Circular Façade Systems

Pragya Chauhan
5319110

Mentors – Thaleia Konstantinou, Atze Boerstra

P5 Presentation
16th June 2022
This impact is because for a long time, we have followed a linear economy model.
The solution to this problem is the circular economy model.
Built before 2001
220 million building units

85 – 95% of these will still be standing in 2050!
Need to be upgraded to match the current standards

35 million buildings expected to be renovated by 2030
Embodied carbon
Operational carbon

Need to reduce

(Ebrahimi, 2020)
Circular Economy

Circularity in the Built Environment

New Building Design

Building Renovations

Building Envelope
Contribution to Embodied Carbon

- Architectural demands
- Thermal performance
- Indoor comfort
- Actors
- Complex geometry

17%
There is a lack of a clear and strategic approach to designing a circular façade. The process is complex due to many interconnected factors involved.
“How can we implement circularity in façades during the planning and design processes of building renovation projects in the Netherlands?”
“How can we implement circularity in façades during the planning and design processes of building renovation projects in the Netherlands?”
Literature

- Building Renovation Goals
- Circular Economy in Built Environment
# Building Renovation Goals

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Design</td>
<td>Improvement of the urban and architectural quality, preventing vacancy in a neighborhood to avoid social problems are important factors related to the urban context in which the building is placed.</td>
</tr>
<tr>
<td>Architectural Design</td>
<td>Avoid the decay of valuable architectural heritage and construction, update the appearance of the overall building, and change the character to suit the current times.</td>
</tr>
<tr>
<td>Function</td>
<td>Transform the building spatially, optimize the spaces as per requirement</td>
</tr>
<tr>
<td>User Comfort</td>
<td>Eliminate unpleasant indoor conditions, hygiene, and ventilation problems, avoid sick building syndrome or building related illnesses.</td>
</tr>
<tr>
<td>Technical Installations</td>
<td>Reduce the high operational energy demand and maintenance needs</td>
</tr>
<tr>
<td>Hazardous Materials</td>
<td>Get rid of hazardous materials if any have been used in the original construction</td>
</tr>
<tr>
<td>Building Physics</td>
<td>Eliminate building physics concerns like lack of insulation, wind or water leaks, fire protection deficiencies while planning for climate change and the current climatic conditions.</td>
</tr>
<tr>
<td>Fire Regulation</td>
<td>Introduce compulsory fire safety improvements as per current building standards and regulations</td>
</tr>
<tr>
<td>Safety</td>
<td>Avoid danger or damage to third party</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>Meet the current energy consumption standards as per building norms.</td>
</tr>
<tr>
<td>Operational Costs</td>
<td>Avoid the high maintenance costs and high energy demands of building</td>
</tr>
<tr>
<td>Lett ability</td>
<td>Bring and vacant building back into the market</td>
</tr>
<tr>
<td>Marketing</td>
<td>Users’ representation needs</td>
</tr>
<tr>
<td>Financial Market</td>
<td>Investment from institutional investors</td>
</tr>
</tbody>
</table>

Outcomes

- Repairs in Facade
- Insulation upgraded
- Windows added or removed
- Whole façade replaced

(Ebbert, 2010)
Circular Economy in the Built Environment

Circular Economy aims to: close and extend the loops of material cycles, in order to preserve value of materials, resulting in decreased virgin material consumption and waste generation in our current society.

**Slow**
- use longer

**Narrow**
- use less

**Close**
- use again
Circular Economy in the Built Environment

Literature

Slow
use longer

Narrow
use less

Close
use again

Design for Longevity
Design for Adaptable / Disassembly
Design for Minimal Materials

Design for Reusability
Design for Circular Supplies

ResOLVE

General Frameworks

Specific Frameworks

Systemation
Functional Decomposition
Base Element
Geometry
Connections
Case Study Analysis

Planning Process
Case Study Analysis

Building Grid

- 1350 mm
- 2100 mm
- 450 mm
- 450 mm
- 1350 mm
Case Study Analysis

Building Materials

- Maggia stone panels
- Brick Masonry
- Air gap
- Poriso stone
- Precast concrete panels
- Air gap
- Poriso stone

