BIM: Aiding Architects for a Sustainable Façade Design during the design stage

Student name: Pinal A Desai
Student Nr.: 4325141
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Studio: Sustainable Design
Graduation Studio

Mentors | Arie Bergsma,
          Winfried Meijer,
          Andy van den Dobbelsteen

External Examiner | Reinout Kleinhans
Introduction

Building Information Modeling

Sustainability

Better Buildings

VMRG
Goal of Research

To test the hypothesis of a BIM based library for window elements
Scope of research:

Users: Architects & Sus. Designers

Which design stage?

Window Choices

Information Gap
Boundary conditions

Non-loadbearing window elements

Prelim design stage (Only design stage)

Dutch Market
Research Question

Main:
How to effectively define the contents of a ‘BIM library for curtain wall facade window elements’, such that it guides architects towards a sustainable facade design during the design stage?
Methodology
Sustainability...
3 pillars of sustainability

Breakdown of CO2 emissions and Building Industry
Embodied Energy: LCA

Cradle to grave (LCA)

Other databases around the world:

- **BEES**: Building for Environment & Economic Sustainability
- **ATHENAsmi**: Athena Sustainable Materials Institute
- **Eco-Indicator 99**: Damage oriented
- **Ecoinvent3.1**: LCI
- **Envest2**: Environmental Impact and Whole Life Cycle Cost analysis
- **IMPACT**: Integrated Material Profile and Costing Tool

**Initial Embodied Energy**

**Recurring Embodied Energy**

**Demolition Energy**

**Extract raw materials** → **Process** → **Assemble** → **Transport to site** → **Assemble on building** → **Refurbishment and maintenance** → **Demolish and dispose**
Embodied Energy: LCA

Cradle to grave (LCA)

Inventory of Carbon and Emission (ICE)
CO₂ Footprint
Uni/ Bath

Embodied Energy
Initial Embodied Energy
Recurring Embodied Energy
Demolition Energy

Extract raw materials → Process → Assemble → Transport to site → Assemble on building → Refurbishment and maintenance → Demolish and dispose

Nederlands Instituut voor Bouwbiologie en Ecology (NIBE)

CO₂ footprint
Environmental Product Declaration (EPD), Certification for EPD
Operational Energy:

LEED

BREEAM-NL

EPC
Operational Energy:

LEED
Part of 6.8%

BREEAM-NL
Part of 8.4%

EPC - Legislations = Technical standards
Sub Research Questions: Sustainability

1. How to measure sustainability for the built environment in general and for window in specific?

2. What are the Dutch and international norms and tools to calculate sustainability?

3. What parameters relate to sustainable facade design?
Facade...
# Type of window: Material

<table>
<thead>
<tr>
<th>Type of Glass</th>
<th>U-Value (W/m² K)</th>
<th>Price (€/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Glass</td>
<td>&gt;5.4-3.0</td>
<td>65</td>
</tr>
<tr>
<td>Double Glass</td>
<td>2.8 - 2.2</td>
<td>70</td>
</tr>
<tr>
<td>HR Glass</td>
<td>2.0 - 1.8</td>
<td>75</td>
</tr>
<tr>
<td>HR+ Glass</td>
<td>1.6 - 1.4</td>
<td>80</td>
</tr>
<tr>
<td>HR++ Glass</td>
<td>1.2 - 0.9</td>
<td>120</td>
</tr>
<tr>
<td>HR+++ Glass</td>
<td>0.7 - 0.5</td>
<td></td>
</tr>
</tbody>
</table>

- Wood
- Aluminium
- Steel
- PVC
Type of window: Opening

- Awning
- Casement
- Fixed
- Horizontal slider
- Single Hung
- Double Hung
- Tilt an Turn
- Hopper
Parameters to define facade

Visual Light Transmittance

Operable windows

Color, finish

Illustration: Knaack, U., et. al. (2007)
Sustainability related parameters

Embodied energy

Operational energy
Sustainability in facade design

Embodied energy

Operational energy

Primary Energy Total (Life Cycle) = Operational energy per year + LCA Embodied energy
Per year
Service life (years)
Sustainability in facade design

