci's wider renewable-transition culture (ZEZ-led energy democracy and crowdfunded solar; KLIK-led climate-energy advisory work).

- **Governance.** Cooperative governance with one-member-one-vote; partnership between City of Križevci, Open Architecture cooperative, ZEF, MOBA Housing SCE, and European partners (Energy Cities, SHAPE, RE-DWELL, Climate-KIC) for transnational expertise.

- **Learning.** Pioneering pilot intended to inspire replication across Croatia and Europe; documented by RE-DWELL and SHAPE as a transferable model for small and medium-sized European cities; project awarded a New European Bauhaus Prize in 2025; catalysed national dialogue on cooperative and community-led housing in Croatia.

Figure A6.3: event initiated by KLIK, a pioneering platform involving citizens in Križevci's transition (energy-cites.eu)

6.4 Resident involvement techniques

Table A6.2:Križevci: resident involvement techniques.

Technique	Description
Co-operative governance model	Residents are shareholders and participate in the cooperative's decision-making (management board, voting rights)
Participatory design workshops	Co-design of interior layout and shared spaces with architects and municipal planners
Community assemblies	Open discussions with citizens about cooperative principles and membership
Educational programmes	Organised by KLIK (Climate Innovation Laboratory) and ZEZ (Green Energy Cooperative) on energy literacy, solar self-consumption, and cooperative principles in the wider Križevci context
Crowdfunding / financial participation	Residents and local citizens co-financed solar PV installations, blending financial and social participation

Participation here is institutionalized, residents are both beneficiaries and co-governors of the retrofit.

6.5 Resident values identified.

Table A 6.3:Križevci: resident values identified.

Resident value	Technique used	Evidence
Empowerment and ownership	Cooperative governance, assemblies	Residents co-own housing units: every member has one vote, fostering equality and democratic control
Affordability and stability	Participatory financial model	Cooperative financing ensures below-market rents and stable housing security
Sustainability and energy autonomy	Workshops, crowdfunding	Integration of solar generation and energy-literacy training align with the city's renewable-transition culture
Community and belonging	Co-design workshops	Shared spaces and design decisions reinforce a sense of community ownership and mutual care
Innovation and replicability	Policy dialogue, SHAPE participation	Residents valued being part of a pioneering model inspiring replication across Croatia and Europe

6.6 Level of integration of values in decisions

Table A 6.4:Križevci: integration of values in decisions.

Resident value	Degree of integration	Description
Empowerment	High	Embedded through the cooperative structure, residents are legal co-owners and decision-makers
Affordability	High	Financial model prioritises affordability, with reinvestment of revenues and cost-sharing mechanisms
Sustainability	High	Energy autonomy achieved through solar PV; operational costs minimised by design
Community and belonging	High	Shared governance, co-design, and open spaces institutionalise community building
Innovation	Medium	Supported by European pilot funding, though long-term replication depends on national legislative adaptation

6.7 Challenges

Table A 6.5: Križevci: challenges encountered.

Challenge category	Description
Legal-framework gaps	Croatian housing law did not initially recognise cooperative ownership models, requiring regulatory adaptation
Financing complexity	Combining EU grants, local funds, and cooperative investments demanded cross-sector collaboration
Limited cooperative experience	Residents and authorities had to learn cooperative governance from scratch
Scaling and replicability	Ensuring this pilot influences broader policy without losing affordability remains a key issue

6.8 Outcomes

- **First cooperative housing in Croatia.** A functioning co-owned, energy-efficient social-housing model now operating in Križevci.
- **Energy-positive and affordable**. Solar PV and passive design reduce operational costs; cooperative ownership avoids speculative rent increases.
- **Policy impact**. Catalysed national dialogue on cooperative and community-led housing models in Croatia.
- **Replicability framework.** Documented by RE-DWELL and SHAPE as a transferable model for small and medium-sized European cities.

6.9 Key insights for framework development

- **Empowerment as ownership.** True empowerment requires formal decision-making power, not just participation. Cooperative structures offer measurable empowerment indicators (voting rights, co-management frequency).

- **Affordability as collective design.** Financial sustainability must be built into the ownership model itself, ensuring long-term affordability independent of market dynamics.

- **Sustainability as citizenship.** Energy autonomy reinforces civic engagement , linking technical retrofit with active citizenship and climate awareness.

- **Community as governance fabric.** Shared governance and design embed belonging and trust, making social cohesion a structural element rather than an outcome.

- **Innovation requires legal flexibility**. Policy frameworks should evolve to legitimise cooperative ownership, enabling replication across jurisdictions.

The Križevci project redefines retrofit as a social-innovation process, not merely a technical one. It demonstrates how empowerment, affordability, and sustainability can converge when residents are owners, decision-makers, and beneficiaries simultaneously.

A.7 Els Mestres, Sabadell, Spain

7.1 Project context

The Els Mestres building (Catalan: Bloc dels Mestres) is a residential block in Sabadell, about 20 km north of Barcelona, originally built in the early 1960s to house teachers working at the adjacent Joan Sallarès i Pla school (HOUSEFUL Consortium, 2018–2023; Housing Evolutions Hub, 2019).

The building has eight residential floors with two flats per floor , sixteen four-bedroom flats of approximately 100 m² each, plus a ground floor reserved for community use (HOUSEFUL Consortium, 2018–2023; RE-DWELL, 2023).

It had long been vacant and in need of deep renovation before HOUSEFUL (HOUSEFUL Consortium, 2018–2023).

Prior to retrofit, the solid brick and ceramic structure suffered from poor thermal performance, outdated systems, and disuse. Sabadell itself has areas of socioeconomic vulnerability and demographics including larger families at risk of social exclusion, making affordable social housing and comfort improvements key goals. Els Mestres is one of four pilot buildings in Spain and Austria selected for HOUSEFUL, designed to integrate circular and sustainable solutions across materials, water, waste, and energy systems.

Figure A7.1:Bloc dels Mestres en Sabadell (Redwell Consha.es)

Figure A 7.2: Close up facade building (Redwell.com)

7.2 Stakeholders and governance structure

Table A 7.1:Els Mestres: stakeholders and roles.

Stakeholder	Responsibility
Agència de l'Habitatge de Catalunya (AHC)	Building owner and social-housing authority responsible for management and overall retrofit coordination
Sabadell Council	Local authority facilitating planning and community alignment
LEITAT, ITEC, Aiguasol, WE&B, Housing Europe	Technical partners and researchers co-creating circular solutions; conducted life-cycle analyses and performance modelling. Other HOUSEFUL partners involved at Els Mestres included Saneseco, Fundació EVEHO, Incasòl, and CARTIF (the wider HOUSEFUL consortium has 16 partners)
Tenants' association and community representatives	Participated in consultation and feedback sessions; tenants provided input on system operation and acceptability
HOUSEFUL consortium	EU Horizon 2020 partnership steering methodology development, baseline tools (e.g., SaaS), and cross-site knowledge exchange across the four demo buildings (two in Spain, two in Austria)

Governance structure: blended municipal social-housing leadership, EU project coordination, and tenant engagement through targeted outreach and co-creation workshops.

7.3 Renovation goal

The overarching goal of the Els Mestres retrofit was to demonstrate a circular, resource-efficient approach to deep renovation in social housing, minimising environmental impact while enhancing comfort and long-term affordability.

A core aim was also to develop methodologies and tools (e.g., circularity indicators, stakeholder-engagement methods) replicable across other housing retrofits.

Sub-goals are structured here in six categories, each grounded in HOUSEFUL project documentation and AHC reporting:

Technical. Deep energy retrofit (DER) through envelope upgrades (cork and other insulation), airtightness enhancements, mechanical ventilation, and renewable systems including solar thermal.

- **Social.** Transform the derelict building into social rental housing for families at risk of exclusion; strengthen inclusion and access to quality homes; build resident capacity to operate complex technical systems.
- **Economic.** Long-term affordability for social-housing tenants; bill neutrality; training residents on efficient system use to keep operational costs low and predictable.
- **Environmental.** ~50% reduction in non-renewable energy consumption via passive (insulation) and active (solar thermal, energy-system) measures; circular-economy solutions across materials reuse, waste reduction, water recycling (greywater and rainwater), and biogas-valorisation pilot concepts.
- **Governance.** Coordinated governance combining municipal social-housing leadership (Agència de l'Habitatge de Catalunya), local authority (Sabadell Council), and EU project consortium (HOUSEFUL with LEITAT, ITEC, Aiguasol, WE&B, Housing Europe and 11 other partners including Saneseco, Fundació EVEHO, Incasòl, CARTIF), with tenant engagement through the tenants' association.
- **Learning.** Develop replicable methodologies and tools. circularity indicators, stakeholder-engagement methods, the proposed circularity-agent role, for transfer to other housing retrofits across Europe through the HOUSEFUL cross-site knowledge exchange.

7.4 Resident involvement techniques

Table A7.2:Els Mestres: resident involvement techniques.

Technique	Description
Workshops and interviews	Residents and tenants were engaged in technical-systems operation training and feedback sessions to build capacity and align retrofit systems with user needs
Tenant-association engagement	Involvement of tenants'-association members in discussions about circular solutions and building-performance priorities
Feedback sessions with stakeholders	Multi-actor dialogues among AHC, tenants, Sabadell Council, and technical partners to assess barriers and agree on pilot elements (e.g., water systems)
Proposed "circularity agent" role	Suggested role for training tenants in system use, reflecting co-learning and capacity building

HOUSEFUL also aimed to pioneer new methodologies for stakeholder engagement, emphasising co-creation and inclusive participation in retrofit planning and design.

7.5 Resident values identified.

Table A 7.3:Els Mestres: resident values identified.

Resident value	Technique used	Description
Comfort	Interviews and workshops	Residents prioritised comfortable indoor environments, reflected in DER measures (insulation, airtightness)
Affordability and bill neutrality	Tenant-association feedback	Social-housing focus meant keeping energy costs low and predictable, with training on efficient system use
Circularity and sustainability	Multi-stakeholder co-creation sessions	Engagement emphasised waste reduction and resource efficiency (material reuse, NBS water treatment)
Learning and inclusion	Operation training and proposed circularity-agent role	Residents valued understanding and operating complex technical systems to ensure usability and ownership

7.6 Level of integration of values in decisions

Table A 7.4:Els Mestres: integration of values in decisions.

Resident value	*Integration level*	*Description*
Comfort	High	Retrofit actions (insulation, airtightness improvements) directly focus on improved thermal and indoor-environmental comfort
Affordability and bill neutrality	Medium–High	Social-housing status and emphasis on energy efficiency suggest alignment with resident-cost concerns; formal metrics for long-term bills are part of HOUSEFUL evaluation tools
Circularity and sustainability	High	Multiple circular solutions (materials, water, waste, energy) are embedded into pilot specifications and building-performance goals
Learning and inclusion	Medium	Training and workshops introduce user-capability components, though long-term monitoring is needed to assess ongoing inclusivity

7.7 Challenges

Table A 7.5:Els Mestres: challenges encountered.

Challenge category	Description
Managing technical complexity	Balancing integrated circular systems (water recyclability, recycled materials, biogas concepts) increased design complexity and required cross-actor coordination
Resident accessibility	Language and technical-comprehension gaps were identified — requiring accessible manuals and multi-modal communication solutions
Conflict and expectation management	Feedback highlighted the need to manage expectations (e.g., water-treatment system deployment), requiring trust building and phased implementation agreements
Material-sourcing priorities	Identification and use of local circular materials demanded deeper supply-chain engagement

7.8 Outcomes

- **Significant energy-performance improvements**. Implementation of cork insulation, airtightness, and solar-thermal systems is projected to reduce non-renewable energy use by ~50% relative to pre-retrofit conditions.

- **Demonstrated circular solutions.** Pilot measures for water recycling, waste management, and low-impact materials showcase practical circular-economy applications in housing retrofits.

- **Social-housing revitalisation.** The building will provide 16 social rental flats for families at risk of exclusion, revitalising disused stock.

- **Improved resident capacity.** Workshops and proposed circularity-agent roles enhance resident understanding of energy systems and efficient living.

- **Methodological contributions**. Co-creation engagement strategies and circularity-assessment indicators developed through HOUSEFUL aim for replication across Europe.

7.9 Key insights for framework development

- **Comfort and circularity must be combined.** Technical retrofit must deliver both thermal comfort and resource efficiency for socially inclusive outcomes.

- **Participatory tech training deepens ownership**. Teaching residents to operate systems increases confidence and supports long-term acceptance.

- **Circular retrofit requires multi-dimension metrics**. Frameworks should evaluate materials, water, waste, and energy systems holistically, not just thermodynamics.

- **Stakeholder co-creation tools matte**r. Engagement methodologies and participatory co-creation improve alignment between resident values and retrofit solutions.

- **Adaptability and replicability**. Integrated circular solutions and co-creation processes developed here provide transferable approaches for similar social-housing contexts.

A.8 Comprehensive cross-case synthesis tables

This section presents the comprehensive cross-case data underlying the synthesis in §3.5 of the main text. See the table at the end of the report to see the full cross case synthesis table.
The same ten analytical categories used to structure each individual case (project context; stakeholders and governance; renovation goal; resident involvement techniques; resident values identified; how values were identified; level of integration of values in decisions; challenges; outcomes; and key framework insights) are read across all eight cases simultaneously. Where the case-by-case format in §A.1–§A.7 reads each case in depth, the tables here read each analytical category in breadth across the cases, supporting direct cross-case comparison.

Cross-case analysis - Dutch cases (4 of 8)

Analytical category	**Reigersbos** *(Amsterdam)* *JustPrepare*	**Bospolder–Tussendijken** *(Rotterdam)* *JustPrepare*	**Dukenburg** *(Nijmegen)* *JustPrepare*	**NOM-woningen** *Gemert-Bakel* *JustPrepare*
Project context	Post-war 1980s Amsterdam Zuidoost. Ten VvE; ~280 apts in concrete blocks above commercial plinth. Pre-renovation E–F label. JustPrepare / EnergyLab Zuidoost.	Veerkrachtig BoTu 2028 (launched 2019). Gijsinglaan: 5 galerijflats, 360 apts, built 1959. Renovation Nov 2020–Mar 2022. F/G→A label. First phase of ~1,600 BoTu homes off gas.	1960s–70s suburban hoogbouw. PAW proeftuin since 2018 (€480k rijksbijdrage). 2,425 dwellings (700 koop, 1,725 huur). First phase 642 dwellings (Zwanenveld + Lankforst-Noord). Aardgasvrij target 2035.	Goed Wonen Gemert: ~2,850 dwellings across Gemert + 6 kerkdorpen. Programme since 2018 (started with 2-dwelling pilot, now ~50–60/year). 55-dwelling Den Elding renovation in 2026.
Stakeholders & governance	10 VvE (initiators); Stadgenoot; !WOON; Municipality of Amsterdam; AMS Institute; TU Delft; EnergyLab Zuidoost; TNO. Horizontal Living Lab governance with Co-Creation Roadmap Manual.	Municipality of Rotterdam; Havensteder; BAM Wonen; Eneco; Team Gijsingflats sociaal team (Frontlijn, WMO Radar, Zorgvrijstaat, De Verbindingskamer); BoTu12 bewonersraad; Veldacademie; Erasmus University. ABCD principles.	Gemeente Nijmegen; Portaal, Woonwaarts, Talis; Firan, InWarmte, ARN. Nijmegen Warmte B.V. (publicly owned, est. 9 July 2025). JustPrepare. Bewonersinitiatief: 'No' (NPLW).	Goed Wonen Gemert (housing corp; programme owner); Huybregts-Relou (construction + prefab); Nathan Systems (heat pumps); Gemeente Gemert-Bakel; residents (individually). JustPrepare.
Renovation goal	Modular circular façade retrofit improving comfort, energy efficiency, and affordability through co-creation and transparent governance. Budget-neutral. 40–60% heating-demand reduction target.	Just gas-free transition combining technical retrofit + social inclusion. Warmtenet aansluiting. Aspirational target: ~1,600 BoTu homes off gas across the wider neighbourhood programme.	Data-driven, monitored aardgasvrij retrofit with collective warmtenet rollout. Comfort-feedback mechanisms. Phased transition aligned with Wijkwarmteplan.	NOM (Nul-op-de-Meter) gas-free retrofit using prefabricated façade elements + biobased materials. Minimal disruption. Portfolio-scale phased rollout.
Resident involvement techniques	Co-creation sessions. Semi-structured interviews. Demo house. Plain-language B1 communication. Shared Miro boards. Reflection sessions. Three resident-led VvE working groups (technical, finance, communication).	Bewonersbegeleiders on-site. Team Gijsingflats sociaal team. Living Lab activities. Participatory monitoring. Story cafés. Informal community-network mapping.	Workshops with model houses. Public meetings. Info centres (Duurzaam Wonen). Klankbordgroepen. Comfort-feedback diaries.	Door-to-door communication. In-home consultations. Tenant briefings. Newsletters. Formal consultation only (informing → consultation on Arnstein's ladder).
Resident values identified	Comfort • Affordability • Fairness • Empowerment • Identity • Sustainability (all six)	Fairness • Trust • Identity • Empowerment	Comfort • Affordability • Participation • Learning	Affordability • Comfort • Trust • Sustainability
How values were identified	Living Lab co-design with three resident working groups. On-site walkthroughs. Post-occupancy interviews. Plain-language summaries enabling broader resident participation.	Participatory mapping + storytelling. Social-network analysis (Veldacademie). Ongoing monitoring through Resilient BoTu 2028 toolkit.	Workshops, dialogues, public meetings. Resident surveys feeding into Wijkwarmteplan documentation.	Resident communication + feedback meetings, mostly individual. Tenant briefings during in-home consultations.
Integration of values into decisions	Comfort: high (technical brief). Affordability: medium–high (budget-neutral principle). Fairness: medium (governance tools mid-project). Empowerment: high (formal subcommittees). Identity: medium (façade preserved). Sustainability: medium–low (cost-constrained).	Fairness: embedded in governance via ABCD. Empowerment: partly procedural (bewonersraad BoTu12). Identity + trust: addressed through long-term sociaal-team continuity rather than formal subcommittees.	Comfort + affordability moderately integrated. Learning procedural. Bewonersinitiatief absent (project is municipally led; structured participation runs alongside but not at decision level).	Affordability strongly prioritised at strategic level. Trust integrated via individual communication. Engagement remains at consultation level rather than co-decision.
Challenges	Ten-VvE governance fragmentation. Procurement-driven standardisation. 2022–23 inflation pressure on bio-based options. Uneven resident participation. Embodied-carbon decisions deferred.	Multi-actor governance complexity. Resident fatigue across multi-year transition. COVID-era execution constraints during 2020–2022 works.	Multi-actor system complexity. Long timelines (2018 designation → 2035 target). Limited bewonersinitiatief. Revised target year (2030 → 2035) signalling delivery difficulty.	Technical scalability of NOM approach across diverse stock. Depth of engagement limited by consultation-only model. Comfort indices not formally captured at portfolio level.
Outcomes	Heating demand reduced 35–50% in monitored sample (vs 40–60% target). Co-Creation Roadmap Manual retained by Stadgenoot. Budget-neutral at portfolio level. First-year affordability concerns reported by lower-income residents.	360 apartments delivered. 8.2/10 resident rating on completion. 125,000 m³/year gas savings. ~225,000 kg/year CO_2 reduction. Strengthened community networks documented in Veldacademie monitoring.	Warmtenet rollout in progress. Nijmegen Warmte B.V. established 9 July 2025. 642 dwellings in first phase. Community learning through Duurzaam Wonen centre. Revised completion horizon 2035.	Hybrid heat pumps deployed across Goed Wonen Gemert portfolio. ~50–60 dwellings/year throughput. Comfort improvements reported via 1-on-1 feedback. Low-carbon trajectory consistent with national 2050 commitment.
Key framework insights	Comfort metrics should include adaptive + daylight dimensions. Transparency tools = governance instruments. Timing of cost recovery is itself a value-design parameter. Empowerment delivered through formal subcommittees, not ad-hoc engagement.	Fairness + empowerment measurable through engagement-intensity indicators. Bewonersbegeleider model = transferable institutional design. Long-term sociaal-team continuity matters more than one-off engagement events.	Comfort + learning needs to be paired with data-ethics + participation metrics. Municipally led ('bewonersinitiatief: No') projects deliver technical results but limit empowerment. Long-horizon proeftuinen require revision-of-target as built-in governance feature.	Comfort + affordability integration requires measurable comfort indices in technical brief. Consultation-only models can deliver technical retrofit at portfolio scale but do not surface fairness, empowerment, or identity. Methodologically important as the consultation-end pole of the spectrum.