(Peutz, DGMR, 2015)
Building Materials

Case Study Analysis

Single glazed window with timber frame (partially openable)

- Good watertightness
- Poor airtightness

- Services not connected to the Skin

- 8 mm Glass
- 100 mm Air gap
- Wooden frame

(IN) (OUT)

(Peutz, DGMR, 2015)
Case Study Analysis

Building Facade Layers

- Exterior Finish
- Window
- Insulation
- Sheathing
- Primary Frame
- Interior Finish
Design Process

Planning and Design Process
10R Framework

- **Refuse**: prevent raw material use
- **Reduce**: decrease raw material use
- **Renew**: redesign product in view of circularity
- **Re**-use: use product again
- **Repair**: maintain and repair product
- **Refurbish**: revive product
- **Remanufacture**: make new product from second-hand
- **Repurpose**: reuse product with a different function
- **Recycle**: salvage material streams with highest possible value
- **Recover**: incinerate waste with energy recovery

*(Vermeulen, et.al. 2019)*
**Design Process**

### Materials

#### Type of Materials
- Leaf
- Gear

#### Type of Feedstock
- Recycle
- Mix
- New

#### End-of-life Scenario
- Operating
- Repurpose
- Salvage
- Recovery
- Landfill

#### Service Life
- < 25
- 25-50
- 50 >

### Design for Disassembly

- Materials
- Connections
- Assembly Order

#### Connections
- Direct
- Indirect
- Filled

#### Assembly Order
- Parallel
- Stuck
- Base Element in stuck
- Sequential
Design Options

Option 1: Reclaim
Option 2: Renew
Option 3: Recycle
Option 4: Reduce
Reclaim

Reclaimed Timber frames

Reclaimed Bricks

Design Process

Reclaimed Timber frames

Reclaimed Bricks

422 [mm]

0.21 [W/m²K]
Design Process

Renew

Straw insulation

Rice Fleece Composite Panels

Cross Laminated timber boards

262 [mm]

0.24 [W/m²K]

Timber frame

Airtight film and fibre board

Fibre board

Rice fleece composite inside panels
Design Process

Recycle

Ceramic Façade Tiles

Recycled Textile Insulation

Recycled Aluminum

283 [mm]

0.23 [W/m²K]
Reduce

Reused stone panel

Reused timber frames

Design Process

255 [mm]

0.23 [W/m²K]
**Design Options**

1. **Option 1:** Reclaim
   - Thickness: 422 mm
   - Thermal Resistance: 0.21 W/m²K

2. **Option 2:** Renew
   - Thickness: 262 mm
   - Thermal Resistance: 0.24 W/m²K

3. **Option 3:** Recycle
   - Thickness: 283 mm
   - Thermal Resistance: 0.23 W/m²K

4. **Option 4:** Reduce
   - Thickness: 255 mm
   - Thermal Resistance: 0.23 W/m²K
Design Process

Design Framework

Physical attributes of building

Strategies for Circularity in the Built Environment

Degree of Intervention

Existing Building

Stage 1

New Design

Stage 2
Evaluation and Recommendations
**Life Cycle Approach**

<table>
<thead>
<tr>
<th>Product Stage</th>
<th>Construction Process Stage</th>
<th>Use Stage</th>
<th>End-of-Life Stage</th>
<th>Benefits and Loads beyond the System Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material supply</td>
<td>Transport</td>
<td>Installation</td>
<td>C1</td>
<td>Disposal</td>
</tr>
<tr>
<td>A1</td>
<td>A2</td>
<td>B1</td>
<td>C2</td>
<td>D</td>
</tr>
<tr>
<td>Transport</td>
<td>A3</td>
<td>B2</td>
<td>C3</td>
<td>D</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>A4</td>
<td>B3</td>
<td>C4</td>
<td>D</td>
</tr>
<tr>
<td>Transport to building site</td>
<td>A5</td>
<td>B4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use/application</td>
<td>Maintenance</td>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>B2</td>
<td>B5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair</td>
<td>B3</td>
<td>B6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replacement</td>
<td>B4</td>
<td>B7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refurbishment</td>
<td>B5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational energy use</td>
<td>B6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational water use</td>
<td>B7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deconstruction/demolition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Waste processing</td>
<td>Disposal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>A2</td>
<td>C1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>A4</td>
<td>C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5</td>
<td>A6</td>
<td>C3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>A7</td>
<td>C4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(OneClickLCA, 2020)
## Life Cycle Approach

