Upgradable Building Envelope System for Energy Reduction Renovation of Dutch Post-war Apartments

Mick Simmering
4236130

Mentors:
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Dr.Ir. P.J.W. van den Engel
PROBLEM STATEMENT & METHODOLOGY
20-20-20 EU Goals for 2020

-20%  
+20%  
+20%
20-20-20 EU Goals for 2020

-20% 0% +20% 5.5%
EU Goals for 2050

-90%
Energy Consumption All Sectors

- Transport: 31.7%
- Services: 25.3%
- Agriculture: 26.7%
- Industry: 13.2%
- Households: 2.2%
- Other: 0.9%
Households

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- Services: 26.7%
- Industry: 13.2%
- Agriculture: 25.3%
- Other: 2.2%
- Households: 0.9%
EPBD Regulations for New Buildings (2020)

nZEB - Nearly Zero Energy Building
“A building that produces nearly as much energy as it consumes”
EPBD Regulations for New Buildings (2020)

nZEB - Nearly Zero Energy Building
“A building that produces nearly as much energy as it consumes”

Renewal Rate 1%
Thermal Resistance through the Years

U-Value (W/m*K)
Energy Crisis

U-Value (W/m*K)
Old Stock?

Amount of Dwellings: 7,266,295

- Pre-1945: 20%
- 1945-1970: 26%
- 1971-1990: 32%
- Post-1990: 22%

1+2 Rooms: 9%
3 Rooms: 19%
4 Rooms: 32%
5+ Rooms: 40%

Renters: 40%
Buyers: 60%

Single-Family: 71%
Multi-Family: 29%
Old Stock?

3.358,000 Dwellings

- Pre-1945: 20%
- 1945-1970: 26%
- 1971-1990: 32%
- Post-1990: 22%

- 1+2 Rooms: 9%
- 3 Rooms: 19%
- 4 Rooms: 32%
- 5+ Rooms: 40%

- Renters: 40%
- Buyers: 60%

- Single-Family: 71%
- Multi-Family: 29%
Post-war Apartments
Ctrl C + Ctrl V
The Tactic
(Source: Akkerman, n.d.)
Prefabricated Module 2ndSkin
Prefabricated Module 2ndSkin

- Unity
- Maintenance
- Time
- Quality
Service Life

- 100+ Years
- 30 Years
- 50+ Years
- 80-100 Years

- 30 Years
Weakest Link
Renovate Now, Redo when goals are reached
The “Learning Curve”

Renovation costs €/m²

- nZEB
- deep
- moderate
- minor
## BPIE Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Unit</th>
<th>0</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
<td><strong>Unit</strong></td>
<td><strong>Baseline</strong></td>
<td><strong>Deep</strong></td>
<td><strong>Two-stage</strong></td>
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<tr>
<td>Annual Energy Saving</td>
<td>TWh/a</td>
<td>365</td>
<td>2.795</td>
<td>2.896</td>
</tr>
<tr>
<td>2050 Saving as % of Today</td>
<td>%</td>
<td>9%</td>
<td>68%</td>
<td>71%</td>
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<tr>
<td>Investments Costs (Present Value)</td>
<td>€ Billion</td>
<td>164</td>
<td>937</td>
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### Fast Decarbonisation

<table>
<thead>
<tr>
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<th>932</th>
<th>939</th>
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<tbody>
<tr>
<td>Annual CO₂ saving in 2050</td>
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<th>755</th>
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<tbody>
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<td>Annual CO₂ saving in 2050</td>
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“In what way can a prefabricated building envelope system for energy reduction renovation of building envelopes of Dutch post-war apartment blocks be designed to be future proof by taking into account service life and changing standards?”
Study Design

I Research Definition
- 1 | Introduction
  - Background & problem statement
- 2 | Methodology
  - Utilised method & study design

II Literature Review
- 3 | Building Stock in the Netherlands
  - Scale of the market & energy focus points
- 4 | Principles of Renovation
  - Principles for present & future proof renovation
- 5 | State-of-the-Art Renovation Systems
  - Assessment of current systems

III Design Strategy
- 6 | Case Study Analysis
  - Parameters necessary for design phase
- 7 | Design Methodology
  - Design method, tools & assessment

IV Preliminary Design
- 8 | Concept Design
  - Production of concepts & variants

V Final Design
- 9 | Case Study Application
  - Verification of design through case study

VI Conclusions
- 10 | Evaluation Design
  - Final evaluation based on formulated criteria
- 11 | Conclusions & Recommendations
  - Final reflection on research question
Concept Design

1 | Introduction
   1.1 | Background & problem statement

2 | Methodology
   2.1 | Utilised method & study design

3 | Building Stock in the Netherlands
   3.1 | Scale of the market & energy focus points