Primary Energy Total (Life Cycle) = Operational energy per year + LCA Embodied energy
Per year

\[ \text{Kg.} \text{CO}_2(\text{e}) \]

1 kWh = 0.57 kg CO\text{e}

Carbon conversion value as indicated in publication issued by CBS, ECN, PBL
Sub Research Questions: Facade

4. Types of facade systems?

5. Parameters to define facade at design stage?

6. Role of sustainability in facade design?
BIM + Technology...
BIM- Introduction
BIM- Tools

- Designing
  - Revit Architecture
  - Bentley
  - ArchiCAD
  - NEMETSCHENK Vectorworks

- Cost estimation
- Constructability analysis
- Clash detection
- Energy analysis

- Sustainability
- Operations & Real asset management

TOOL KITS IN IES

- FaciliVue
- Drawbase Software
- FM:Systems
- Archifm.net
- Whitestone MARS
- NET Facilities
BIM- Tools

- Heating Loads
- Cooling Loads
- Effect of changing design

IES Energy Analysis
BIM - Tools

- Heating Loads
- Cooling Loads
- Effect of changing design
Tools in the Netherlands

EPC: NEN 7120

EP-Check

GPR GEBOUW
Sub Research Questions: BIM+ Technology

7. How does BIM help in sustainable design?

8. What are the Green-BIM tools available globally and in the Netherlands?

9. Where does it still need development?
BIM + Management...
Level of Development: LOD

- **LOD 100**: Conceptual
  - <Estimate it>

- **LOD 200**: Generic Placeholders
  - <Specify it>
  - Physical/virtual clash control

- **LOD 300**: Specific Assemblies
  - <Buy it>
  - Intelligent Clash control

- **LOD 400**: Details
  - <Install it>
  - Generate Finance Schedule Planning

- **LOD 500**: Field Verification
  - <Operate it>
  - Manage and Maintain

- **LOD 250**:
  - Approximate energy simulation,
  - Cost based on measurements,
  - Simple geometry,
  - Type of window,
  - Dimensions of window.

Based on TNO Research by van Berlot et al., 2014
Library use: Project Delivery Method

LOD 100
- Conceptual
  - Estimate it

LOD 200
- Generic Placeholders
  - Specify it
  - Physical/virtual clash control

LOD 300
- Specific Assemblies
  - Buy it
  - Intelligent Clash control

LOD 400
- Details
  - Install it
  - Generate Finance Schedule Planning

LOD 500
- Field Verification
  - Operate it
  - Manage and Maintain

LOD 250
- Develop Request for Proposals

LOD 300-400
- Issue Request for Proposals and receive Proposals

LOD 400
- Administer Contracts

LOD 500
- Occupy

LOD 500
- Maintenance and Operation

- Concept of program and functions
- Schematic design
- Technical details
- Tender stage
- Manufacturer Specifications
- Construction, installation details
- Performance details
- Operation details
Role of BIM in Project Delivery

- **Acquisition planning**
- **Pre-design Activities**
- **Develop Request for Proposals**
- **Tender**
- **Administer Contracts**
- **Build**
- **Occupy**

<table>
<thead>
<tr>
<th>Effort/Effect</th>
<th>Project timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Impact of design changes</td>
<td>Traditional design process</td>
</tr>
</tbody>
</table>

- **Effort/Effect**
- **Project timeline**

The chart illustrates the role of BIM in project delivery, showing the effort and effect of traditional and BIM design processes over the project timeline.
Sub Research Questions: BIM+ Management

10. What BIM Design stage is appropriate for the Library?

11. What are current project delivery method based design stages in the Netherlands?

12. How does BIM assist the project delivery method?
Main Research Question:

How to effectively define the contents of a ‘BIM library for curtain wall facade window elements’, such that it guides architects towards a sustainable facade design during the design stage?
Current Libraries