Cross-case analysis -Overvecht-Noord + European pilots (4 of 8)

Analytical category	**Overvecht-Noord** *(Utrecht)* *Distinct Dutch*	**Sutton Estate** *(London)* *Kensa / Clarion*	**Križevci** *(Croatia)* *SHAPE / RE-DWELL*	**Els Mestres** *(Sabadell)* *HOUSEFUL*
Project context	Large 1960s social-housing district. 8,000 dwellings (~2,000 koop, rest social rental). 2016 municipal decision: first Utrecht aardgasvrij neighbourhood by 2030. Project halted April 2024.	Edwardian Baroque built 1912–1914 (Sutton Model Dwellings Trust; architect E.C.P. Monson). 15 mid-rise red-brick blocks within Chelsea Estates Conservation Area. Refurbishment 2019–2024; phase 1 = 4 blocks, 159→81 flats remodelled.	Small town, northern Croatia (<50,000 inhabitants). 4-storey former military dormitory. 77,000 m² ex-military base ownership transferred to City 2018. Pilot started 2021.	Bloc dels Mestres, Sabadell (~20 km north of Barcelona). Built early 1960s for teachers of adjacent Joan Sallarès i Pla school. 8 floors + community ground floor; 16 four-bedroom flats ~100 m². HOUSEFUL EU H2020 grant 776708 (2018–2023).
Stakeholders & governance	Gemeente Utrecht; Eneco (withdrew Apr 2024); Stedin; Woonin, Portaal, Bo-Ex (corporations as 'passengers' per audit); Energie-U; resident core groups Klopvaart Aardgasvrij + Nieuwe Energie voor Vechtstroom; Rekenkamer Utrecht audit (Apr 2025).	Clarion Housing Group; Kensa Group; HTA Design (architect); RBKC; Resident's Steering Group; Chelsea Chat newsletter; Save Our Sutton 2018 campaign as resident counter-mobilisation against earlier demolition proposal.	City of Križevci; Open Architecture cooperative; ZEF (Cooperative for Ethical Financing); MOBA Housing SCE. KLIK + ZEZ as wider energy-democracy context (not direct partners). Croatian legal grey area (Zakon o zadrugama 2011).	AHC (Catalonia Housing Agency); Sabadell Council; HOUSEFUL consortium of 16 partners (LEITAT coordinator; ITEC; Aiguasol; WE&B; Housing Europe; Saneseco; Fundació EVEHO; Incasòl; CARTIF). Tenant association. Tenant participation 'low' (consultation + collaboration per Arnstein).
Renovation goal	Just gas-free transition by 2030 (original ambition). Pathway: warmtenet aansluiting + insulation upgrades. Halted because Eneco's 7.5% return made aansluiting €4,000–€8,000/dwelling unaffordable.	Decarbonise heritage social housing via networked GSHP while preserving Edwardian character. 75% energy-demand reduction (HTA Design). Zero carbon at point of use (Kensa).	Transform 4-storey former military dormitory into Croatia's first community-owned cooperative housing pilot. Energy-efficient retrofit. 50 kW PV planned. Recycled materials prioritised.	Circular renovation integrating water, waste, energy reuse for social housing. Cork ETICS insulation. Sabadell circularity-agent training programme. Demonstration of HOUSEFUL methodology in real social-housing pilot.
Resident involvement techniques	Klankbordgroepen. Surveys. Dialogue sessions. Voorbeeldwoning Jouwhuisslimmer (Costa Ricadreef 183). Resident core-group self-organisation around alternative collective-heat-pump proposals.	Resident Steering Group. Public consultations. Design workshops. Chelsea Chat newsletter. Resident-campaigning legacy from Save Our Sutton 2018.	Cooperative governance principles (one-member-one-vote). Co-design workshops. Assemblies. KLIK + ZEZ educational programmes (wider context). Pilot residents not yet installed (still in development through 2025).	Workshops. Stakeholder feedback sessions. 'Circularity agent' training. Tenant association consultation. HOUSEFUL D3.1 social-engagement strategy (Medina et al., 2019).
Resident values identified	Affordability • Fairness • Trust • Participation	Comfort • Affordability • Heritage continuity • Inclusion	Empowerment • Affordability • Sustainability • Community	Comfort • Affordability • Circularity • Learning
How values were identified	Surveys, focus groups, klankbordgroepen during 2016–2024 transition. Alternative-proposal drafting by resident core groups. Rekenkamer audit interviews + document analysis (Apr 2025).	Resident Steering Board meetings. Consultation sessions. Save Our Sutton 2018 campaign as counter-mobilisation surfacing heritage + continuity values.	Cooperative decision-making (planned for resident-installation phase). Educational programmes. SHAPE + RE-DWELL replication-framework workshops with European partners.	Workshops + co-creation feedback documented in HOUSEFUL D3.1. Tenant-association consultation. Circularity-agent training as a value-surfacing instrument.
Integration of values into decisions	Affordability decisive (halted unfeasible plan in April 2024). Fairness partly integrated through Rekenkamer audit + resident-core-group recognition. Trust eroded over the 2016–2024 timeline.	Comfort + affordability fully integrated (heating cost £301–£712/year, avg £441, 2025). Heritage retained via HTA conservation approach. Resident-steering-group input shaped phasing.	Empowerment institutionalised through co-ownership and one-member-one-vote. Affordability intrinsic to cooperative model. Structural value-integration ahead of physical occupation.	Comfort + circularity fully embedded technically. Learning integrated medium (circularity-agent training). Tenant participation explicitly low — values surfaced but with limited resident decision-rights.
Challenges	Affordability barriers (€30,000–€80,000 for some homeowners on individual conversions). Unclear governance ('passengers' in audit). Loss of trust over time. Rekenkamer concluded failure was foreseeable.	Heritage retrofit logistics (27 boreholes drilled to 200 m in dense urban site). Residual trust deficit after 2018 Save Our Sutton campaign. Conservation-area constraints on external interventions.	Croatian legal grey area (no explicit cooperative-housing law). Financing complexity. Pilot still in development through 2025. Replicability constrained by national regulatory landscape.	Technical complexity of HOUSEFUL circular package. Comprehension barriers for tenants. Expectation management across H2020 timeline (2018–2023). Tenant participation depth structurally limited.
Outcomes	Project halted April 2024. Policy learning via Rekenkamer 'kroniek van voorspelbare beëindiging' (April 2025). Two resident-core-groups continue alternative collective-heat-pump development. Gemeente working on alternative plan.	75% energy-demand reduction. Zero carbon at point of use. £301–£712/year heating cost (avg £441 in 2025). 39% biodiversity net gain. London's first Building with Nature accreditation. Green Heat Project of the Year 2025.	Pilot still in development through 2025. New European Bauhaus Prize 2025. First Croatian energy crowdfunding (Sunčani krovovi 2018, ZEZ). 50 kW PV planned for cooperative roof.	~50% reduction in non-renewable energy use. 16 social units renovated within HOUSEFUL methodology. Bloc dels Mestres positioned as circular-retrofit benchmark in HOUSEFUL deliverables and AHC's circularity legacy programme.
Key framework insights	Affordability + trust = gating conditions for participation success. Financing structures with high return demands incompatible with social-housing energy transition at scale. Resident counter-organisation can produce viable alternatives when official channels falter.	Identity + heritage linked to comfort + satisfaction indicators. Resident campaigning can shift demolition trajectories into refurbishment. Conservation-area constraints can be reframed as design-discipline rather than design-limitation.	Empowerment measurable through co-decision + ownership structures rather than consultation rights. Cooperative form enables structural value-integration but requires legal-framework alignment to scale. Pilot timelines (2021–2025+) must be acknowledged when reading 'outcomes' in real time.	Circularity measurable via reuse metrics + participatory co-learning indicators. Technical-circular ambition can run ahead of resident participation depth. Circularity-agent training = transferable instrument linking sustainability values to procedural-fairness values.

Appendix B- Component catalogue

See included document in this assessment.

Appendix C: Additional tables and information

This appendix records the technical and regulatory material supporting the façade system in Chapter 5 (§5.2) and the evaluation in Chapter 8. The main text presents only summarised results; the underlying reference base, calculations, and source mapping are documented here. The appendix has four sections.

C.1: State of the art of modular façade systems documents the unitised façade tradition from which Layer 1 inherits its logic, so the system reading in §5.2 can stay focused on the Value–Indicator criteria.

C.2 :Comparative assessment of reference systems gives the full system-by-system reading behind Table 5.1, placing the five reference systems of §5.2.2 against the seven criteria of §5.2.1.

C.3 : Thermal calculation of the Layer 1 envelope records the Layer 1 build-up calculation for the Gijsingstraat case (§7.4), the resulting Rc and U-values reported in §5.6.2, and the benchmarking behind KPIs C1 and C2.

C.4 : KPI sources and calculation tables records the source of each of the seventeen KPIs and the full calculations for the design variants V02–V04, complementing the worked V01 evaluation in §8.6.

C.1 State- of-the art modular façade system

This appendix records the technical reference base on which the Value-Integrated Modular Façade System of Chapter 5 builds. It is organised in three thematic sections that follow the framework's own logic. The first section identifies the unitised façade as the typological starting point and names the component logic that the framework inherits from it. The second section examines the connection and joint systems that determine how the façade interacts with the existing building during installation. The third section examines the materials and openings that carry the configurable Layer 2 responses to resident values.

VIMFS Layer 1 inherits four elements from the unitised façade tradition: the structural-frame logic, slab-edge anchoring, multi-stage joint and gasket strategies, and factory prefabrication discipline. This appendix records that tradition so the system comparison in Chapter 5 §5.2 can stay focused on the V-I criteria rather than on technical specification.

C.1.1 Development and terminology of the modular facade

The modular facade can be read as part of a longer development from massive load-bearing walls, through skeletal construction, to non-load-bearing envelopes fixed back to a separate structural frame. In early wall construction, structure, enclosure and thermal mass were combined in one element. The gradual separation of load-bearing structure from external envelope allowed the facade to become a lighter and more specialised building layer. This separation created the technical conditions for curtain walls, prefabricated facade systems and, eventually, unitised facade modules (Knaack et al., 2014).

One of the earliest patents for a modular façade concept was registered in 1974 by Lore Brown, describing sectionalised interlocking façade components enabling repetitive assembly (Brown, 1974). Since then, numerous patents have refined prefabricated building and façade construction methods, reflecting the increasing industrialisation of envelope systems.

In 2008, Hövels introduced the concept of the open modular façade, advocating interchangeable, multifunctional, and flexible modules with standardised interfaces (Hövels, 2008). This approach integrated open-source thinking into façade design, promoting interoperability, adaptability, and long-term upgradeability.(Li et al,2020)

In the literature, several related terms appear:

- Multifunctional Façade Module (MFM) emphasises integration of multiple performance functions (energy, ventilation, shading) into one module.
- Responsive Building Elements (RBEs) and Advanced Integrated Façades (AIFs) highlight control of energy and mass flows
- Adaptive Façades (AF) or Climate Adaptive Building Shells (CABS) refer to envelopes that dynamically respond to climatic conditions and occupant requirements.

These concepts show that contemporary facade development is no longer only about enclosure. It also concerns energy, comfort, adaptability, and user interaction. VIMFS does not adopt a fully kinetic or responsive facade model. It uses the unitised tradition for Layer 1 and introduces resident-facing adaptability through a separate Layer 2.

In the context of this thesis, modularity does not mean unlimited interchangeability. It refers to a repeated assembly logic in which the facade is divided into transportable, manufacturable, and installable units. The modular facade must therefore coordinate module size, structural interface, installation sequence, tolerances, environmental control, and future replacement. These questions are particularly important in retrofit, where the new system must connect to an existing building whose grid, slab edges and masonry conditions were not designed for a new prefabricated facade layer.

C.1.2 Façade typology and component logic

VIMFS Layer 1 adopts the curtain-wall principle: a non-load-bearing external façade system fixed back to the main building structure. The façade resists self-weight, wind pressure and suction, thermal movement, and weather exposure, but it does not carry floor slabs or primary structural loads. This distinction is important because VIMFS is conceived as an externally added refurbishment layer rather than as a replacement of the building's structural system.

Within curtain-wall construction, two assembly routes are relevant: stick-built systems and unitised systems. Both use comparable component families, such as mullions, transoms, insulated glazing units, seals, gaskets, drainage paths, and anchors. The difference lies in where the façade is assembled and where quality control takes place.

In a stick-built system, mullions are fixed to the building first, after which transoms, glazing, insulation panels, cladding, and seals are installed piece by piece on site. This route offers site adjustability, which can be useful when working with irregular existing structures, but it is labour-intensive and highly dependent on-site access, weather conditions, and on-site sealing quality.

In a unitised system, large façade modules are prefabricated under factory-controlled conditions and installed on site as complete units, often storey-high and hung onto slab-edge or structural anchors.

Each module can integrate the structural frame, insulation, membranes, glazing, gaskets, drainage paths and finishing components into one transportable element. This improves dimensional control, installation speed, joint quality, airtightness, and watertightness. For this reason, VIMFS Layer 1 adopts the unitised approach as the technical reference for its standardised performance layer.

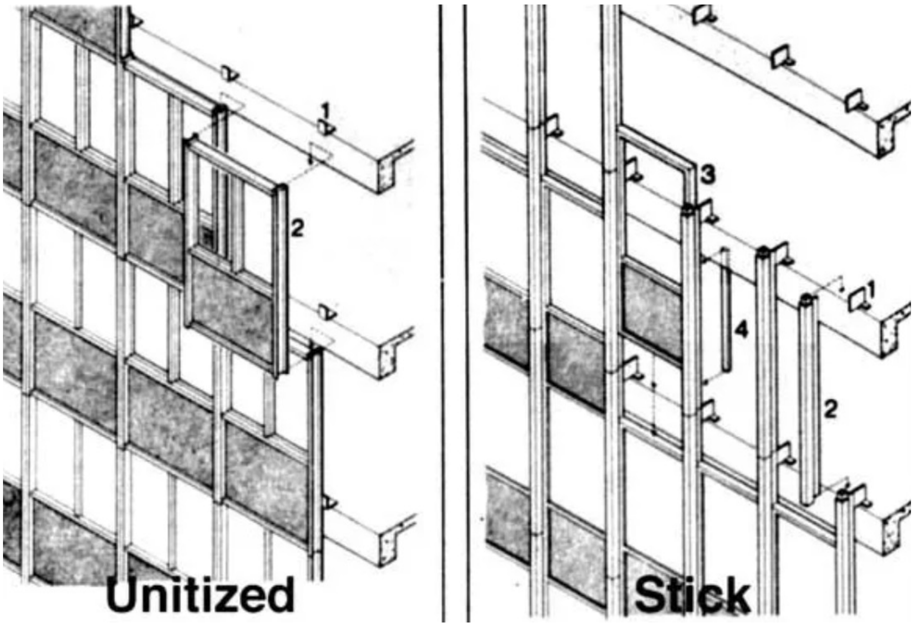


Figure C.1 Stick-built vs unitized facade system (Mannlee building materials,2026))

C.1.1.2 Primary components

A unitised module can be reduced to three main component groups: *framing, panel, and joints. (Table C.1 & figure C.1.1)*

- Framing forms the structural skeleton and geometric form of the module. It carries wind and dead loads, defines the grid, and transfers forces back to the existing building through the anchoring system.
- The panel forms the functional infill. It contains the climatic and user-facing elements, such as insulation, membranes, window modules, ventilation inserts, solar-control components, and cladding.
- Joints form the perimeter interfaces between modules and between the module and the existing building. They maintain load transfer, airtightness, watertightness, drainage, and movement accommodation.

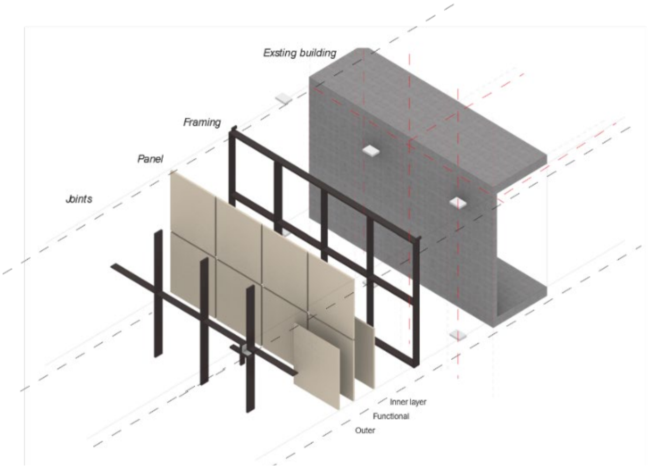


Figure C.1.1. Exploded component logic of a unitised façade module: framing, panel, and joints (own work).

Main Component	Sub-components	Technical role	Relevance to VIMFS
FRAMING *(Primary structural system)*	• Primary structural frame (mullions & transoms) • Anchoring system to existing building • Grid dimension	Holds the system in place; carries wind and dead loads; transfers loads to existing structure; ensures structural continuity between modules	Forms the Layer 1 carrier and fixes the equal technical baseline.
PANEL *(Infill & functional systems)*	• Inner control layer (airtightness, vapour, WRB) • Insulation layer • Window module • Integrated environmental modules (ventilation, PV) • Solar control elements • External cladding	Infill of the framing, provides thermal performance, moisture control, daylighting, ventilation, renewable energy integration, and architectural expression	Carries the main opportunities for Layer 2 variation once resident-facing elements are decoupled.
JOINTS *(Interface joint system)*	• Structural joints (module-to-module, module-to-building) • Environmental joints (gaskets, seals) • Cladding fixing interface	Maintain continuity between modules and between the module and existing building. Ensures structural load transfer; guarantees airtightness and watertightness; enables reversible assembly and façade continuity	Enable airtightness, watertightness, and replacement without disturbing the full system.

This component decomposition clarifies what the VIMFS framework leaves fixed and what it makes variable. The framing, anchoring and primary environmental control layers belong to Layer 1, because they secure the shared technical baseline across all dwellings. They are therefore kept stable for reasons of performance, buildability, and fairness. The resident-facing elements are organised in Layer 2.

These include cladding, shading, greening, threshold components, privacy elements, and accessible fixing interfaces. Layer 2 variation is only possible if these elements can be attached, replaced, or adjusted without compromising the Layer 1 carrier.

The relation between Layer 1 and Layer 2 therefore follows the engineering logic of the unitised façade tradition but adapts it for value-led refurbishment. In conventional unitised systems, the visible external finish is often integrated into the cassette and changes only when the whole unit changes. In VIMFS, the stable carrier and the adaptable resident-facing layer are separated. This allows the system to combine the reliability of factory-made unitised construction with the possibility of bounded variation in response to resident value priorities.

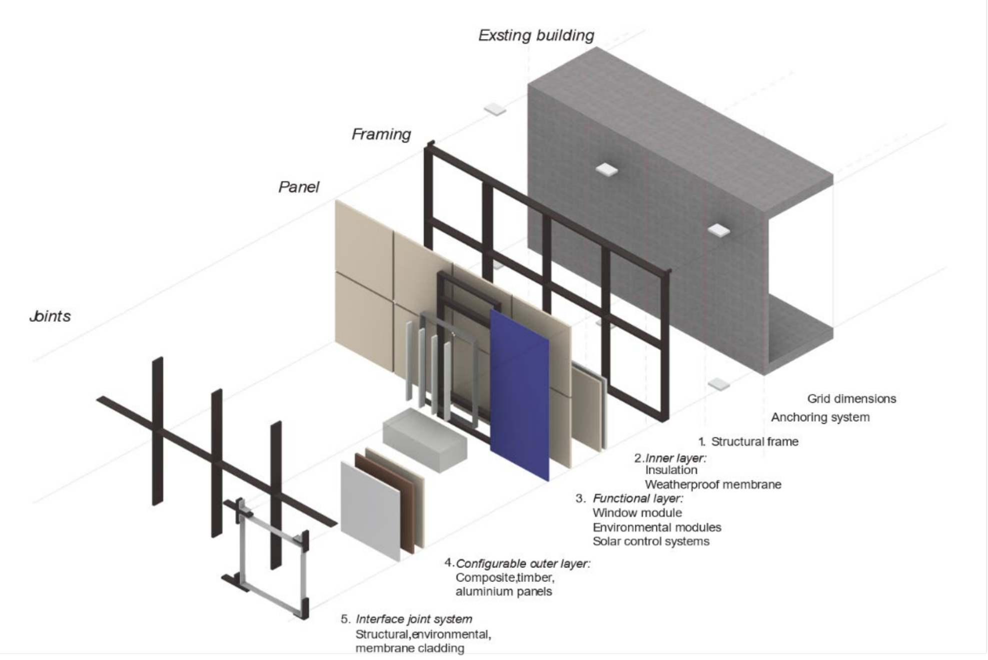


Figure C.1.2: Analysing components and subcomponents unitised curtain wall system for VIMFS (own work)

C.1.3 Grid, anchoring, and joints

The grid and anchoring strategy define how a prefabricated façade module is positioned, transported, lifted, and structurally connected to the existing building. In a unitised façade system, the module is not designed as an isolated object. Its dimensions, joints, load paths, and installation sequence all depend on the relationship between the façade grid and the existing structural grid.

The structural grid is the geometric backbone of the unitised façade, which requires careful coordination. In new construction, the facade grid can be coordinated with the structural grid from the start. In retrofit, the new facade must respond to existing slab positions, masonry tolerances, balcony edges, and window rhythms. This makes grid coordination one of the first design decisions in the application of a modular facade system.

Two grid readings are relevant which are in found in practice.
A centreline grid uses the centreline of structural or facade elements as the reference, which is useful when dimensions are still being coordinated.
A modular grid repeats a fixed module size and is more useful for industrialised production.
Primary and secondary grids can coincide, but they can also be offset to improve proportions or align windows. Offsetting can improve architectural expression, but it introduces joint and anchoring complexity.
The façade can be positioned *in front of, flush with or behind t*he load-bearing structure. Each position has different consequences for fire stopping thermal continuity and anchoring. In residential retrofit, an external position is usually preferred because the new performance layer can wrap the existing envelope from the outside while residents remain in the building. This supports occupied renovation and reduces the need for internal demolition. However, it also makes the anchoring system the critical interface between industrialised module logic and the irregularity of the existing building.