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Proof of Concept by Application

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LITERATURE REVIEW
Energy Consumption per Household

- Space Heating: 57%
- Cooking: 11%
- Water Heating: 7%
- Electric Appliances: 25%
Space Heating

- Space Heating: 57%
- Cooking: 11%
- Water Heating: 25%
- Electric Appliances: 7%
Circular Economy

Linear Economy

- Raw Materials
- Production
- Use
- Non-recyclable Waste

Reuse Economy

- Raw Materials
- Production
- Recycling
- Use
- Non-recyclable Waste

Circular Economy

- Raw Materials
- Production
- Recycling
- Use
## Comparison Assessment

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Grade Endis</th>
<th>Grade TES</th>
<th>Grade MeeFS</th>
<th>Average</th>
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<tbody>
<tr>
<td>Customisation</td>
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<td>●●●●●</td>
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<tr>
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<tr>
<td>Adaptability</td>
<td>●●●</td>
<td>●●●●●</td>
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<tr>
<td>Disturbance</td>
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<td>Construction Time</td>
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(Source: Rozanska, 2015)

(Source: Cronhjort, et al., 2015)

(Source: ENDIS, 2012)
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<tr>
<td>Integration</td>
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<td>Sustainable Materials</td>
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<tr>
<td>Maintenance</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
Design Tools
DESIGN METHODOLOGY
Parameters

Balconies

Chimneys & Rainpipes

Windows

Entrances
Criteria

Requirements

Energy
- Energy Reduction
- Energy Generation

Architecture
- Appearance
- Construction
- Application
- Off-site Production Ability
- Structural Adjustments
- Integration
- Adaptability
- Sustainable Materials
- Disturbance
- Construction Time

Future Proof
- Upgradability
- Maintenance
Architecture

Requirements

Energy
- Energy Reduction
- Energy Generation

Architecture
- Appearance
  - Customisation
- Construction
  - Off-site Production Ability
- Application
  - Structural Adjustments
- Future Proof
  - Upgradability
  - Maintenance

Energy Future Proof
- Requirements
Future Proof

Requirements

Energy
  - Energy Reduction
  - Energy Generation

Architecture
  - Appearance
    - Energy Reduction
    - Customisation
  - Construction
    - Off-site Production Ability
    - Structural Adjustments
  - Application
    - Integration
    - Adaptability

Future Proof
  - Upgradability
  - Maintenance
  - Construction Time
  - Sustainable Materials
  - Disturbance
CONCEPT PRODUCTION
## Future Components Changes

<table>
<thead>
<tr>
<th>Components</th>
<th>Functionality</th>
<th>Reason For Upgradeability/ Flexibility</th>
<th>New Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cladding</td>
<td>Appearance</td>
<td>Fashion, Damage, Exceeded Service Life</td>
<td>New Cladding, potentially different substructure.</td>
</tr>
<tr>
<td>Water Barriers</td>
<td>Water &amp; Airtightness</td>
<td>Technology Upgrade, Stricter Regulations, Damage, Exceeded Service Life</td>
<td>Different form of water barrier, either thinner or thicker.</td>
</tr>
<tr>
<td>Insulation</td>
<td>Thermal Insulation, Sound Insulation</td>
<td>Technology Upgrade, Stricter Regulations, Enhanced Awareness, Environmental Change, Damage, Exceeded Service Life</td>
<td>Thinner insulation in different form. Same insulation with added layer.</td>
</tr>
<tr>
<td>Windows</td>
<td>Appearance, Thermal Insulation, Sound Insulation, Daylight</td>
<td>Fashion, Technology Upgrade, Stricter Regulations, Enhanced Awareness, Different User, Different Use, Damage, Exceeded Service Life</td>
<td>Thinner or thicker frame, potentially manufactured from a different material. Demountable window that allows for replacement of individual glazing layers. Bigger windows</td>
</tr>
<tr>
<td>Shading</td>
<td>Appearance, Daylight</td>
<td>Fashion, Different User, Different Use, Damage, Exceeded Service Life</td>
<td>Shading out of different material or shape. Different functioning shading, from static to movable or vice versa. Adding additional shading elements</td>
</tr>
<tr>
<td>Building Installations</td>
<td>Heating/Cooling, Ventilation</td>
<td>Technology Upgrade, Different User, Different Use, Damage, Exceeded Service Life</td>
<td>More efficient installation requiring less space/ Additional components integrated in the facade. Additional components mounted on the exterior of the facade.</td>
</tr>
<tr>
<td>Piping</td>
<td>Heating/Cooling, Ventilation</td>
<td>Technology Upgrade, Different User, Different Use, Damage, Exceeded Service Life</td>
<td>Different size or material piping. Additional pipes. Removing pipes.</td>
</tr>
</tbody>
</table>
Concept Production