<table>
<thead>
<tr>
<th>Variable for each Option</th>
<th>Acidification</th>
<th>Eutrophication</th>
<th>Ozone depletion Potential</th>
<th>Global Warming Potential (Embodied Carbon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embodied Carbon (as per EPD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport Distance (as per EPD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Life</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reused</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Common for all Options</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy used (same for all options)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation Period (same for all options)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Life of Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| kgCO2eq/sqm |
Evaluation & Recommendations

Life Cycle Approach

1. Option 1: Reclaim
2. Option 2: Renew
3. Option 3: Recycle
4. Option 4: Reduce

- Uses more materials
- Greater energy for processing at EOL

kgCO2eq/sqm
Life Cycle Approach

Evaluation & Recommendations

Option 2: **Renew**
- Greater maintenance/repair/refurbishment

Option 4: **Reduce**
- More waste processing due to complex disposal

(OneClickLCA, 2020)
# Building Circularity

## Evaluation & Recommendations

### Variable for each Option

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Service Life</th>
<th>Content (recycled, reused, renewable)</th>
<th>Wastage during construction</th>
<th>DfID</th>
<th>DfA</th>
<th>EOL Process</th>
</tr>
</thead>
</table>

### Common for all Options

- Weighing factors
- Calculation Period

---

Building Circularity – Materials Used and Recovered

%
Evaluation & Recommendations

Building Circularity

Option 1: Reclaim
Option 2: Renew
Option 3: Recycle
Option 4: Reduce

Greater % content of virgin materials
Overview

Evaluation & Recommendations
Final Design

Materials used
- Biobased
- Renewable

Extent of Intervention
- Window
- Parapet
Final Design

- Least variation in panel sizes
- Existing Building as Material Bank
- High volume of renewable, reused materials
- Materials support design for disassembly
- Designed to be prefabricated
Conclusions
Conclusions

A Circular System

Strategic Definition
- Demolition audit; information of harvested materials
- Research on creative use of materials
- Development of circular material databases / detailed information

Design
- Efficient prefabrication
- Facade disassembly plan
- Creative end of life design
- Incorporate business models specific for the facade
- BIM, Digital twin to monitor performance of facade elements
- Renovation & materials passport for facade

Construction

End-of-Life
- Market development of circular materials,
- Skilled teams for disassembly of facade

Educate, learn; Policy making and Certifications

(multiple sources)
Conclusions

Answering the Research Question

“How can we implement circularity in façades during the planning and design processes of building renovation projects in the Netherlands?”
## Answering the Research Question

### Planning
- Thorough analysis of building conditions
- Material specific information flow; low embodied energy / material composition
- Develop design framework

### Design
- Systematic approach, layer wise breakdown of components
- Reduced virgin resource use and reduced waste generation
- Higher volume of reused and bio-based materials
- Support disassembly
Information
The most significant information about the product is the embodied carbon and material feedstock composition.
Conclusions

Discussion

Information
The most significant information about the product is the embodied carbon and material feedstock composition.

Façade System
Component should be broken down into layers, for systematic design. This can be applied to other building components also.
Conclusions

Discussion

Information
The most significant information about the product is the embodied carbon and material feedstock composition.

Facade System
Component should be broken down into layers, for systematic design. This can be applied to other building components also.

Materials
1. Materials need to be prioritized greatly in the design of facades. They have a significant impact on embodied carbon. This is followed by the connections.
Conclusions

Discussion

Information
The most significant information about the product is the embodied carbon and material feedstock composition.

Façade System
Component should be broken down into layers, for systematic design. This can be applied to other building components also.

