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

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Studio : Sustainable Design
Graduation Studio

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Introduction

Building Information Modeling

Sustainability

Better Buildings

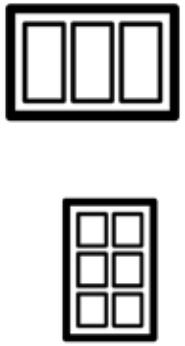
Goal of Research

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

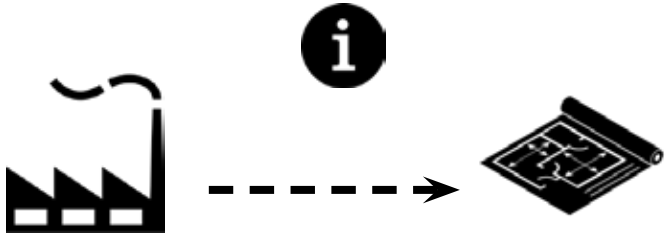
Scope of research:

Users:
Architects &
Sus. Designers

Which design stage?

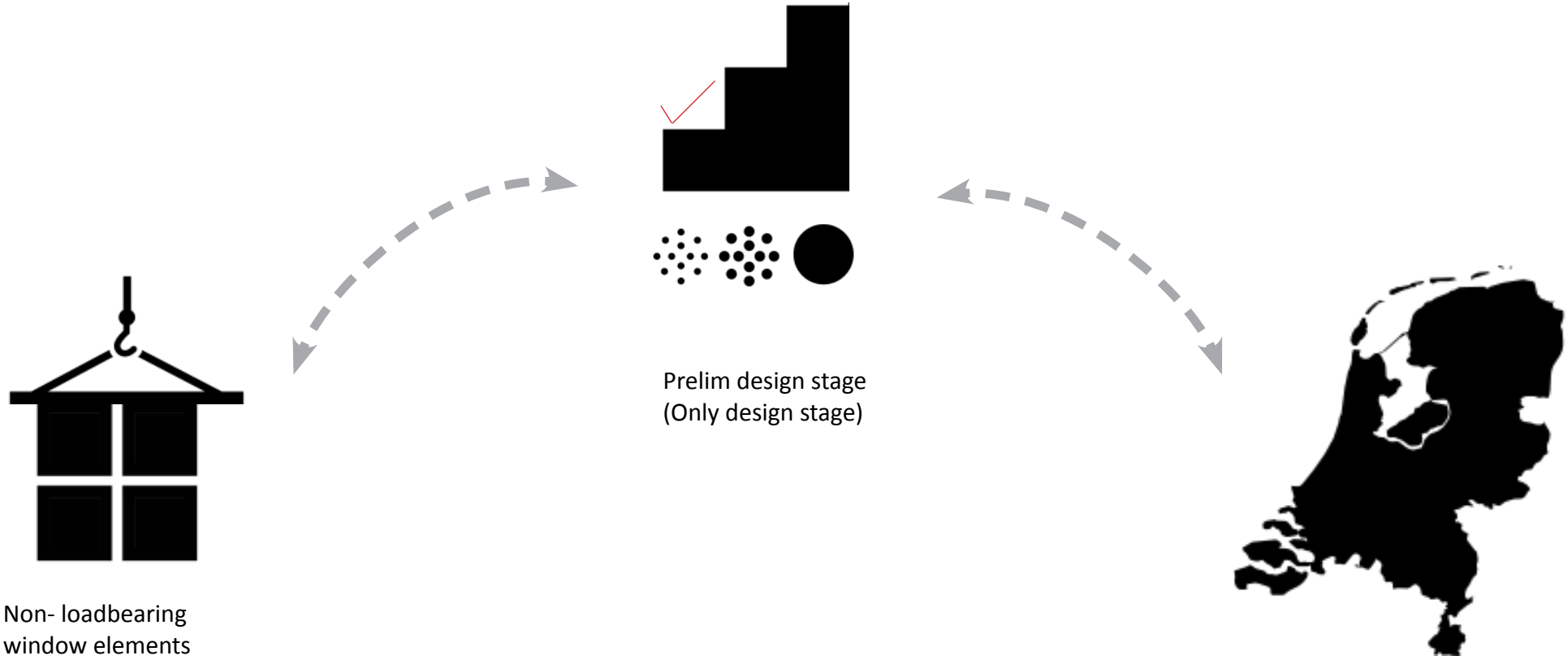


Window Choices



Information Gap

Boundary conditions



Non- loadbearing
window elements

Prelim design stage
(Only design stage)

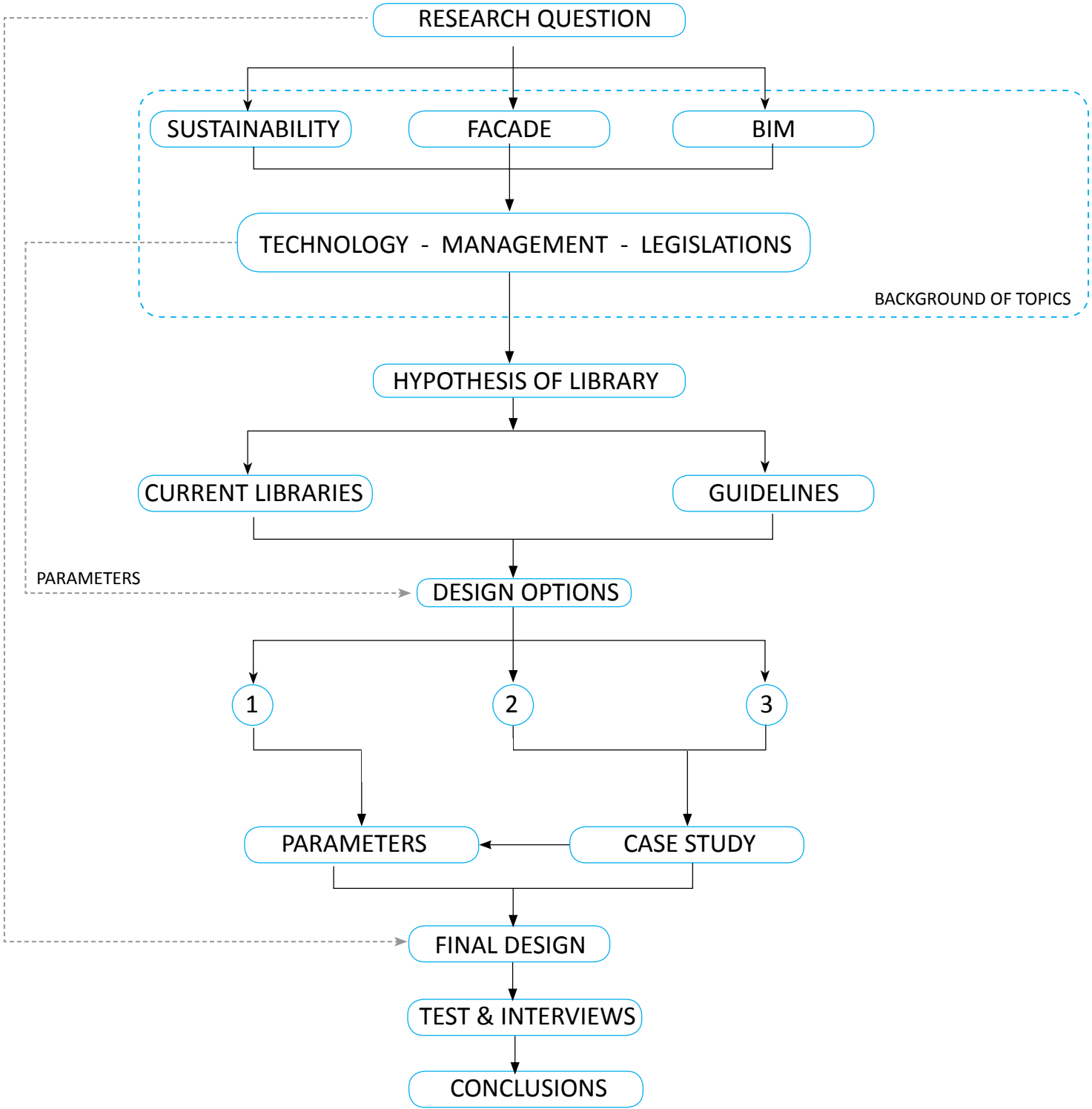
Dutch Market

Research Question

Main:

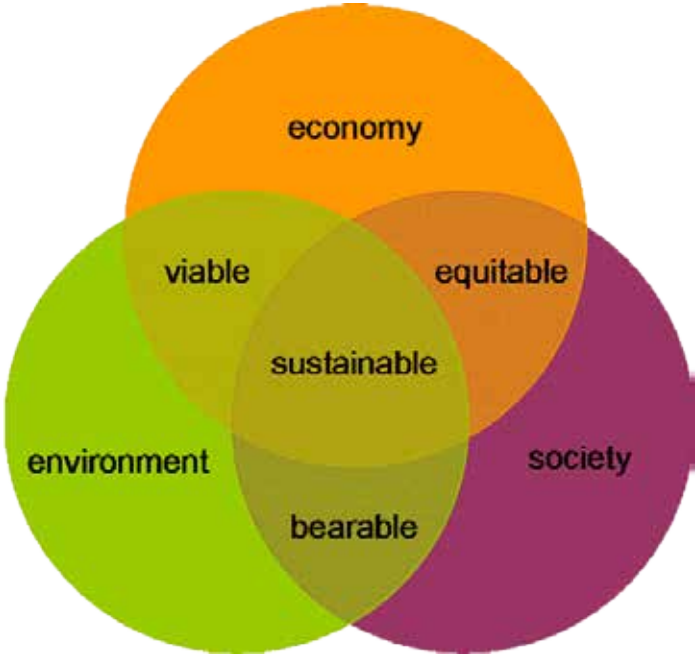
How to effectively define the contents of a ‘BIM library for curtain wall facade window elements’, such that it guides architects towards a sustainable facade design during the design stage?

Methodology

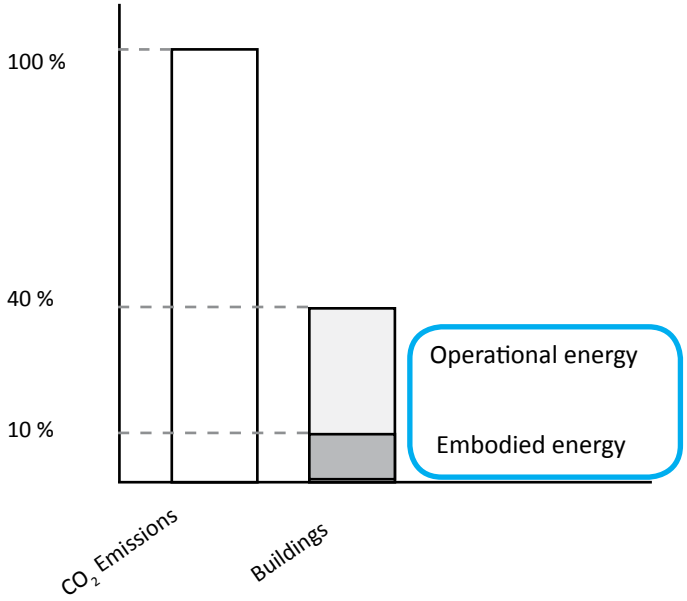


Sustainability...

Sustainability

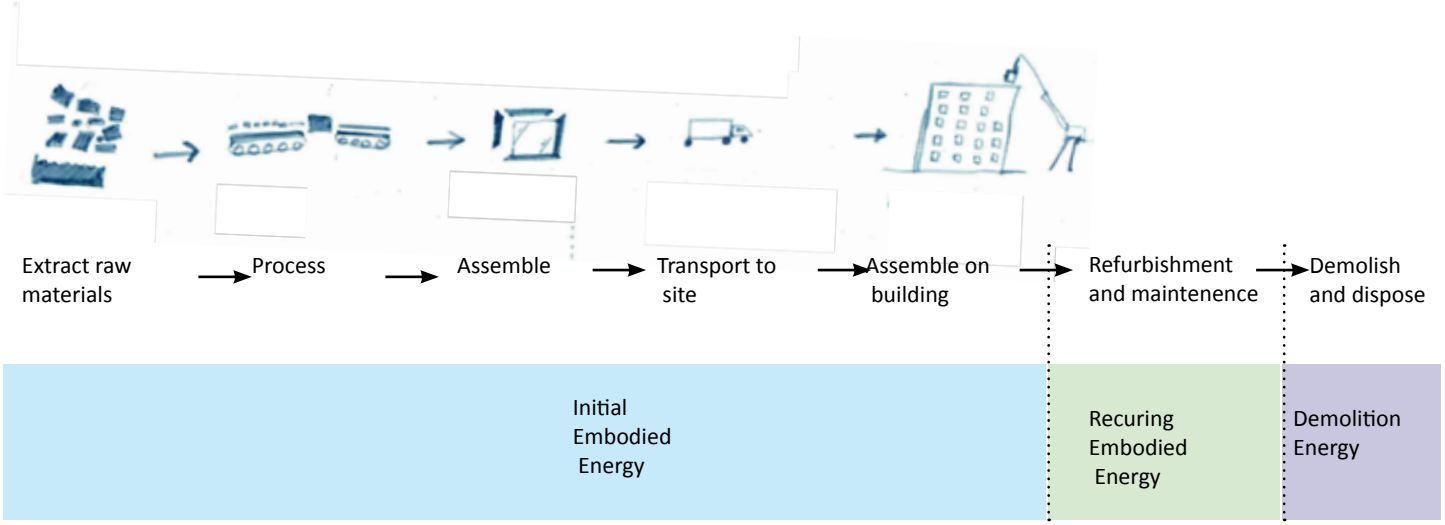


3 pillars of sustainability



Breakdown of CO2 emissions and Building Industry

Embodied Energy : LCA



Cradle to grave (LCA)

SIMA PRO

CO_2 footprint,
H_2O Footprint

Nederlands Instituut voor Bouwbiologie en Ecology (NIBE)

CO_2 footprint
Environmental Product Declaration (EPD),
Certification for EPD

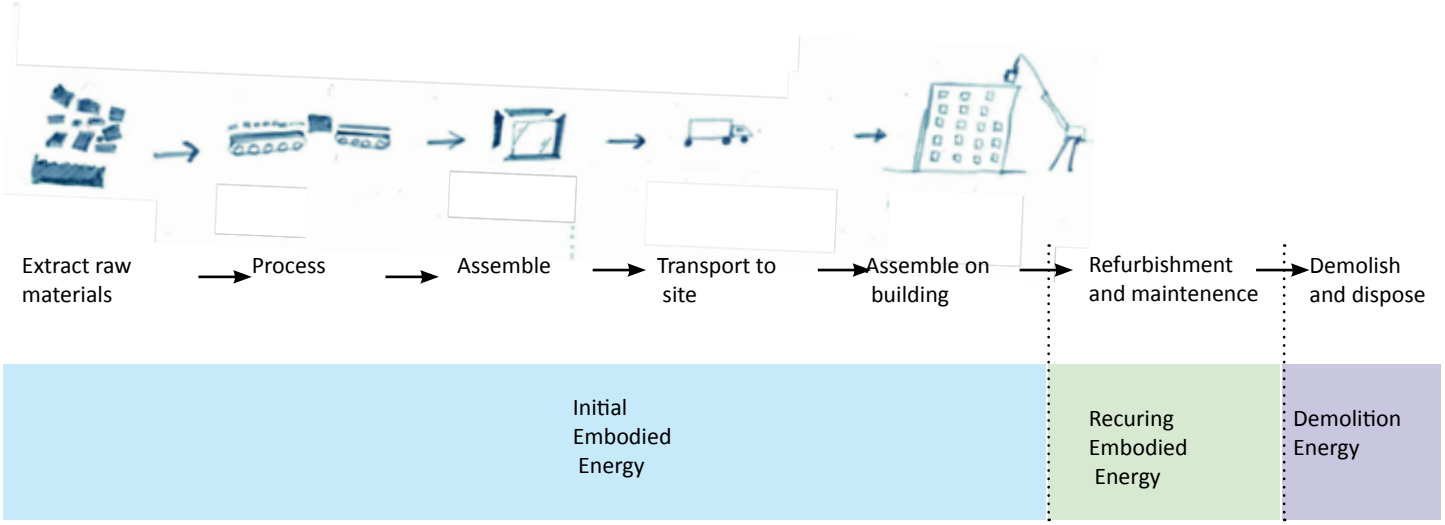
IVAM LCA Data 4.0

CO_2 Footprint
ISO 14040

Other databases around the world:

BEES	Building for Environment & Economic Sustainability
ATHENAsmi	Athena Sustainabile 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

Embodied Energy : LCA



Cradle to grave (LCA)

Inventory of Carbon and Emission (ICE)
CO_2 Footprint
Uni/ Bath

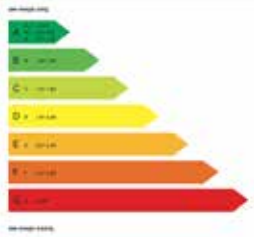
Nederlands Instituut voor Bouwbiologie en Ecology (NIBE)

CO_2 footprint
Environmental Product Declaration (EPD),
Certification for EPD

Operational Energy:

LEED

BREEAM-NL

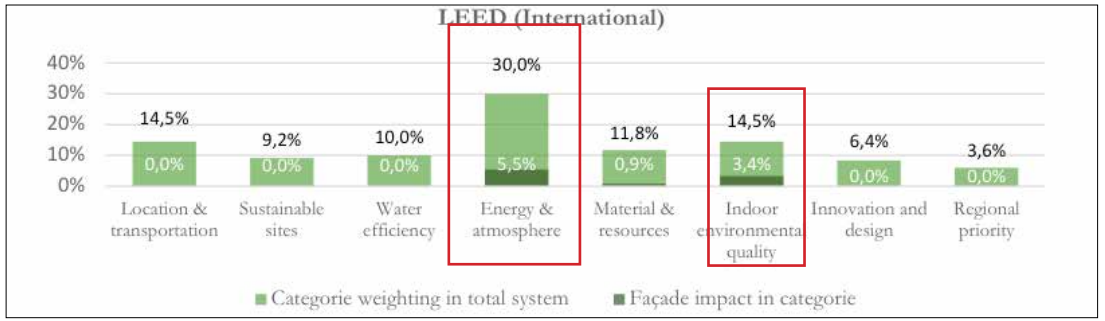


EPC

Operational Energy:

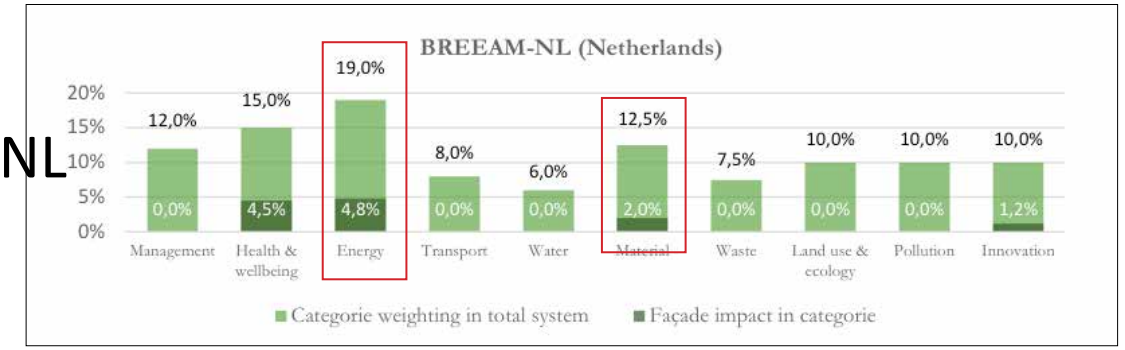
LEED

Part of 6,8%

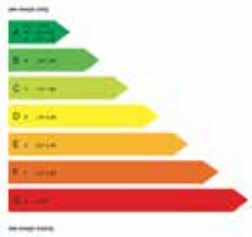


BREEAM-NL

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...