Company’s in-house library

Fab- Window by Itannex

BIM object

2-D Brochures
Current Libraries

Company’s in-house library

Fab- Window by Itannex

BIM object

Manufacturers’ BIM object

www.itannex.com

2-D Brochures

Inserted object into architect’s model

Updation and monitoring by BIMObject developers

Approved by BIMObject developers

BIM object cloud
Proposal for Library

Fab- Window by Itannex

- Limited non-Geometrical Data
- All possible variations of window type in one file: easy of comparison

BIM object

- Too many manufacturers: confusing
- Data from manufacturers
Guidelines of the Library

- LOD 250
- Generic Library
- Min. geometric detail
- CO₂ comparison
- LCA
- Operational Energy
- Legislations
- Reference

INVENTORY OF CARBON & ENERGY (ICE)
Version 1.6a
Prof. Geoff Hammond & Craig Jones

GUIDELINES FOR GREEN BUILDING
LEED USGBC

BREEAM
EXPERT NIEUWBOUW
The Library in BIM...
Case Study 1

NEN 7120

Case Study 2
### Embodied energy based parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Frame</td>
<td>Select from drop down</td>
</tr>
<tr>
<td>KG CO2 value (frame)</td>
<td></td>
</tr>
<tr>
<td>Glass type</td>
<td>Select from drop down</td>
</tr>
<tr>
<td>KG CO2 value (glass)</td>
<td></td>
</tr>
<tr>
<td>Fill type (between glass)</td>
<td>Select from drop down</td>
</tr>
<tr>
<td>KG CO2 value (infill)</td>
<td></td>
</tr>
<tr>
<td>Service Life</td>
<td>value (years)</td>
</tr>
<tr>
<td>Recyclability</td>
<td>value (%)</td>
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### Operational energy based parameters

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<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>U-value glass</td>
<td></td>
</tr>
<tr>
<td>U-value frame</td>
<td></td>
</tr>
<tr>
<td>U-total</td>
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</table>

### General data:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>thickness-profile</td>
<td></td>
</tr>
<tr>
<td>Colour frame</td>
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<td>Select from drop down</td>
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<tr>
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<td>In model</td>
</tr>
<tr>
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<td>price (per unit)</td>
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### EPC based Parameters:

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<tr>
<td>air tightness</td>
<td>0.2 cubic decimeters/second</td>
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<tr>
<td>Solar heat gain</td>
<td>requirement</td>
</tr>
<tr>
<td>daylighting</td>
<td>depending on interior function</td>
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<td>requirement</td>
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## Final Product: Toolkit

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</table>

### Building Typology

<table>
<thead>
<tr>
<th>Select from dropdown list</th>
<th>PC value</th>
</tr>
</thead>
</table>

### Green Building Standard (GBS)

<table>
<thead>
<tr>
<th>Criteria to fulfill</th>
<th>LEED/BREEAM-NL Points</th>
</tr>
</thead>
</table>

### Contextual Analysis Tool

<table>
<thead>
<tr>
<th>Weather data</th>
<th>Terrain Type</th>
<th>Predefined weather/location data (drop down menu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location data</td>
<td>Wind exposure rating</td>
<td>Ground Reflectance rating</td>
</tr>
</tbody>
</table>

### Space Usage

<table>
<thead>
<tr>
<th>Number of building occupants</th>
<th>Client brief</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting Types</td>
<td>Client brief</td>
</tr>
<tr>
<td>Equipment types</td>
<td>Client brief</td>
</tr>
<tr>
<td>Occupancy schedules</td>
<td>Client brief</td>
</tr>
</tbody>
</table>

### Building Envelope Performance (Only Windows)

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
</table>

### Building Envelope Initial Embodied Energy

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
</table>

### Primary Total Energy: parameters

| Operational energy per year | Value from simulation + | Value from parameters table |

### Resultant value =

| Value from simulation + | Pre-calculated value from parameters table |

### Cost estimation

| Data from Parameters table | Sr. Of units from model |
Final Product

Demonstration of Excel tool
Design options: Type of User Interface

BIM Platform

Model Entry

Entry into the BIM Design Software

BIM-Object
Design options: Type of User Interface

BIM Platform

Model Entry

Entry into the BIM Design Software

BIM-Object

Plug-in
Design options: Type of User Interface

- BIM Platform
  - Model Entry
    - Entry into the BIM Design Software
      - BIM-Object
        - Design options: Type of User Interface
          - Cloud Based software
            - Cloud based computation
              - ✔️ ✔️ ✔️ ✔️ ✔️ ✔️ ☑️ ☑️
              - ✔️ ✔️ ✔️ ✔️ ✔️ ✔️ ☑️ ☑️