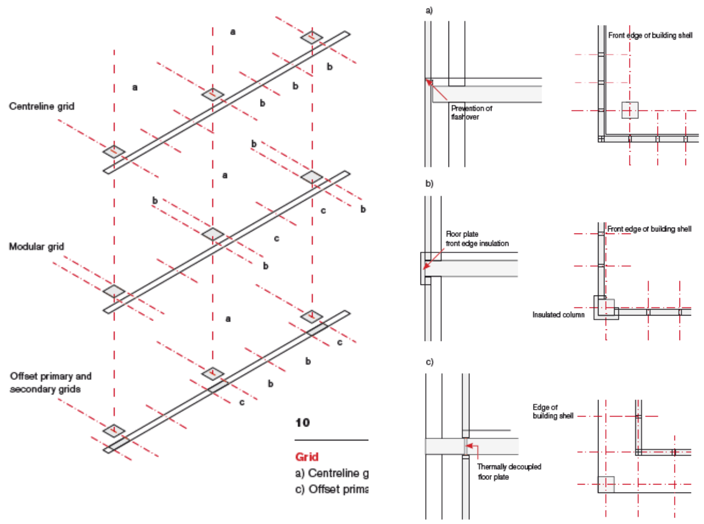
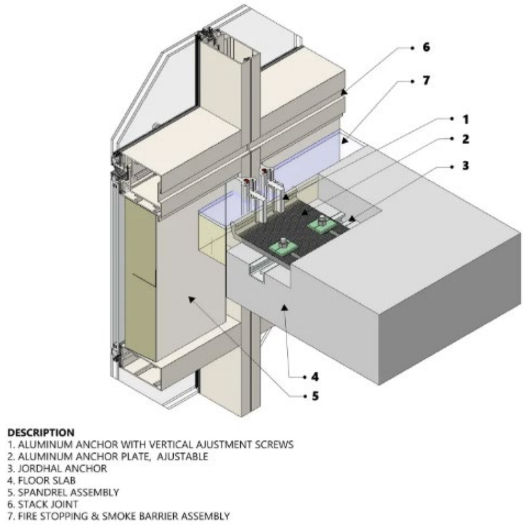


Figure C.1.3: Grid explanation (L) and facade positioning (R) (Knaack et al,2007)

Anchoring as structural interface: Anchoring is the interface between the prefabricated module and the existing building. It determines whether the retrofit is structurally safe, installable, thermally continuous, and potentially reversible. In retrofit, this interface is rarely straightforward. Existing concrete or masonry may be irregular, carbonated, weak, interrupted by balconies or misaligned with the intended façade grid. For that reason, anchoring must be treated as a project-specific design condition rather than as a standard catalogue item.

The anchoring system transfers the self-weight of the façade module, wind pressure and suction, thermal movement, and inter-storey drift into the existing structure.

Unitised systems commonly use either top-of-slab or edge-of-slab anchoring. Top-of-slab anchoring places the bracket on the horizontal upper surface of the slab. It can be useful where internal access is possible or where slab edges are irregular. Edge-of-slab anchoring fixes the bracket to the vertical face of the slab and is common in high-rise unitised construction because it supports a direct hook-on installation sequence.(see figure c.1.4 & c.1.5)



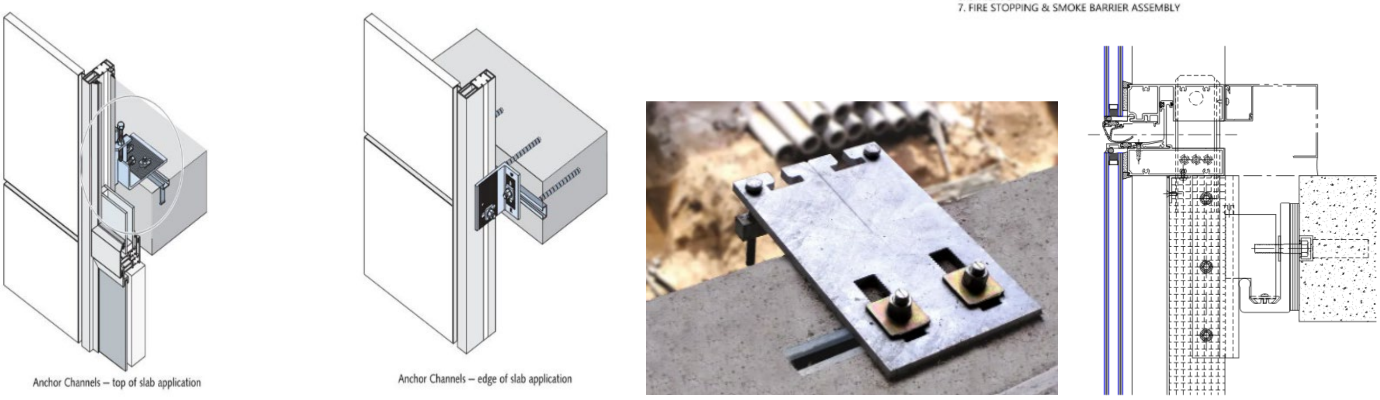


Figure c.1.4 Halfen HCW B1 and Halfen HCW-ED/EW for post-beam facades. Two anchoring type Halfen HTA-CE Cast-in channels -YUW 750 TU unitised curtain wall edge anchor

In both cases, the load path is usually separated. A load-bearing bracket carries the vertical dead load of the module, while a secondary restraint bracket resists wind, rotation, and movement. Adjustment slots, shims, or tolerance zones allow the module to be aligned during installation. For VIMFS, this is essential because Layer 1 must be structurally and thermally reliable before any resident-facing Layer 2 variation is added.

Assembly and transport logic the grid and anchoring strategy are also linked to transport and assembly. A unitised module must be large enough to reduce site labour, but small enough to be manufactured, transported, lifted, and installed safely. Storey-high elements are common because they align with the floor-to-floor rhythm of the building and allow one module to close a complete vertical façade zone. Width is usually governed by the façade rhythm, truck dimensions, crane capacity, lifting stability and the maximum size that can be handled on site.

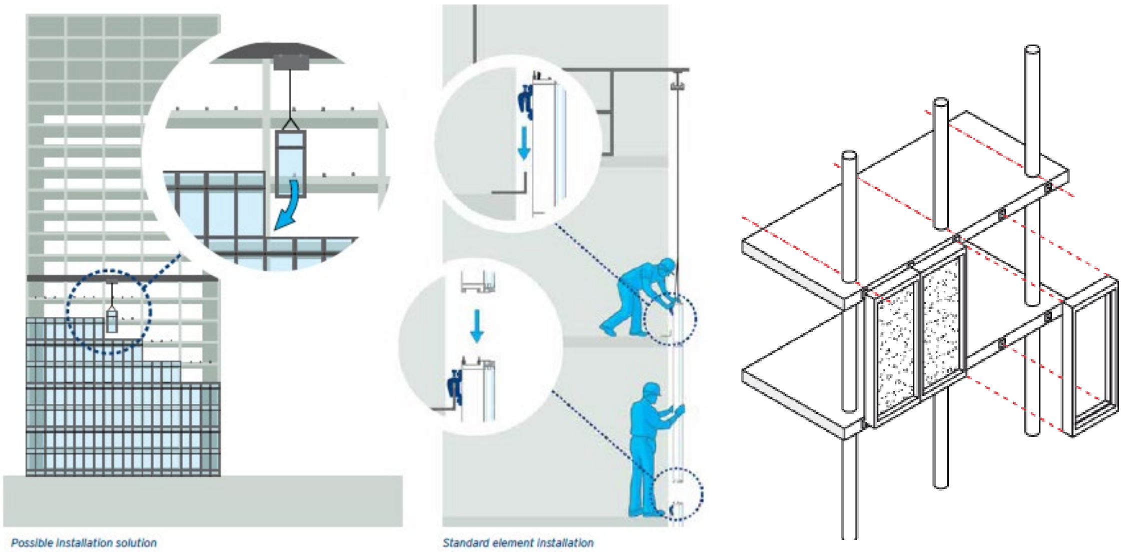


Figure C.1.5: Assembly sequency unitised facade (L) and grid alignment (R)(Reynears brochure and Knaack et al 2007)

This has direct consequences for VIMFS. The Layer 1 carrier should be designed as a repeatable, transportable module that can be factory-assembled and externally installed. The more regular the grid, the more efficient the production and installation process becomes. However, retrofit conditions often require tolerance zones at edges, corners, balconies, and existing openings. These tolerance zones prevent small dimensional deviations from disrupting the entire module sequence.

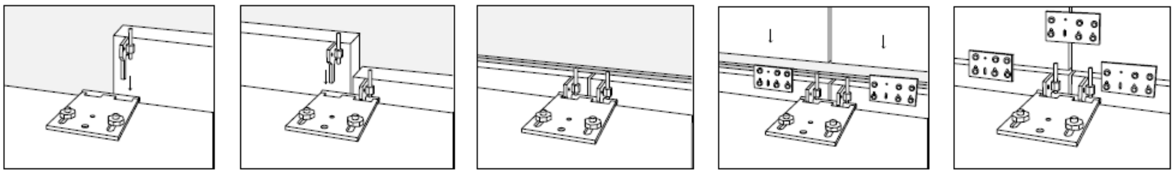


Figure C.1.6: Assembly sequency top of slab anchoring system (reynear)

Joints and weatherproofing: Joints are the critical interfaces between unitised modules. They maintain airtightness, watertightness, drainage continuity, and movement accommodation across the façade. In a unitised system, weatherproofing is not produced by one impermeable outer skin, but by a sequence of structural alignment, mechanical compression, secondary air control, and controlled drainage.

The critical area is the joint between adjacent modules. (see figure c.1.7) This joint must absorb several actions at once: wind pressure and suction, thermal expansion, inter-storey drift, installation tolerance, and rain exposure. If the joint loses alignment or compression, airtightness and watertightness can fail even when the individual module performs well.

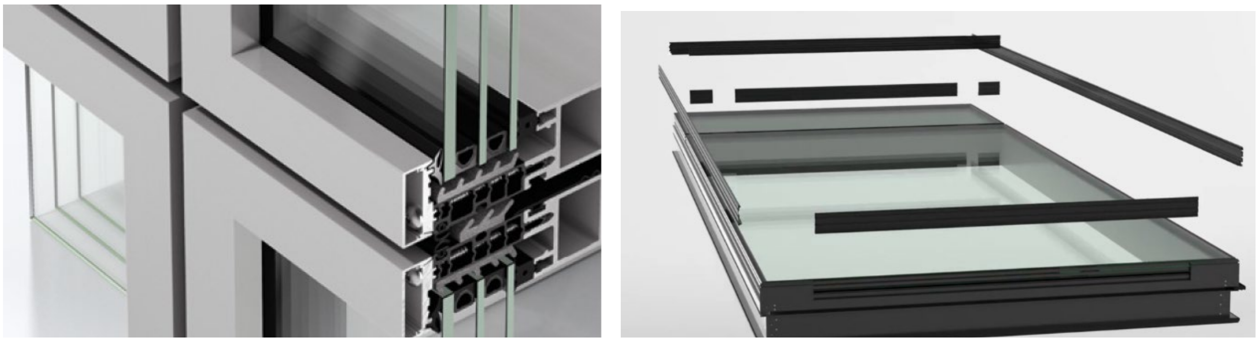


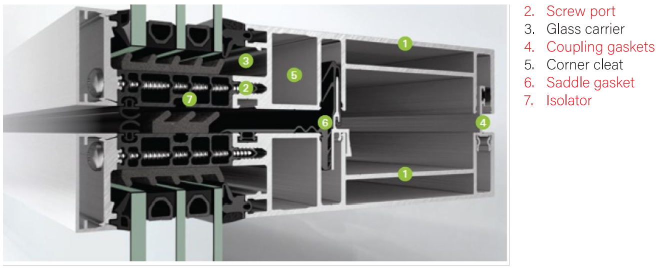
Figure C.1.7:The horizontal joint gaps between the units (L) and internal control layer through multi-chamber push in isolator (Schuco AF UDC 80 brochure)

The unitised tradition moves much of this environmental control into the factory. Gaskets, membranes, thermal breaks, and drainage paths are integrated before the module arrives on site. On site, the weather strategy is activated when the module is hung, aligned, and coupled to adjacent modules. The perimeter interfaces interlock, bringing the gaskets into compression. This reduces dependence on wet, site-applied sealants and improves the reliability of airtightness and watertightness.

The joint strategy is also important for the reversibility of the system. In conventional construction, chemically bonded sealants can make later removal difficult because disassembly damages the seal, the panel, or the neighbouring component. In a unitised logic, mechanical compression joints allow controlled coupling and decoupling, if access and replacement are designed from the start. In figure c.1.8 are the weatherproofing component shown of traditional unitised façade modules

For VIMFS, this has a direct relation to Layer 1 and Layer 2. The airtight and weatherproofing layers belong to Layer 1 and must remain stable across all variants. Layer 2 components should be removable without disturbing the primary environmental control line of Layer 1. This is only possible if the joints and fixing interfaces are accessible from the exterior and organised as reversible connections.

Figure c.1.8:Weatherproofing component unitised facade frame (Schuco brochure



Components assembly facade system Schuco AF UDC80

Implication for VIMFS

For VIMFS, grid coordination, anchoring and joint design have a direct relation to fairness, buildability, transferability, and adaptability. Layer 1 must provide the same technical baseline across all dwellings, but that baseline can only be achieved if the grid, anchoring, and joint strategy are correctly adapted to the existing building. A modular façade system cannot simply be copied from one building to another without recalibrating slab edges, anchor positions, tolerances, load paths, and joint interfaces.

The framework is therefore transferable as a method, while the structural carrier remains project specific. The value-translation logic can travel across buildings, but the technical interface must be redesigned for each building condition.

C.1.4 Panel, materials, and openings: Layer 2 configurability

The panel is the functional infill held by the structural frame of the unitised module. It contains the layers and inserts that deliver thermal performance, acoustic performance, daylight, ventilation, solar-gain control, and architectural expression. While the frame and anchoring system define the structural logic of the module, the panel is where most façade performance and resident-facing variation become visible.

In residential renovation, the opaque zones often offer the largest thermal improvement potential. Spandrel panels, parapets, infill panels, balcony edges, and service zones can carry continuous insulation and external sheathing without the transparency constraints of glazing. Window zones, by contrast, become the main interface for daylight, view, ventilation, operability, and user control. This distinction is important for VIMFS: opaque panel areas support the repeatable performance baseline, while openings and resident-facing inserts allow variation in response to comfort, empowerment, sustainability, and identity.

Insulation choice in opaque areas must balance several criteria: thermal performance, fire safety, acoustic absorption, build-up depth, embodied carbon, cost, and durability. Mineral wool, especially stone wool, is widely used in unitised and high-rise façade systems because it is non-combustible and acoustically effective. Bio-based materials such as wood fibre, cellulose, hemp, and flax can support sustainability-oriented variants because they reduce embodied impact and offer moisture-buffering potential, but they require careful detailing for moisture, fire, and durability. Synthetic foams and high-performance insulation products can reduce thickness where depth is constrained, but they raise questions about cost, fire behaviour, and circularity. (see comparative table)

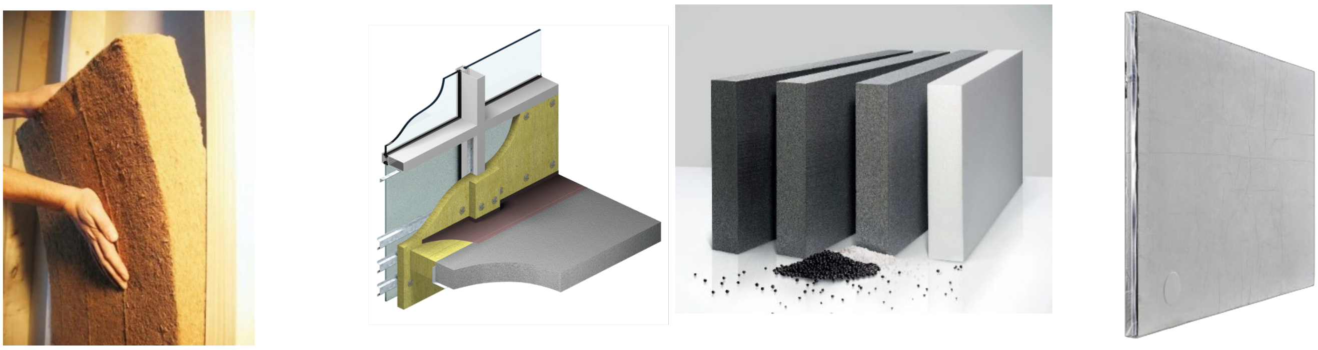


Figure C.1.9: Mineral based: ROCKWOOL CURTAINROCK® 80, oil: BASF Neopor eps I, high performance : Aerogel vacuum insulation panel (vip)

Material Category	**Typical Materials**	**Thermal Conductivity λ (W/mK)**	**Fire Classification (Euroclass)**	**Density (kg/m^3)**	**Relevance for VIMFS**
Organic materials	Wood fibre, cellulose, hemp, flax	0.038 – 0.050	B–E (depending on treatment)	30 – 180	Lower embodied impact and material expression; requires careful moisture and fire detailing.
Mineral-based insulation	Stone wool, glass wool	0.032 – 0.040	A1 (non-combustible)	30 – 200	Non-combustible and acoustically effective; suitable for standardised Layer 1 performance.
Oil-derived insulation	PIR, PUR, EPS, XPS, phenolic foam	0.020 – 0.035	B–E (varies by product)	15 – 45 (EPS/XPS) 30 – 60 (PIR)	High thermal performance per millimetre; raises fire, circularity, and end-of-life questions.
High-Performance Insulation	Aerogel VIP panels, Thermax	0.004 – 0.020	A2–E (varies)	100 – 250 (aerogel composites)	Useful in depth-constrained areas; higher cost and more difficult replacement logic.

Window modules are the most user-oriented elements within the modular grid. They mediate daylight, view, ventilation, overheating, acoustic exposure, privacy, cleaning, and residents' sense of control. Common opening types in unitised systems include tilt-turn windows, top-hung or projected vents, parallel-opening vents, sliding elements and concealed vent systems integrated within curtain-wall profiles. Operable units must be coordinated with reinforced gasket systems, drainage paths, and hardware so that repeated user movement does not compromise airtightness or water resistance.

In VIMFS, the opening type is therefore not only a technical specification. It is also a value-led design decision. A tilt-turn window, a projected vent, or a parallel-opening element each produces a different relation between comfort, ventilation, safety, cleaning access, façade depth, and user control. For this reason, the framework does not prescribe one opening mechanism for all variants. Instead, opening type becomes a configurable decision that must remain compatible with the unitised carrier, gasket strategy, maintenance access, and long-term replacement logic.

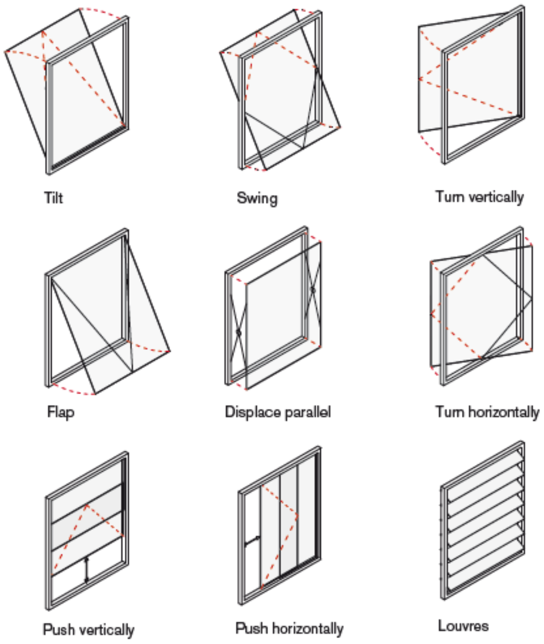


Figure C.1.10:Window modules with different kinds of operation (Knaack et al, 2007)

Window systems are commonly produced in four material configurations, each with different structural, thermal, maintenance and architectural implications. (see table 1.3)

Table C.1.3:Window-module material categories and design implications.