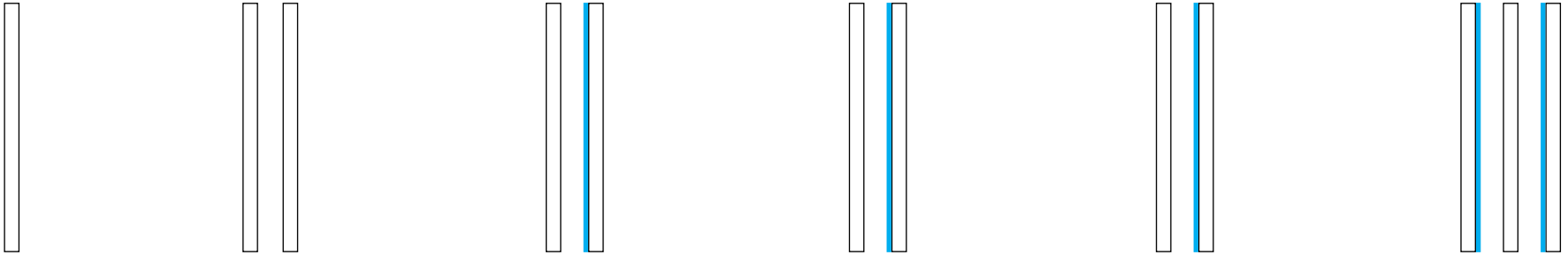
Type of window: Material

Wood

Aluminium

Steel

PVC



Single Glass

>5.4-3,0 W/m² K

Double Glass

2,8 - 2,2 W/m² K

65 €/m²

HR Glass

2,0- 1,8 W/m² K

70 €/m²

HR+ Glass

1,6 - 1,4 W/m² K

75 €/m²

HR++ Glass

1,2 - 0,9 W/m² K

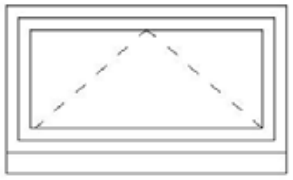
80 €/m²

HR+++ Glass

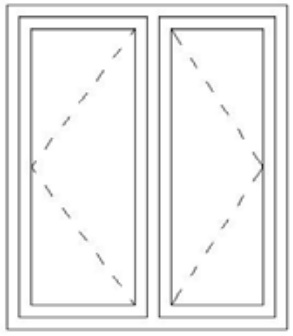
0,7 - 0,5 W/m² K

120 €/m²

Type of window: Opening

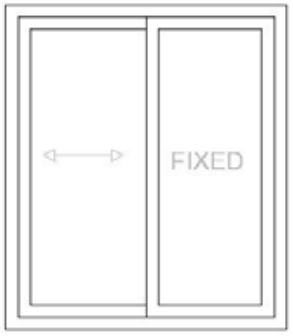


Awning

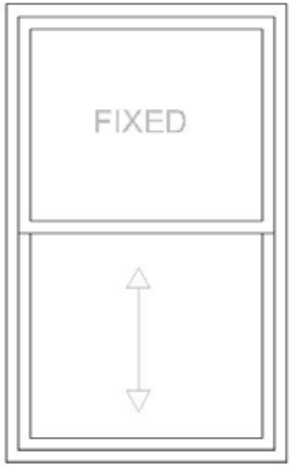


Casement

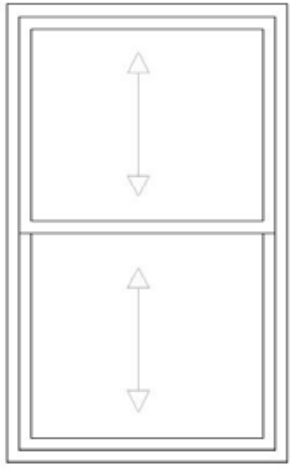
Fixed



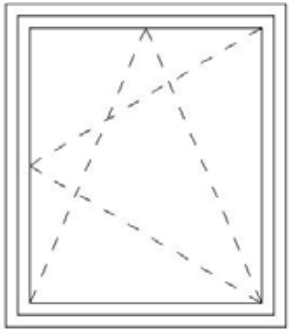
Horizontal slider



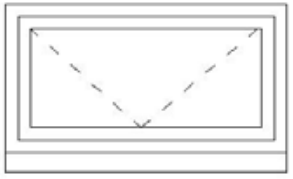
Single Hung



Double Hung



Tilt an Turn



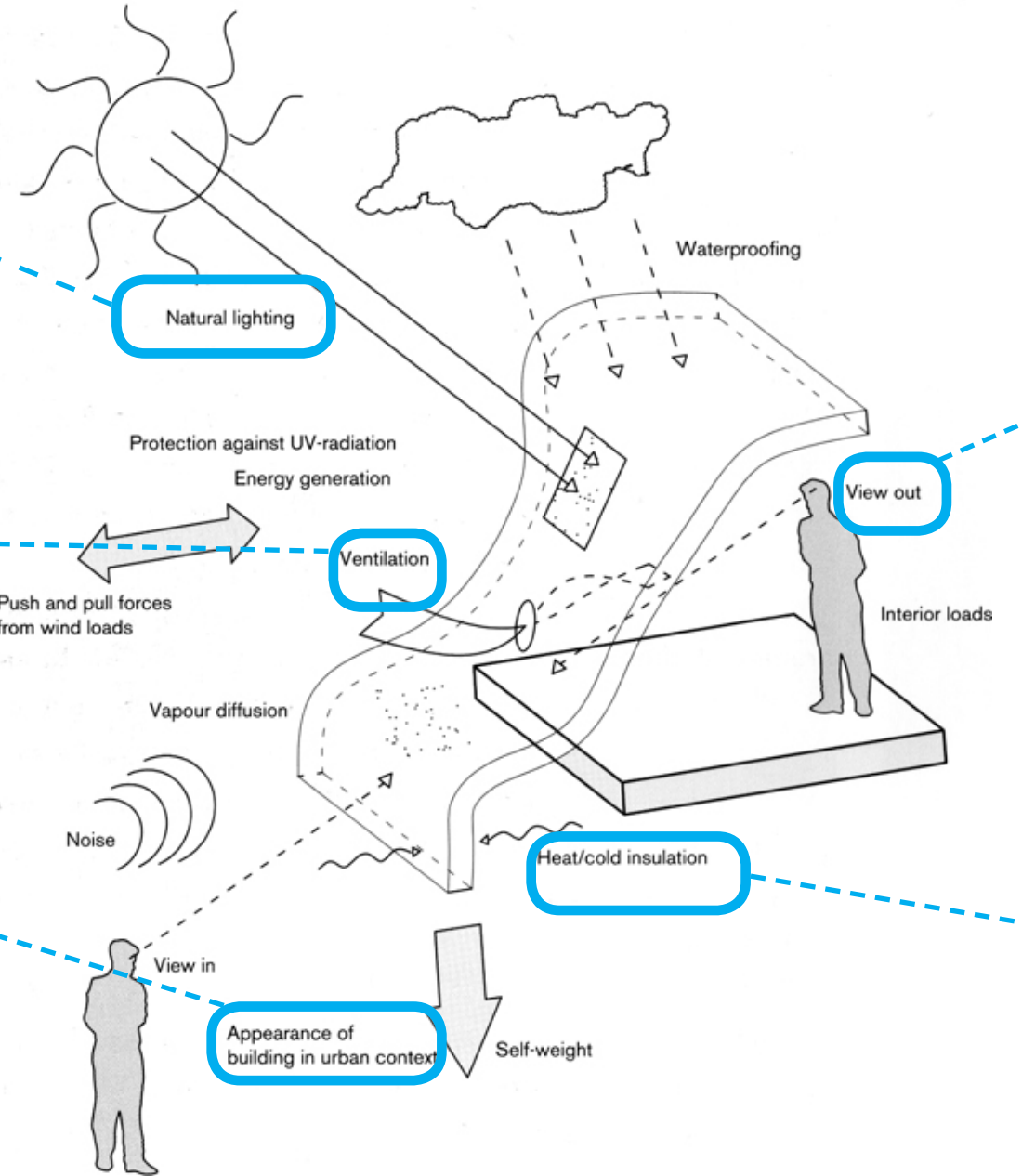
Hopper

Parameters to define facade

Visual Light Transmittance

Operable windows

Color, finish



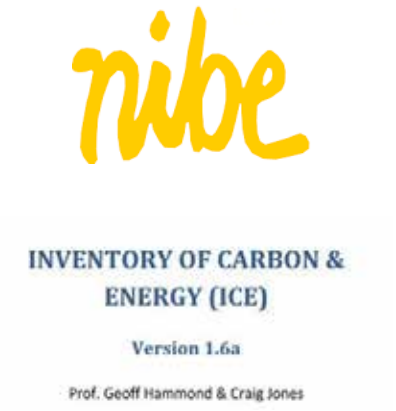
% transparant surfaces

U- Value

Illustration: Knaack, U., et. al. (2007)

Sustainability related parameters

Embodied energy



Operational energy

Sustainability in facade design

Embodied energy

Operational energy

nibe

INVENTORY OF CARBON & ENERGY (ICE)

Version 1.6a

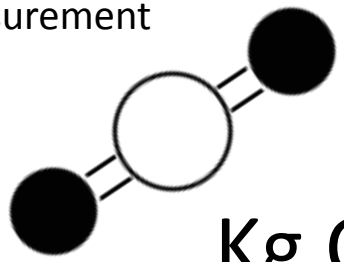
Prof. Geoff Hammond & Craig Jones

Primary Energy Total (Life Cycle) = Operational energy per year + $\frac{\text{LCA Embodied energy}}{\text{Service life (years)}}$

Per year

Sustainability in facade design

Units of measurement



$Kg.CO_2(e)$ 1 kWh = 0.57 kg CO_c

Primary Energy Total (Life Cycle) = Operational energy per year + $\frac{\text{LCA Embodied energy}}{\text{Service life (years)}}$

Per year

Carbon conversion value as indicated in publication issued by CBS, ECN, PBL

Sub Research Questions: Facade

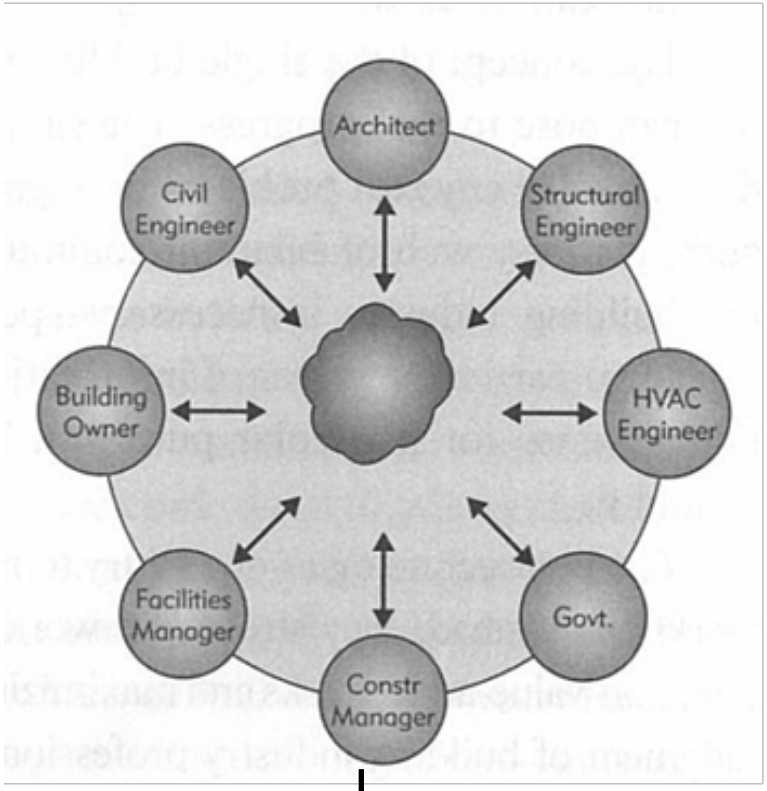
4. Types of facade systems?

5. Parameters to define facade at design stage?

6. Role of sustainability in facade design?

BIM + Technology...