- Plug-in
  - ✔️ ✔️ ☑️ ☑️
  - ✔️ ✔️ ✔️ ✔️ ☑️ ☑️
Design options: Type of User Interface

BIM Platform

Model Entry
Entry into the BIM Design Software

Cloud Based software
Cloud based computation

BIM-Object

Plug-in
Sub Research Questions:

15. What would the new library look like? On which platform should it be developed?
Testing the Toolkit...
Testing the toolkit : Location
Testing the toolkit: Volume and orientation

1.2x1.2 standard windows
24x24x10m room for 100 people
Testing the toolkit: Analysis

25.5%

Operational Energy

22.9 T.CO₂

29.6 T.CO₂
Testing the toolkit : Analysis

Embodied Energy : Recyclability

Values in kg.CO₂ Per m² material
Testing the toolkit: Analysis

Embodied Energy: Durability

Wood:
- 1 Replacements
- 14.4 T CO₂

Steel:
- 0replacement
- 12.3 T CO₂

Aluminium:
- 1 replacement + 50 years of additional usage
- 7.6 T CO₂

Initially installed frame

Initially installed frame

Initially installed frame

Replaced frame after 50 years

Replaced frame after 75 years

Start
- 50 years
- 75 years
- 100 years
- 150 years
The embodied energy of the frame material is quite small and negligible. However, the embodied energy of glass makes a large impact. It should be noted that the embodied energy GHG emission also includes the other elements of the building such as the exterior wall, roof, and floor. When adding all together the values are significantly higher and hence, important to consider.

Recyclability:
The energy calculations consider the materials usage only for the first application of the material. However, for the second application, recyclability plays a very important factor. By using recyclable materials, as seen in the case of meals, about more than half of the embodied energy can be re-used in the next cycle.

This means that although HR+ glass with timber frame shows better total CO2 impact, for its replacement, the same amount of CO2 will have to be spent which is 3.589 T.CO2. Whereas for the production of HR+ glass with aluminium frame of 65% recyclability, about 3.747 T.CO2 of the 5.703 T CO2 is already available. Thus for the replacement additional 1.956 T.CO2 will be required, which is one third of that required for production of wooden window frames.

Durability:
Another aspect is the durability. A steel frame lasts for 100 years whereas the wooden frame lasts for 50 years. By using the embodied GHG frame value from the table, we can get a comparable per year value of the material within the project. Thus, for a 100 year time span, a steel frame would consume 12.338 TCO2 whereas a wooden window would require 14.356 TCO2. The aluminium equivalent (without recyclability factor) for 100 years is 7.605 TCO2. This concludes that wooden windows are a bad choice if durability and recyclability are the priority.

Wood (for 100 years): 14.356
Steel for 100 years: 12.338
Aluminium: 7.605

Testing the toolkit: Analysis

Embodied energy = 2%
Operational energy = 98%

Embodied Energy v.s operational energy
Testing the toolkit : Conclusion

- Operational energy = Choosing the right material

- Embodied energy : Role of recyclability and durability

- Embodied energy can be considered as an asset for refurbishment and after building usage
Conclusions of the Research...
Conclusions: Role of library in sustainable facade design

Current situation
Conclusions: Role of library in sustainable facade design process

Current situation

- Acquisition Planning
- Pre-design activities
- Develop request for proposals
- Issue RFP & receive proposals (Tender Stage)
- Administer contracts
- Occupy
- Post Occupancy Evaluation & Maintenance and operation

Due to use of Library, information available earlier in design stage

Input of Performance related information in traditional CAD based process

Role of Library

- Acquisition Planning
- Pre-design activities
- Develop request for proposals
- Issue RFP & receive proposals (Tender Stage)
- Administer contracts
- Occupy
- Post Occupancy Evaluation & Maintenance and operation
Conclusions: Role of library in sustainable facade design
- Environmental impact
  - Importance of Embodied Energy
    - Material Comparison = Better engineered at early stage buildings