Materials
1. Materials need to be prioritized greatly in the design of facades. They have a significant impact on embodied carbon. This is followed by the connections.
2. Within materials, priority should be given to first reused materials, then biobased, lastly recycled and downcycled.
Conclusions

Discussion

Information
The most significant information about the product is the embodied carbon and material feedstock composition.

Façade System
Component should be broken down into layers, for systematic design. This can be applied to other building components also.

Materials
1. Materials need to be prioritized greatly in the design of facades. They have a significant impact on embodied carbon. This is followed by the connections.
2. Within materials, priority should be given to first reused materials, then biobased, lastly recycled and downcycled.
3. The compatibility of materials within layers is dependent on the service life, and end-of-life scenarios.
Limitations

Conclusions

Design Oriented (Impacting the measurable results)

1. **Exact information not available**
   For reused materials, even some circular materials.

2. In some cases, to receive a **comparable thermal performance value**, the thickness of material marginally modified (manufacturer data).

Research Oriented (Challenge in answering RQ)

1. **There is no ideal design framework!**
   Can vary from building to building, especially in renovations.

2. **All strategies not explored**
   Add / Wrap it interventions might have different functions of layers, therefore different materials.
Conclusions

Future Work

Need for Innovation
In reused material applications and end-of-life solutions.
Through research and experimentation.
Conclusions

Future Work

Need for Innovation
In reused material applications and end-of-life solutions.
Through research and experimentation.

Need for Information
All circular materials – biobased and reused, need more technical information which can be used in databases – development of EPD’s.
Through testing of products.
Conclusions

Future Work

Need for Innovation
In reused material applications and end-of-life solutions.
Through research and experimentation.

Need for Information
All circular materials – biobased and reused, need more technical information which can be used in databases – development of EPD's. Though testing of products.

Developing Strategies
More design-based and favorable to application. Currently they are more vision based.
Through documentation.
Conclusions

Future Work

Need for Innovation
In reused material applications and end-of-life solutions. Through research and experimentation.

Need for Information
All circular materials – biobased and reused, need more technical information which can be used in databases – development of EPD’s. Though testing of products.

Developing Strategies
More design-based and favorable to application. Currently they are more vision based. Through documentation.

Mapping Design Decisions
Processes related to sustainability – product and building to make roadmaps, frameworks. Through workshops.
Conclusions

Future Work

Need for Innovation
In reused material applications and end-of-life solutions. Through research and experimentation.

Need for Information
All circular materials – biobased and reused, need more technical information which can be used in databases – development of EPD’s. Though testing of products.

Developing Strategies
More design-based and favorable to application. Currently they are more vision based. Through documentation.

Mapping Design Decisions
Processes related to sustainability – product and building to make roadmaps, frameworks. Through workshops.

Standard Evaluation
Developing benchmarks, scorecards to evaluate circularity in design of building components. Through research and application.
Thank you.

Questions?

Pragya Chauhan
5319110
P.Chauhan-1@student.tudelft.nl
"How can we implement circularity in façades during the planning and design processes of building renovation projects in the Netherlands?"

1. What is the state of the art of non-residential building renovations especially for the building facade, in cold countries like the Netherlands?

2. What are the design strategies applicable for circular facade design?

3. What is the design process to implement circularity during façade renovation projects?

4. What steps undertaken in the pre-design and post-design stages of the building renovation process influence the circularity of the façade?
Reclaim Design Process