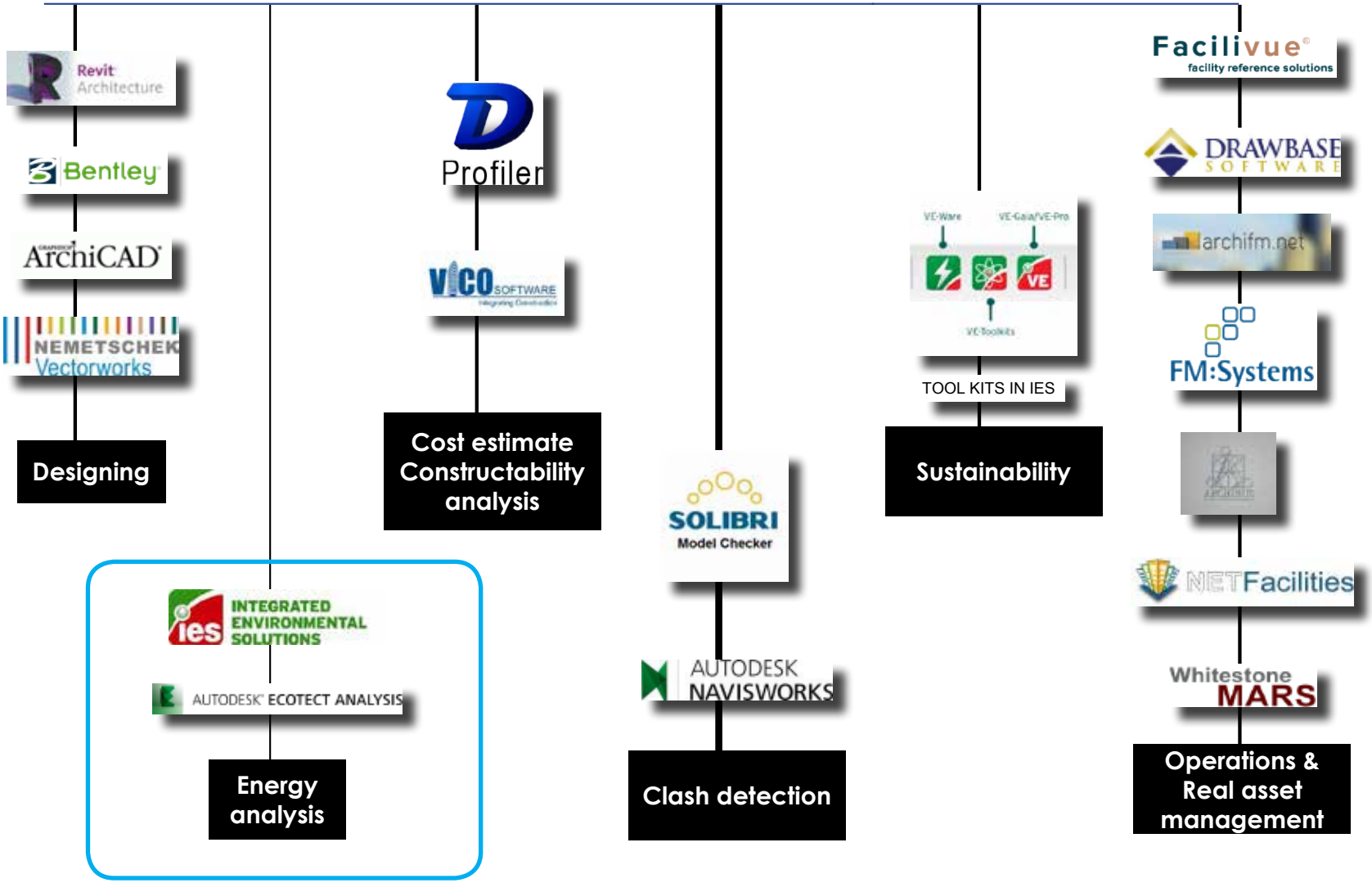
BIM- Introduction



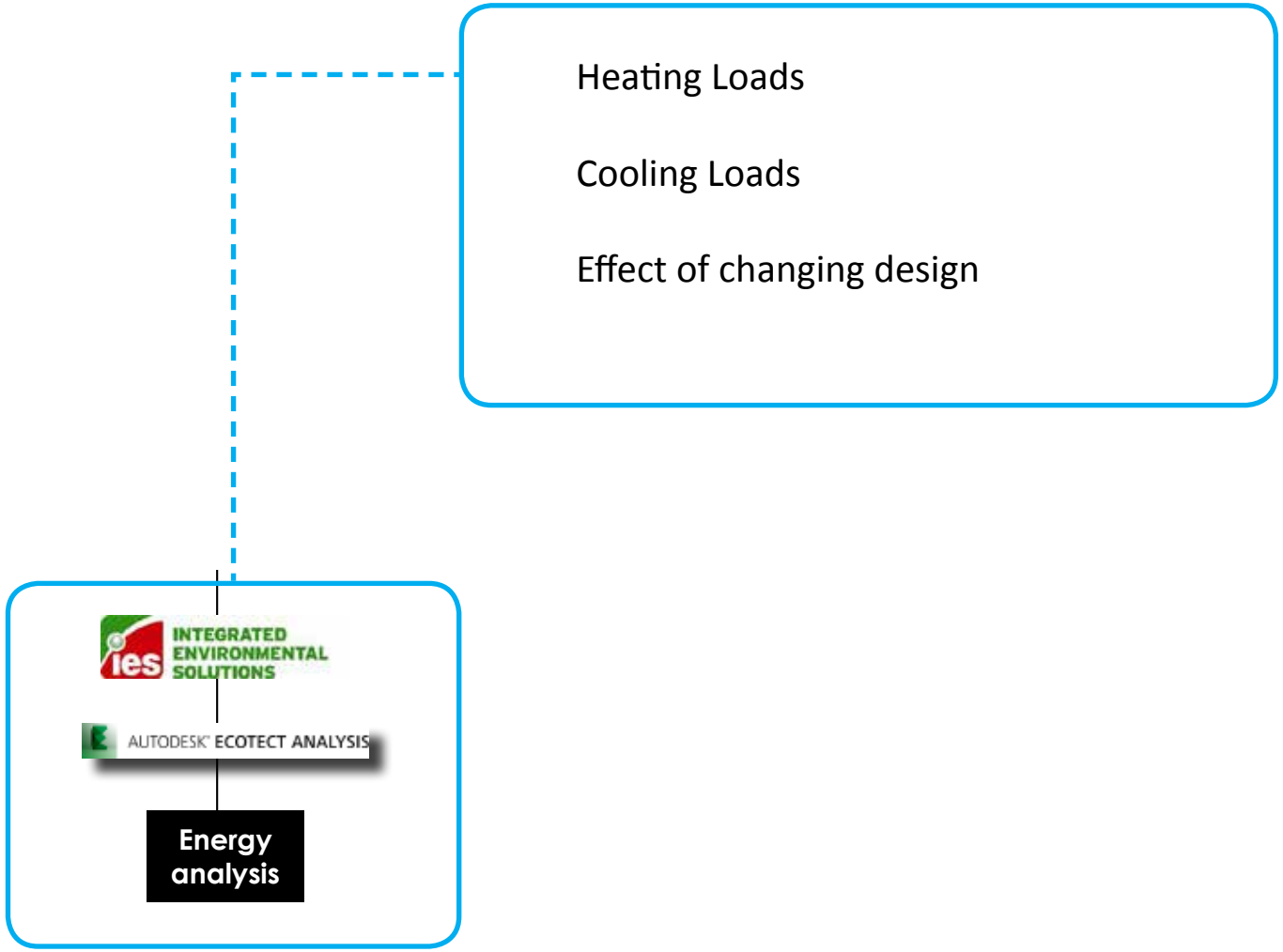
Technology

Management

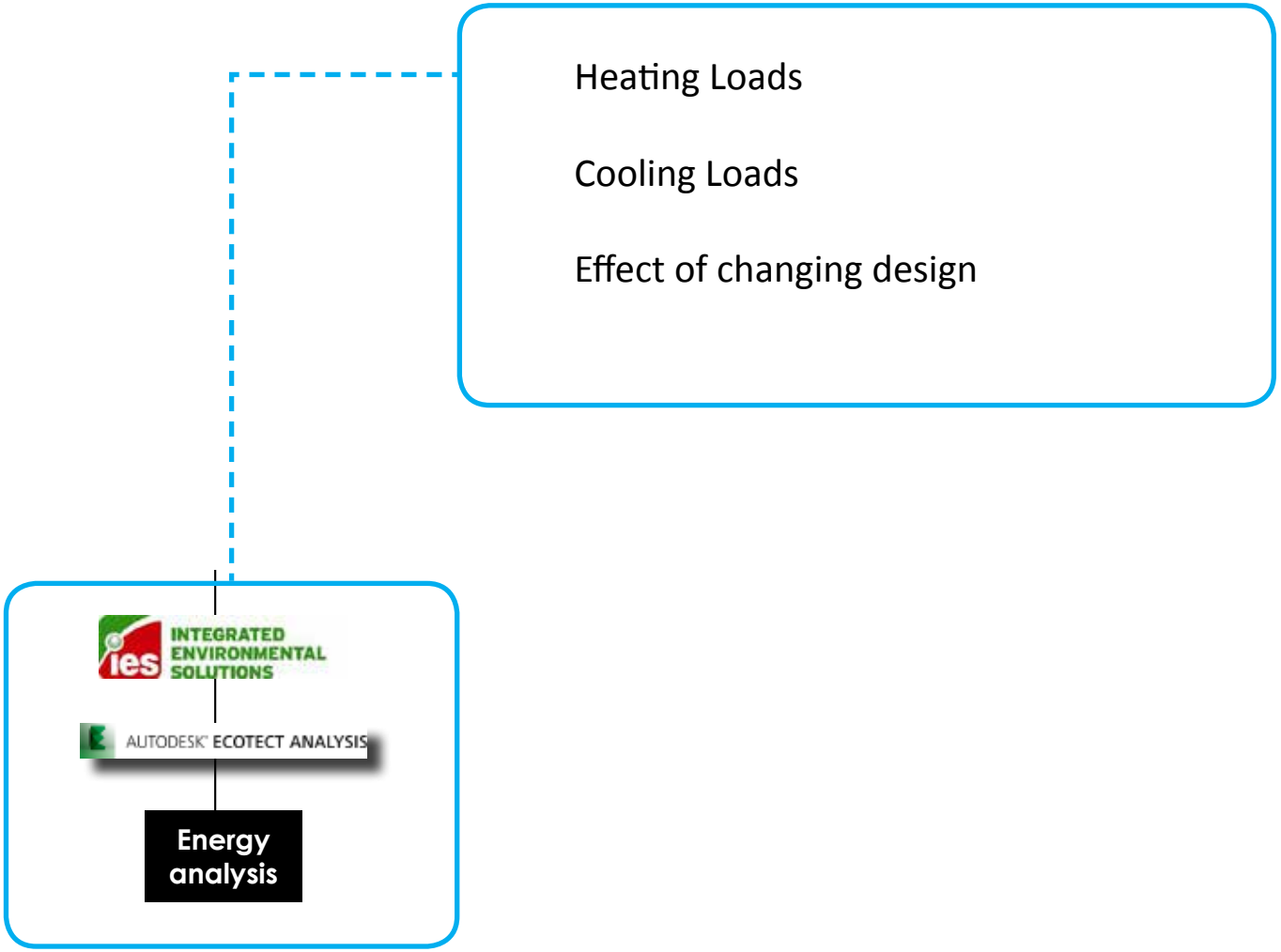
BIM- Tools


Revit Architecture
Bentley
ArchiCAD
NEMETSCHEK Vectorworks
Designing
Profiler
VICO SOFTWARE
Cost estimate Constructability analysis
SOLIBRI Model Checker
AUTODESK NAVISWORKS
Clash detection
TOOL KITS IN IES
Sustainability
Facilivue facility reference solutions
DRAWBASE SOFTWARE
archifm.net
FM:Systems
NETFacilities
Whitestone MARS
Operations & Real asset management
ies INTEGRATED ENVIRONMENTAL SOLUTIONS
AUTODESK ECOTECT ANALYSIS
Energy analysis

BIM- Tools


Heating Loads
Cooling Loads
Effect of changing design
INTEGRATED ENVIRONMENTAL SOLUTIONS
AUTODESK' ECOTECT ANALYSIS
Energy analysis

BIM- Tools


Heating Loads
Cooling Loads
Effect of changing design
INTEGRATED ENVIRONMENTAL SOLUTIONS
AUTODESK' ECOTECT ANALYSIS
Energy analysis

Tools in the Netherlands

EPC : NEN 7120

EP-Check

Sub Research Questions: BIM+ Technology

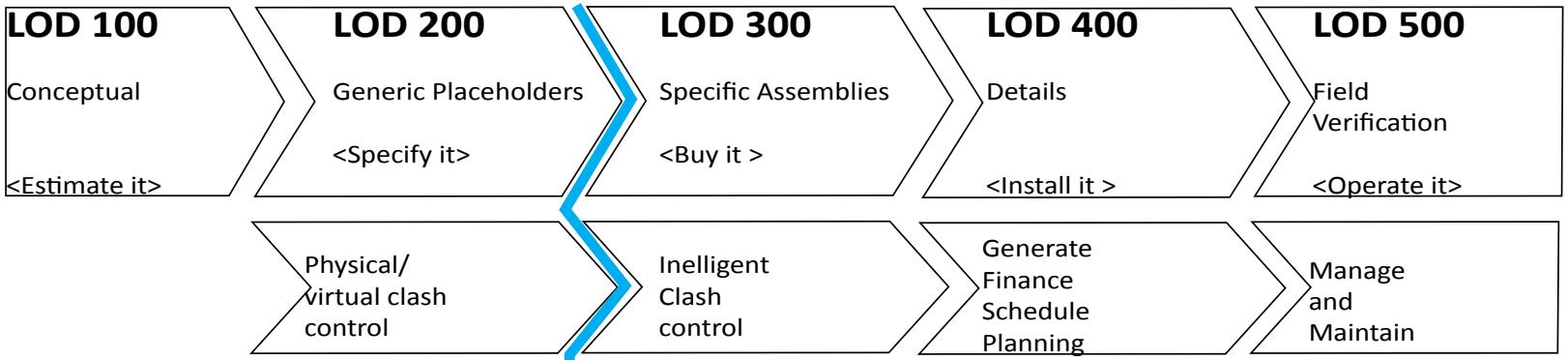
7. How does BIM help in sustainable design?

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

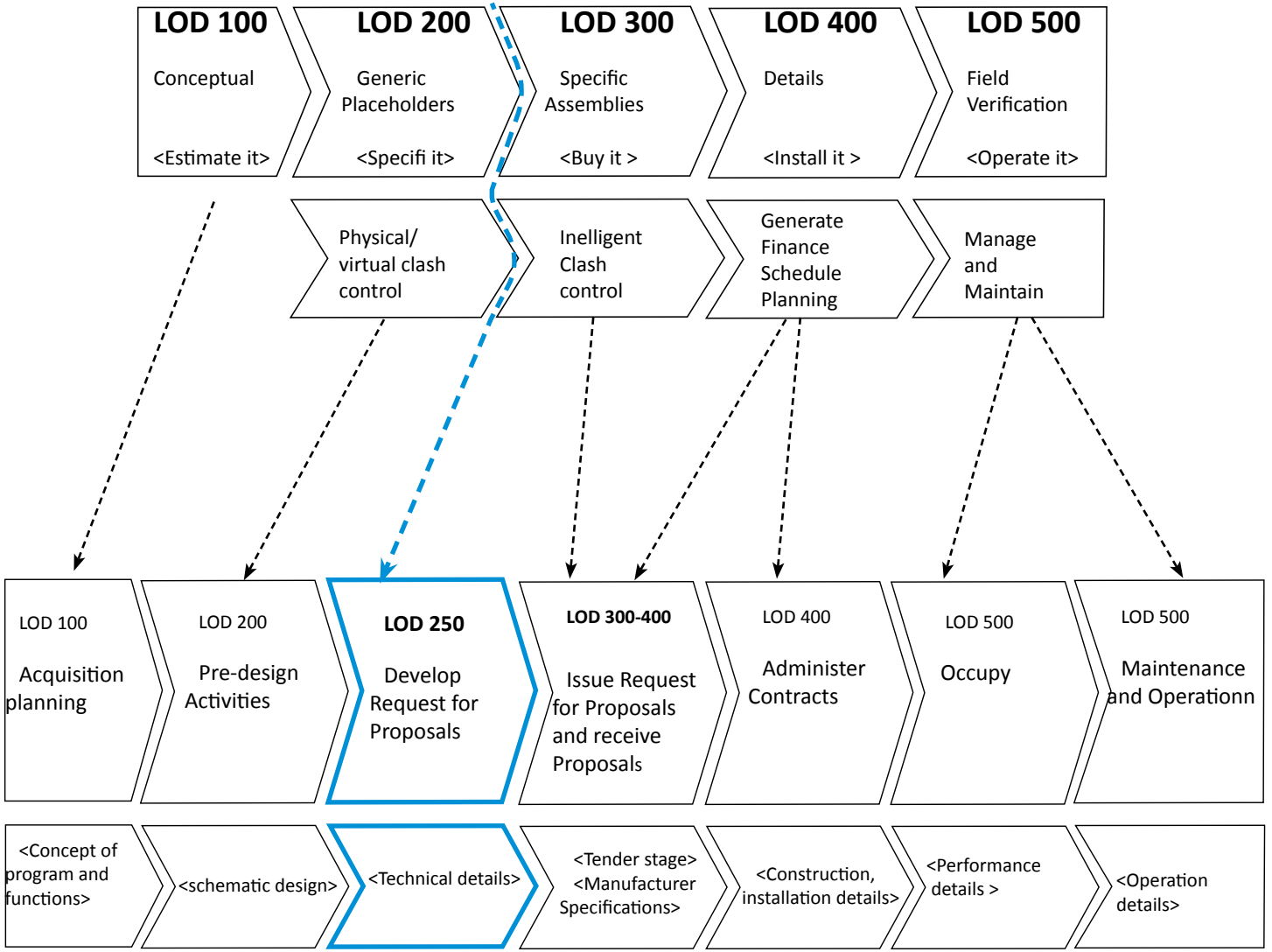


-**LOD 250**:

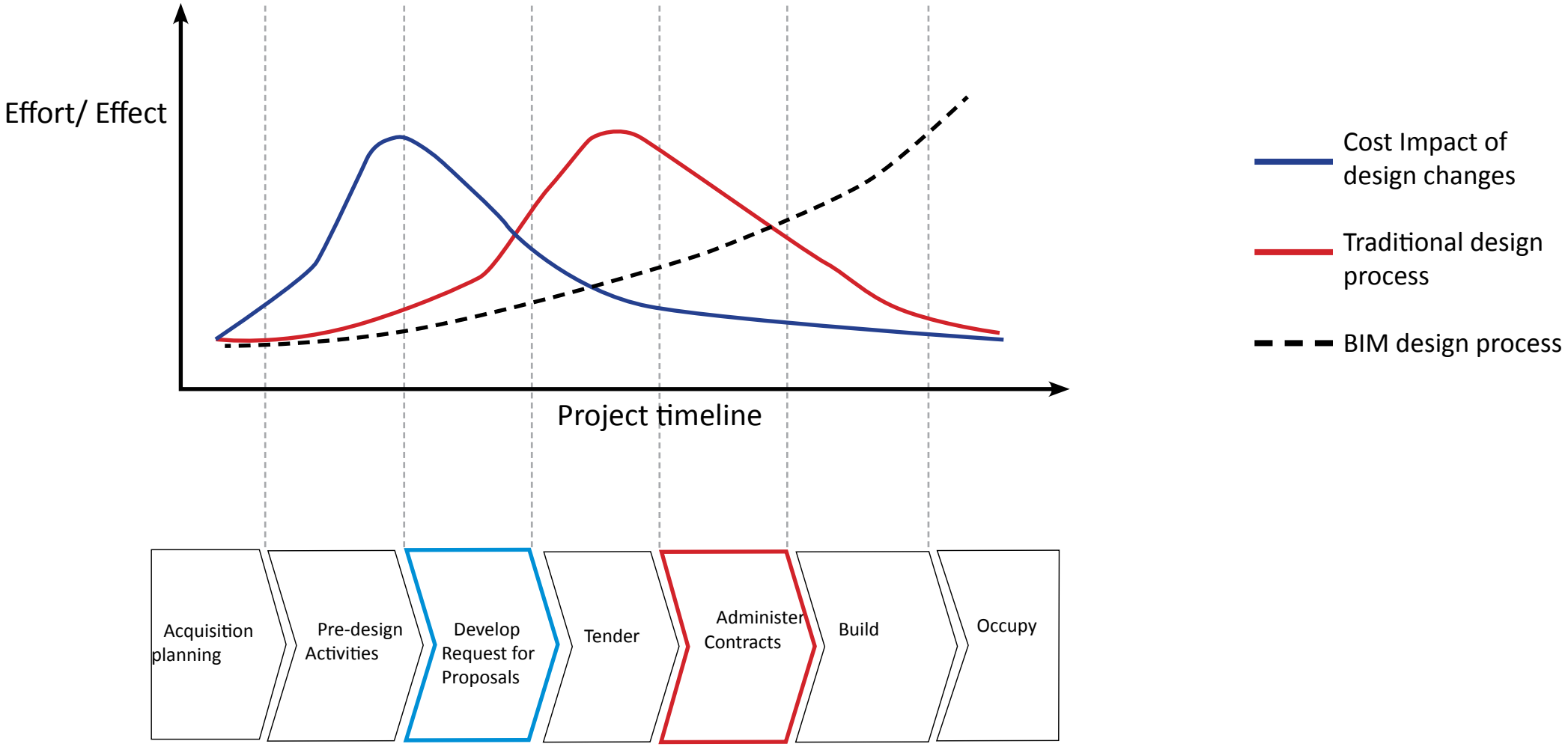
- Approximate energy simulation,
- Cost based on measurements,
- Simple geomtery,
- Type of window,
- Dimensions of window.