- Economic impact
  - Social impact

- Environmental impact
Environmental impact

- Importance of Embodied Energy
- Material Comparison = Better engineered at early stage buildings

Economic impact

Social impact

Addition of reduced embodied energy as a valuable asset for costing
Reduction of cost error in later stages
Importance of Embodied Energy

- Material Comparison: Better engineered at early stage buildings

Environmental impact

Economic impact

Social impact

Addition of reduced embodied energy as a valuable asset for costing
Reduction of cost error in later stages

Educating Client on importance of Embodied Energy
Possibility of new laws
Better = Better designs designers
Conclusion: Adoption of BIM library

Restricted because:

Architects (or Sustainable Designers)

Developing/ Maintaining authority of the BIM Library
Sub Research Questions:

15. How it is supposed to help in sustainable facade design? Will architects use it? Are there any benefits for the manufacturer?
Main Research Questions:

How to effectively define the contents of a ‘BIM library for curtain wall facade window elements’, such that it guides architects towards a sustainable facade design during the design stage?
Main Research Questions:

How to effectively define the contents of a ‘BIM library for curtain wall facade window elements’, such that it guides architects towards a sustainable facade design during the design stage?

- By defining the parameters relating to EPC, Operational energy and LCA database, as indicated in the toolkit.
Main Research Questions:

- By defining the parameters relating to EPC, Operational energy and LCA database, as indicated in the toolkit.

- By providing possibility to calculate also the recyclablity and durability of the curtain wall facade window frame material and comparing it with the building’s service life.
Recommendations...
Recommendations

Total environmental impact


Recommendations

Total environmental impact

All building elements- for total embodied energy
Recommendations

Total environmental impact

All building elements- for total embodied energy

Define Re-use and Re-cycle potential within database
Recommendations

Total environmental impact

All building elements- for total embodied energy

Define Re-use and Re-cycle potential within database

Possibility of feedback to designers using BIM
Recommendations

Total environmental impact

All building elements- for total embodied energy

Define Re-use and Re-cycle potential within database

Possibility of feedback to designers using BIM

Design intent lost during operations stage.
Thank you.
Extra Slides...
Library use: Project Delivery Method

Integrated Project Delivery (IPD)

BIM Workflow
Library use: Project Delivery Method

Integrated Project Delivery (IPD)

BIM Workflow

Integrated Project Delivery (IPD)
Library use: Project Delivery Method

Aquisition Planning
- Pre-design activities
- Develop request for proposals
- Issue RFP & receive proposals (Tender Stage)
- Administer contracts
- Occupy
- Post Occupancy Evaluation & Maintenance and operation

Design Bid Build (DBB)

BIM Workflow

Integrated Project Delivery (IPD)
Primary Energy Total (Life Cycle) = (Operational energy per year) X Service Life + LCA Embodied energy
BIM Definition

Modelling Information

- shaping
- forming
- presenting, scoping

Building

- a structure, an enclosed space, a constructed environment

- to virtually construct a
- to extend the analysis of a
- to explore the possibilities of
- to study what-if scenarios for a
- to detect possible collisions within a
- to calculate construction costs of
- to analyse constructability of a
- to plan the deconstruction of a
- to manage and maintain a

an organised set of data:
meaningful, actionable

(Succor, 2008)
Commonly used Dutch BIM LOD Levels

![Diagram showing the levels of digital information exchange in BIM]

**Operating Procedure**

<table>
<thead>
<tr>
<th>Data</th>
<th>Models, objects</th>
<th>Models, objects, common libraries</th>
<th>Integrated, interoperable data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawings, lines, arcs, text, etc.</td>
<td>2D, 3D</td>
<td>File based collaboration &amp; library management, 4D, 5D, ...</td>
<td>Integrated web-services</td>
</tr>
<tr>
<td>Paper (CAD, Excel, Word, etc.)</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Level of Cooperation**