Window material	Characteristics	Advantages	Limits	Manufacturers
Timber / timber-aluminium	Timber core with exterior aluminium protection.	Warm interior expression; lower embodied impact; aluminium cladding improves durability.	Periodic maintenance: dimensional stability and moisture protection need attention.	Internorm, VELFAC, Rationel, Gaulhofer
Aluminium	Extruded profiles with thermal breaks.	High precision, slim profiles, durability, and limited maintenance.	Thermal break is essential; high embodied carbon unless recycled content is used.	Schüco, Reynaers, WICONA, Kawneer, SAPA, Aluprof
Steel	Slender sections with thermal separation.	High strength, fire resistance, and refined appearance.	Higher cost and corrosion protection requirements.	Jansen, Forster, RP Technik
uPVC	Multi-chamber plastic profile, often steel reinforced.	Low cost and low maintenance.	Lower rigidity, fire limitations and less suitable for high-end unitised retrofit.	VEKA, Rehau, Deceuninck, Kömmerling

Other panel-related components may include external cladding, solar-control devices, greening systems, photovoltaic elements, decentralised ventilation inserts, and threshold components. These are not developed in detail in this section, because their value-led selection is addressed separately through the component catalogue. The role of this appendix is to clarify the technical logic of the panel as part of the unitised façade tradition; the catalogue then explores how selected panel and Layer 2 components can support different resident value priorities. As summary off all components of unitised façade see figure C.1.11

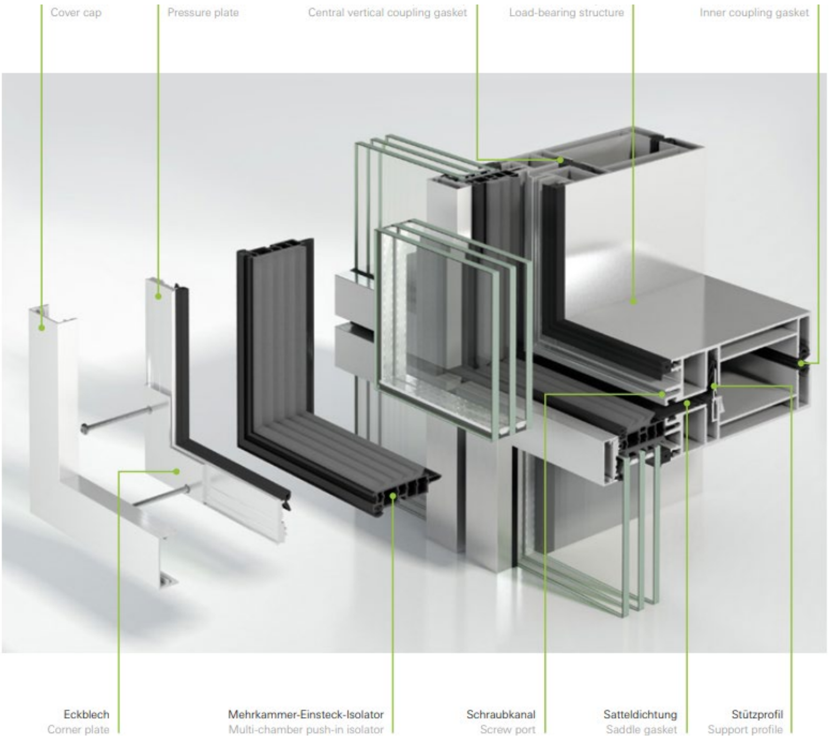


Figure C.1.11: Schuco unitised façade exploded component overview(docucenter schuco)

C.1.6 Reading the unitised tradition against VIMFS

Several unitised and modular façade systems are already available or documented in practice, including manufacturer systems such as Schüco AF UDC 80, Reynaers Element Façade, WICONA WICTEC (see figure C.1.12). In different materials : Timber LVL/CLT, steel , aluminium profiles, hybrid steel–timber frames, or FRP/GRP structural profiles.

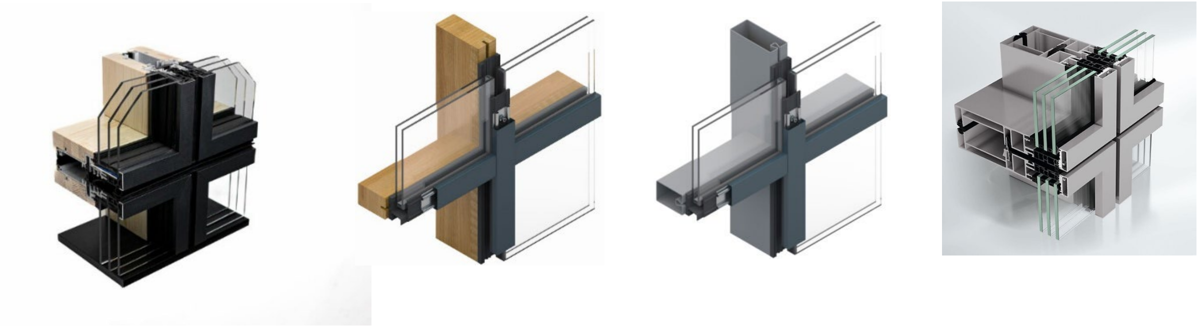


Figure C.1.12: Unitized curtainwall system exterior view. A) Schuco AF UDC 80 system B)Lindner ECO_N® Hybrid C)Stabalux H D)Stabalux SR

These systems demonstrate that prefabricated façade modules can deliver industrialised production, improved quality control, faster installation and coordinated environmental performance. For this thesis, however, the state of the art is not read as a list of products to copy, but as a set of technical conventions that VIMFS reorganises.

The unitised tradition gives VIMFS Layer 1 four working principles. First, the prefabricated structural carrier provides the module geometry, load transfer, and factory quality control.

Second, slab-edge anchoring forms the primary structural interface to the existing building.

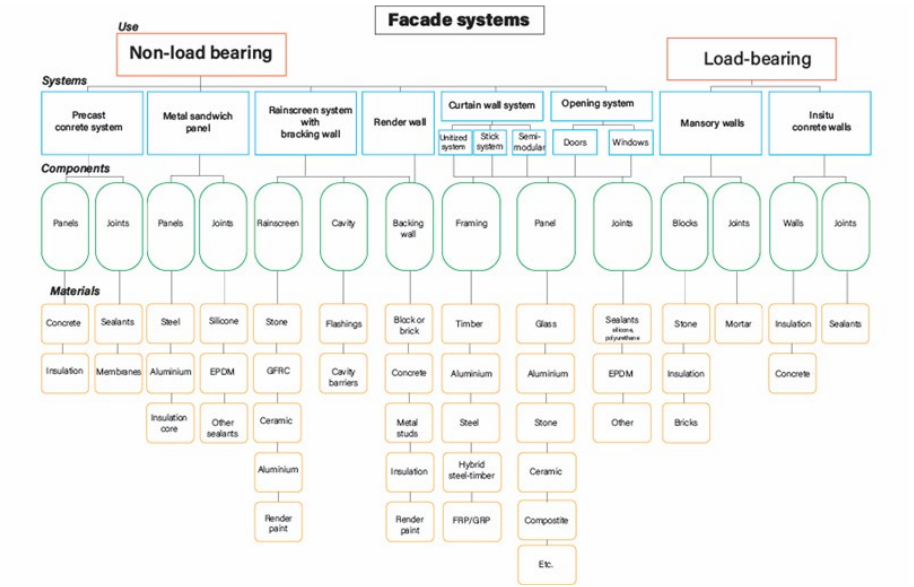
Third, multi-stage gasket, membrane and drainage strategies protect airtightness and watertightness. Fourth, factory prefabrication supports dimensional control, repeatability, and reduced installation on-site time. These principles are adopted because they make the technical baseline reliable.

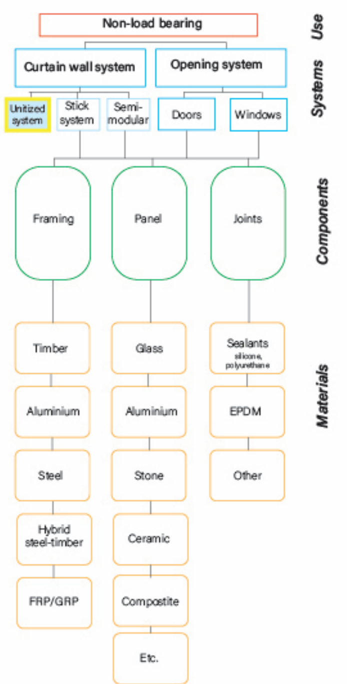
The break from the unitized tradition depends on how you design and approach the resident-facing layer. In many manufacturer systems, the external finish is integrated into the cassette and therefore coupled to the structural and environmental performance core. Changing the visible façade expression then often means changing, adapting, or replacing the cassette itself. In VIMFS, this relation is reorganised. The stable structural frame, insulation line, airtightness strategy, and weatherproofing remain in Layer 1; while cladding and other resident-facing components are moved into Layer 2 where they can be attached reversibly.

This separation allows resident-facing variation without redesigning the performance core for every variant. Layer 1 remains the shared technical baseline across dwellings; Layer 2 becomes the adaptable interface through which different value priorities can be expressed. Resident-led variation therefore becomes possible not because the unitised tradition is rejected, but because its industrialised carrier logic is separated from the visible and usable components that residents experience most directly.

Unitised principle	Adopted in VIMFS Layer 1	Changed by VIMFS
Prefabricated structural carrier	The carrier provides geometry, load transfer, and factory quality control.	Resident-facing components are separated from the carrier where possible.
Slab-edge anchoring	Anchoring remains the project-specific structural interface.	Anchoring is not treated as universal; it must be recalibrated for each existing building.
Multi-stage joint logic	Airtightness, watertightness, drainage, and movement accommodation are protected in Layer 1.	Layer 2 fixings must not compromise the control layers.
Integrated panel and cladding	Insulation, membranes, and environmental control layers remain in the performance layer.	Cladding, shading, and threshold elements become replaceable Layer 2 choices.
Factory prefabrication	Prefabrication supports dimensional control, repeatability, and reduced site time.	The repeated carrier is used to support bounded variation rather than one uniform façade outcome.

The appendix therefore clarifies the technical basis of VIMFS Layer 1. The unitised façade tradition provides the industrialised structural framing: frame, anchor, joint, panel, and factory-control discipline. The Value–Indicator Framework adds the missing selection logic: which resident values justify which variation, where that variation is applied, and how it is later evaluated. This is the point at which the technical reference of the unitised façade becomes a value-integrated modular façade system.





C.2 Comparative assessment of reference modular façade systems

Criterion	**2ndSkin**	**4RinEU**	**TES Energy Façade**	**MeeFS**	**Schüco AF UDC 80 (unitised tradition)**
1. Deep-retrofit performance	Deep-retrofit envelope on Dutch row housing; meets Rc and Uw targets	Multifunctional timber-frame deep retrofit with integrated insulation and service components	CNC-fabricated timber-frame retrofit dimensioned to existing geometry; deep retrofit	Multifunctional façade module integrating insulation, ventilation, solar control, energy	Deep-retrofit performance achievable through unitised carrier with insulated infill
2. Prefabrication and installation	Factory production; external mounting onto existing brickwork	Factory production; prefabricated multifunctional timber elements	CNC-fabricated timber-frame elements; geometry-matched factory production	Factory production of integrated multifunctional modules	Industrial unitised production from manufacturer reference; mature factory logic
3. Structural interface	Brackets onto existing brickwork; thermally broken per element	Timber-frame carrier with bracket interface to existing structure	Timber-frame carrier dimensioned per geometry; bracket interface	Module-level interface; specific to MeeFS substrate	Documented unitised carrier with thermally broken slab-edge anchoring; shared anchoring convention
4. Dwelling-level configurability	Cassette typically uniform across the test row	Some sub-module variation; project-level rather than dwelling-level	Limited to project-level variation in dimensional fit	Sub-module variation possible (insulation, ventilation, solar)	Configurability inherent to the unitised tradition; modular sub-elements available
5. Resident-facing adaptability	Cladding choice per project; resident agency not a system feature	Service-integration suggests resident-facing potential, not formalised	Timber-jointing supports adjustability over time, not formalised	Sub-module replaceability is part of the system	Sub-component replacement supported by the system; not framed as resident agency
6. Value-led selection logic	Not formalised	Not formalised; closer to a multifunctional packaging logic	Not formalised	Not formalised; design choices are functional rather than value-led	Not formalised; system is performance-and-cost-led, not value-led
7. Transparency and fairness of variation	Variation per project; no documented bounded set	Variation per project	Variation per project	Variation per project	Variation potentially documented per manufacturer line, not as fairness-of-baseline argument

C.3 Thermal calculation of the Layer 1 performance envelope

This section documents the thermal performance calculation introduced in Chapter 5. The calculation establishes the Rc and U-values of the post-retrofit wall when the Layer 1 cassette is added to the existing Gijsingstraat baseline wall.

For this thesis, the Layer 1 thermal target is not read as the minimum renovation requirement, but as a new-build-equivalent deep-retrofit benchmark. For an “andere woonfunctie,” Bbl 2024 gives Rc values of 4.7 m²K/W for vertical external constructions, 6.3 m²K/W for roofs, and 3.7 m²K/W for floors.

Table C.2 sets out the calculation layer by layer. The pre-retrofit wall is calculated first, representing the existing Gijsingstraat condition. The Layer 1 addition is calculated second, and the totals are reported at the bottom. R-values for each opaque layer are computed as:

$R = d / \lambda$ where d is layer thickness (m) and λ is thermal conductivity (W/m·K). The membrane and ventilated cavity contribute no usable R in this calculation per the conventions of NEN-EN-ISO 6946.

C.3.1. Existing wall (pre-retrofit)

The existing wall is documented from inside to outside. Material thicknesses are taken from the original construction drawings; thermal conductivity (λ) values are from EN ISO 10456 reference data, which is the standard source for stated values in Dutch building regulation calculations.

The existing wall is chosen as baseline condition type 300 mm which is a 210 mm solid clay brick masonry wall with a 20 mm interior cement plaster, a 60–75 mm drywall installation cavity, a 0.5 mm vapour retarder, and a 15 mm gypsum fibre board interior finish.

Layer 1 of the modular façade system adds a compressible insulation strip, a wooden substrate sheet, the carrier-frame insulation zone, an external wood-fibre sheathing, and a wind-tight membrane to the outside of this existing wall, all behind a ventilated cavity and the Layer 2 cladding.

Table C2.1:Existing wall buildup, pre-retrofit.

Layer (inside → outside)	**Thickness**	**λ (W/mK)**	**R (m²K/W)**
Gypsum fibre board (Fermacell or equivalent)	15 mm	0.32	0.047
Vapour retarder	0.5 mm	—	≈ 0
Drywal installation cavity (uninsulated,with timber studs at intervals)	60–75 mm	—	≈ 0.18 (cavity)
Cement plaster (interior)	20 mm	0.93	0.022
Solid clay brick masonry	210 mm	0.85	0.247
Existing Rc (excluding surface films, with drywall cavity un-insulated)	≈ 285 mm	—	≈ 0.51 m²K/W
Existing U-value (with Rsi 0.13 and Rse 0.04)	—	—	**≈ 1.83 W/m²K**

The pre-retrofit wall sits at Rc ≈ 0.5 m²K/W and U ≈ 1.5 W/m²K.

Both numbers are typical for unrenovated post-war walk-ups . The retrofit must therefore add at least Rc ≈ 4.2 m²K/W of new insulation to reach the Bouwbesluit new-construction minimum of 4.7 m²K/W.

C.3.2. New Layer 1 additions (post-retrofit)

Layer 1 is the standardised performance layer of VIMFS, installed externally onto the existing façade. The build-up developed in Chapter 5, §5.6 and confirmed in Chapter 7, §7.4 is reproduced here with each layer's contribution to the overall Rc. The compressible strip and wooden substrate compensate for surface irregularity in the existing brick (typical tolerance ± 15–25 mm). The carrier-frame mineral wool is high-density rock wool selected for fire performance and dimensional stability over the modular element's transport and lifting cycle. The external wood-fibre sheathing provides continuous insulation that reduces the thermal-bridge effect of the aluminium carrier verticals. λ values from EN ISO 10456; insulation manufacturer datasheets confirm the same values for project-specification grades.

Table C.2.2 post-retrofit thermal calculation of the Layer 1 build-up at Gijsingstraat. Rc ≈ 7.7 m²K/W; U ≈ 0.13 W/m²K.

Layer	Thickness (mm)	λ (W/mK)	R (m²K/W)	Source/Note
Internal surface resistance Rsi	—	—	*0.13*	*NEN-EN-ISO 6946*
Existing wall (230 mm brick, dominant condition)	*230*	*0.85*	*0.27*	*Pre-existing; included in retrofit Rc*
Compressible mineral-wool tolerance strip	*40*	*0.035*	*1.14*	*Tolerance and air-tightness layer at interface*
Wooden substrate sheet	*18*	*0.13*	*0.14*	*OSB or equivalent panel-grade timber*
High-density mineral wool (carrier zone)	*160*	*0.035*	*4.57*	*Primary thermal layer*
Continuous wood-fibre external sheathing	*60*	*0.040*	*1.50*	*Continuous insulation; reduces thermal bridging*
Wind-tight membrane	—	—	*0.00*	*Air-tightness layer; negligible R*
Ventilated rainscreen cavity	*30*	—	*0.13*	*Convention per NEN-EN-ISO 6946 for ventilated cavity*
External surface resistance Rse	—	—	*0.04*	*NEN-EN-ISO 6946*
Total Rc (sum of all R values)			*≈ 7.92*	*Conservative round to 7.7 m²K/W*
Reported Rc post-retrofit			*≈ 7.7*	*Exceeds BBL 2024 minimum (Rc ≥ 4.7) by ~64%*
Installed U = 1 / Rc			*≈ 0.13 W/m²K*	

The dominant thermal contribution comes from the 160 mm high-density mineral-wool carrier zone (R = 4.57 m²K/W). The 60 mm continuous wood-fibre sheathing adds R = 1.50, taking the assembly above the BBL minimum on the insulation contribution alone. The 40 mm compressible mineral-wool tolerance strip adds R = 1.14, providing a substantial bonus while serving its primary function as the airtightness and tolerance layer at the interface with the existing wall. The remaining contributions (existing wall, substrate sheet, surface resistances, ventilated cavity) bring the total to approximately 7.92 m²K/W, conservatively reported as 7.7.

The post-retrofit envelope therefore exceeds the Bbl 2024 new-build-equivalent façade benchmark by approximately 64%. This calculation is identical across all four design variants of the Gijsingstraat application; variation between variants happens entirely in Layer 2.

C.3.3 Regulatory benchmarking

The regulatory benchmark is read against the current Besluit bouwwerken leefomgeving (Bbl) 2024

For new construction, Bbl article 4.152 refers to thermal resistance values determined according to NTA 8800 and table 4.148B. For an “andere woonfunctie,” table 4.148B gives the following reference values: Rc ≥ 4.7 m²K/W for vertical external constructions, Rc ≥ 6.3 m²K/W for roofs, and Rc ≥ 3.7 m²K/W for floors.

For renovation, the Bbl uses a different and lower threshold. RVO summarises Bbl article 5.20 as using the level obtained by law with a lower limit of Rc ≥ 1.4 m²K/W for general renovation. When insulation layers are renewed or replaced, the lower limits are Rc ≥ 1.4 m²K/W for façades, Rc ≥ 2.1 m²K/W for roofs, and Rc ≥ 2.6 m²K/W for floors.

This thesis deliberately uses the new-build-equivalent façade value of Rc ≥ 4.7 m²K/W as a design-stage target because the proposed Layer 1 cassette is intended as a deep-retrofit performance platform. It should therefore not be described as the minimum legal requirement for renovation.

Reference	**Component/ renovation situation**	**Rc / U-value benchmark**
Bbl 2024, art. 4.152 + table 4.148B	Façade / vertical external construction, new construction, “andere woonfunctie”	*Rc ≥ 4.7 m²K/W*
Bbl 2024, art. 4.152 + table 4.148B	Roof, new construction, “andere woonfunctie”	*Rc ≥ 6.3 m²K/W*
Bbl 2024, art. 4.152 + table 4.148B	Floor, new construction, “andere woonfunctie”	*Rc ≥ 3.7 m²K/W*
Bbl 2024, art. 5.20 / RVO summary	General renovation / partial alteration	*Rc ≥ 1.4 m²K/W lower limit*
Bbl 2024, art. 5.20 / RVO summary	Façade insulation layer renewed or replaced	*Rc ≥ 1.4 m²K/W lower limit*
Bbl 2024, art. 5.20 / RVO summary	Window/door/frame replacement	*U ≤ 2.2 W/m²K lower limit*
Layer 1 of this thesis	Post-retrofit façade	*Rc ≈ 7.7 m²K/W*
Passive House Standard	External wall	*approx. U ≤ 0.15 W/m²K*

C.4 Supporting tables and KPI source reference list

This appendix collects the supporting tables and the regulatory benchmarking that inform the evaluation in Chapter 8. To keep the evaluation chapter readable, the main text presents only the summarised results and the reasoning behind each criterion; the underlying calculation tables, assumptions, and the full mapping of each performance criterion to its regulatory reference are documented here.