Based on TNO Research by van Berlot et. al., 2014

Library use: Project Delivery Method



Role of BIM in Project Delivery



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?

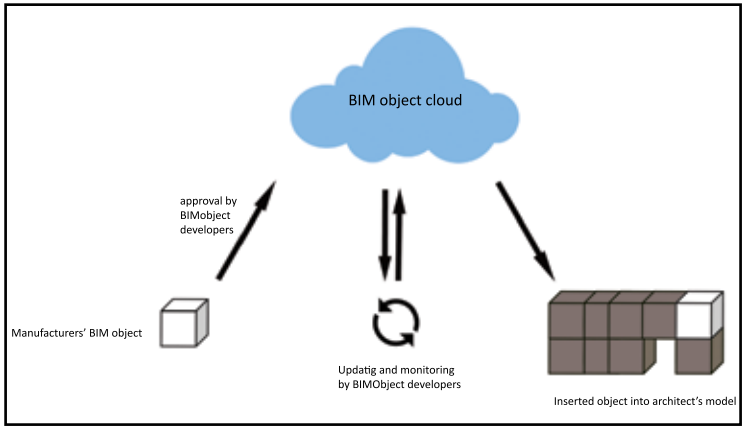
12. How does BIM assist the project delivery method?

Main Research Question:

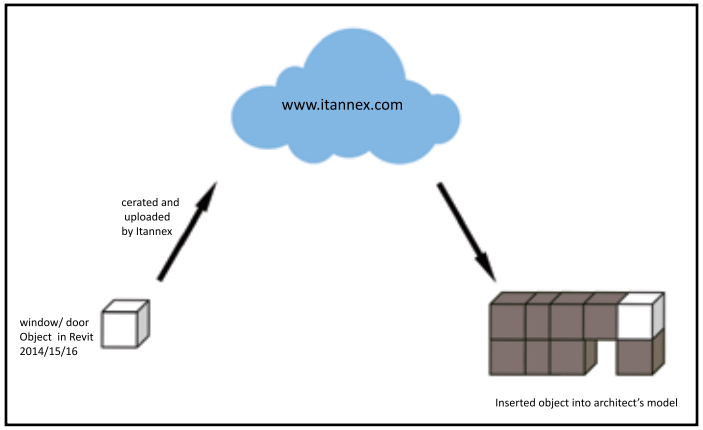
How to effectively define the contents of a ‘BIM library for curtain wall facade window elements’, such that it guides architects towards a sustainable facade design during the design stage?

Current Libraries

Company's in-house library



BIM object

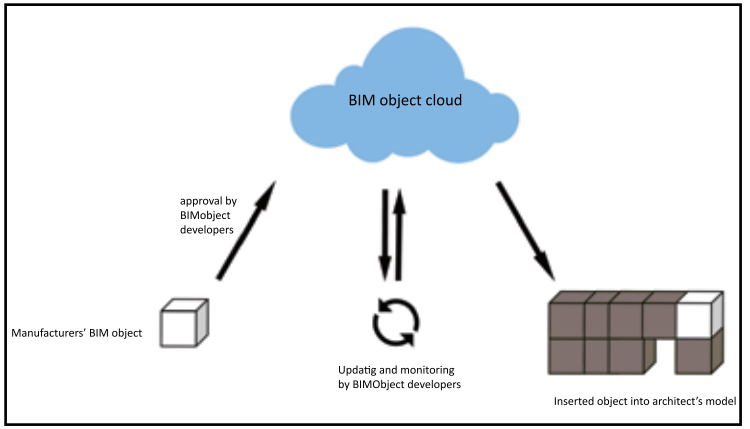


Fab- Window by Itannex

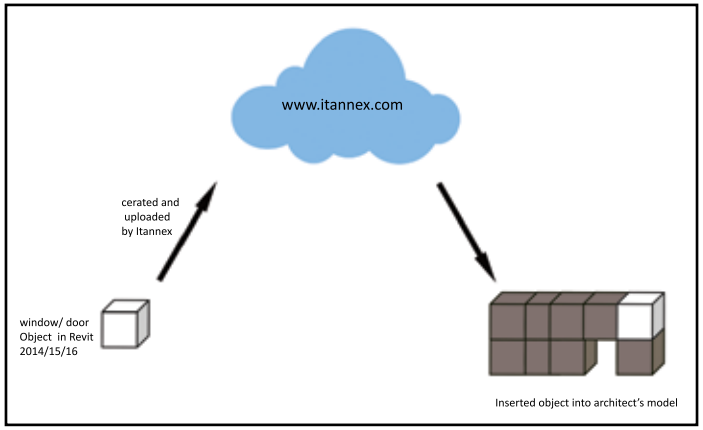
2-D Brochures

Current Libraries

Company's in-house library



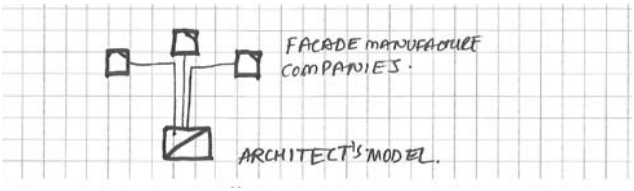
BIM object



Fab- Window by Itannex

2-D Brochures

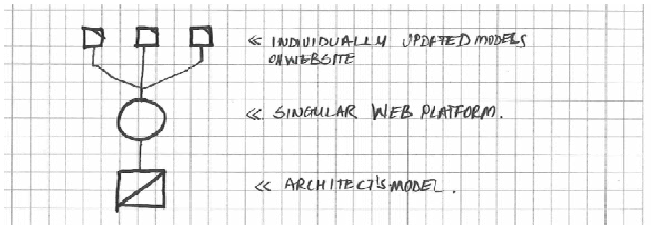
Proposal for Library



Fab- Window
by Itannex

Limited non-Geometrical Data

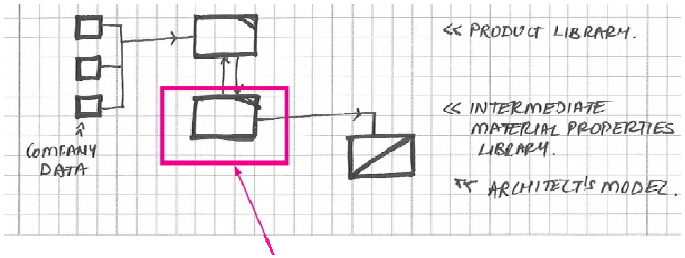
All posible variations of window type in one file: easy of comparision



BIM object

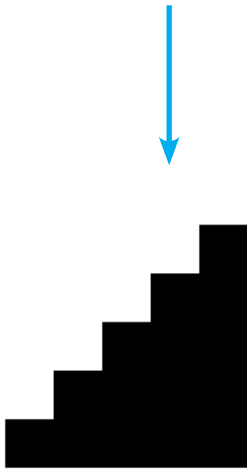
Too many manufacturers : confusing

Data from manufacturers



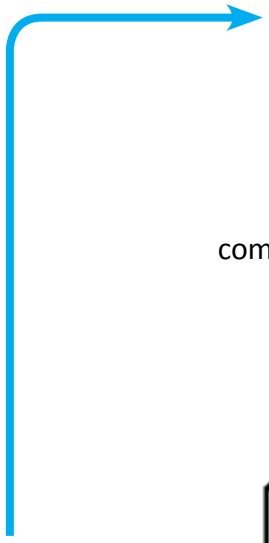
Proposal for Library

Guidelines of the Library



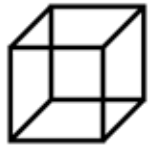
LOD 250

Generic Library



CO_2

comparision



Min. geometric detail

LCA

INVENTORY OF CARBON & ENERGY (ICE)

Version 1.6a

Prof. Geoff Hammond & Craig Jones

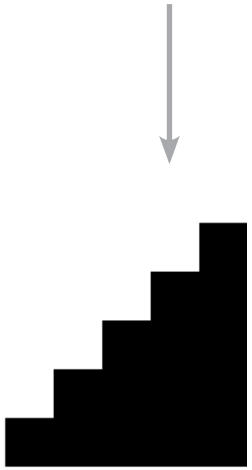
Operational Energy

Legislations

Reference

The Library in BIM...

Guidelines of the Library

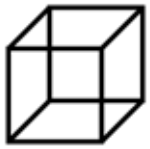


LOD 250

Generic Library

CO_2

comparision



Min. geometric detail

LCA

Operational Energy

Legislations

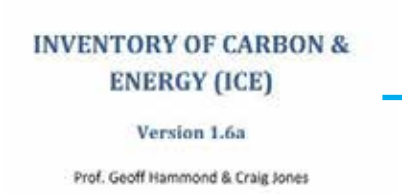
Window selection → Case Study 1

Orange Hall → Case Study 2

Technical standards → NEN 7120

Final Product

LCA

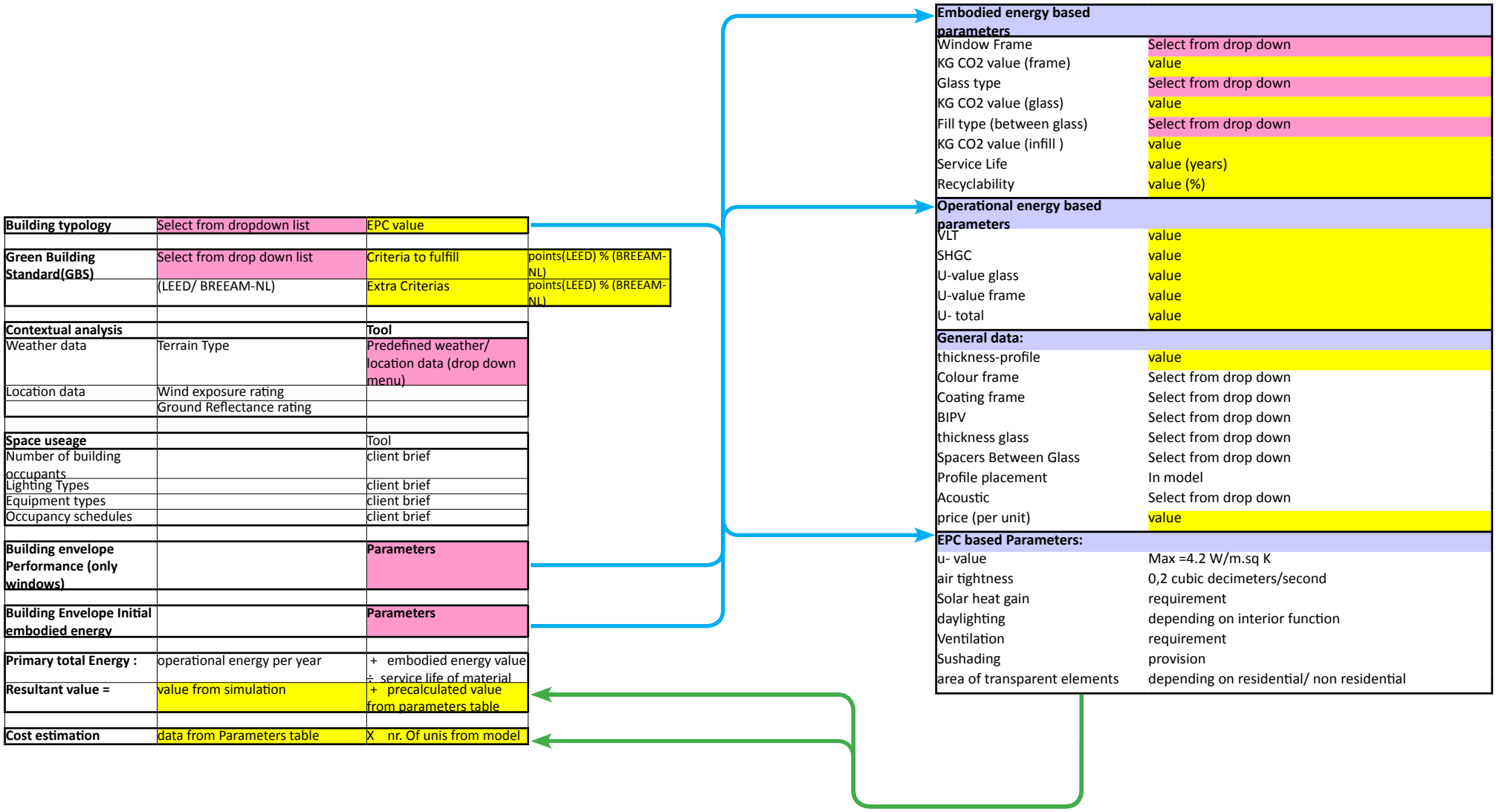


Operational Energy

Legislations

Embodied energy based parameters	
Window Frame	Select from drop down
KG CO2 value (frame)	value
Glass type	Select from drop down
KG CO2 value (glass)	value
Fill type (between glass)	Select from drop down
KG CO2 value (infill)	value
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/m.sq 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

Final Product : Toolkit



Building typology	Select from dropdown list	EPC value	
Green Building Standard(GBS)	Select from drop down list	Criteria to fulfill	points(LEED) % (BREEAM-NL)
	(LEED/ BREEAM-NL)	Extra Criterias	points(LEED) % (BREEAM-NL)
Contextual analysis		**Tool**	
Weather data	Terrain Type	Predefined weather/ location data (drop down menu)	
Location data	Wind exposure rating		
	Ground Reflectance rating		
Space useage		Tool	
Number of building occupants		client brief	
Lighting Types		client brief	
Equipment types		client brief	
Occupancy schedules		client brief	
Building envelope Performance (only windows)		**Parameters**	
Building Envelope Initial embodied energy		**Parameters**	
Primary total Energy :	operational energy per year	+ embodied energy value ÷ service life of material	
Resultant value =	value from simulation	+ precalculated value from parameters table	
Cost estimation	data from Parameters table	X nr. Of unis from model	

Embodied energy based parameters	
Window Frame	Select from drop down
KG CO2 value (frame)	value
Glass type	Select from drop down
KG CO2 value (glass)	value
Fill type (between glass)	Select from drop down
KG CO2 value (infill)	value
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/m.sq 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