- Coordination
- Coordination
- Collaboration
- Integration

*Based in part on Bouw-Richards UK 2008*
<table>
<thead>
<tr>
<th>Level of Detail -&gt;</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
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</thead>
<tbody>
<tr>
<td><strong>Model Content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design &amp; Coordination (function / form / behavior)</td>
<td>Non-geometric data or line work, areas, volumes zones, etc.</td>
<td>Generic elements shown in three dimensions</td>
<td>Specific elements Confirmed 3D Object Geometry</td>
<td>Shop drawing fabrication</td>
<td>As-built</td>
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<td>As-built</td>
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<tr>
<td><strong>Authorized uses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4D Scheduling</td>
<td>total project construction duration</td>
<td>Time-scaled, ordered appearance of major activities</td>
<td>Time-scaled, ordered appearance of detailed assemblies</td>
<td>Fabrication and assembly detail including construction means and methods (cranes, man-lifts, shoring, etc.)</td>
<td>As-built</td>
</tr>
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<td></td>
<td>total project construction duration</td>
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<td>Time-scaled, ordered appearance of detailed assemblies</td>
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<td>As-built</td>
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<tr>
<td><strong>Cost Estimating</strong></td>
<td>Conceptual cost allowance Example $/sf of floor area, $/hospital bed, $/parking stall, etc.</td>
<td>Estimated cost based on measurement of generic element E.g., generic interior wall.</td>
<td>Estimated cost based on measurement of specific assembly E.g., specific wall type.</td>
<td>Committed purchase price of specific assembly at Buyout.</td>
<td>Record costs</td>
</tr>
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<tr>
<td><strong>Program Compliance</strong></td>
<td>Gross departmental areas</td>
<td>Specific room requirements</td>
<td>FF&amp;E, casework, utility connections</td>
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<td>FF&amp;E, casework, utility connections</td>
</tr>
<tr>
<td><strong>Sustainable Materials</strong></td>
<td>LEED strategies</td>
<td>Approximate quantities of materials by LEED categories</td>
<td>Precise quantities of materials with percentages of recycled/locally purchased materials</td>
<td>Specific manufacturer selections</td>
<td>Purchase documentation</td>
</tr>
<tr>
<td><strong>Environmental: Lighting, Energy use, air movement Analysis/Simulation</strong></td>
<td>Strategy and performance criteria based on volumes and areas</td>
<td>Conceptual design based on geometry and assumed system types</td>
<td>Approximate simulation based on specific building assemblies and engineered systems</td>
<td>Precise simulation based on specific manufacturer and detailed system components</td>
<td>Commissioning and recording of measured performance</td>
</tr>
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<td>Precise simulation based on specific manufacturer and detailed system components</td>
<td>Commissioning and recording of measured performance</td>
</tr>
<tr>
<td>Material Description</td>
<td>Service Life (years)</td>
<td>Kg CO2 Kg CO2 Per year</td>
<td>Recyclability (%)</td>
<td>Price (per unit) (EURO)</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>European hardwood (67x114) acrylic painted</td>
<td>50</td>
<td>8,95</td>
<td>0,179</td>
<td>0,0%</td>
<td>1,20</td>
</tr>
<tr>
<td>European softwood (67x114); painted, acrylic</td>
<td>35</td>
<td>10,38</td>
<td>0,256</td>
<td>0,2%</td>
<td>1,44</td>
</tr>
<tr>
<td>European softwood (67x114); painted, acrylic</td>
<td>50</td>
<td>9,24</td>
<td>0,185</td>
<td>0,1%</td>
<td>1,48</td>
</tr>
<tr>
<td>European softwood (67x114); painted, acrylic</td>
<td>35</td>
<td>10,38</td>
<td>0,256</td>
<td>0,2%</td>
<td>1,66</td>
</tr>
<tr>
<td>Tropical hardwood (67x114); painted, acrylic</td>
<td>50</td>
<td>15,7</td>
<td>0,314</td>
<td>0,1%</td>
<td>2,36</td>
</tr>
<tr>
<td>Pine (67x114); acetylated modified</td>
<td>50</td>
<td>17,6</td>
<td>0,352</td>
<td>0%</td>
<td>2,42</td>
</tr>
<tr>
<td>97% secondary aluminum (68x72), anodized</td>
<td>75</td>
<td>17,5</td>
<td>0,233</td>
<td>63,0%</td>
<td>2,92</td>
</tr>
<tr>
<td>Steel (80x50); Powder</td>
<td>100</td>
<td>31,8</td>
<td>0,318</td>
<td>62,6%</td>
<td>3,39</td>
</tr>
<tr>
<td>Steel (80x70); Powder</td>
<td>100</td>
<td>33,1</td>
<td>0,331</td>
<td>65,6%</td>
<td>3,59</td>
</tr>
</tbody>
</table>