KPI	Document	Reference unit	Type
C1	Schüco AWS 90.SI+ and 60 technical datasheet	Industry/deep-retrofit benchmark; Schuco AWS window datasheet; EN ISO 10077 logic.	Manufacturer datasheet
C2	Besluit Bouwwerken Leefomgeving (Bbl), in force 1 January 2024. NEN-EN-ISO 6946:2017 + Cor. 2022-04. NEN-EN-ISO 10456:2008. NTA 8800:2024	Afdeling 4.4 Duurzaamheid, §4.4.1 Energiezuinigheid, Article 4.148 lid 1 (BENG functional requirement) and Article 4.152 lid 2 (gemiddelde warmteweerstand verticale uitwendige scheidingsconstructie, calculated per NTA 8800). Clauses 6 and 7 (thermal-resistance calculation method for opaque components, surface-resistance values).Clause 5 and Annex A (declared and design thermal-conductivity values for building materials). Section 8 (Heat-loss calculation method for the building envelope)	Dutch national regulation en international standard via NEN
C3	Besluit Bouwwerken Leefomgeving (Bbl)	Afdeling 4.3 Gezondheid, §4.3.6 Luchtverversing, Article 4.122 (ventilatiecapaciteit verblijfsgebied en verblijfsruimte). Spuivoorziening (operable openings for purge ventilation): Article 3.73 for existing buildings.	Design criterion / resident-control
C4	Besluit Bouwwerken Leefomgeving (Bbl)	Afdeling 4.3 Gezondheid, §4.3.10 Daglicht, Article 4.147 (minimale daglichtoppervlakte per gebruiksfunctie). Threshold values per gebruiksfunctie listed in BBL Table 4.146. Calculation method per NEN 2057.	Dutch national regulation
C5	Besluit Bouwwerken Leefomgeving (Bbl) and NEN 1087:2001	Afdeling 4.3 Gezondheid, §4.3.6 Luchtverversing, Article 4.122 lid 1 (woonfunctie ventilation: 0.9 dm^3/s per m^2 with minimum 7 dm^3/s per verblijfsgebied; equivalent to ≈ 25 m^3/h per typical habitable room).	Regulation
E1	V–I Framework, Chapter 4	§4.3.3 Empowerment design indicators, Table 4.5 row E1.	VI framework reference
E2	V–I Framework, Chapter 4	§4.3.3 Empowerment design indicators, Table 4.5 row E2.	VI framework reference
I1	V–I Framework, Chapter 4	§4.3.3 Identity design indicators, Table 4.5 row I1.	VI framework reference
I2	V–I Framework, Chapter 4	§4.3.3 Identity design indicators, Table 4.5 row I2.	VI framework reference
S1	Industry benchmark on bio-based retrofit	Convention used in EU H2020 retrofit research; ≥ 50% bio-based mass share is the standard threshold for variants targeting bio-based renewal. Cross-reference: 4RinEU project (CORDIS, 2021) and TES Energy Façade case studies (Cronhjort et al., 2009).	Component catalogue; manufacturer material data
S2	EN 15804:2012+A2:2019/ Stichting Nationale Milieudatabase, Bepalingsmethode Milieuprestatie Bouwwerken	Clause 5.2 System boundary; Annex A Modules; Module A1–A3 cradle-to-gate scope. Category 3 generic reference values per material category, accessible at milieudatabase.nl. Aligns with EN 15804+A2. Cat. 3 carries a 30% uplift penalty relative to Cat. 1/2 verified data. Declarations have a 5-year validity period.	European standard via NEN and Dutch environmental database
S2	Schüco AWS 90.SI+ Green EPD	Verified GWP of 1.99 $kgCO_2eq$ per kg recycled aluminium profile, A1–A3 cradle-to-gate. EPD reference: bauforumstahl.de or Schüco environmental product declaration documentation.	Manufacturer EPD
S3	Durmisevic, E. (2006) disassembly logic;	Calculated as weighted score: reversible fixing 30%, independent removal 25%, accessibility 20%, reuse potential 15%, documentation 10%.	Design-for-disassembly method
A1	Product / cost estimate with BPIE (2021) benchmark	Deep Renovation: Shifting from Exception to Standard Practice in EU Policy. Cost-benchmark section on retrofit-envelope costs per m^2 in northern European context	Industry research report + own calculation
A2	Appendix B component catalogue	Counts distinct Layer 2 catalogue entries used in one variant. Repeated use of the same component family counts once.	Component catalogue
A3	Layer 1 system logic; scenario drawings	≥ 90% Layer 1 repetition is consistent with industrial prefabrication practice in Dutch unitised systems (2ndSkin etc.)	Design framework / drawing take-off
F1	V–I Framework, Chapter 4	§4.3.3 Fairness design indicators, Table 4.5 row F1.	VI framework
F2	V–I Framework, Chapter 4	Each selected Layer 2 component must be traceable through: resident value → design indicator → façade criterion → component code → drawing location.	VI framework reference

C.4 KPI calculation tables for V02, V03 and V04

These tables make the scenario scoring auditable by showing the actual design-stage inputs used for each KPI. The values are calculated from the case-study façade area, the Layer 1 baseline, the Layer 2 component selections and the evaluation thresholds used in Chapter 8. They remain design-stage calculations and should be replaced by final take-offs, supplier quotations, LCA data and daylight/ventilation calculations in technical development.

Shared assumptions. The Layer 1 baseline is €380/m^2 and excludes cladding. V02 and V03 are calculated per evaluated level using two façade faces: 14.18 m × 3.00 m × 2 = 85.08 m^2. V04 includes the same two façade faces plus a 25.00 m^2 plinth/threshold zone, giving 110.08 m^2. A1 is calculated as: A1 = €380/m^2 + total Layer 2 component cost / evaluated façade area.

Scoring mechanism: Met = 1; partial = 0.5; not met = 0. The thresholds follow the Chapter 8 KPI framework. Where exact engineering data are not yet available, the table uses design-stage values from the façade drawings and component-catalogue logic.

V02: Fair and affordable

Value	KPI	Threshold	Calculation	Calculated value	Score
Comfort	C1	Uw ≤ 0.9 W/m^2K; partial 0.91–1.30	Selected economical high-performance window package: Uw ≈ 1.30 W/m^2K	Uw ≈ 1.30 W/m^2K	0.5
Comfort	C2	Rc ≥ 4.7 m^2K/W	Layer 1 uses ROCKWOOL Rockfit Duo 160 mm: RD ≈ 4.70 m^2K/W	Rc/RD ≈ 4.70 m^2K/W	1
Comfort	C3	≥ 1 operable opening per habitable room	2 habitable rooms checked; 2 rooms receive an operable opening: 2/2	1.0 opening/room	1
Comfort	C4	Daylight proxy ≥ 1:7 window-to-floor ratio	Awindow glazing south+north 32/ A floor area 2 app)120= 32/120=0,266= 26.7%, i.e. 1:3.75.	≈ 1:3.75	1
Comfort	C5	Ventilation ≥ 25 m^3/h per habitable room	Decentralised/basic ventilation DucotTon 80 SR: 25 m^3/h available per habitable room (catalogue product)	44 m^3/h Airflow: 44,3 m^3/h/m @ 2 Pa	1
Affordability	A1	≤ €450/m^2; partial €451–550/m^2	A1 = €380/m^2 + €10,480/85.08 m^2 = €380 + €123.18	≈ €503/m^2	0.5
Affordability	A2	≤ 12 component families per variant	Distinct Layer 2 catalogue families selected = 7	7 families	1
Affordability	A3	Layer 1 repetition ≥ 90%	Identical Layer 1 area = 85.08 m^2; total Layer 1 area = 85.08 m^2; 85.08/85.08 × 100	100%	1
Fairness	F1	100% equal Layer 1 baseline	Dwellings receiving equal Layer 1 package = 100%; no scenario-specific technical downgrade	100%	1
Fairness	F2	100% documented selection logic	Documented selections = 7; total selected families = 7; 7/7 × 100	100%	1
Empowerment	E1	≥ 4 resident-operable façade elements	Operable windows + basic controllable ventilation/shading elements counted: 3 elements	3 elements	0.5
Empowerment	E2	≥ 30% façade area under resident control	Resident-controlled area ≈ 18.0 m^2; 18.0/85.08 × 100 = 21.2%	21.2%	0.5
Sustainability	S1	Bio-based share ≥ 50%; partial 25–49%	Bio-based mass in selected cladding/finish scope ≈ 0%; 0/selected mass × 100 = 0%	0%	0
Sustainability	S2	A1–A3 embodied carbon ≤ 200 kgCO$_2$eq/m^2; partial 201–250	Design-stage material estimates for aluminium cassette + ROCKWOOL + basic Rockpanel-type cladding	≈ 230 kgCO$_2$eq/m^2	0.5
Sustainability	S3	Disassembly index ≥ 0.70	Weighted score: reversible fixing 0.30 + independent removal 0.20 + accessible connections 0.15 + reuse potential 0.05 + documentation 0.05 = 0.75	0.75	1
Identity	I1	≥ 4 distinct Layer 2 combinations	Catalogue combinations selected for affordability scenario: basic cladding rhythm (neighbourhood face) + limited shading (Climate) and social threshold options= 3 combinations	3 combinations	0.5
Identity	I2	≥ 20% variation between dwellings	Differing Layer 2 elements = 8; total Layer 2 elements = 42; 8/42 × 100 = 19.0%	19.0%	0.5
				Score	12.5/17

V03:Ecological renewal

Value	KPI	Threshold	Calculation	Calculated value	Score
Comfort	C1	Uw ≤ 0.9 W/m^2K	Selected high-performance triple-glazing window package: Uw ≈ 0.80 W/m^2K	Uw ≈ 0.80 W/m^2K	1
Comfort	C2	Rc ≥ 4.7 m^2K/W	Layer 1 uses ROCKWOOL Rockfit Duo 160 mm: RD ≈ 4.70 m^2K/W	Rc/RD ≈ 4.70 m^2K/W	1
Comfort	C3	≥ 1 operable opening per habitable room	2 habitable rooms checked; 2 rooms receive an operable opening: 2/2	1.0 opening/room	1
Comfort	C4	Daylight proxy ≥ 1:7 window-to-floor ratio	Awindow glazing south+north 32/ A floor area 2 app)120= 32/120=0,266= 26.7%, i.e. 1:3.75.	≈ 1:3.75	1
Comfort	C5	Ventilation ≥ 25 m^3/h per habitable room	Decentralised ventilation provision: 70 m^3/h available per habitable room / zone	70 m^3/h	1
Affordability	A1	≤ €450/m^2; partial €451–550/m^2; not met > €550/m^2	A1 = €380/m^2 + €33,000/85.08 m^2 = €380 + €387.87	≈ €768/m^2	0
Affordability	A2	≤ 12 component families per variant	Distinct Layer 2 catalogue families selected = 12	12 families	1
Affordability	A3	Layer 1 repetition ≥ 90%	Identical Layer 1 area = 85.08 m^2; total Layer 1 area = 85.08 m^2; 85.08/85.08 × 100	100%	1
Fairness	F1	100% equal Layer 1 baseline	Dwellings receiving equal Layer 1 package = 100%	100%	1
Fairness	F2	100% documented selection logic	Documented selections = 12; total selected families = 12; 12/12 × 100	100%	1
Empowerment	E1	≥ 4 resident-operable façade elements	Operable windows, screens/ventilation, and adjustable interface elements counted: 5	5 elements	1
Empowerment	E2	≥ 30% façade area under resident control	Resident-controlled area ≈ 32.0 m^2; 32.0/85.08 × 100 = 37.6%	37.6%	1
Sustainability	S1	Bio-based share ≥ 50%	Bio-based material mass in cladding/finish scope ≈ 55% of relevant mass	55%	1
Sustainability	S2	A1–A3 embodied carbon ≤ 200 $kgCO_2eq/m^2$	Design-stage estimate for ecological material package: bio-based cladding + BIPV/greening balance	≈ 180 $kgCO_2eq/m^2$	1
Sustainability	S3	Disassembly index ≥ 0.70	Weighted score: reversible fixing 0.30 + independent removal 0.20 + accessible connections 0.15 + reuse potential 0.07 + documentation 0.10 = 0.82	0.82	1
Identity	I1	≥ 4 distinct Layer 2 combinations	Distinct ecological/neighbourhood combinations selected = 5	5 combinations	1
Identity	I2	≥ 20% variation between dwellings	Differing Layer 2 elements = 12; total Layer 2 elements = 45; 12/45 × 100 = 26.7%	26.7%	1
				Score	16/17

V04: Community threshold

Value	KPI	Threshold	Actual calculation / checked input	Calculated value	Score
Comfort	C1	Uw ≤ 0.9 W/m^2K	Selected high-performance triple-glazing window package: Uw ≈ 0.80 W/m^2K	Uw ≈ 0.80 W/m^2K	1
Comfort	C2	Rc ≥ 4.7 m^2K/W	Layer 1 uses ROCKWOOL Rockfit Duo 160 mm: RD ≈ 4.70 m^2K/W	Rc/RD ≈ 4.70 m^2K/W	1
Comfort	C3	≥ 1 operable opening per habitable room	2 habitable rooms checked; 2 rooms receive an operable opening: 2/2	1.0 opening/room	1
Comfort	C4	Daylight proxy ≥ 1:7 window-to-floor ratio	Awindow glazing south+north 32/ A floor area 2 app)120= 32/120=0,266= 26.7%, i.e. 1:3.75.	≈ 1:3.75	1
Comfort	C5	Ventilation ≥ 25 m^3/h per habitable room	Decentralised ventilation provision: 70 m^3/h available per habitable room / zone	70 m^3/h	1
Affordability	A1	≤ €450/m^2; partial €451–550/m^2	A1 = €380/m^2 + €12,100/110.08 m^2 = €380 + €109.92	≈ €490/m^2	0.5
Affordability	A2	≤ 12 component families per variant	Distinct Layer 2 catalogue families selected = 11	11 families	1
Affordability	A3	Layer 1 repetition ≥ 90%	Identical Layer 1 dwelling-façade area = 85.08 m^2; total Layer 1 dwelling-façade area = 85.08 m^2; 85.08/85.08 × 100	100%	1
Fairness	F1	100% equal Layer 1 baseline	Dwellings receiving equal Layer 1 package = 100%	100%	1
Fairness	F2	100% documented selection logic	Documented selections = 11; total selected families = 11; 11/11 × 100	100%	1
Empowerment	E1	≥ 4 resident-operable façade elements	Operable windows, shading, threshold elements, and social interface elements counted: 6	6 elements	1
Empowerment	E2	≥ 30% façade area under resident control	Resident-controlled/inhabitable façade area ≈ 36.0 m^2; 36.0/110.08 × 100 = 32.7%	32.7%	1
Sustainability	S1	Bio-based share ≥ 50%; partial 25–49%	Bio-based material mass in selected cladding/threshold finishes ≈ 30%	30%	0.5
Sustainability	S2	A1–A3 embodied carbon ≤ 200 $kgCO_2eq/m^2$; partial 201–250	Design-stage material estimates for threshold components + aluminium cassette + cladding	≈ 220 $kgCO_2eq/m^2$	0.5
Sustainability	S3	Disassembly index ≥ 0.70	Weighted score: reversible fixing 0.30 + independent removal 0.20 + accessible connections 0.15 + reuse potential 0.06 + documentation 0.05 = 0.76	0.76	1
Identity	I1	≥ 4 distinct Layer 2 combinations	Distinct social threshold/neighbourhood combinations selected = 6	6 combinations	1
Identity	I2	≥ 20% variation between dwellings	Differing Layer 2 elements = 14; total Layer 2 elements = 48; 14/48 × 100 = 29.2%	29.2%	1
				Score	15.5/17

C.4.1: KPI scoring all scenarios

Value	**KPI**	**Threshold**	**V01 Control & Comfort**	**V02 Clear & Affordable**	**V03 Ecological Renewal**	**V04 Community Threshold**
Comfort	C1: Window thermal transmittance	Uw ≤ 0.9 W/m^{2}K	✓ Met (Uw 0.8 triple)	◐Partial (Uw 1.3–1.5 double)	✓ Met (Uw 0.8 triple, recycled Al)	✓ Met (Uw 0.8 triple)
	C2:Opaque wall thermal resistance	Rc ≥ 4.7 m^{2}K/W	✓ Met (Rc ≈ 7.7)	✓ Met (Rc ≈ 7.7)	✓ Met (Rc ≈ 7.7)	✓ Met (Rc ≈ 7.7)
	C3:Operable openings per habitable room	≥ 1 per room	✓ Met	✓ Met	✓ Met	✓ Met
	C4:Window-to-floor area ratio	≥ 1:7	✓ Met	✓ Met (1:3.75)	✓ Met	✓ Met
	C5 :Ventilation rate per habitable room	≥ 25 m^3/h per room	✓ Met	Met(44m3/h)	✓ Met	✓ Met
Affordability	A1:Cost-efficiency	≤ €450/m^2 façade	◐Partial (~€440–490 band)	◐Partial(~€451–550band)	◐Partial (~€460–520 band)	◐Partial (~€440–490 band)
	A2:Bounded variety of configurable elements	≤ 12 distinct element types	✓ Met (9 types)	✓ Met (7 types)	✓ Met (12 types)	✓ Met (11 types)
	A3 :Module repetition	≥ 90% identical modules	✓ Met (95%)	✓ Met (98%)	✓ Met (95%)	✓ Met (95%)
Fairness	F1 :Performance equality across dwellings	100% (same baseline)	✓ Met	✓ Met	✓ Met	✓ Met
	F2 :Documented selection logic	100% selections traceable	✓ Met	✓ Met	✓ Met	✓ Met
Empowerment	E1: Resident-operable elements per dwelling	≥ 4 per dwelling	✓ Met (6)	◐Partial (3)	✓ Met (5)	✓ Met (6)
	E2: Resident-controlled façade area	≥ 30% of façade	✓ Met (~35%)	◐Partial (~22%-20-29% band)	✓ Met (~32%)	✓ Met (~38%)
Sustainability	S1 :Bio-based material share	≥ 50% mass share	✗ Not met	✗ Not met (0%)	✓ Met (~62% bamboo+Nabasco+L1)	◐Partial (~32% Rockpanel+L1)
	S2 :Embodied carbon (A1–A3)	≤ 200 kgCO$_2$eq/m^2	◐ Partial (~200–250 band)	◐Partial (~201–250 band)	✓ Met (<200)	◐Partial (~201–220 band)
	S3 :Reuse / disassembly index	≥ 0.7 (Durmisevic 2006)	✓ Met (mechanical interfaces)	✓ Met	✓ Met (click-system, reversible bamboo cladding)	✓ Met
Identity	I1:Configurable combinations available	≥ 4 distinct combinations	✓ Met (4)	◐Partial (3-4 band)	✓ Met (4)	✓ Met (4)
	I2: Variation between dwellings	≥ 20% varying elements	✓ Met (~22%)	◐Partial (10-19% band)	✓ Met (~25%)	✓ Met (~28%)
Total	**17 KPIs evaluated**	.	**15/17 (88%)**	**12.5/17 (73.5%)**	**16/17 (94%)**	**15.5/17 (91%)**

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Appendix D:Design variants V02-V04

This appendix develops design variants V02, V03, and V04 in full, completing the case-study application of Chapter 7, where V01 is developed end-to-end (§7.6) and V02–V04 are read only comparatively (§7.7). Each variant follows the same nine-section reading template as V01: living situation, façade tensions identified, value priorities, criteria set, Layer 1 confirmation, Layer 2 cluster activation, component selection by cluster, resulting façade response, and a trace-back table from value to component code, so that the four variants remain directly comparable.

The appendix is organised in six sections. D.1–D.3 develop V02 (Clear and affordable upgrade), V03 (Future-oriented ecological renewal), and V04 (Community threshold) in full. D.4 reads the four variants side by side against the five axes of Table 6.4. D.5 presents the supporting technical drawings and rhino renders for all variants, and D.6 documents the Layer 1 base-platform drawings shared across them.

All four variants share the same building, the same Value–Indicator Framework, and the same Layer 1 specification; they differ only in their Layer 2 component selection from the catalogue (Appendix B). The trace-back tables here provide the full chain that the evaluation in Chapter 8 measures and complement the per-KPI calculations for V02–V04 in Appendix C.4.

D.1 Variant 02: Clear and affordable upgrade

D.1.1 Living situation

Variant 02 addresses a more budget-sensitive and less personalised dwelling condition within the unit. The apartments may be occupied by younger couples, starters, students, or small working households who prioritise affordability, clarity, and low-maintenance living conditions.

The distinction between left and right apartment remains present in plan, but it is intentionally less visible in the façade response.

The north façade still addresses controlled street-facing comfort and opening logic, and the south façade still addresses balcony and solar conditions, but both are resolved through the same repeated and standardised façade package. The combined living situation therefore foregrounds the façade as the place where a fair, robust, and repeatable upgrade quality is delivered equally across both apartments of the unit.

D.1.2 Façade tensions identified

The combination of building condition and living situation surfaces four tensions that the design must address. Read through a budget-sensitive living situation, the baseline produces:

- **Weak environmental performance**: mixed window quality and limited insulation; comfort still requires improvement.
- **Maintenance and durability:** ageing façade with high upkeep risk; the upgrade must remain robust and low maintenance over time.
- **Weak façade identity**: no clear or coherent renovation language; the façade should read as one legible building-wide upgrade.
- **Technical and procurement complexity:** dwelling-by-dwelling variation increases cost and slows installation; the design must reduce on-site variation.

D.1.3 Value priorities

Affordability and fairness are foregrounded as primary values because the dominant tensions surface as delivery and equity concerns that affect both apartments of the unit equally. Comfort is secondary because environmental quality still must be lifted to a deep-retrofit baseline, but it is delivered through a repeated and standardised package rather than through dwelling-specific configuration.

Table D.1.1: Variant 02:value priorities in relation to façade tensions and design direction.

Value dimension	Priority level	Why it matters in this variant	Typical design direction
Affordability	Primary	Renovation must remain feasible, robust, and simple across the building	Standardisation, repeated modules, low-maintenance materials
Fairness	Primary	Both dwellings should receive the same visible and environmental quality	Shared baseline, bounded variation, transparent selection logic
Comfort	Secondary	Environmental quality still needs improvement, but through a repeated package	Insulated openings, one shading family, intuitive operation

D.1.4 Façade criteria set

Translating affordability, fairness, and comfort through the V–I Framework (Chapter 4, Table 4.5) produces the criteria set for the variant.