Final Product

Demonstration of Excel tool

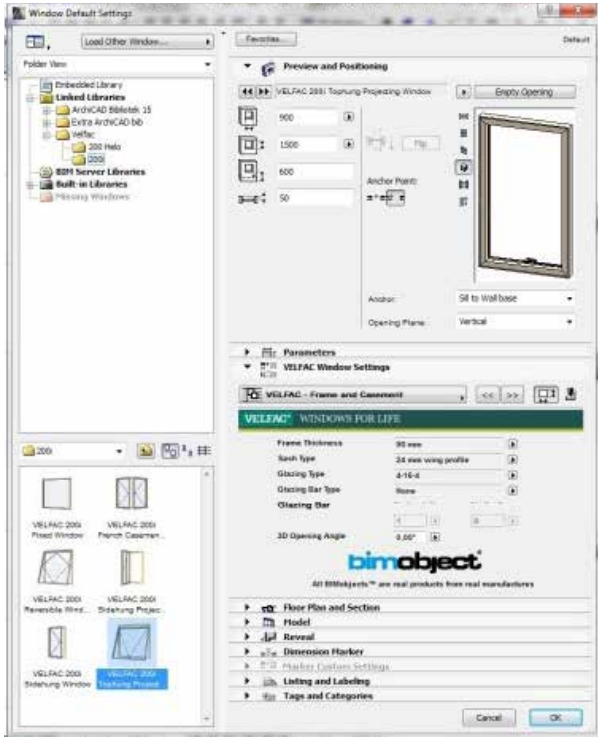
Design options: Type of User Interface

BIM Platform

Model Entry

Entry into the BIM Design Software

BIM-Object



Design options: Type of User Interface

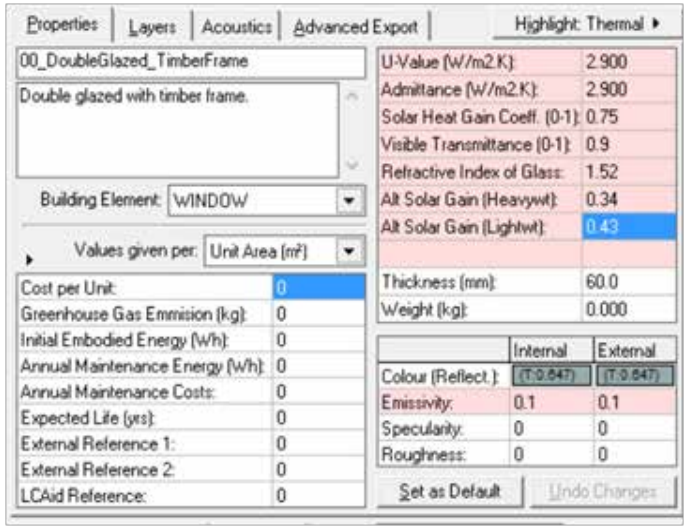
BIM Platform

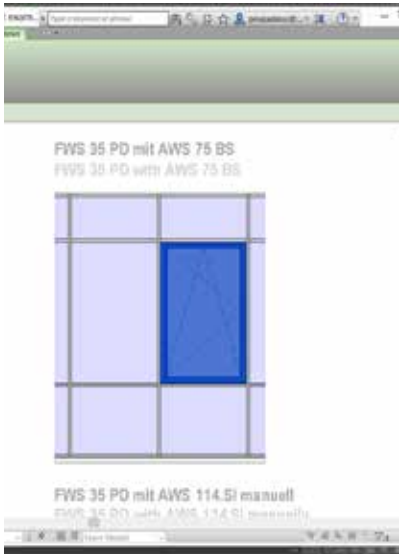
Model Entry

Entry into the BIM Design Software

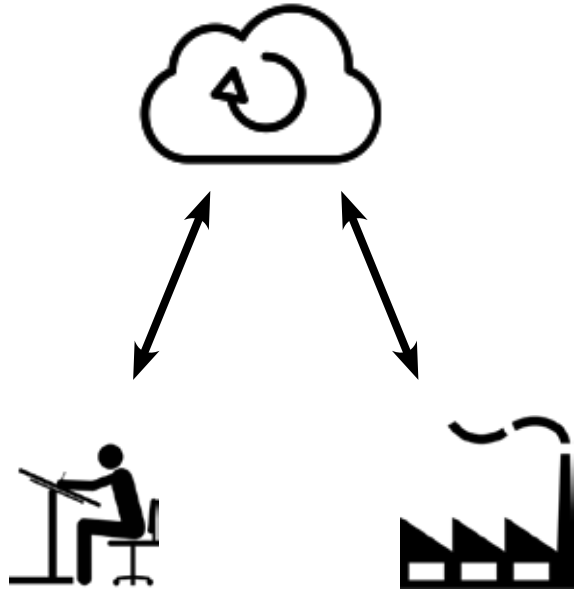
BIM-Object

Plug-in





Design options: Type of User Interface



BIM Platform

Model Entry

Entry into the BIM Design Software

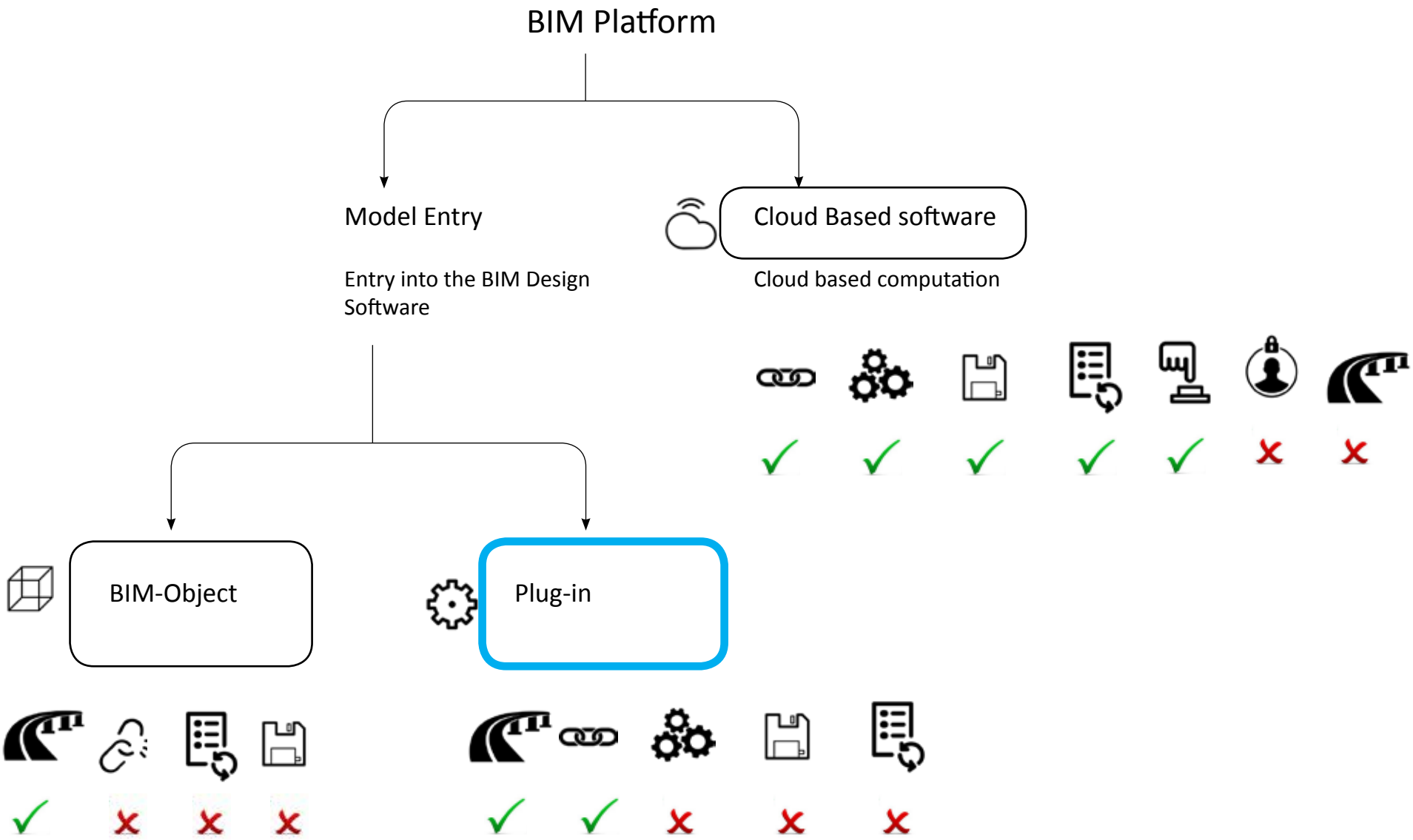
Cloud Based software

Cloud based computation

BIM-Object

Plug-in

Design options: Type of User Interface

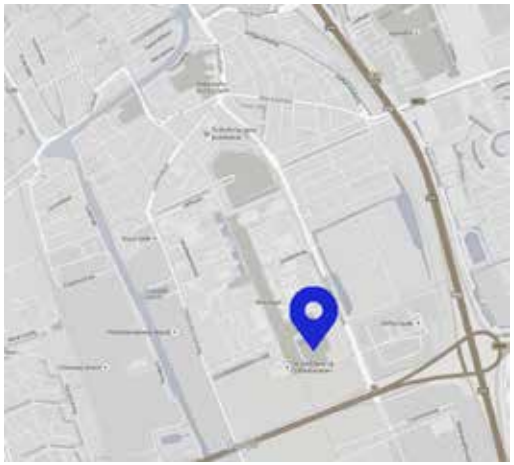


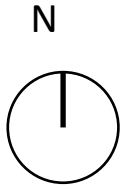
Sub Research Questions:

15. What would the new library look like? On which platform should it be developed?

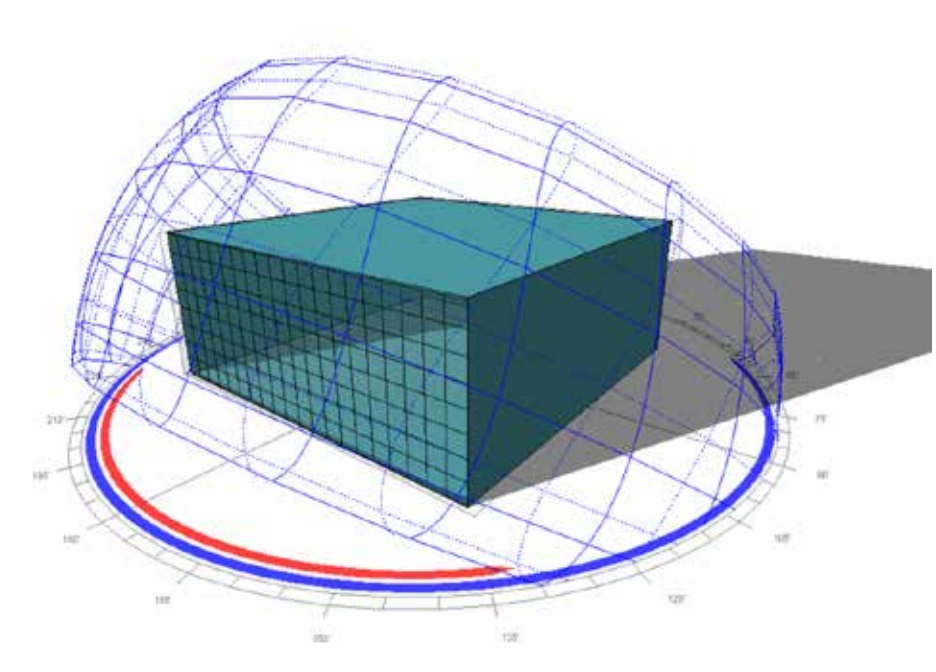
Testing the Toolkit...

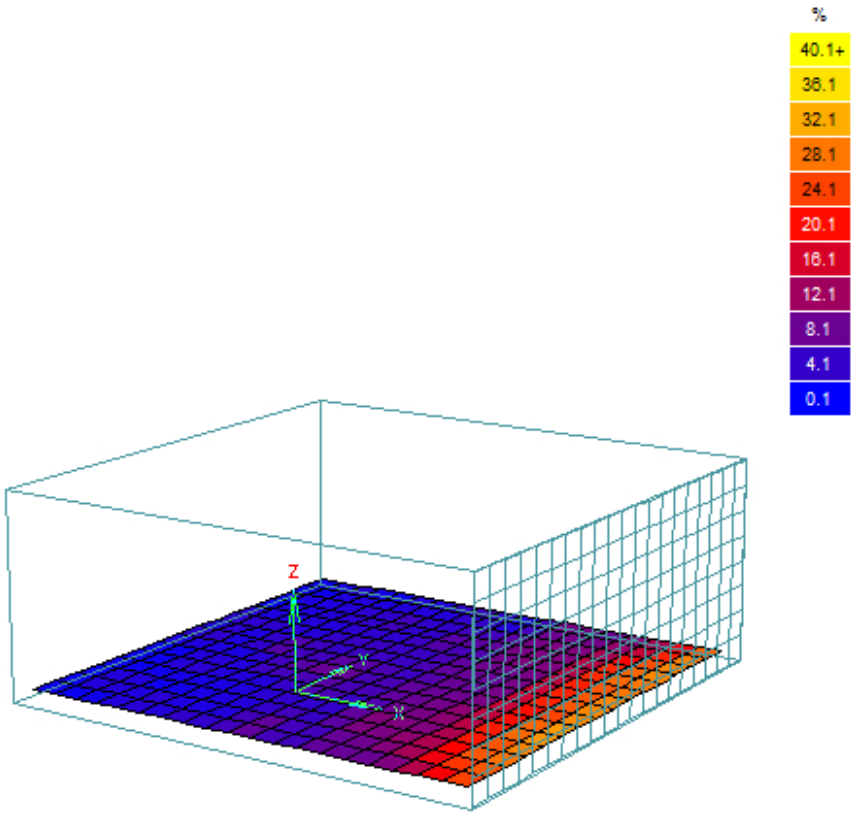
Testing the toolkit : Location





Testing the toolkit : Volume and orientation





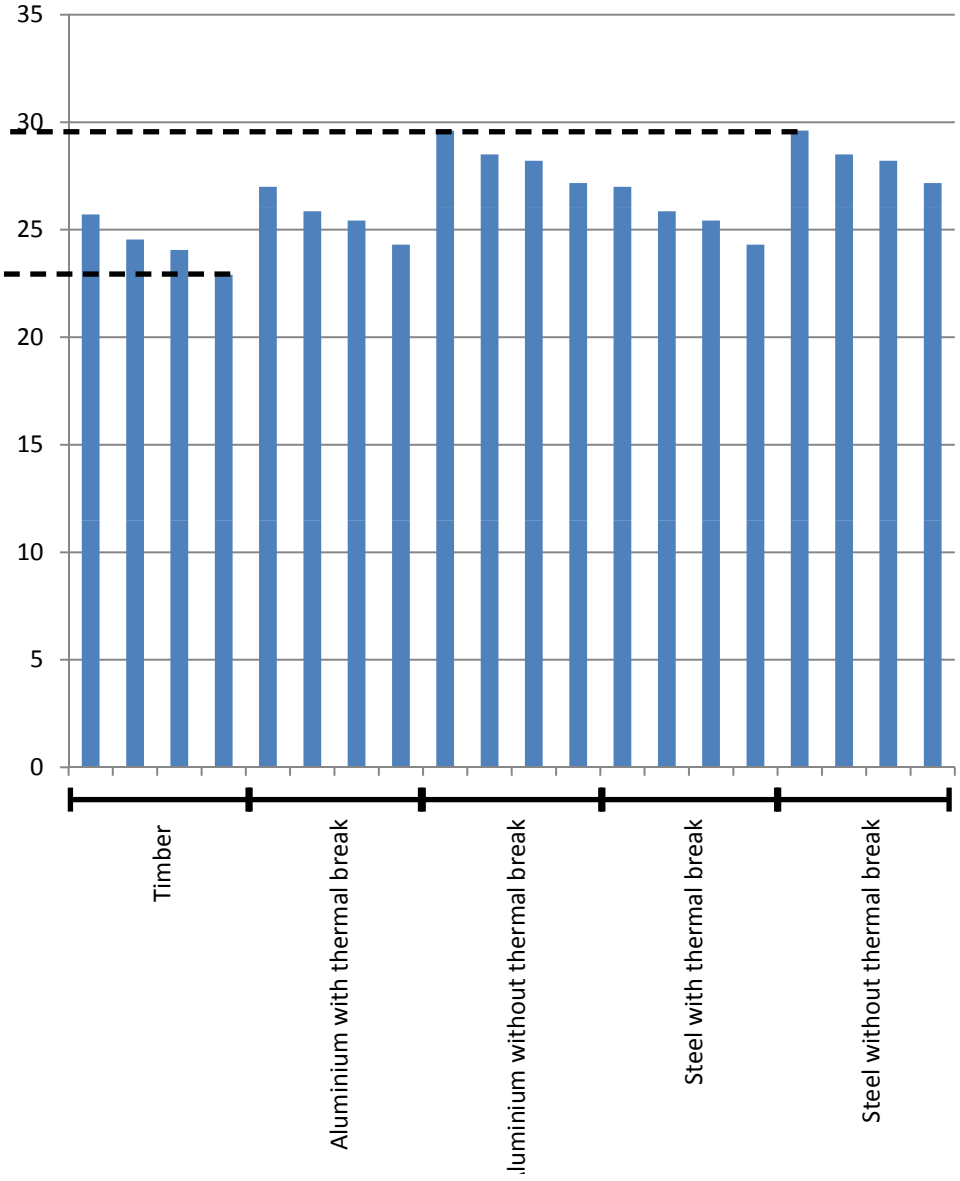
1.2x1.2 standard windows
24x24x10m room for 100 people