Material Study

Thermal Performance

Source – U-value calculator | ubakus.com

0.21 [W/m²K] 422 [mm]
<table>
<thead>
<tr>
<th>Code</th>
<th>Product</th>
<th>Layer</th>
<th>Quantity</th>
<th>Transport (1st Leg)</th>
<th>Service Life</th>
<th>Reused Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGW</td>
<td>Double glazing windows with wooden frame, 30.7 kg/m², 1.4 W/m²K, biogenic CO₂ not subtracted (for CML), FDES collective utilisable par toute entreprise qui produit en France des fenêtres et portes fenêtres, double vitrage acoustique ou standard, en bois tropicaux. (INSTITUT TECHNOLOGIQUE FCBA)</td>
<td>Windows</td>
<td>839 sqm</td>
<td>320</td>
<td>40</td>
<td>No</td>
</tr>
<tr>
<td>PST</td>
<td>Planed and strength-graded timber, pine or spruce, 460 kg/m³, planed timber: thickness 15-89 mm, moisture 8-15 ± 2%, strength-graded timber: thickness 34.89 mm, moisture 15-18 ± 2% (Stora Enso)</td>
<td>Structural Frame</td>
<td>75 cum</td>
<td>220</td>
<td>120</td>
<td>Yes</td>
</tr>
<tr>
<td>WCD</td>
<td>Wooden cladding and decking, pine or spruce, 445 kg/m³, 7-29 mm, 8-18%, moisture content (Stora Enso)</td>
<td>Interior Finish</td>
<td>1078 sqm</td>
<td>220</td>
<td>120</td>
<td>Yes</td>
</tr>
<tr>
<td>OSB</td>
<td>Oriented Strand Board (OSB), 6 - 40 x 590 - 1250 x 1840 - 6250 mm, 600 kg/m³, AGEPAN (Sonae Indústria)</td>
<td>Insulation</td>
<td>1078 sqm</td>
<td>340</td>
<td>120</td>
<td>No</td>
</tr>
<tr>
<td>LCI</td>
<td>Loose fill cellulose insulation, for wall application, L = 0.045 W/m²K, Rₐ = 1.11 m²K/W, 50 mm, 3.25 kg/m², 65 kg/m³</td>
<td>Insulation</td>
<td>1076 sqm</td>
<td>350</td>
<td>120</td>
<td>No</td>
</tr>
<tr>
<td>BCW</td>
<td>Bricks from construction waste, 210mm x 100mm x 50mm, 215mm x 102.5mm x 65mm, 228mm x 108mm x 55mm, 490/390/290mm x 90mm x 40mm, Caramel (StoneCycling)</td>
<td>Exterior Finish</td>
<td>215600 kg</td>
<td>60</td>
<td>120</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Renew

Material Study

Thermal Performance

Design Process

Source – U-value calculator | ubakus.com

0.24 [W/m²K]  262 [mm]
<table>
<thead>
<tr>
<th>Code</th>
<th>Product Description</th>
<th>Layer</th>
<th>Quantity</th>
<th>Transport (1st Leg)</th>
<th>Service Life</th>
<th>Reused Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIP</td>
<td>Straw insulation panels for exterior walls, L = 0.0493 W/mK, R=8.1 m2k/W, 400 mm, 66.19 kg/m², Lambda=0.0493 W/(m.K) (EcoCocon)</td>
<td>1078 sqm</td>
<td>Interior Finish, Insulation</td>
<td>350</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>DGW</td>
<td>Double glazing windows with wooden frame, 30.7 kg/m², 1.4 W/m²K, biogenic CO2 not subtracted (for CML), FDES collective utilisable par toute entreprise qui produit en France des fenêtres et portes fenêtres, double vitrage acoustique ou standard, en bois tropicaux. (INSTITUT TECHNOLOGIQUE FCBA)</td>
<td>839 sqm</td>
<td>Windows</td>
<td>380</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>WCD</td>
<td>Wooden decking, cladding and planed timber for joinery applications, 755kg/m³, Moist. 3-5%, Accoya Beech (Accsys Technologies PLC)</td>
<td>1078 sqm</td>
<td>Exterior Finish</td>
<td>220</td>
<td>60</td>
<td>No</td>
</tr>
</tbody>
</table>
Reduce