Each prioritised value is decomposed into its specific design indicators, and each indicator is operationalised as a façade criterion.

- **Affordability** translates into repeated panel sizes and standardized module logic, one standard window family, and limited component variation.
- **Fairness** translates into the same visible façade treatment (cladding) and the same environmental package (shading) for both apartments.
- **Comfort** translates into upgraded insulated openings, integrated ventilation, and one repeated solar control strategy.

Table D.1.2: Variant 02 façade criteria set. P = primary, S = secondary.

Value (priority)	Specific design indicators activated	Façade criteria for the variant
Affordability (P)	A1 component-family economy · A2 repetition of the shared baseline · A3 per-m² cost	≤ 12 distinct configurable component families across the catalogue; ≥ 90% identical Layer 1 baseline module across dwellings; façade cost ≤ €450/m² retrofit envelope
Fairness (P)	F1 baseline equality across dwellings · F2 documented selection logic	100% of dwellings share the same baseline specification regardless of configurable selections; every Layer 2 selection traceable to a value priority and an indicator
Comfort (S)	C1 Uw · C2 Rc · C3 operable openings · C5 acoustic separation	Uw ≤ 0.9 W/m²K (triple glazing); Rc ≥ 4.7 (achieved 7.7 by Layer 1); ≥ 1 operable opening per habitable room; airborne-sound performance per Bouwbesluit dwelling-type table

D.1.5 Layer 1 confirmation

Layer 1 stays as specified in §7.4 (Table 7.2). The carrier frame, the inner performance core (Rc ≈ 7.7 m²K/W), the sealant and joint system, and the mix of three base platforms (closed, open, service-ready) deployed across the building are all identical to those used in V01, V03, and V04.

For Variant 02, Layer 1 carries the central argument of the variant: it secures the same deep-retrofit envelope and the same fairness baseline for every dwelling, independent of any Layer 2 selection. The affordability gain therefore does not come from lowering the performance baseline, but from minimising Layer 2 variation.

D.1.6 Layer 2 cluster activation

Layer 2 is deliberately restrained and repeated. The active clusters are:

- **Cluster III-CA: Climate Agency** carries the repeated environmental package (window family, ventilation, shading)
- **Cluster IV-NF: Neighbourhood Face** carries the repeated cladding strategy and the coherent whole-building expression.

D.1.7 Component selection by cluster

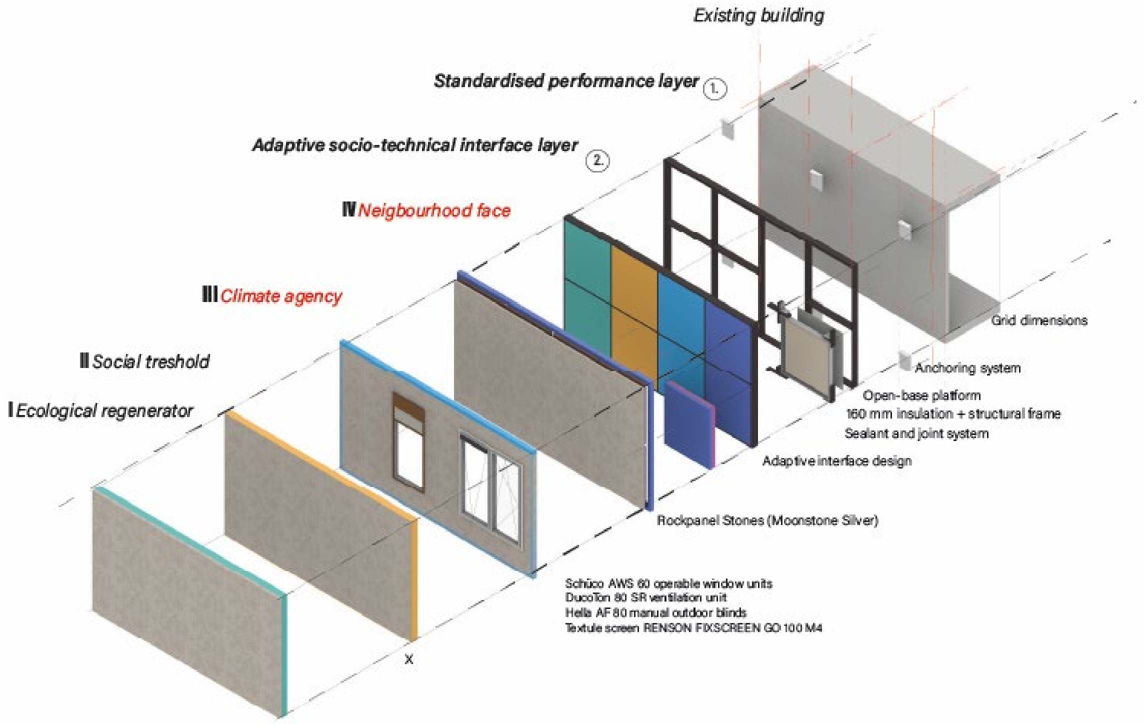
Within each active cluster, components are selected from the component catalogue (Appendix B) to satisfy the criteria set of §D.1.4. Each component is recorded with its catalogue code so that the selection is traceable across variants and auditable against the V–I Framework.

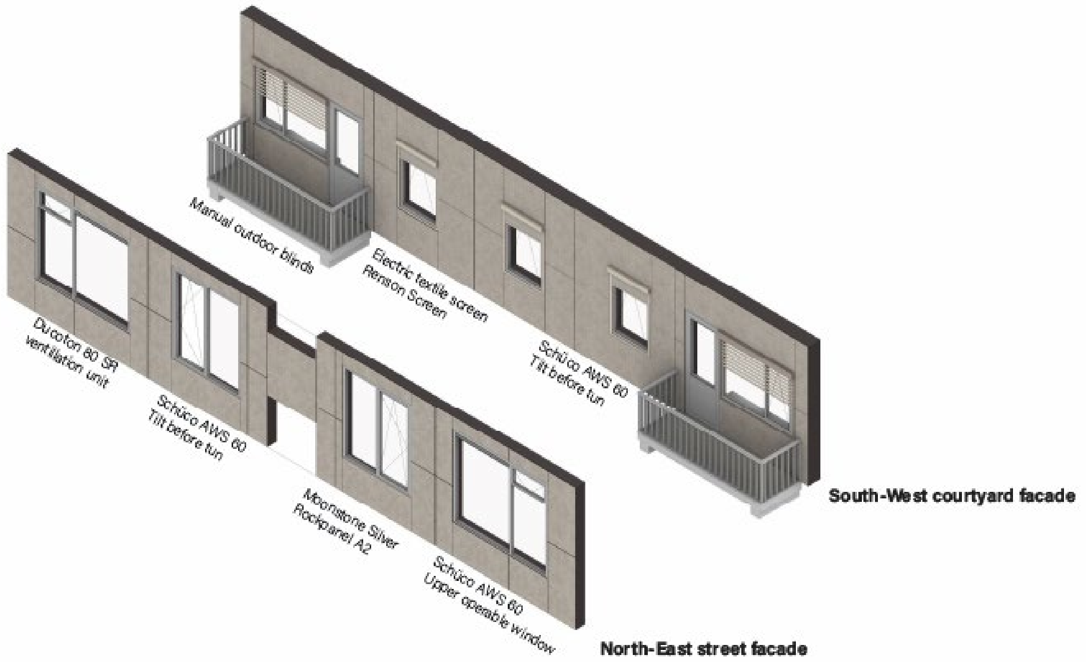
Table D.1.3: Component selection for Variant 02 by cluster. Component codes refer to the catalogue in Appendix B

Cluster	Component code	Component specification	Located on
Climate Agency	CA01:operable insulated window, Schüco AWS 60	Triple glazing Uw ≤ 0.9 W/m²K; tilt-and-turn operability; thermally broken aluminium frame; one window family across both apartments	North-east street and south-west courtyard façades, both apartments
Climate Agency	CA02:decentralised ventilation, DucoTon 80 SR	Self-regulating window-mounted ventilation, L = 1340 mm; integrated below window head	Below window heads on both façades, both apartments
Climate Agency	CA04:solar control, textile screen-RENSON FIXSCREEN GO 100 M4	Electric textile screen; uniform specification across both apartments	South-west courtyard façade, middle south-facing windows
Climate Agency	CA05:solar control, Hella AF 80 manual outdoor blind	External roller blind with manual adjustment; identical across both apartments	South-west courtyard façade, balcony-side window
Neighbourhood Face	NF01:Rockpanel Stones, Moonstone Silver	Mineral-bound façade panel, 9 mm; robust, low-maintenance, repeated panel sizes; reduced variation in rhythm; same cladding on both façades	North-east street and south-west courtyard façades, across the unit

The climate agency components create one repeated and understandable environmental package across both apartments. On the north façade, the same opening logic is applied on both apartments; on the south façade, the same shading package is applied to both apartments. This is exactly how the variant expresses fairness and affordability: variation is removed at the level of the climate interface, not at the level of envelope performance.

The cladding strategy of the north façade: Rockpanel Stones; south façade: Rockpanel Stones. Rockpanel Stones is selected on both façades because it supports durability, low maintenance, repeated application, and a robust building-wide identity.
Using the same cladding on both sides deliberately reduces visible differentiation and reinforces the whole-building logic.


Existing building
Standardised performance layer ①
Adaptive socio-technical interface layer ②
IV Neigbourhood face
III Climate agency
II Social treshold
I Ecological regenerator
Grid dimensions
Anchoring system
Open-base platform
160 mm insulation + structural frame
Sealant and joint system
Adaptive interface design
Rockpanel Stones (Moonstone Silver)
Schüco AWS 60 operable window units
DucoTon 80 SR ventilation unit
Hella AF 80 manual outdoor blinds
Textule screen RENSON FIXSCREEN GO 100 M4
X


Manual outdoor blinds
Electric textile screen
Renson Screen
Schüco AWS 60
Tilt before tun
Ducoton 80 SR
ventilation unit
Schüco AWS 60
Tilt before tun
Moonstone Silver
Rockpanel A2
Schüco AWS 60
Upper operable window
South-West courtyard facade
North-East street facade

D.1.8 Resulting façade response

Variant 02 deliberately reduces the visible difference between the two apartment types. The north façade still resolves the street-facing conditions of the unit, and the south façade still responds to balcony and solar conditions, but both dwellings receive the same repeated façade package. Rockpanel Stones on both façades reinforces a robust and collective architectural language.
The design rationale is to avoid over-complication and to remove visible inequality between dwellings. Cluster CA carries the repeated comfort package, while Cluster NF ensures the façade reads as one coherent whole-building upgrade. The variant therefore expresses value not through strong dwelling-level differentiation, but through equal visible treatment, a bounded component family, and reduced technical complexity.

D.1.9 Trace-back from value to component

The following table records the full chain from each value priority to the criterion it activates, the cluster in which the criterion is satisfied, and the specific components selected. As in V01, every Layer 2 selection is traceable back to a value priority and a documented criterion.

Table D.1.4.: Trace-back table for Variant 02.

Value priority	Indicator	Criterion satisfied	Cluster	Component(s) selected
Affordability	A1 per-m² cost	≤ €450/m² envelope	CA + NF	Bounded selection from CA and NF only in component catalogue
Affordability	A2 component-family economy	≤ 12 configurable families (achieved: 2 CA + 1 NF)	CA + NF	AWS 60 window family + DucoTon 80 SR + Rockpanel Stones A2 9mm
Affordability	A3 baseline repetition	≥ 90% identical Layer 1 baseline across dwellings	Layer 1	Layer 1 specification per §7.4
Fairness	F1 baseline equality	100% dwellings share Layer 1 + same Layer 2 family	Layer 1 + CA + NF	Identical AWS 60 + textile screen + blinds across both apartments
Fairness	F2 documented selection logic	Every selection recorded against a value and indicator	—	This trace-back table
Comfort	C1 Uw	≤ 0.9 W/m²K	CA	AWS 60 window family (triple-glazed)
Comfort	C2 Rc	≥ 4.7 m²K/W (achieved 7.7)	Layer 1	Layer 1 carrier and insulation core
Comfort	C3 operable openings	≥ 1 per habitable room	CA	AWS 60 tilt-and-turn across habitable rooms
Comfort	C5 ventilation rate per habitable room	Per Bouwbesluit dwelling-type table	Layer 1 + CA	Layer 1 buildup plus DucoTon 80 SR

D.2 Variant 03: Future-oriented ecological renewal

D2.1: Living situation.

This scenario assumes that the two neighbouring apartments are occupied by residents who are more climate-aware, future-oriented, and conscious of their environmental footprint. Compared with the previous scenarios, these residents attach more importance to the long-term ecological impact of the renovation.

They do not only want the façade to become more comfortable; they want it to reflect a broader attitude toward sustainability, climate adaptation, and responsible material use. They are willing to accept that some façade choices may initially be more expensive, require a more careful installation process, or involve more specialised components, if the result contributes to lower embodied carbon, a more future-proof building, visible ecological improvement, and a stronger architectural identity.

D2.2: Façade tension

The combination of building condition and living situation surfaces four tensions that the design must address:

- **Weak environmental performance:** the existing envelope underperforms; comfort still requires improvement on the same deep-retrofit baseline as the other variants.
- **No visible ecological identity:** no greening, no biodiversity support, no visible carbon-storage materials; sustainability is currently invisible.
- **Weak façade identity:** the building still reads as an ageing post-war envelope; the façade should visibly express ecological transformation.
- **Maintenance and lifecycle awareness:** ecological systems must remain serviceable; reversibility and disassembly become part of the design problem, not only the visible appearance.

D2.3: Value priorities

Sustainability and identity are foregrounded as primary values. Sustainability is primary because the ecological ambition must be measurable as well as visible (bio-based material selection, embodied carbon, design for disassembly). Identity is primary because the ecological strategy is only legible to residents and neighbours if the façade visibly expresses it through materials and articulation. Comfort is secondary because the variant still must deliver the same deep-retrofit envelope as the other variants, but it is no longer the ambition that drives Layer 2 selection.

Table D.2.1: Variant 03:value priorities in relation to façade tensions and design direction.

Value dimension	Priority level	Why it matters in this variant	Typical design direction
Sustainability	Primary	Lower embodied carbon, visible environmental systems, lifecycle awareness	Bio-based materials, reversible connections, greening, visible ecological systems
Identity	Primary	Façade should visibly express ecological renewal	Material articulation, continuity, ecological recognisability
Comfort	Secondary	Ecological strategy must still improve use and climate performance	High-performance windows, operability, shading, ventilation

D2.4: Façade criteria set.

- **Sustainability** is prioritised through recycled content, reduced embodied carbon, lifecycle awareness, reuse, and disassembly.
- **Identity** is prioritised through material continuity, façade articulation, and dwelling recognisability.
- **Comfort** remains necessary through daylight, visual comfort, user control, ease of interaction, and maintainability.

Table D.2.2.:Variant 03, facade criteria set.

Value (priority)	Specific design indicators activated	Façade criteria for the variant
Sustainability (P)	S1 bio-based material share · S2 embodied carbon · S3 reuse and disassembly	≥ 50% of cladding and insulation by mass are bio-based; ≤ 200 kgCO₂eq/m² façade; disassembly index ≥ 0.7 on a 0–1 scale
Identity (P)	I1 distinct configurable combinations · I2 variation between dwellings	≥ 4 distinct combinations per dwelling type; ≥ 20% of configurable elements vary between left and right apartment
Comfort (S)	C1 Uw · C2 Rc · C3 operable openings · C4 daylight · C5 ventilation rate per habitable room	Uw ≤ 0.9 W/m²K (AWS 90.SI+ Green); Rc ≥ 4.7 (achieved 7.7 by Layer 1); ≥ 1 operable opening per habitable room; window-to-floor ≥ 1:7; airborne-sound per dwelling-type table

D.2.5 Layer 1 confirmation

Layer 1 stays as specified in §7.4 (Table 7.2). The carrier frame, the inner performance core (Rc ≈ 7.7 m²K/W), the sealant and joint system, and the mix of three base platforms across the building are identical to those used in V01, V02, and V04. For Variant 03, the disassembly logic of Layer 1 carries additional weight: the mechanical, reversible Layer 2 interfaces specified in Chapter 5 are what allow the bio-based and greening components of Layer 2 to be installed, serviced, and replaced without breaching the deep-retrofit envelope. The ecological ambition of the variant is therefore not a Layer 1 modification, but a Layer 2 expression made possible by Layer 1’s reversible interface.

This scenario is navigated primarily through Ecological Regenerator for biobased cladding, greening, biodiversity, and visible environmental systems; through Climate Agency for insulated window systems and summer control; and through Neighbourhood Face for coherent façade articulation and recognisability.

D.2.6: Layer 2 cluster activation

Layer 2 becomes more materially and technically expressive than in the previous variants. The active clusters are:

- **Cluster I- ER: Ecological Regenerator** carries the bio-based, greening, biodiversity, and visible-energy components.
- **Cluster III- CA: Climate Agency** carries the insulated window system and summer comfort control.
- **Cluster IV-NF: Neighbourhood face:** retained living-room window composition on the north façade improving recognizability, but no cladding selection.

D.2.7 Component selection by cluster

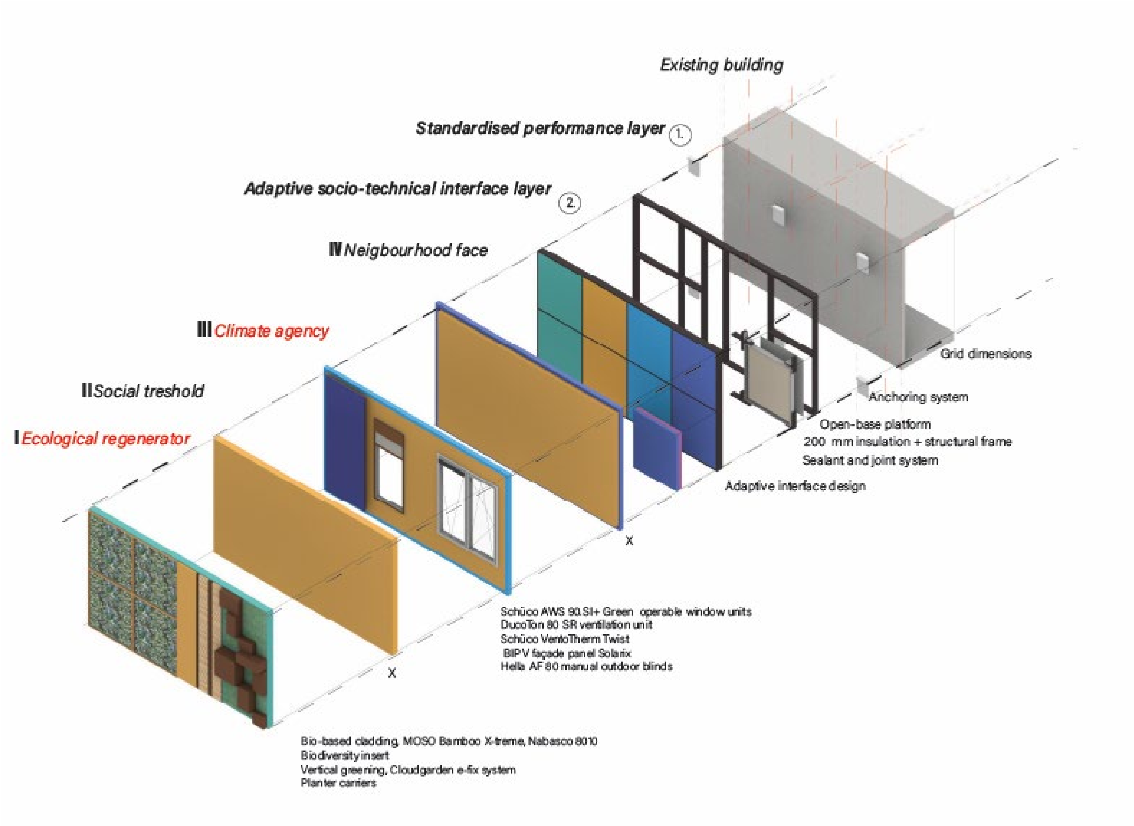
Within each active cluster, components are selected from the component catalogue Appendix B) to satisfy the criteria set of §D.2.4. Each component is recorded with its catalogue code so that the selection is traceable across variants and against the V–I Framework.

The Ecological Regenerator components (ER01, ER02, ER03) carry the visible ecological transformation. ER01 (MOSO Bamboo and Nabasco 8010) expresses bio-based material selection (S1) and contributes to the low embodied-carbon target (S2). ER03 (Cloudgarden) makes greening part of the façade build-up. The ER02 staircase biodiversity package strengthens collective ecological identity, and the species-responsive entrance-hole sizing makes the design generative rather than decorative. CA03 (Solarix BIPV) makes the south façade energy productive rather than only protective. The ER01 click-based bamboo system and the removable service panel deliver the disassembly index ≥ 0.7 of S3.