Testing the toolkit : Analysis

25.5%

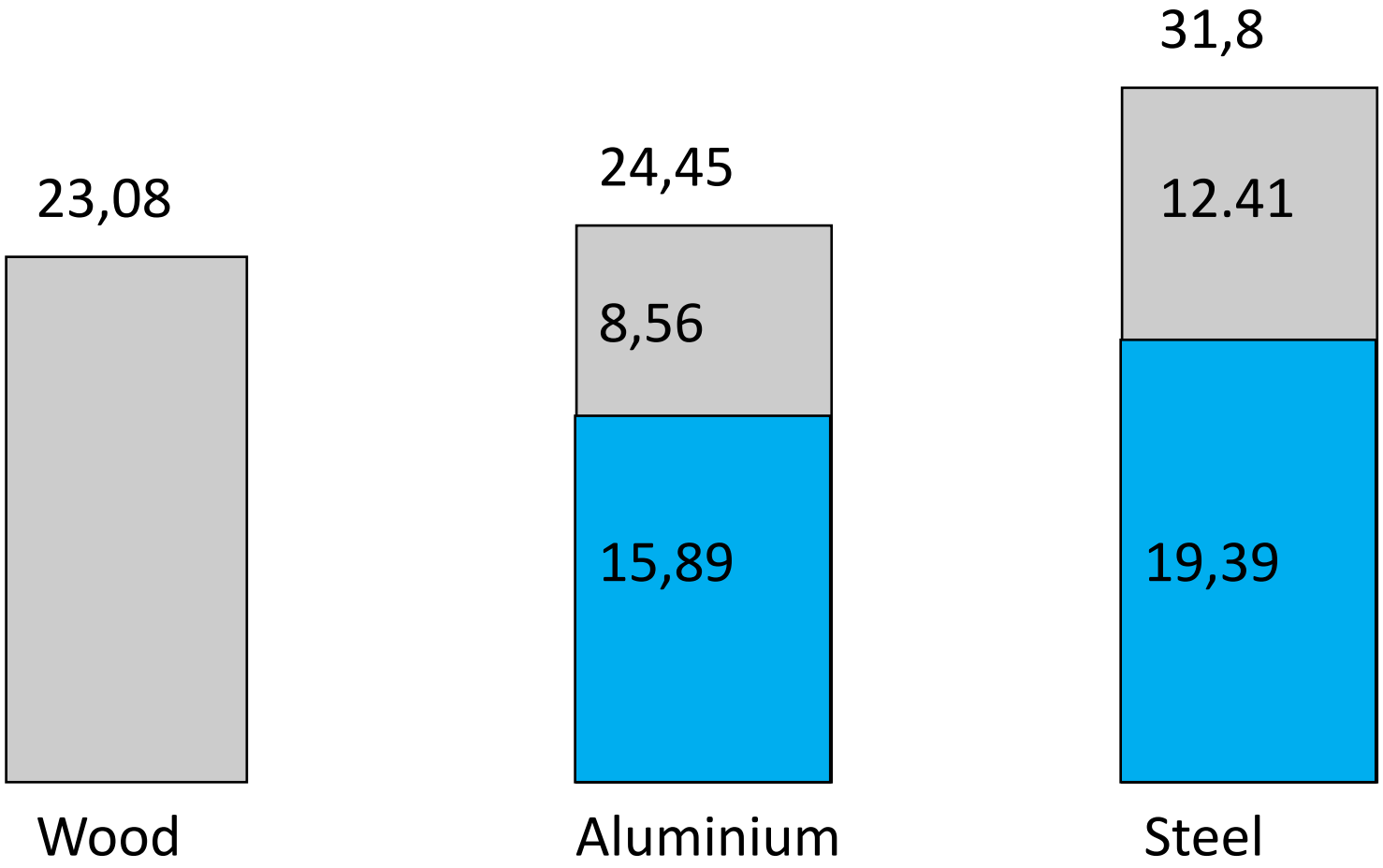
29.6 T.CO_2

22.9 T.CO_2



Operational Energy

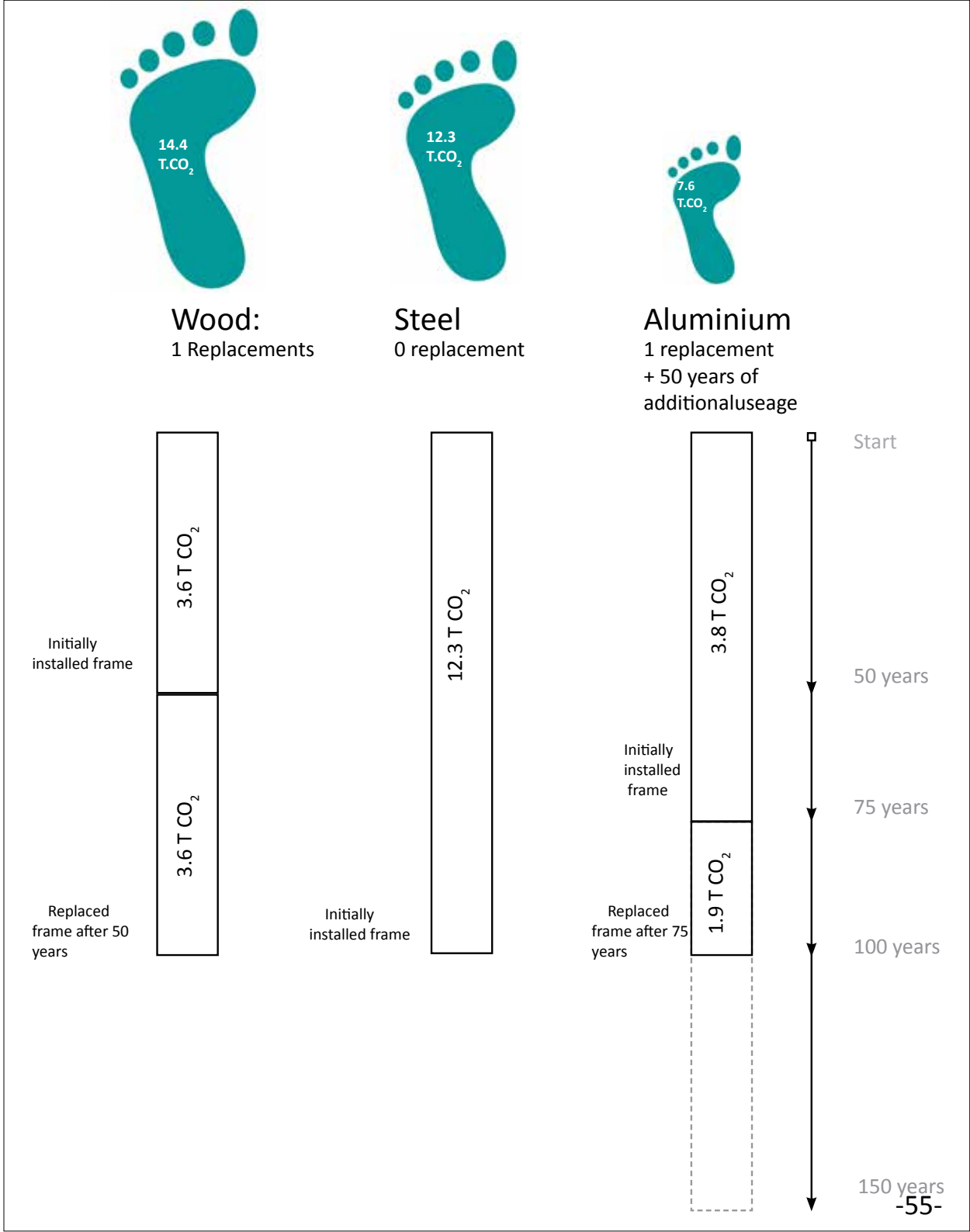
Testing the toolkit : Analysis



Embodied Energy :
Recyclability

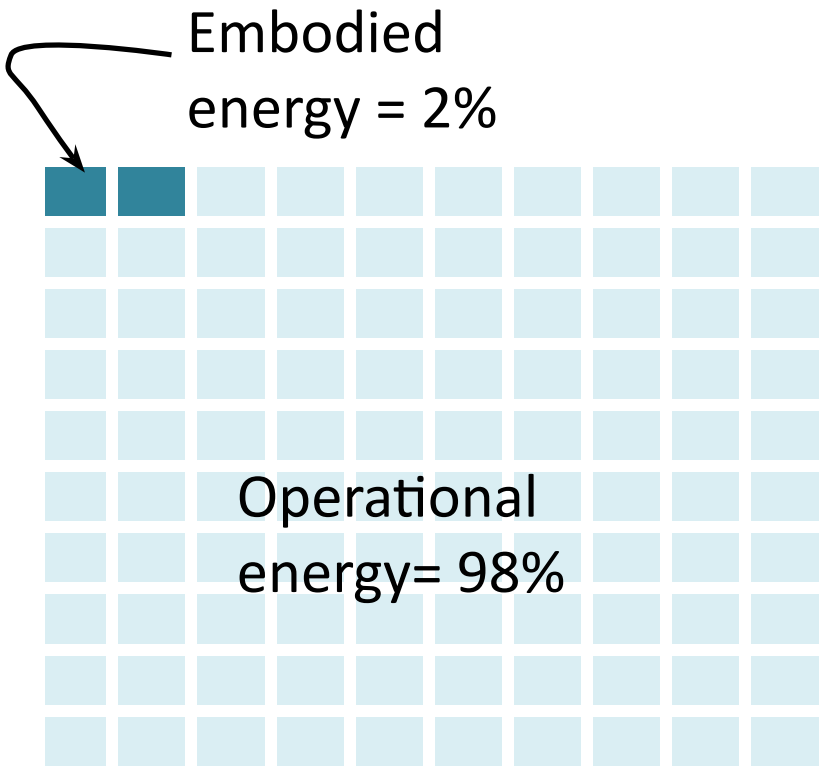
Values in kg.CO_2 Per m^2 material

Testing the toolkit : Analysis



Embodied Energy : Durability

Testing the toolkit : Analysis



Embodied Energy v.s operational energy

Testing the toolkit : Conclusion

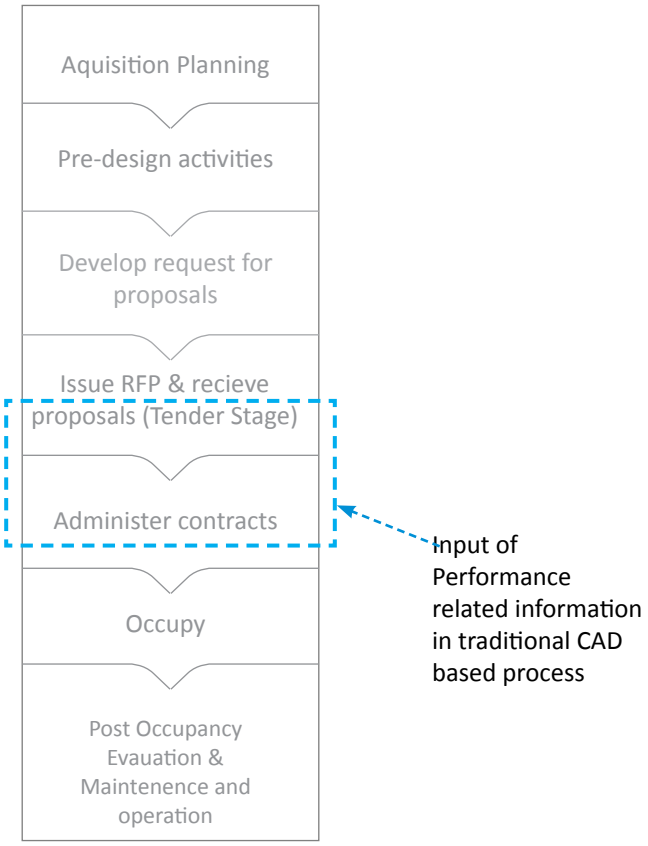
- Operational energy = Choosing the right material

- Embodied energy : Role of recyclability and durability

- Embodied energy can be considered as an asset for refurbishment and after building useage

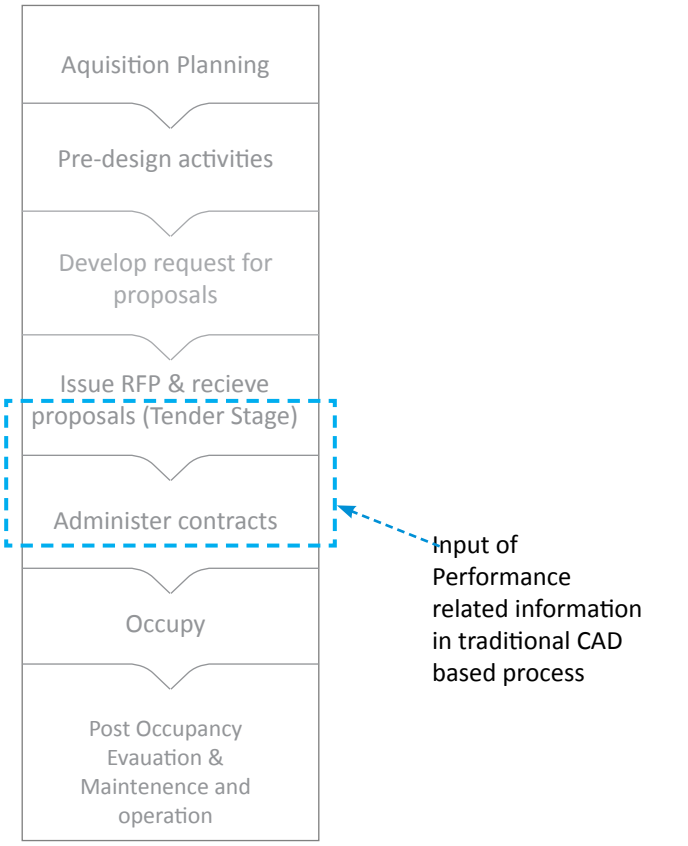
Conclusions of the Research...

Conclusions: Role of library in sustainable facade design

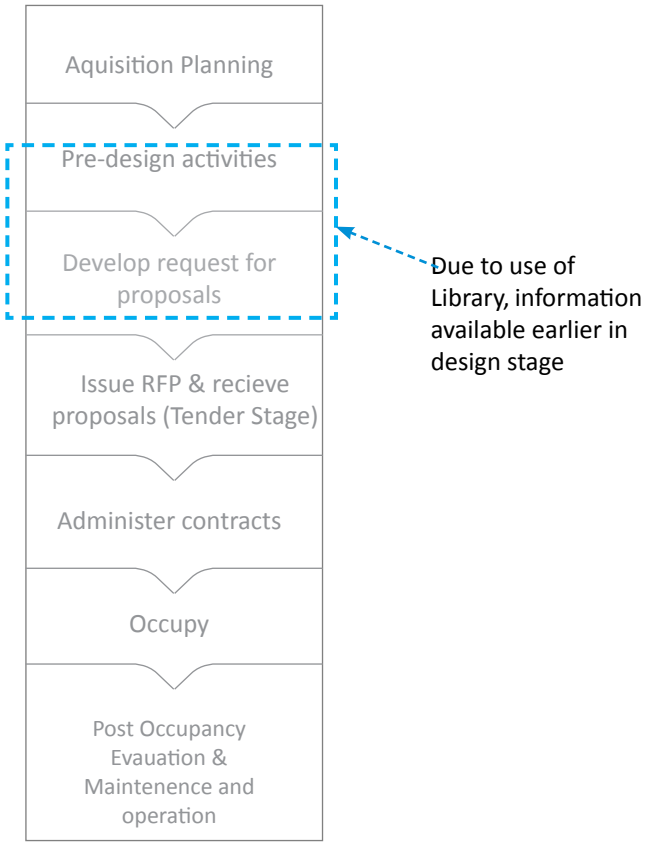


Current situation

Conclusions: Role of library in sustainable facade design process

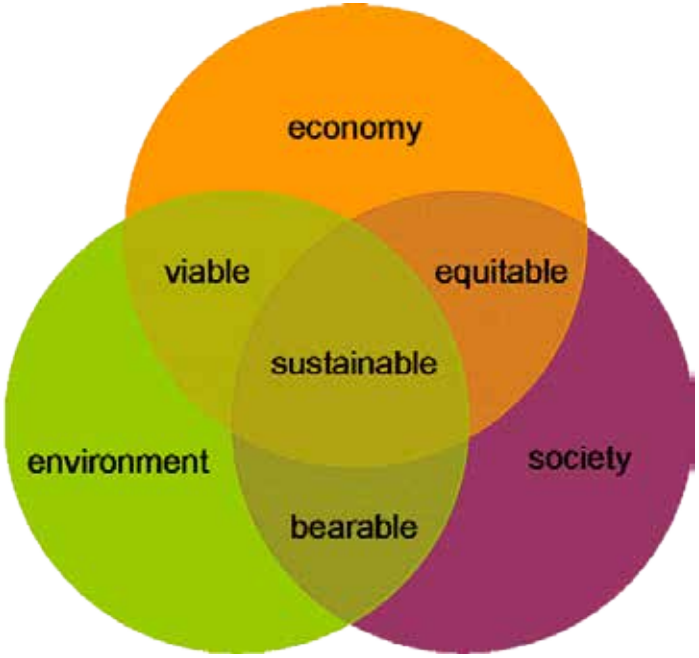


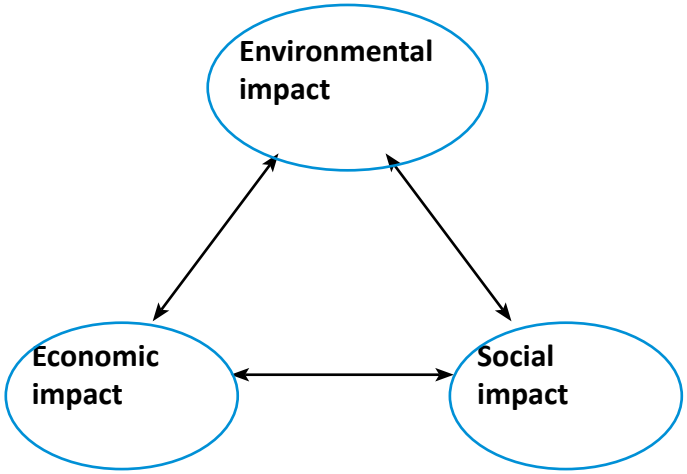
Current situation

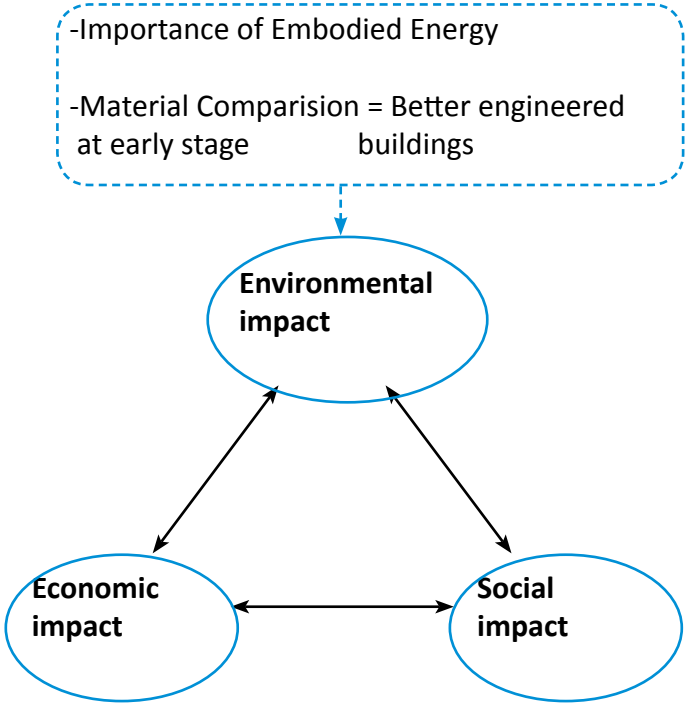


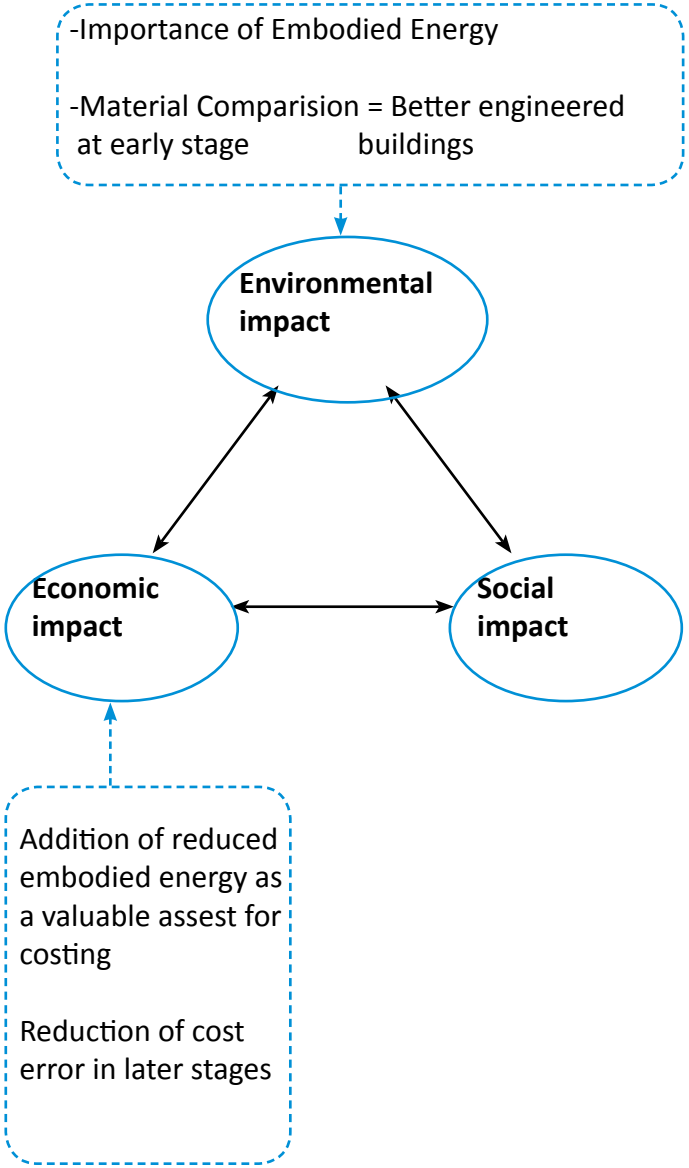
Rol of Library

Conclusions: Role of library in sustainable facade design






-Importance of Embodied Energy
-Material Comparision = Better engineered at early stage buildings
Environmental impact
Economic impact
Social impact