Vertical Frame     Horizontal Frame     Drawer Frame     Surrounding Frame     Self-Sup. Frame

Slot System      Add-in System      Open Frame      Pin Frame      Closed Modules
Chosen Concept

- Vertical Frame
- Horizontal Frame
- Drawer Frame
- Surrounding Frame
- Self-Sup. Frame
- Slot System
- Add-in System
- Open Frame
- Pin Frame
- Closed Modules
Concept Variants

Standardised Size | Unlayered

Adjustable Size | Unlayered

Standardised Size | Layered

Adjustable Size | Layered
Chosen Variant

Standardised Size | Unlayered
Adjustable Size | Unlayered
Standardised Size | Layered
Adjustable Size | Layered
Boxes
Protection Layer
Cladding
Window Integration
Connections
Adaptation Layer
Completed System
AS

RT 72 Reflex Operable Window Frame
Mounted in clamp profile
Rubber Interbox Connection
Airtight connection between boxes
Rubber Compression Profile

Evening Lathe (200 x 40 mm)
Support structure for modules
Steel Connection Flat
Screwed to support structure
Steel Concrete Screw
Attachment of evening lathe to floor

R7

STANDARD MODULE CONFIGURATION
Stucco Finish (10 mm)
Existing Concrete Wall (12 mm)
Air Cavity (70 mm)
Existing Brick Facade (100 mm)
Adaptation Layer (50 mm)
MDF Panel (12 mm)
EPS Insulation (226 mm) (Rc = 7,7 m²/W*K)
MDF Panel (12 mm)
Air Cavity (9 mm)
Bamboo Composite Panel (12 mm)

80/20 T-slot Profile 45x45L
Aluminium extrusion profile (two-flange)
Aluminium Clamp Profile
Connected to T-slot with Insulated Stud
Aluminium Finishing Cap
Customisable shape and material
Plastic Thermal Break
Mounted in clamp profile
RT 72 Reflex Fixed Window Frame
Mounted in clamp profile
HR++ Double Glazing
(S-20-4) U = 1.1 W/m*K

IV
CASE STUDY APPLICATION
Centralised Ventilation
Decentralised Heat Exchanger Unit
Decentralised Ventilation
Nocturnal Ventilation
Static Solar Shading
Solar Panel
Placeholder Frame
Solar Comb
## Evaluation

<table>
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<th>Assessment Final Design</th>
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<tr>
<td>Architecture</td>
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Limitations

- What are the exact costs of implementing such system? Production line, training construction workers, application, etc.

- “Fool proof” system? Will the production process, as well as the application and upgradation process be “simple” enough to be an effective strategy.

- Will the BPIE scenario proof to be an effective strategy?

- Effectiveness of the system increases when the amount of buildings renovated with the system increases.
“In what way can a prefabricated building envelope system for energy reduction renovation of building envelopes of Dutch post-war apartment blocks be designed to be future proof by taking into account service life and changing standards?”
Answer

- **Designing a system with long-term effectiveness in mind instead of short-term success.**
- By separating functional layers, as well as functionalities.
- By offering the ability to adapt to changes in functionality, technology and regulations, either foreseen or unforeseen, through changing of boxes and layers, as well as layout of box areas or module sizes.
Why?

**Government:**
- A larger chance of widespread acceptance due to spreading of costs due to gradual renovation.

**Building Industry:**
- Be able to adjust to new technologies.
- Increase the lifespan of the complete system.
- Interchangeability between different apartments.
- Different levels of energy reduction possible, catered to individual projects needs.

**Homeowners:**
- Variety of choice between building installations, be able to adapt if a system becomes outdated, for lowered costs.

**Architects:**
- Customisation options in appearance, while incorporating sustainable design.
RE\textsuperscript{∞}NOVATE