The Climate Agency components (CA01, CA02, CA03, CA05, CA06) secure climatic performance. CA01 (AWS 90.SI+ Green) improves thermal performance while aligning with the sustainability narrative through lower-carbon aluminium. DucoTon and VentoTherm improve ventilation and user control. Outdoor blinds or fixed louvres mitigate overheating on the south façade.

Table D.2.3: Component selection for Variant 03 by cluster. Component codes refer to the catalogue.

Cluster	Component code	Component specification	Located on
Ecological Regenerator	ER01:bio-based cladding, MOSO Bamboo X-treme	Boards 1850 × 136 × 20 mm, 10 mm spacing hidden CLIP-SCREW BX08/09 click-fixing (boards and fixings separable, recyclable, supports reversible connections);one custom removable bamboo panel in front of service-ready Layer 1 module for maintenance access	North-east street and facade
Ecological Regenerator	ER01: bio-composite cladding, Nabasco 8010	Bio-composite façade panels providing material continuity between bamboo, BIPV, and planted zones;	Staircase and south-west courtyard façade
Ecological Regenerator	ER02: biodiversity inserts, staircase package	Bird nesting boxes mounted on Nabasco 8010 support elements; species-responsive entrance-hole sizing:28 mm (blue/coal tits), 32 mm (house sparrows, nuthatches, great tits), 45 mm (starlings), oval/open-front (robins, wagtails, spotted flycatchers)	Staircase wall, north-east façade
Ecological Regenerator	ER03:vertical greening, Cloudgarden e-fix system	60 mm U-profile support frame, 30 mm L-profile, 80 mm aluminium edge frame; panel build-up 2 × 610 / 2 × 450 / 2 × 320 mm; 50 mm aluminium gutter, 40 mm drainage pipe	North-east street facade. Selected areas
Ecological Regenerator	ER02 (planter carriers' south façade)	Planter carrier 1500 × 520 mm overall; planter bucket 210 × 320 mm; steel substructure H.O.H. 1400 mm; hanging profile 20 × 25 mm	South-west courtyard façade, balcony
Climate Agency	CA01:operable insulated window, Schüco AWS 90.SI+ Green	Triple glazing, $U_w \leq 0.9$ W/m²K; tilt-and-turn operability; aluminium frame with ≥ 75% post-consumer recycled content (GWP 1.99 kgCO₂eq/kg)	North-east street and south-west courtyard façades, both apartments
Climate Agency	CA02:decentralised ventilation, DucoTon 80 SR + Schüco VentoTherm Twist	Self-regulating window-mounted vent below window head, combined with decentralised heat-recovery ventilation unit	Below window heads, both façades; VentoTherm at selected positions
Climate Agency	CA03: BIPV façade panel, Solarix	Panel sizes 2950 × 550 / 2950 × 700 / 2950 × 850 mm; omega back-profile 86 × 25 × 2950 mm; horizontal carrier profiles 70 × 32 mm; ventilated mounting system	South-west courtyard façade
Climate Agency	CA05: solar control, manual outdoor blind	External roller blind with manual adjustment	South-west courtyard façade, balcony-side windows
Climate Agency	CA06: solar control, fixed aluminium louvres	(Optional alternative solar-control strategy at south-facing zones)	South-west courtyard façade, selected zones


Existing building
Standardised performance layer ①
Adaptive socio-technical interface layer ②
IV Neigbourhood face
III Climate agency
II Social treshold
I Ecological regenerator
Grid dimensions
Anchoring system
Open-base platform
200 mm insulation + structural frame
Sealant and joint system
Adaptive interface design
X
Schüco AWS 90.SI+ Green operable window units
DucoTon 80 SR ventilation unit
Schüco VentoTherm Twist
BIPV façade panel Solarix
Hella AF 80 manual outdoor blinds
X
Bio-based cladding, MOSO Bamboo X-treme, Nabasco 8010
Biodiversity insert
Vertical greening, Cloudgarden e-fix system
Planter carriers


Planter boxes
+ irrigation pipe (left)
Hella AF80
Manual outdoor blinds
BIPV facade panels
Solarix
Nabasco 8010 cladding
South-West courtyard facade
Bamboo X-treme cladding
Vertical greenery
Cloudgarden E-fix
Birdboxes
Schüco AWS 90si+ green
Retained windowdesign
North-East street facade

D.2.8 Resulting façade response

Variant 03 translates sustainability, identity, and comfort into a visibly ecological façade proposition. On the north façade, MOSO Bamboo cladding, Cloudgarden greening, the staircase biodiversity package, and AWS 90.SI+ Green windows create a public ecological façade that still responds to the original building character. On the south façade, Solarix BIPV panels, Nabasco cladding, planter carriers, outdoor blinds, and decentralised ventilation create a productive and climate-responsive courtyard façade.

The design rationale is to make ecological ambition legible through both material and technical systems. Cluster ER carries the main environmental transformation, and Cluster CA secures climatic performance.

Figure D.2.1 and D2.2.: Visulisation South-west courtyard facade including facade component (toplevel)- Front façade.

D.2.9 Trace-back from value to component

Table D.2.4 records the full chain from each value priority to the criterion it activates, the cluster in which the criterion is satisfied, and the specific components selected.

Table D.2.4.: Trace-back table for Variant 03.

Value priority	Indicator	Criterion satisfied	Cluster	Component(s) selected
Sustainability	S1 bio-based share	≥ 50% bio-based cladding + insulation by mass	ER	ER01 (MOSO Bamboo) + wood-fibre sheathing in Layer 1 +ER01 (Nabasco 8010)
Sustainability	S2 embodied carbon	≤ 200 $kgCO_2eq/m^2$ façade (achieved band ~140–200)	ER + CA + Layer 1	ER01 (bamboo) + CA01 (AWS 90.SI+ Green, GWP 1.99) + Layer 1
Sustainability	S3 reuse/disassembly	Disassembly index ≥ 0.7 on 0–1 scale	ER + Layer 1	ER01 CLIP-SCREW BX08/09 fixing + removable service panel + reversible Layer 1 interfaces
Identity	I1 ≥ 4 combinations	Achieved through ER × NF combinations	ER + NF	ER01 + ER02 + ER03 + CA03 + NF01 + retained window composition
Identity	I2 ≥ 20% variation between dwellings	Achieved through differentiated south-side BIPV/planter zones	ER + CA	ER02 planter carriers + CA03 (Solarix BIPV) applied per dwelling
Comfort	C1 Uw	≤ 0.9 W/m^2K	CA	CA01 (AWS 90.SI+ Green, triple-glazed)
Comfort	C2 Rc	≥ 4.7 m^2K/W (achieved 7.7)	Layer 1	Layer 1 carrier and insulation core
Comfort	C3 operable openings	≥ 1 per habitable room	CA	CA01 operable across habitable rooms
Comfort	C4 daylight 1:7	Maintained at upgraded openings	CA + NF	Existing openings preserved by CA01; retained living-room composition
Comfort	C5 ventilation rate per habitable room	Per Bouwbesluit	Layer 1 + CA	Layer 1 buildup + CA02 (DucoTon 80 SR / VentoTherm Twist)

D.3 Variant 04:Community threshold and shared garden edge

D.3.1 Living situation

Variant 04 addresses the ground-floor condition of the unit. The two apartments at ground level differ from the upper floors because they have a direct relation to the street on the north side and a direct relation to the shared courtyard or garden on the south side.

The variant imagines households who value informal neighbour contact, outdoor use close to the dwelling, and a stronger relation between home and collective outdoor space. The north façade is therefore understood as a more protected but socially visible street plinth, while the south façade is understood as a more usable and collective garden-facing threshold.

The living situation foregrounds the façade as an inhabitable edge between dwelling and neighborhood, not only as an envelope.

D.3.2 Façade tensions identified

The combination of building condition and ground-floor living situation surfaces four tensions:

- **Underused threshold:** the ground-floor façade edge is currently weakly inhabitable on both the street side and the garden side.
- **Privacy and neighbour relation**: the north side lacks a clear balance between openness and privacy; ground-floor residents are directly exposed to people passing by
- **Limited resident control:** operability and threshold use are central at ground-floor level, but currently absent (no operable shading, weak ventilation provision, shallow windowsills).
- **Weak plinth identity:** the lower façade lacks a recognizable plinth character that would visibly distinguish the street side from the courtyard side.

D.3.3 Value priorities

Empowerment and comfort are foregrounded as primary values because the dominant tensions are tensions of everyday use: residents should be able to appropriate the façade edge in daily life. Identity is secondary because the street plinth and the garden edge should also become visibly recognizable as two different ground-floor conditions.

Table D.3.1:Variant 04: value priorities in relation to façade tensions and design direction.

Value dimension	Priority level	Why it matters in this variant	Typical design direction
Empowerment	Primary	Residents should be able to use and appropriate the façade edge	User-accessible elements, threshold occupation, operable systems
Comfort	Primary	Ground-floor façade must support easy use, ventilation, daylight, and shading	High-performance openings, intuitive interaction, climate-responsive elements
Identity	Secondary	Façade should visibly express protected street plinth vs. social courtyard edge	Plinth articulation, material variation, recognisable threshold expression

D.3.4 Façade criteria set

Translating empowerment, comfort, and identity through the V–I Framework produces the criteria set for the variant. Each prioritised value is decomposed into its specific design indicators, and each indicator is operationalised as a façade criterion.

- **Empowerment** translates into façade elements that residents can actively use in daily life.
- **Comfort** translates into operable openings, practical threshold use, intuitive interaction, and climatically responsive façade elements.
- **Identity** translates into a recognisable ground-floor plinth and a clearer difference between the street-facing and courtyard-facing sides.

Table D.3.2: Variant 04 façade criteria set. P = primary, S = secondary.

Value (priority)	Specific design indicators activated	Façade criteria for the variant
Empowerment (P)	E1 resident-operable elements per dwelling · E2 façade area under direct resident control	≥ 4 resident-operable elements distributed across habitable rooms (achieved through window, vent, blind, awning, threshold seating); ≥ 30% of façade area carries adjustable elements
Comfort (P)	C1 Uw · C2 Rc · C3 operable openings · C4 daylight · C5 Ventilation rate per habitable room	Uw ≤ 0.9 W/m²K (AWS 90.SI+); Rc ≥ 4.7 (achieved Rc:7.7 by Layer 1); ≥ 1 operable opening per habitable room; window-to-floor ≥ 1:7; airborne-sound per dwelling-type table
Identity (S)	I1 distinct configurable combinations · I2 variation between dwellings	≥ 4 distinct combinations available (Rockpanel Woods upper + Stones plinth × seating / planter / Juliet rail options); ≥ 20% variation between ground-floor dwellings

D.3.5 Layer 1 confirmation

Layer 1 stays as specified in §7.4 (Table 7.2). The carrier frame, the inner performance core (Rc ≈ 7.7 m²K/W), the sealant and joint system, and the mix of three base platforms are identical to those used in V01, V02, and V03. For Variant 04, the open and service-ready Layer 1 platforms carry weight at ground-floor level: they prepare the field positions for threshold elements (seating, planters, Juliet rails, vertical greenery irrigation system), all of which mount onto Layer 1 through reversible mechanical interfaces but stays accessible through removable cladding,

D.3.6 Layer 2 cluster activation

Layer 2 becomes a community-oriented threshold layer. The active clusters are:

- **Cluster II: ST: Social Threshold** carries the inhabitable-edge elements: deep windowsills, integrated seating, Juliet rails.
- **Cluster III:CA:Climate Agency** carries operability, ventilation unit, and sun control for ground-floor use.
- **Cluster IV: Neighbourhood Face** carries plinth articulation and the coherent cladding strategy that distinguishes street side from courtyard side.

D.3.7 Component selection by cluster

Within each active cluster, components are selected from the component catalogue (Appendix B) to satisfy the criteria set of §D.3.4. Each component is recorded with its catalogue code so that the selection is traceable across variants and against the V–I Framework.

Table D.3.3: Component selection for Variant 04 by cluster. Component codes refer to the catalogue in Appendix B

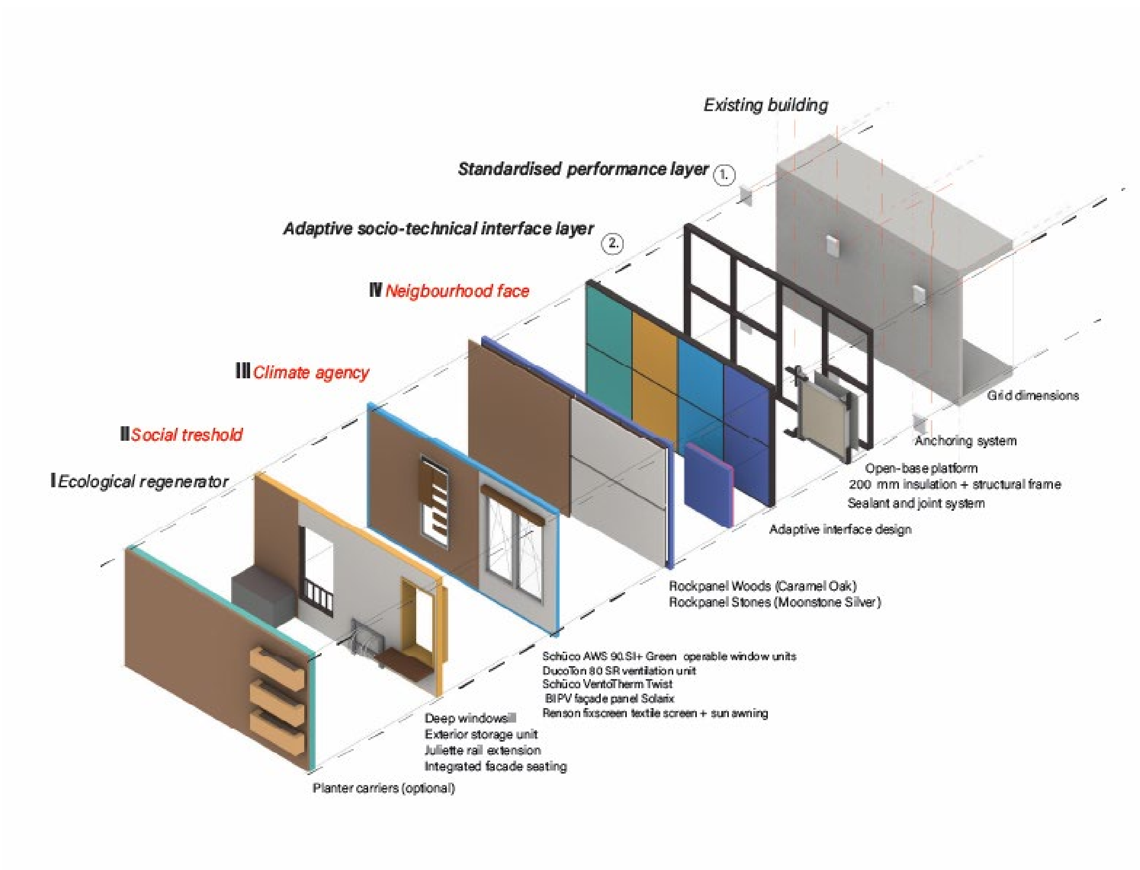
Cluster	Component code	Component specification	Located on
Social Threshold	ST01: deep windowsill	Inhabitable sill, solid timber oak finish; supports everyday occupation at the kitchen window	North-east street façade, kitchen window
Social Threshold	ST02: exterior storage unit	integrated storage units supporting everyday family routines without reducing interior floor area under balcony	South-west courtyard façade, plinth zone
Social Threshold	ST03: Juliet rail extension	Safe interior–exterior continuity at the middle windows	Middle windows, south-west courtyard façade ;
Social Threshold	ST04:integrated façade seating	Built-in bench seating at plinth level (north + south) and at balcony / courtyard zone (south); fixed to Layer 1 carrier	Plinth zone, both façades; balcony zone, south façade
Social Threshold	Special plinth edition	Integrated bike racks, stimulating bike commute and increase movement	Plinth zone, North-east Street facade
Climate Agency	CA01: operable insulated window, Schüco AWS 90.SI+	Triple glazing, Uw ≤ 0.9 W/m²K; tilt-and-turn operability; thermally broken aluminium frame	North-east street and south-west courtyard façades, both apartments
Climate Agency	CA02: decentralised ventilation, DucoTon 80 SR + Schüco VentoTherm Twist + Vento Air	Self-regulating window-mounted vent below window head, combined with decentralised heat-recovery ventilation; VentoAir at selected south middle windows	Below window heads, both façades; VentoAir at south middle windows
Climate Agency	CA04: solar control, textile screen	Electric RENSON textile screen; glare and heat control while preserving view	South-west courtyard façade, middle south-facing windows
Climate Agency	CA05: solar control, sun awning	Manual cassette awning at balcony level for full balcony shading;	South-west courtyard balcony
Neighbourhood Face	NF01: Rockpanel Woods, upper façade	Rockpanel façade panel with Caramel timber finish, 9 mm; warmer, more domestic upper-façade tone	Upper façade, north-east and south-west
Neighbourhood Face	NF01: Rockpanel Stones, plinth	Mineral-bound façade panel, 9 mm; robust and collective plinth character; bike racks integrated at plinth; retained living-room window composition on the north façade	Plinth zone, north-east and south-west; living-room composition retained on north façade
Optional			
Climate agency	CA01: Schüco AWS ASE 80.HI lift-and-slide sliding door	Sliding door to improve connection inside- outside while being in the garden	South-west courtyard façade, balcony opening

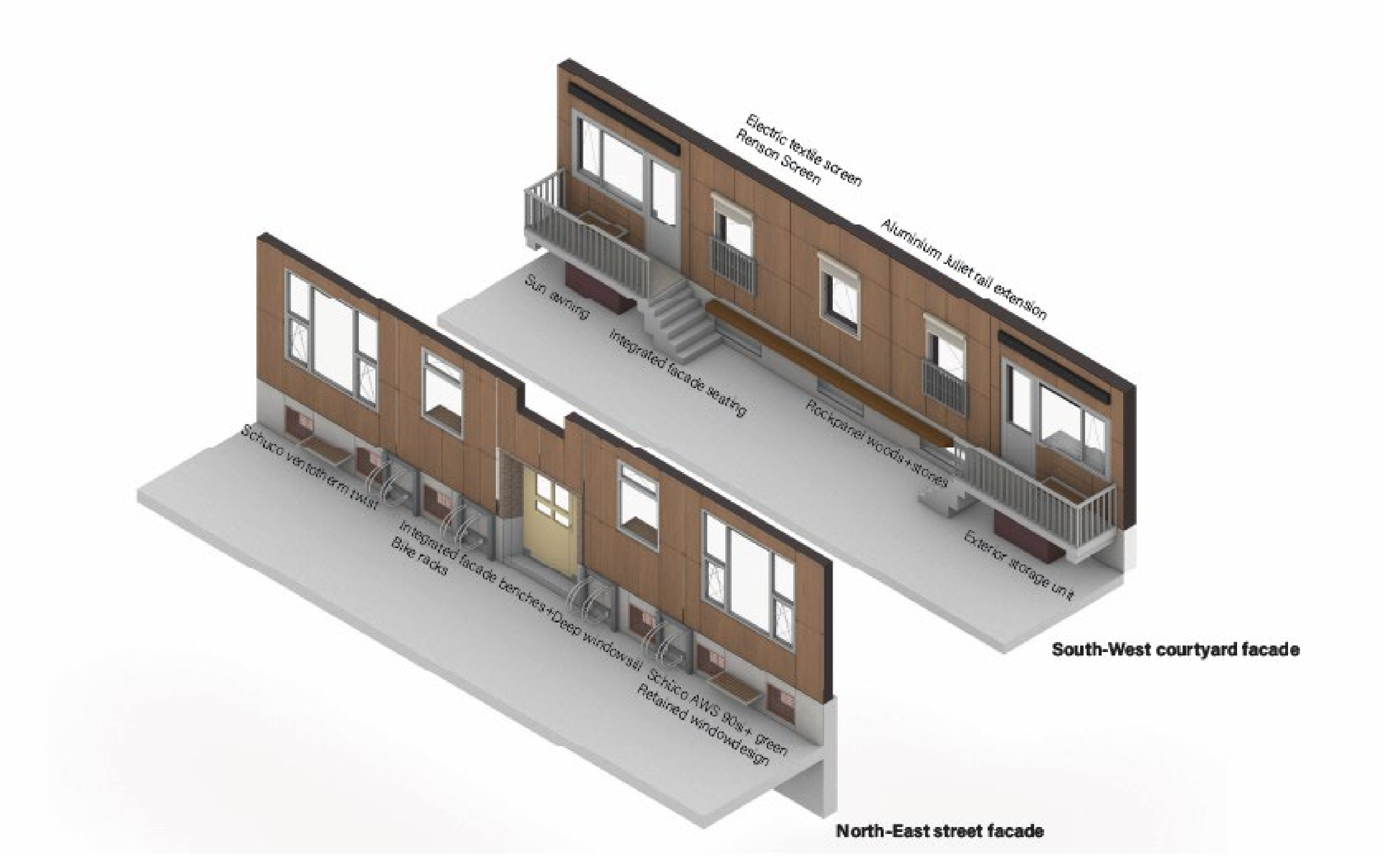
]

The Social Threshold components (ST01, ST02, ST03, ST04) are the central design move of this variant. They turn the façade edge into an inhabitable threshold: ST01 supports everyday occupation at the kitchen window on the north side; ST04 activate the south-facing courtyard threshold seating and optional planters; ST03 provides safe interior–exterior continuity at the middle window. Together they carry the empowerment criteria.