-Importance of Embodied Energy
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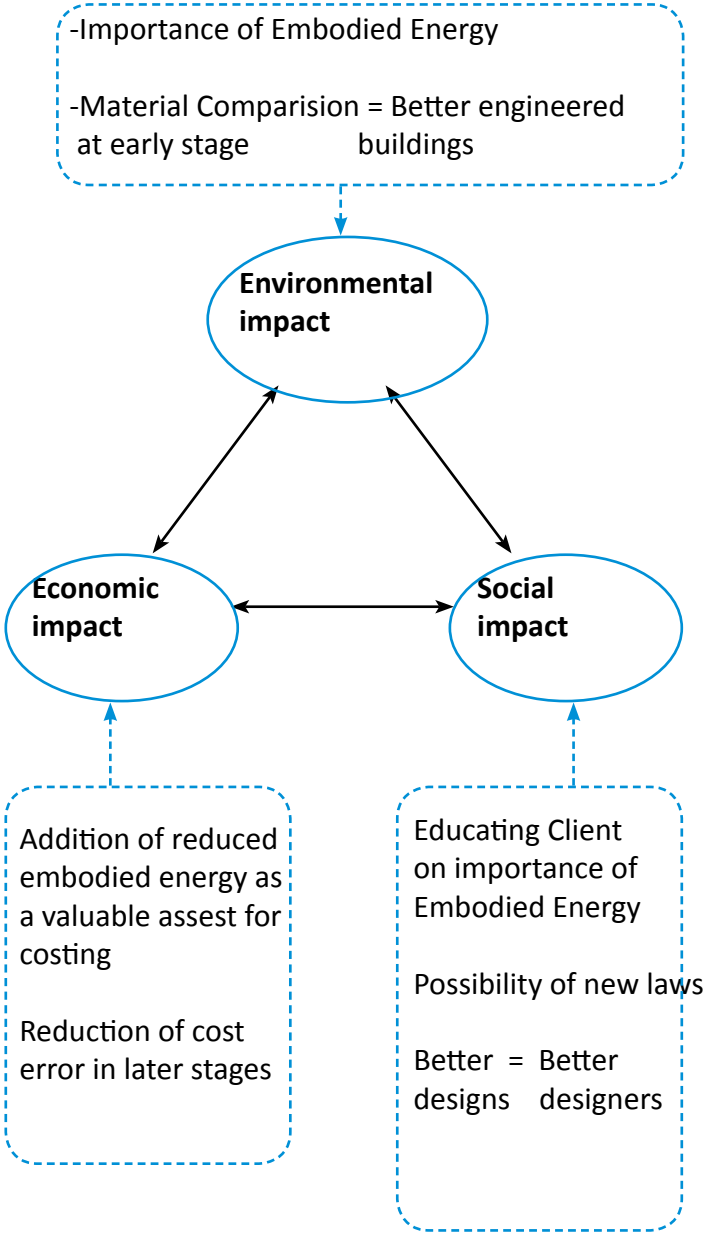
Environmental impact
Economic impact
Social impact
Addition of reduced embodied energy as a valuable assest for costing
Reduction of cost error in later stages


-Importance of Embodied Energy
-Material Comparision = Better engineered at early stage buildings
Environmental impact
Economic impact
Social impact
Addition of reduced embodied energy as a valuable assest 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 authourity 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:

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.

- 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

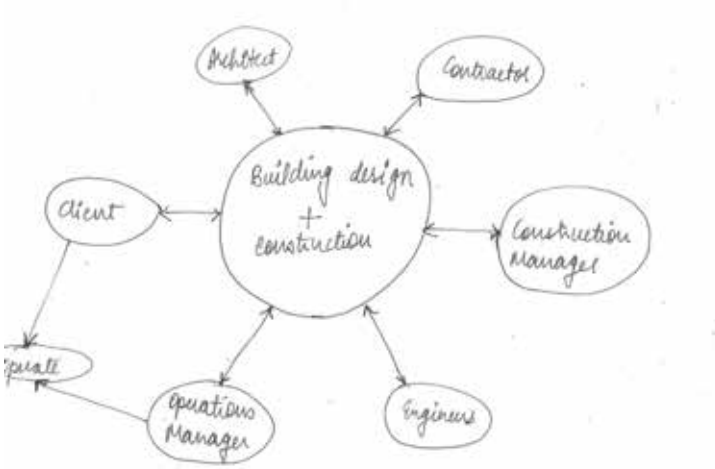
Possibility of feedback to designers using BIM

Design intent lost during operations stage.

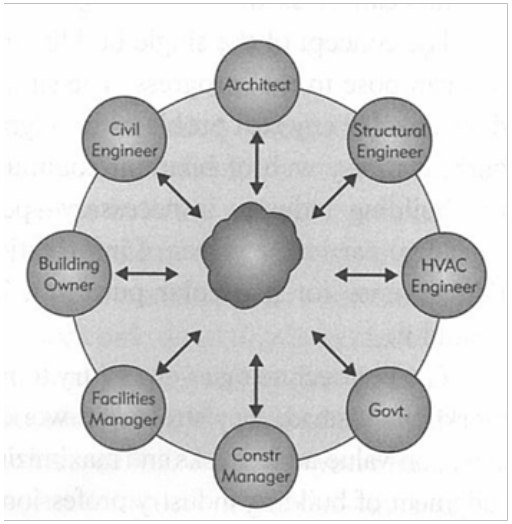
Thank you.

Extra Slides...

Library use: Project Delivery Method

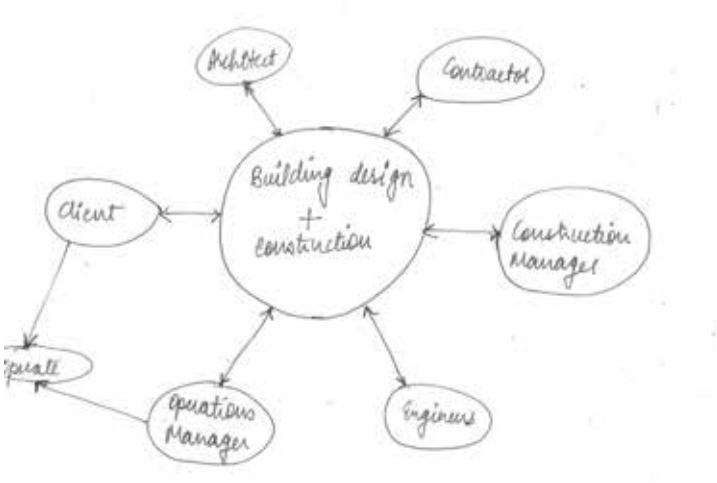


Integrated Project Delivery (IPD)

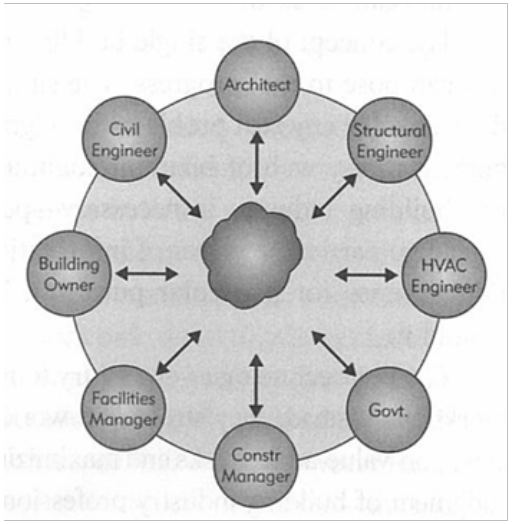


BIM Workflow

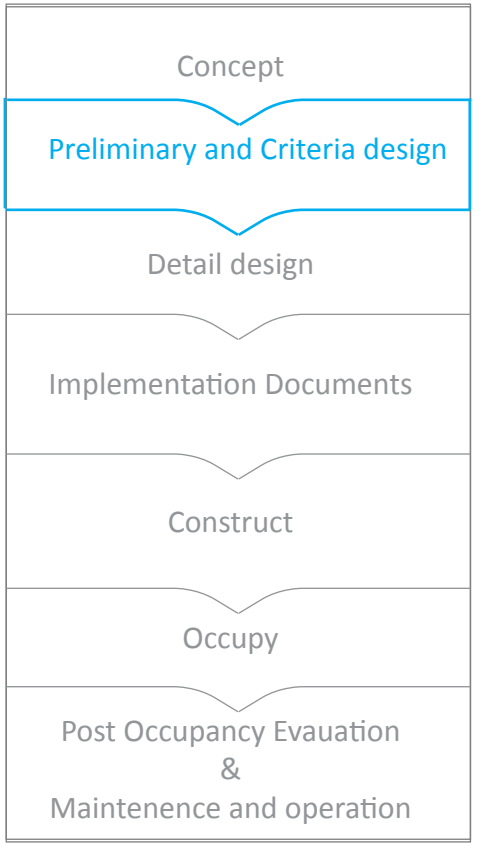
Library use: Project Delivery Method



Integrated Project Delivery (IPD)

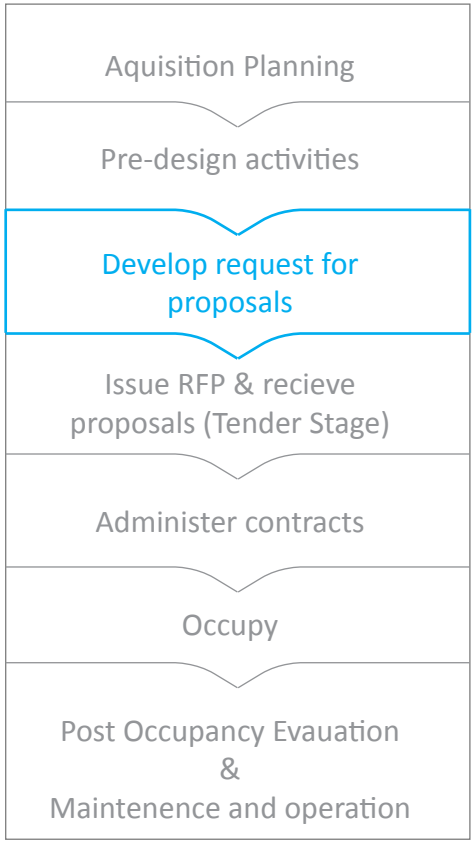


BIM Workflow

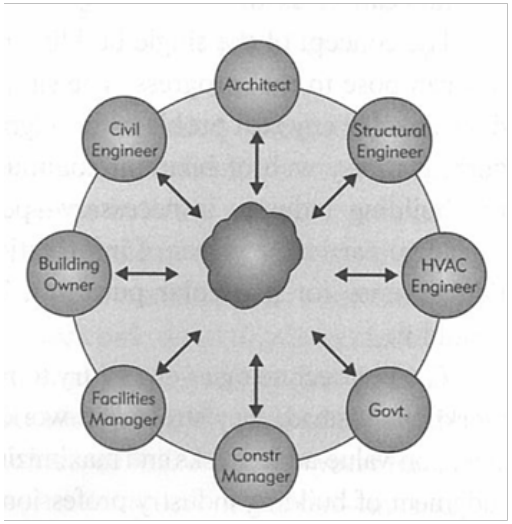


Integrated Project Delivery (IPD)

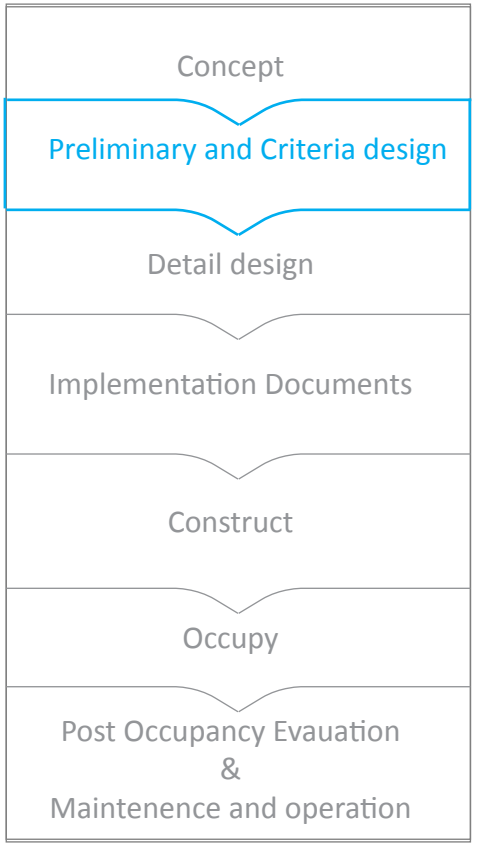
Library use: Project Delivery Method



Design Bid Build (DBB)



BIM Workflow

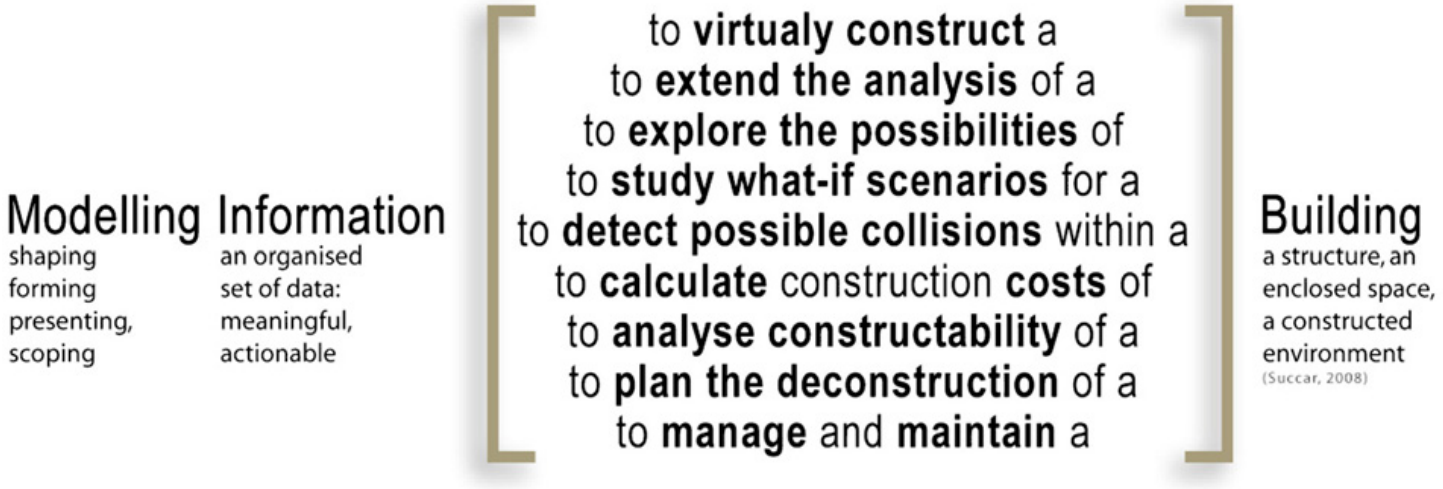


Integrated Project Delivery (IPD)