**Embodied energy based parameters**

- **Window Frame:** Select from drop down
- **KG CO2 value (frame):** Select from drop down
- **Glass type:** Select from drop down
- **KG CO2 value (glass):** Select from drop down
- **Fill type (between glass):** Select from drop down
- **KG CO2 value (infill):** Select from drop down
- **Service Life:** value (years)
- **Recyclability:** value (%)

**Operational energy based parameters**

- **VLT:** value
- **SHGC:** value
- **U-value glass:** value
- **U-value frame:** value
- **U-total:** value

**General data:**

- **thickness-profile:** value
- **Colour frame:** Select from drop down
- **Coating frame:** Select from drop down
- **BIPV:** Select from drop down
- **thickness glass:** Select from drop down
- **Spacers Between Glass:** Select from drop down
- **Profile placement:** In model
- **Acoustic:** Select from drop down
- **price (per unit):** value

**EPC based Parameters:**

- **U-value:** Max = 4.2 W/m² K
- **air tightness:** 0,2 cubic decimeters/second
- **Solar heat gain:** requirement
- **daylighting:** depending on interior function
- **Ventilation:** requirement
- **Sushading:** provision
- **area of transparent elements:** depending on residential/ non residential

**MATERIAL**

- **Krypton filling:** 26
- **Xenon filling:** 229
- **class:** 0,85

**Krypton filling**

<table>
<thead>
<tr>
<th>Glass type</th>
<th>U-value</th>
<th>Wo</th>
<th>Plastic</th>
<th>Metal with thermal break</th>
<th>Metal without thermal break</th>
<th>KLT</th>
<th>SHGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>single glass</td>
<td>3,3</td>
<td>3,3</td>
<td>3,6</td>
<td>3,5</td>
<td>0,95</td>
<td>3,85</td>
<td></td>
</tr>
<tr>
<td>double glass</td>
<td>2,8</td>
<td>2,9</td>
<td>3,3</td>
<td>3,1</td>
<td>0,9</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>HR glass</td>
<td>2,0</td>
<td>2,3</td>
<td>2,8</td>
<td>3,6</td>
<td>0,8</td>
<td>2,75</td>
<td></td>
</tr>
<tr>
<td>HR++ glass</td>
<td>1,2</td>
<td>1,8</td>
<td>2,2</td>
<td>3,0</td>
<td>0,75</td>
<td>2,60</td>
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<tr>
<td>HRS</td>
<td>0,7</td>
<td>1,4</td>
<td>1,3</td>
<td>1,7</td>
<td>0,65</td>
<td>1,60</td>
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</tbody>
</table>
Library use: Project Delivery Method
<table>
<thead>
<tr>
<th>Topic</th>
<th>Fab- Window by Itannex</th>
<th>BIM object</th>
<th>2-D Brochures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable in design stage</td>
<td>yes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexible geometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User interface</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embodied energy related data</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational energy related data</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy of comparison</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Information: needs to be filtered by architect

- Maybe? yes: Flexible geometry
- Maybe? no: no
- Information: needs to be filtered by architect

- Maybe? yes: yes
- Maybe? no: maybe
- Information: needs to be filtered by architect

- Maybe? yes: no
- Maybe? no: Yes
- Information: needs to be filtered by architect

- Maybe? yes: no
- Maybe? no: No
- Information: needs to be filtered by architect
Figure 3.8.a: List of parameters that can be interesting to include in library.