The Climate Agency components (CA01, CA02, CA04, CA05) deliver the operability, ventilation, and sun control that ground-floor threshold use depends on.

The Neighbourhood Face component (NF01) is applied as a paired articulation, Rockpanel Woods on the upper façade gives a warmer, more domestic appearance, while Rockpanel Stones on the plinth gives the base a more robust, collective character. Together they create a clearer street plinth and garden threshold logic. The cladding strategy is part of the value translation, not a decorative finish: it is how the criterion of variation between dwellings and the visible distinction between street and courtyard sides are delivered.


Existing building
Standardised performance layer ①
Adaptive socio-technical interface layer ②
IV Neigbourhood face
III Climate agency
II Social treshold
I Ecological regenerator
Grid dimensions
Anchoring system
Open-base platform
200 mm insulation + structural frame
Sealant and joint system
Adaptive interface design
Rockpanel Woods (Caramel Oak)
Rockpanel Stones (Moonstone Silver)
Schüco AWS 90.SI+ Green operable window units
DucoTon 80 SR ventilation unit
Schüco VentoTherm Twist
BIPV façade panel Solarix
Renson fixscreen textile screen + sun awning
Deep windowsill
Exterior storage unit
Juliette rail extension
Integrated facade seating
Planter carriers (optional)


Electric textile screen
Renson Screen
Aluminium Juliet rail extension
Sun awning
Integrated facade seating
Rockpanel woods+stones
Exterior storage unit
South-West courtyard facade
Schuco ventotherm twist
Integrated facade benches+Deep windowsill
Bike racks
Schüco AWS 90s+ green
Retained windowdesign
North-East street facade

D.3.8 Resulting façade response

Variant 04 uses the north-south distinction at ground-floor level to create two different threshold conditions: a more protected and socially legible street plinth on the north side, and a more active and collective garden edge on the south side. Here, the façade does not only mediate between inside and outside, but also between different forms of neighbour relation and everyday use.

The result is a façade that supports everyday use, neighbour interaction, and a clearer spatial distinction between the street side and the courtyard side. Cluster ST carries the inhabitable-edge ambition, Cluster CA carries the operable, climate-responsive interface, and Cluster NF carries the legible plinth and threshold identity.

Figure D.4.0: Design V04 south courtyard facade with sliding door improving interior-exterior connection.

D.3.9 Trace-back from value to component

Table D.3.4 records the full chain from each value priority to the criterion it activates, the cluster in which the criterion is satisfied, and the specific components selected.

Table D.3.4: Trace-back table for Variant 04.

Value priority	Indicator	Criterion satisfied	Cluster	Component(s) selected
Empowerment	E1 ≥ 4 operable elements	Achieved (window, vent, blind, awning, Juliet rail, seating)	CA + ST	CA01 + CA02 + CA04 + CA05 + ST03 + ST04
Empowerment	E2 ≥ 30% controllable area	Achieved at ground-floor (~35%)	CA + ST	Active CA components plus ST01–ST04 occupiable threshold zone
Comfort	C1 Uw	≤ 0.9 W/m²K	CA	CA01 (AWS 90.SI+, triple-glazed)
Comfort	C2 Rc	≥ 4.7 m²K/W (achieved 7.7)	Layer 1	Layer 1 carrier and insulation core
Comfort	C3 operable openings	≥ 1 per habitable room	CA	CA01 tilt-and-turn across habitable rooms; ST03 ASE 80.HI optional at south for option 2
Comfort	C4 daylight 1:7	Maintained at upgraded openings	CA + NF	Existing openings preserved by CA01; retained living-room composition (NF01)
Comfort	C5 Ventilation rate per habitable room	Per Bouwbesluit dwelling-type table	Layer 1 + CA	Layer 1 buildup + CA02 (DucoTon 80 SR / VentoTherm Twist)
Identity	I1 ≥ 4 combinations	Achieved (NF01 Woods + Stones × ST element mix)	NF + ST	NF01 Woods upper / Stones plinth × ST01 / ST02 / ST03 / ST04 mix
Identity	I2 ≥ 20% variation between dwellings	Achieved (~25%) through ground-floor ST differentiation	ST + NF	Different ST mix per dwelling; bike-rack zone differentiation at plinth (NF01)

D.4: Comparative reading of the scenarios

Overview scenarios:

- **Scenario 01: Control and comfort** focus on resident operability, privacy, and threshold use. It explores how comfort, empowerment, and identity can be translated into façade responses that improve control over ventilation, shading, and everyday use.
- **Scenario 02 :Clear and affordable upgrade** explores a more repeated and standardised façade response. Here, affordability, fairness, and comfort are prioritised through clear module logic, limited component variation, and equal visible upgrade quality across dwellings.
- **Scenario 03:Future-oriented ecological renewal** prioritises sustainability, identity, and comfort. It translates these values into a more visibly ecological façade through biobased cladding, lower-embodied-carbon components, greening, biodiversity elements, and climate-responsive systems.
- **Scenario 04 : Community threshold and garden-facing social edge** focuses on the ground-floor condition. It prioritises empowerment, comfort, and identity through a more active threshold relation to street and courtyard side, with stronger emphasis on neighbour contact, threshold use, and community-oriented occupation.

Figure 4.1:Design variants per level of case study building Gijsingstraat case study render+schematic.

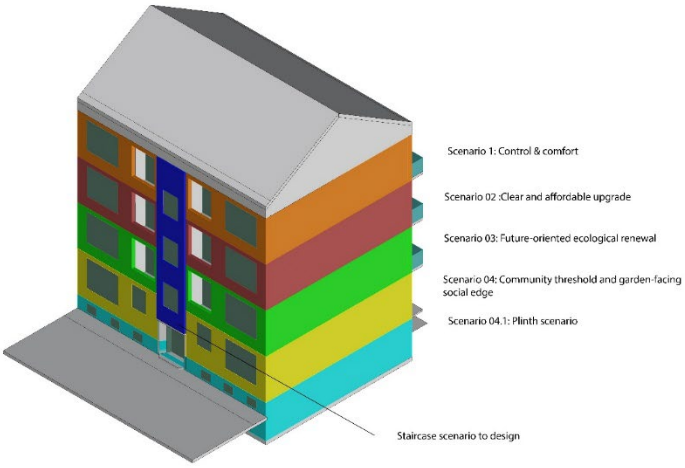


Table D.4.2: Scenario vs dominant values and resulting facade responses per orientation and total.

Scenario	Main ambition	Dominant values	North façade character	South façade character	Main façade response
Scenario 01:Control and comfort	Improve resident control over climate, privacy, and threshold use	**Comfort, Empowerment, Identity**	More protected and controllable street façade with operable windows and privacy adjustment	More domestic and usable courtyard façade with seating/storage and resident-controlled shading	Differentiated façade response with stronger operability and dwelling-specific threshold use
Scenario 02:Clear and affordable upgrade	Deliver a robust, fair, and repeatable façade upgrade	**Affordability, Fairness, Comfort**	Calm and repeated street façade with one shared window logic	Standardised courtyard façade with one repeated shading and ventilation package	Repeated module logic, limited component variation, equal visible quality across dwellings
Scenario 03:Future-oriented ecological renewal	Make ecological transition and sustainability visibly legible in the façade	**Sustainability, Identity, Comfort**	Public ecological façade with biobased cladding, low-carbon windows, greening, and biodiversity	Productive and climate-responsive courtyard façade with planting, BIPV, shading, and decentralised ventilation	Materially expressive ecological façade with visible environmental systems and serviceable build-up
Scenario 04 :Community threshold and garden-facing social edge	Strengthen neighbour contact, threshold use, and community-oriented ground-floor occupation	**Empowerment, Comfort, Identity**	Protected but active street plinth with operable windows, deep sill, bike racks, and seating	More social and inhabited courtyard edge with seating, planting, Juliet rails, and shading	Ground-floor threshold façade that supports everyday use, neighbour interaction, and community-based occupation

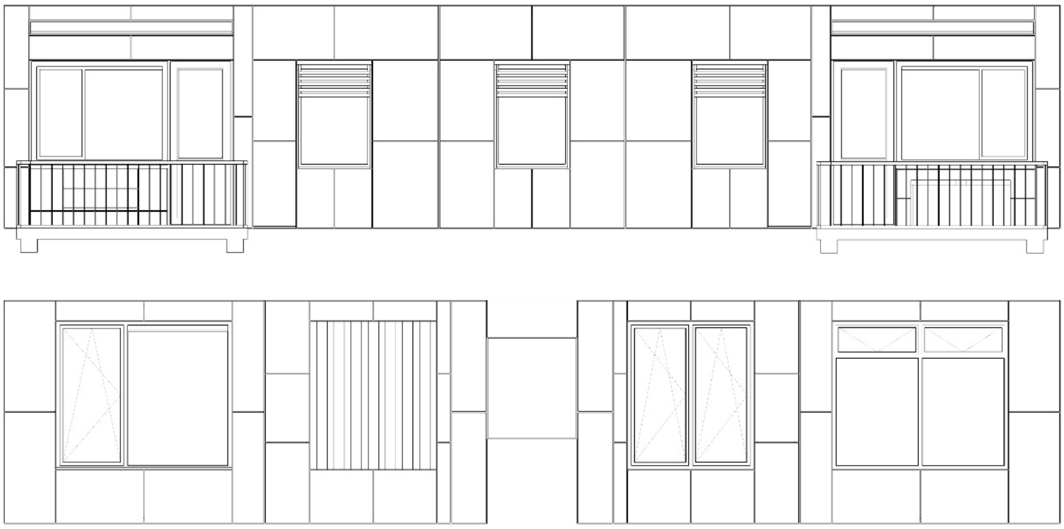
D.4.1 Renders with all design variants applied

Inside and future perspective renders:

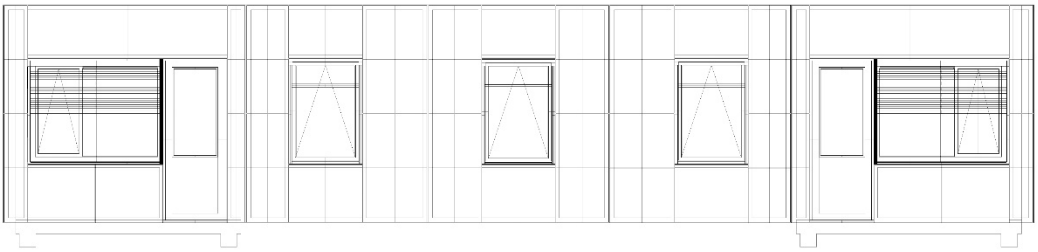
Different building testing the potential.

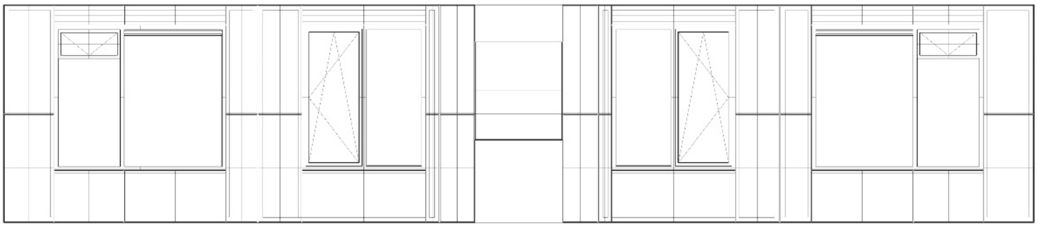
D.5: Technical drawings design variants

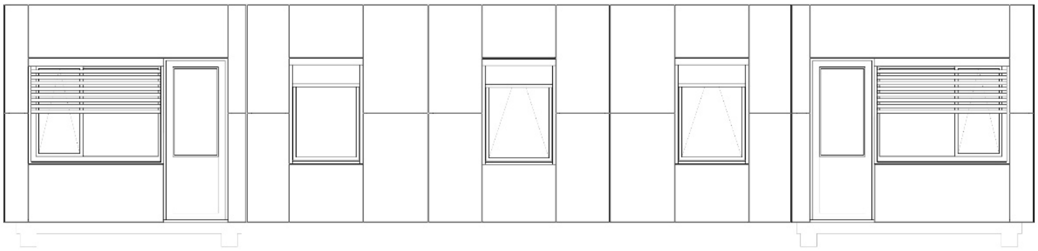
V01:Control and comfort

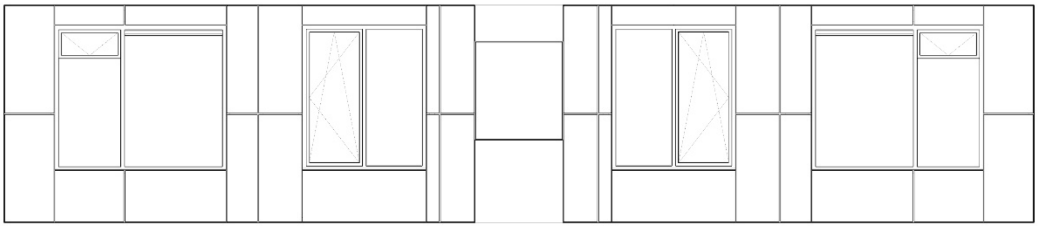


V02:Clear and affordable

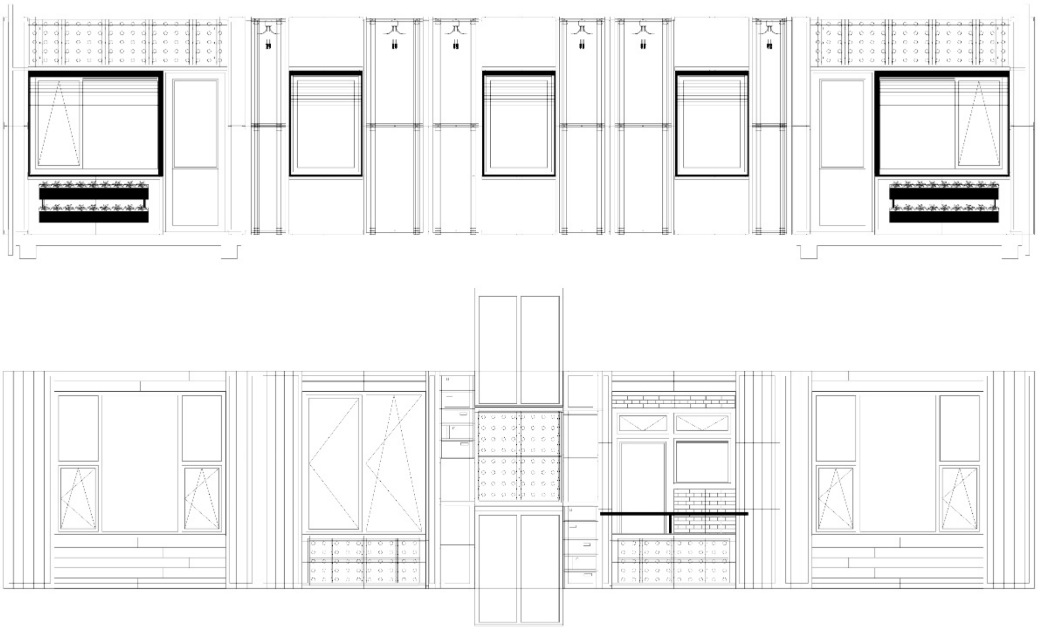


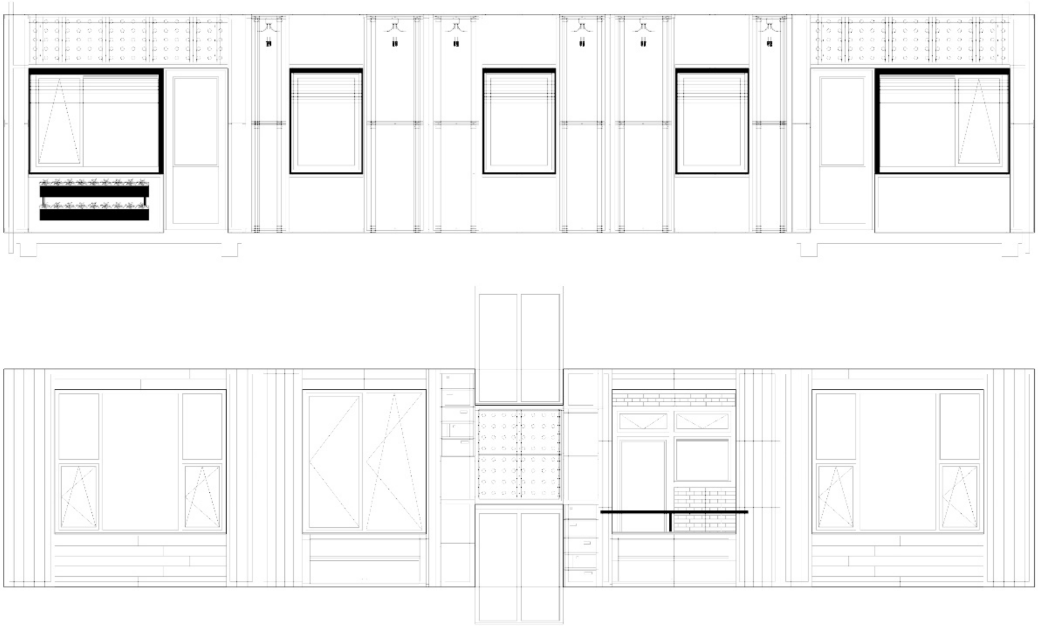




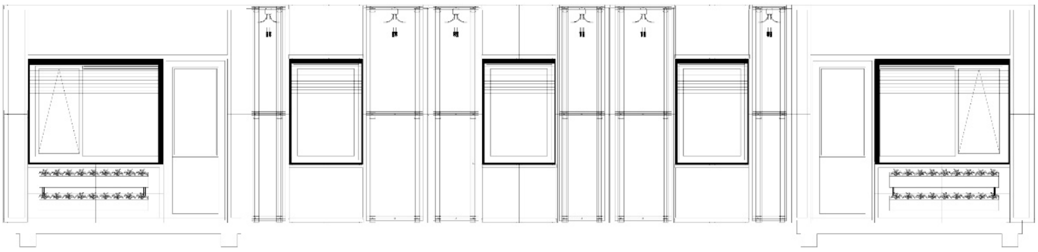


V03:Future-oriented ecological renewal

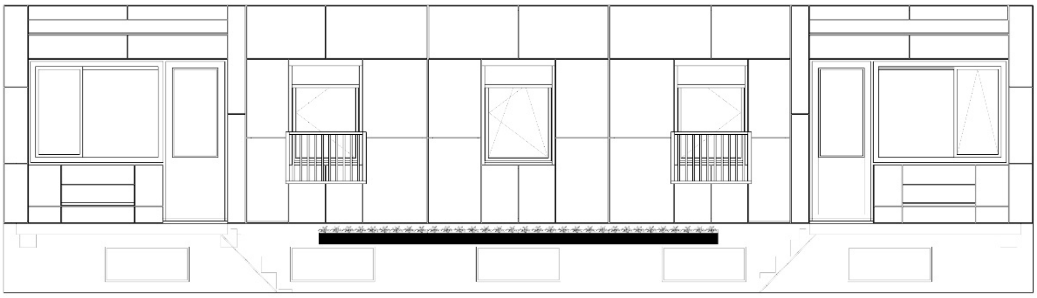




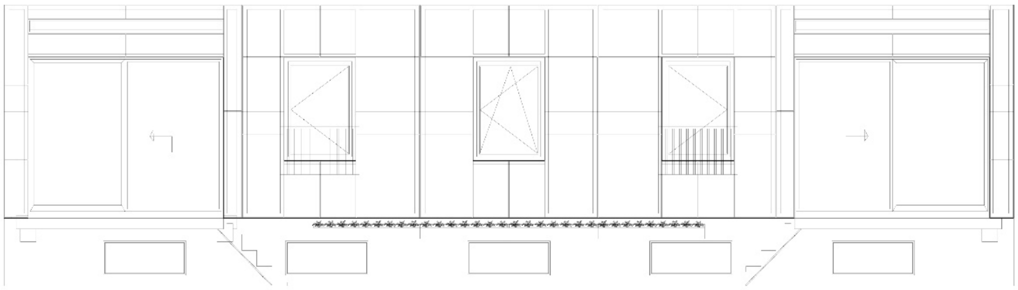
V03: Optional configuration courtyard facade



V04: Community threshold and garden facing edge.

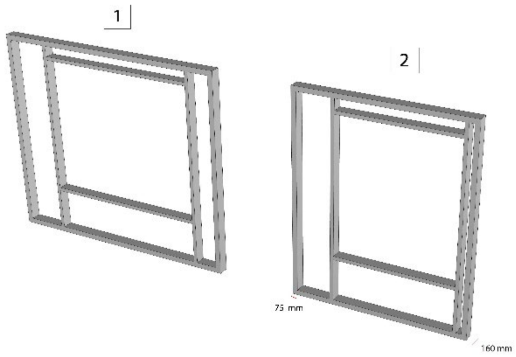


V04: Optional configuration courtyard façade- sliding door



D.6 A1 base platform technical drawings

Street side/ North modules



Courtyard side/ South modules