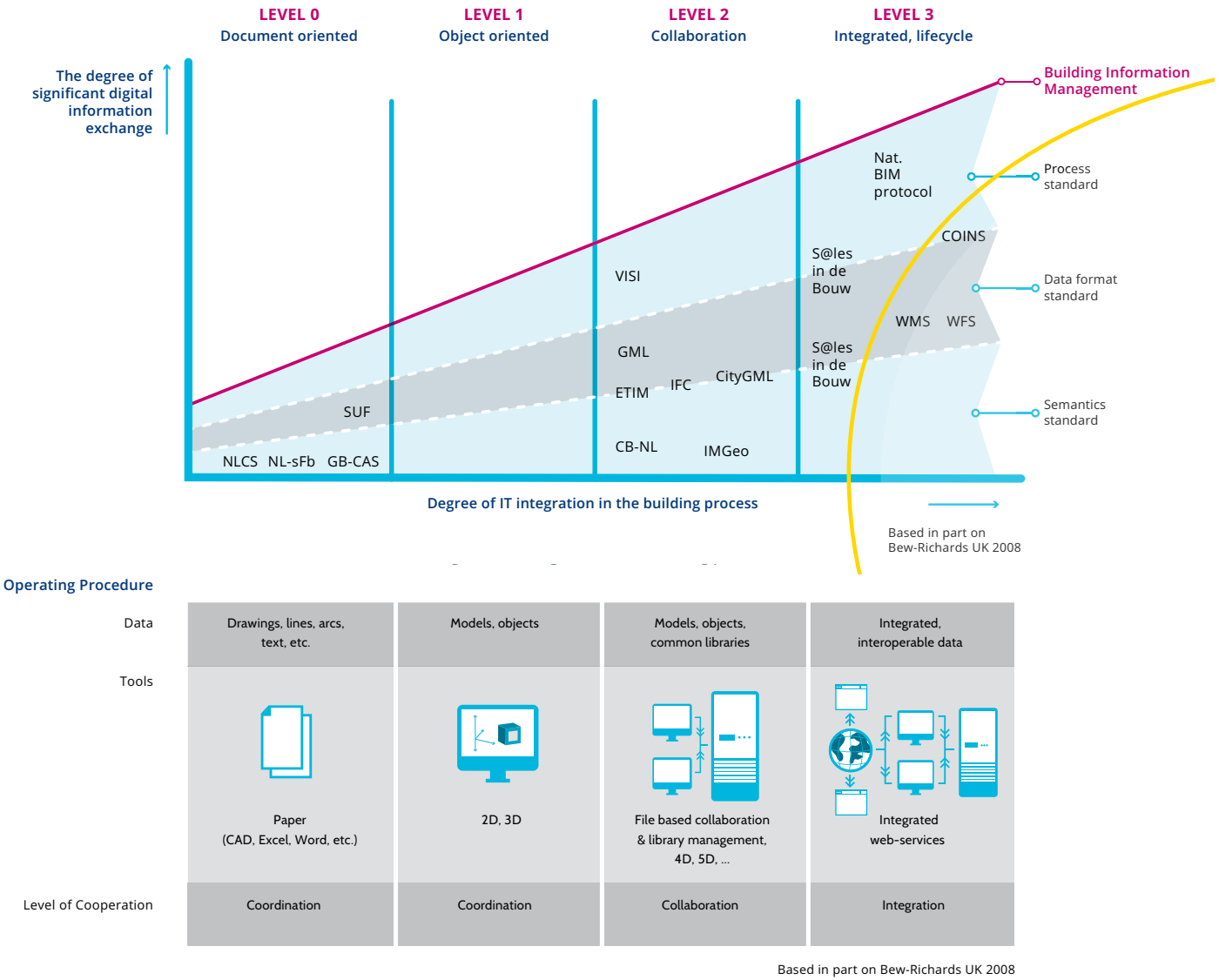
WINDOW FRAME PER M2	ENVIRONMENTAL CLASSIFICATION, DURABILITY	U VALUE KW/M^{2}K	KG CO_2
European hardwood (67x114) acrylic painted	1a, 50 years	2.4	8,95
European softwood (67x114); painted, acrylic	1b, 35 years	2.4	10,8
European hardwood (67x114); painted, acrylic	1b, 50 years	2.4	9,23
European softwood (67x114); painted, acrylic	1c,35years	2.4	10,8
Tropical hardwood (67x114); painted, acrylic	2b, 50 years	2.4	15,7
Pine (67x114); acetylated modified	2b, 50years	2,4	17,6
97% secondary aluminum (68x72), anodized	2c, 75 years	1,299	17,5

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

BIM Definition



Commonly used Dutch BIM LOD Levels



Dutch BIM Levels Given by BIR. (illustrations as draw on Bouw Informatie Raad or BIR Leaflet)

Level of Detail ->	100	200	300	400	500
Model Content					
Design & Coordination (function / form / behavior)	Non-geometric data or line work, areas, volumes zones, etc.	Generic elements shown in three dimensions - maximum size - purpose	Specific elements Confirmed 3D Object Geometry - dimensions - capacities - connections	Shop drawing/ fabrication - purchase - manufacture - install - specified	As-built - actual
Authorized uses					
4D Scheduling	total project construction duration phasing of major elements	Time-scaled, ordered appearance of major activities	Time-scaled, ordered appearance of detailed assemblies	Fabrication and assembly detail including construction means and methods (cranes, man-lifts, shoring, etc.)	
Cost Estimating	Conceptual cost allowance Example $/sf of floor area, $/hospital bed, $/parking stall, etc. assumptions on future content	Estimated cost based on measurement of generic element. E.g., generic interior wall.	Estimated cost based on measurement of specific assembly. E.g., specific wall type.	Committed purchase price of specific assembly at Buyout.	Record costs
Program Compliance	Gross departmental areas	Specific room requirements	FF&E, casework, utility connections		
Sustainable Materials	LEED strategies	Approximate quantities of materials by LEED categories	Precise quantities of materials with percentages of recycled/locally purchased materials	Specific manufacturer selections	Purchase documentation
Environmental: Lighting, Energy use, air movement Analysis/Simulation	Strategy and performance criteria based on volumes and areas	Conceptual design based on geometry and assumed system types	Approximate simulation based on specific building assemblies and engineered systems	Precise simulation based on specific manufacturer and detailed system components	Commissioning and recording of measured performance

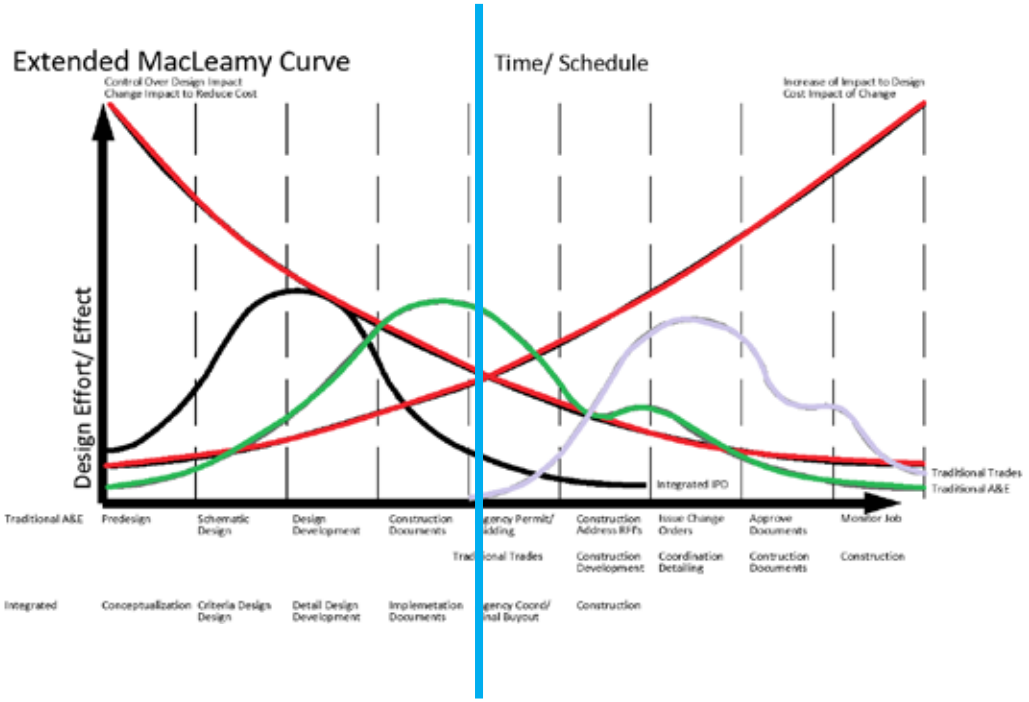
Embodied energy based parameters	
Window Frame	Select from drop down
KG CO2 value (frame)	value
Glass type	Select from drop down
KG CO2 value (glass)	value
Fill type (between glass)	Select from drop down
KG CO2 value (infill)	value
Service Life	value (years)
Recyclability	value (%)
Operational energy 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/m.sq 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

WINDOW FRAME PER M²	Service Life (years)	KG CO_2	KG CO_2 Per year	Recyclability	PRICE IN EURO
European hardwood (67x114) acrylic painted	50	8,95	0,179	0,0%	1,20
European softwood (67x114); painted, acrylic	35	10,8	0,309	0,2 %	1,44
European hardwood (67x114); painted, acrylic	50	9,23	0,185	0,1 %	1,48
European softwood (67x114); painted, acrylic	35	10,8	0,308	0,2 %	1,65
Tropical hardwood (67x114); painted, acrylic	50	15,7	0,314	0,1%	2,36
Pine (67x114); acetylated modified	50	17,6	0,352	0%	2,42
97% secondary aluminum (68x72), anodized	75	17,5	0,233	63,0%	2,92
Steel (80x50); Powder	100	31,8	0,318	62,6%	3,39
Steel (80x70); Powder	100	33,1	0,331	65,6%	3,59
47% secondary aluminum (68x72), anodized	75	17,6	0,234	63,0%	3,69
97% secondary aluminum (68x72), powder	75	15,6	0,208	65,7%	3,70
47% secondary aluminum (68x72), powder	75	14,7	0,196	65,7%	4,47
PVC on steel core (80x112), 0% Secondary	40	36,5	0,9125	73,4%	6,80
Tropical hardwood (67x114); painted, acrylic;	50	15,7	0,314	0,0%	19,90

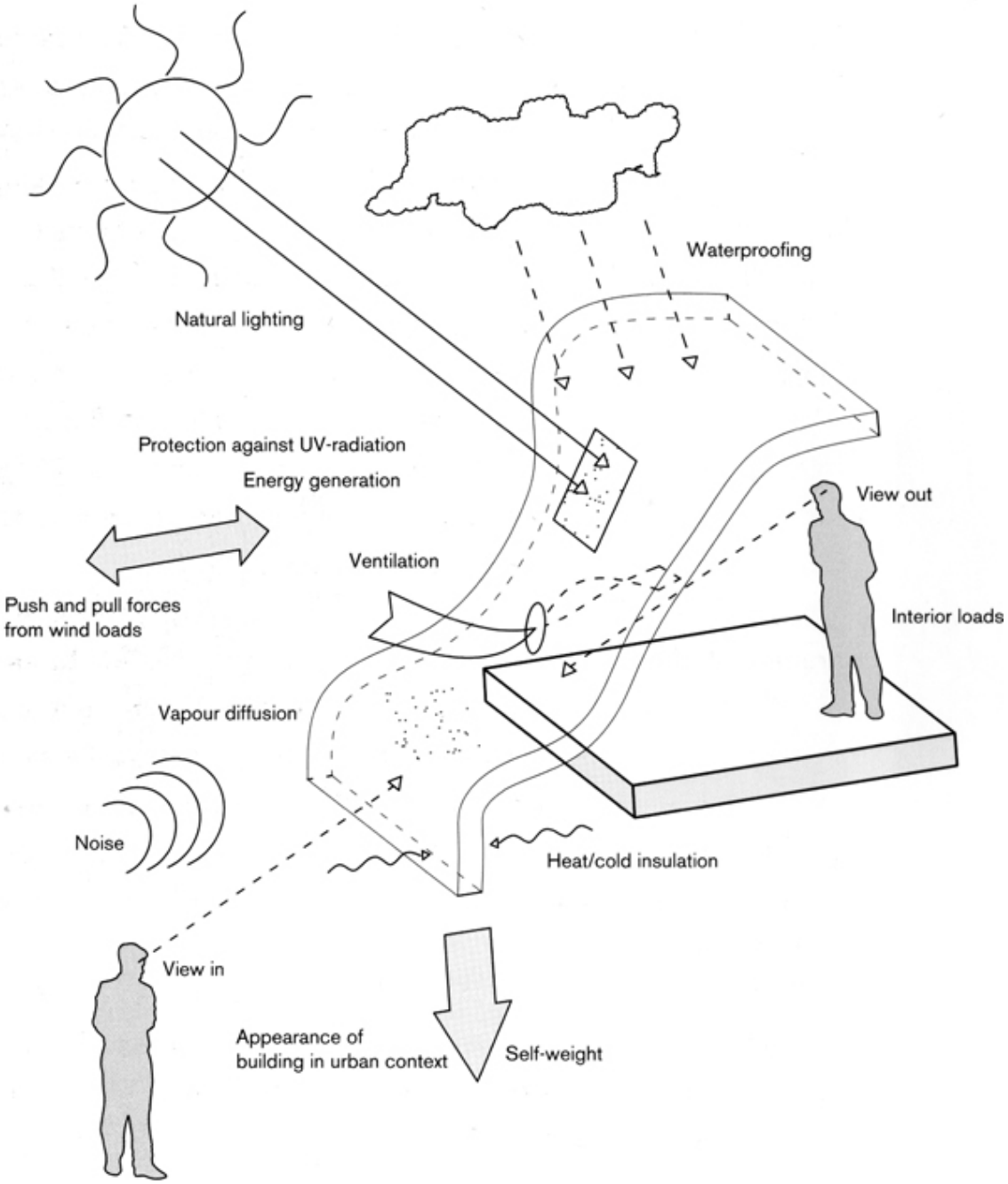
MATERIAL	KG CO_2 PER KG MATERIAL
Krypton filling	26
Xenon filling	229
Glass	0.85

	U_{glass}	wood or plastic	metal with thermal break	Metal without thermal break	VLT	SHGC
		U_{fr} = 2,4	U_{fr} = 3,8	U_{fr} = 7,0		
single glass	3,3	3,3	3,6	4,5	0,95	0,85
	3,2	3,2	3,6	4,4		
	3,0	3,0	3,4	4,2		
double glass	2,8	2,9	3,3	4,1	0,9	0,75
	2,6	2,8	3,2	4,0		
	2,4	2,6	3,1	3,9		
	2,2	2,5	2,9	3,7		
HR glass	2,0	2,3	2,8	3,6	0,8	0,75
	1,8	2,2	2,6	3,5		
HR+ glass	1,6	2,0	2,5	3,3	0,79	0,65
	1,4	1,9	2,4	3,2		
HR++	1,2	1,8	2,2	3,0	0,75	0,60
	1,0	1,6	2,0	2,9		
	0,9	1,5	2,1	2,8		
HR3	0,7	1,4	1,9	2,7	0,65	0,60
	0,5	1,3	1,7	2,5		

Library use: Project Delivery Method



	Fab- Window by Itannex	BIM object	2-D Brochures
applicable in design stage	yes: Flexibe geometry	Maybe?	Information : needs to be filtered by architect
user interface			
Embodied energy related data	no	no	maybe
Operational energy related data	no	Maybe	Yes
Easy of comparision	Yes	No	Yes


Waterproofing
Natural lighting
Protection against UV-radiation
Energy generation
View out
Ventilation
Push and pull forces
from wind loads
Interior loads
Vapour diffusion
Noise
Heat/cold insulation
View in
Appearance of
building in urban context
Self-weight

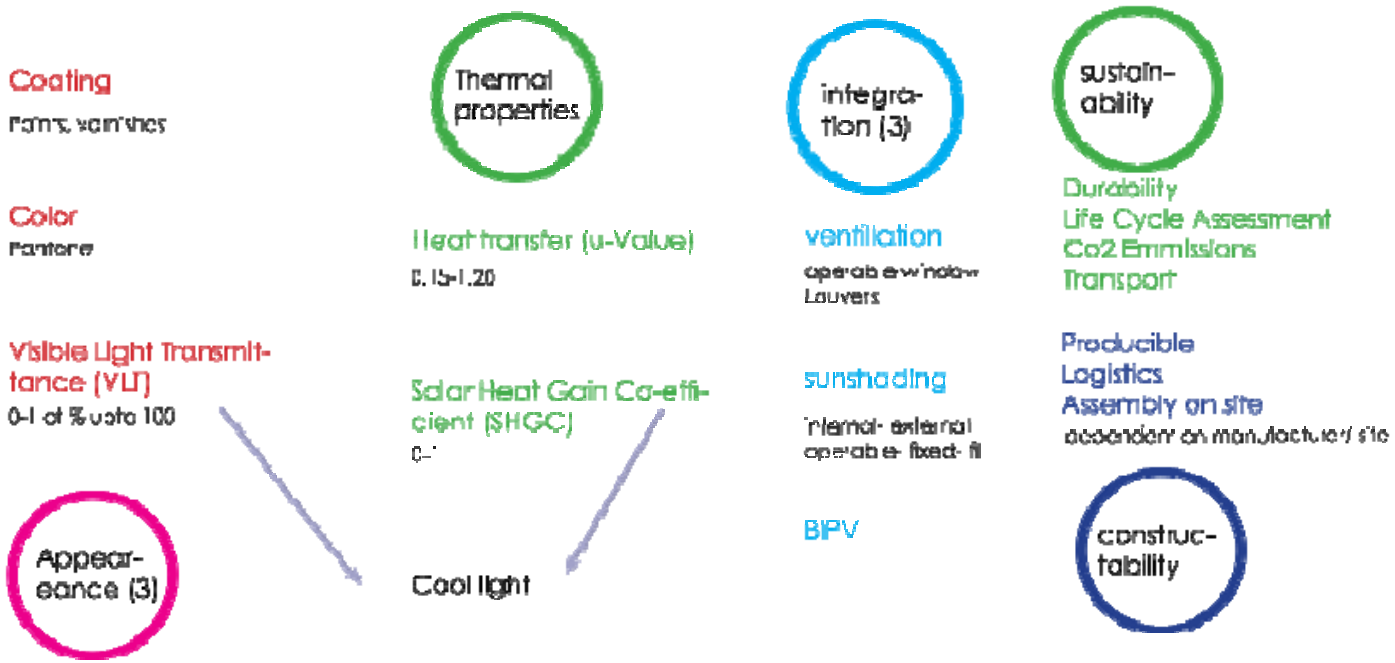

Coating
Color
Pantone
Visible Light Transmittance (VLT)
0-1 or % upto 100
Appearance (3)
Thermal properties
Heat transfer (u-Value)
Solar Heat Gain Coefficient (SHGC)
Cool light
integration (3)
ventilation
Louvers
sunshading
BIPV
sustainability
Durability
Life Cycle Assessment
Co2 Emmissions
Transport
Producible
Logistics
Assembly on site
construct-ability

Figure 3.8.a : List of parameters that can be interesting to include in library.