Thank You!
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<tbody>
<tr>
<td>Customisation</td>
<td>★★★★★</td>
<td>Due to the approach every project can be customised in all aspects.</td>
</tr>
<tr>
<td>Level of Prefabrication</td>
<td>★★★★★</td>
<td>The semi-prefabricated. All components are manufactured in a factory, but have to be assembled on-site.</td>
</tr>
<tr>
<td>Integration</td>
<td>★★★★★</td>
<td>Installations are combined with the thermal renovation but are separated.</td>
</tr>
<tr>
<td>Sustainable Materials</td>
<td>★★★★★</td>
<td>ENDIS uses steel as its main selling points, although it’s highly recyclable the embodied energy is high.</td>
</tr>
<tr>
<td>Structural Adjustments</td>
<td>★★★★★</td>
<td>No structural adjustments are needed to the original building. The shaft needs a separate support structure.</td>
</tr>
<tr>
<td>Adaptability</td>
<td>★★★★★</td>
<td>The approach involves a customised approach per project. The system doesn’t adapt to parameters.</td>
</tr>
<tr>
<td>Disturbance</td>
<td>★★★★★</td>
<td>Although occupants can stay in their homes, a relatively high amount of on-site labour must be performed.</td>
</tr>
<tr>
<td>Construction Time</td>
<td>★★★★★</td>
<td>Approximately seven weeks on average are necessary to wrap a existing building.</td>
</tr>
<tr>
<td>Upgradability</td>
<td>★★★★★</td>
<td>Upgradability is not integrated in the design of the system.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>★★★★★</td>
<td>Maintenance can be easily performed on the installations without occupants present.</td>
</tr>
</tbody>
</table>
# TES Energy Facade Assessment

## Architecture, Construction, Application and Long-Term Functionality

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Grade</th>
<th>Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customisation</td>
<td>5</td>
<td>The TES Energy Facade can be customised on every aspect, the basis of wood construction always used.</td>
</tr>
<tr>
<td>Level of Prefabrication</td>
<td>5</td>
<td>The elements can be four stories high, other sizes are also possible.</td>
</tr>
<tr>
<td>Integration</td>
<td>5</td>
<td>Installations can be integrated into the panel, with piping and ducts tucked into the insulation layer of the panel.</td>
</tr>
<tr>
<td>Sustainable Materials</td>
<td>4</td>
<td>The construction is made out of wood, which is a material with low embodied energy, the other materials are adjustable.</td>
</tr>
<tr>
<td>Structural Adjustments</td>
<td>5</td>
<td>No adjustments have to be made to the structure.</td>
</tr>
<tr>
<td>Adaptability</td>
<td>4</td>
<td>The system comes with standard details that can be used for a large variety of typologies, the details have to be adjusted accordingly.</td>
</tr>
<tr>
<td>Disturbance</td>
<td>5</td>
<td>Disturbance is relatively minimised, with occupants remaining at their homes. Cranes need to be used to place the modules.</td>
</tr>
<tr>
<td>Construction Time</td>
<td>4</td>
<td>Construction period was approximately one and a half years which is, even when considering the scale of the projects, very slow.</td>
</tr>
<tr>
<td>Upgradability</td>
<td>3</td>
<td>The panel doesn’t integrate upgradability in it’s system.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>3</td>
<td>Maintenance is difficult to the installation due to the closed off nature of the system.</td>
</tr>
</tbody>
</table>
RT 72 Reflex Operable Window Frame
- Mounted in clamp profile
- Airtight connection between boxes
- Rubber Interbox Connection
- Airlight connection between boxes
- Rubber Compression Profile

Evening Lathe (200 x 40 mm)
- Support structure for modules
- Steel Connection Flat
- Screwed to support structure
- Steel Concrete Screw
- Attachment of evening lathe to floor

Timber L-Profile
- Attached to extrusion profile
- BD/20 T-slot Profile 45X45L
- Aluminium extrusion profile (two-flange)
- Aluminium Clamp Profile
- Connected to T-slot with insulated stud
- Aluminium Finishing Cap
- Customisable shape and material

Steel Concrete Screw
- Attachment of evening lathe to floor

Evening Lathe (200 x 40 mm)
- Support structure for modules
- Rubber Intermodule Connection
- Placed in slot of extrusion profile
- Rubber Compression Profile
- Connects to adjacent box
- Rubber Compression Profile
- Connects to adjacent clamp

Stucco Finish (10 mm)
- Existing Concrete Wall (12 mm)
- Air Cavity (70 mm)
- Existing Brick Facade (100 mm)
- Adaptation Layer (50 mm)
- MDF Panel (12 mm)
- EPS Insulation (226 mm) (Rc = 7.7 m2/W*K)
- MDF Panel (12 mm)
- Air Cavity (9 mm)
- Bamboo Composite Panel (12 mm)
Stucco Finish (10 mm)
Existing Concrete Wall (12 mm)
Air Cavity (70 mm)
Existing Brick Facade (100 mm)
Adaptation Layer (50 mm)
MDF Panel (12 mm)
EPS Insulation (226 mm) (Rc = 7.7 m²/W*K)
MDF Panel (12 mm)
MDF Panel (12 mm)
Installation Space (710 mm)
Integrated RT 72 Reflex Door (29 mm)
Lease your facade?

(Source: Ir. Juan Azcarate-Aguerre)
Lease your 2ndSkin Renovation?