Design Process

Material Study

Thermal Performance

Construction and Assembly

U-value calculator | ubakus.com

Source

0.23 [W/m²K]
255 [mm]
<table>
<thead>
<tr>
<th>Code</th>
<th>Product</th>
<th>Layer</th>
<th>Quantity</th>
<th>Transport (1x1eq.)</th>
<th>Service Life</th>
<th>Reused Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Acoustic cladding from textile and cotton wool, 1.19 kg/m2, Vibrasto 15 (TEXAA)</td>
<td>Interior finish</td>
<td>1076 sqm</td>
<td>60</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>GSP</td>
<td>Galvanised steel profiles (studs) for internal wall framing, 0.7 mm, 0.2 kg/m, 37 mmx73.5 mm</td>
<td>Structural Frame</td>
<td>4484 m</td>
<td>370</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>RTF</td>
<td>Recycled textile and fabric insulation, blown, R=3.25 m²K/W, L= 0.046 W/mK, 150 mm, 2 kg/m², 13.3 kg/m³, Lambda=0.046 W/(m.K), COTON-FRP DOMOSANIX NITA-COTON-FRP NITA-COTTON ISOTEXTIL INNOCOTON COTON SOLIDAIRE (RMT Isolation SL)</td>
<td>Insulation 1</td>
<td>1076 sqm</td>
<td>60</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>WFI</td>
<td>Wood fibre insulation boards, biogenic CO2 not substracted, L = 0.044 W/mK, 173 kg/m³, EPD coverage: 0.037-0.05 W/mK, 20-240 mm, 80-250 kg/m³ (Gutex)</td>
<td>Insulation 2</td>
<td>1076 sqm</td>
<td>350</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>AFW</td>
<td>Aluminum frame window, size: 1.23 x 1.48m, 27.69 kg/m², double glazing, SUPREME S77 (Alumi)</td>
<td>Window</td>
<td>839 sqm</td>
<td>380</td>
<td>60</td>
<td>No</td>
</tr>
<tr>
<td>CGC</td>
<td>Ceramic façade cladding, 24 - 30 mm, 31 - 42 kg/m², 2000 - 2200 kg/m³ (Argelon)</td>
<td>Exterior finish</td>
<td>1078 sqm</td>
<td>320</td>
<td>50</td>
<td>No</td>
</tr>
</tbody>
</table>
Reduce

Design Process

Material Study

Thermal Performance

Construction and Assembly

0.23 [W/m²K] 255 [mm]

Source – U-value calculator | ubakus.com
<table>
<thead>
<tr>
<th>Code</th>
<th>Product</th>
<th>Layer</th>
<th>Quantity</th>
<th>Transport (1st Leg)</th>
<th>Service Life</th>
<th>Reused Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSS</td>
<td>Natural stone massive slabs (EUROROC)</td>
<td>Exterior Finish</td>
<td>299 sqm</td>
<td>200 km</td>
<td>60 years</td>
<td>Yes</td>
</tr>
<tr>
<td>WFI</td>
<td>Wood fibre insulation boards, R = 3.26 m2K/W, 140 mm, 15.4 kg/m2, 110 kg/m3, STEICOtherm dry (Steico)</td>
<td>Insulation</td>
<td>42 cum</td>
<td>350 km</td>
<td>60 years</td>
<td>No</td>
</tr>
<tr>
<td>MDF</td>
<td>Medium density fiberboard (MDF), sound absorbing, 16 mm, 13.9 kg/m2, 866 kg/m3, α_w = 0.75 (class C)</td>
<td>Interior Finish</td>
<td>299 sqm</td>
<td>340 km</td>
<td>60 years</td>
<td>No</td>
</tr>
<tr>
<td>DGW</td>
<td>Double glazing windows with wooden frame, 30.7 kg/m2, 1.4 Wm2K, biogenic CO2 not subtracted (for CML), FDES collective utilisable par toute entreprise qui produit en France des fenêtres et portes fenêtres, double vitrage acoustique ou standard, en bois tropicaux. (INSTITUT TECHNOLIGIQUE FCBA)</td>
<td>Windows</td>
<td>839 sqm</td>
<td>380 km</td>
<td>40 years</td>
<td>No</td>
</tr>
<tr>
<td>CLT</td>
<td>Cross Laminated Timber (CLT), Thickness: up to 400 mm, 470 kg/m3, 12% moisture content (Derix GmbH &amp; Co)</td>
<td>Structural Frame</td>
<td>9 cum</td>
<td>220 km</td>
<td>60 years</td>
<td>No</td>
</tr>
</tbody>
</table>