Enabling and Assessing ‘Reuse of Secondary Materials’ as a Circular Approach for the Façade Industry

28th June 2021

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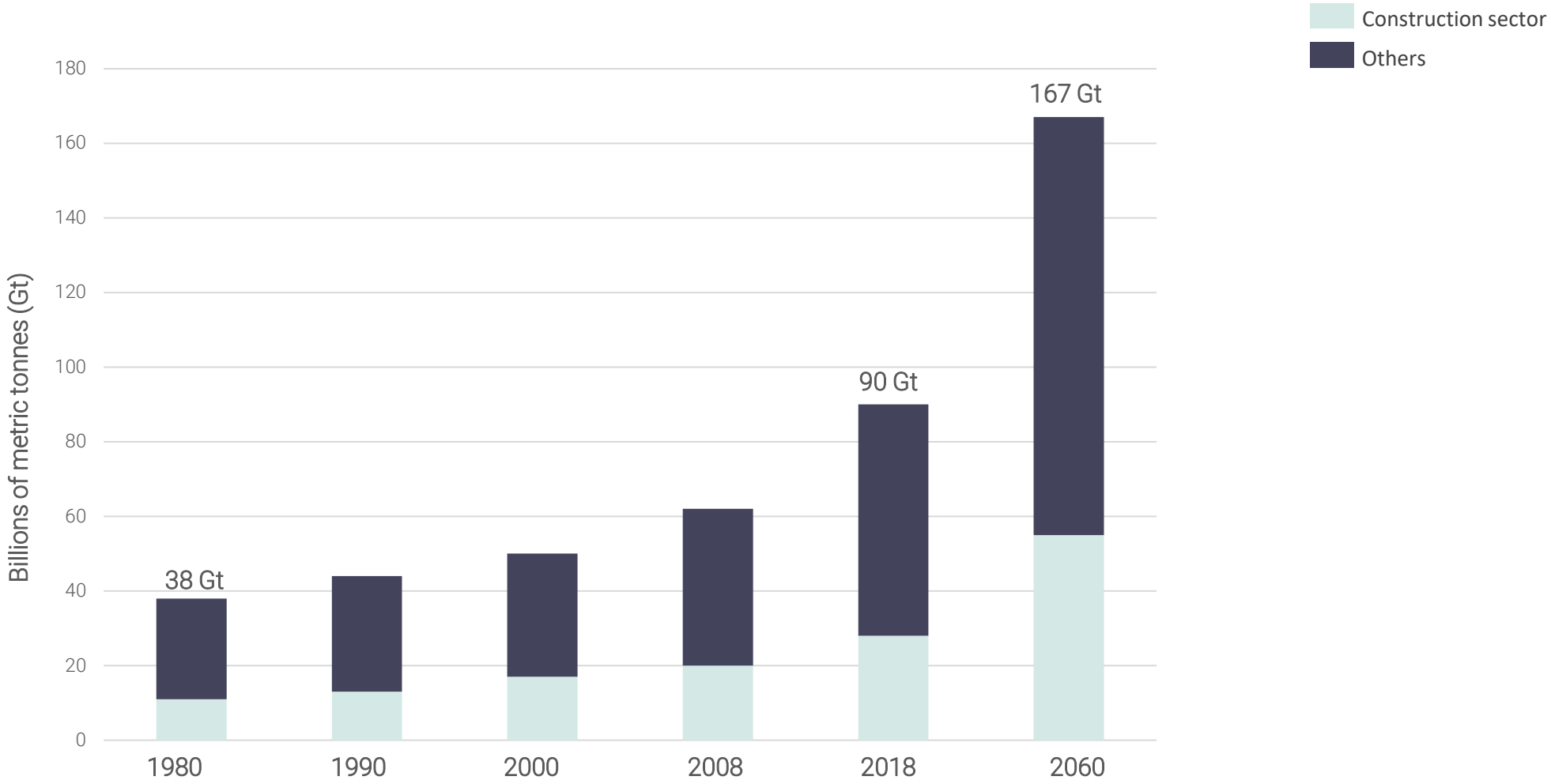
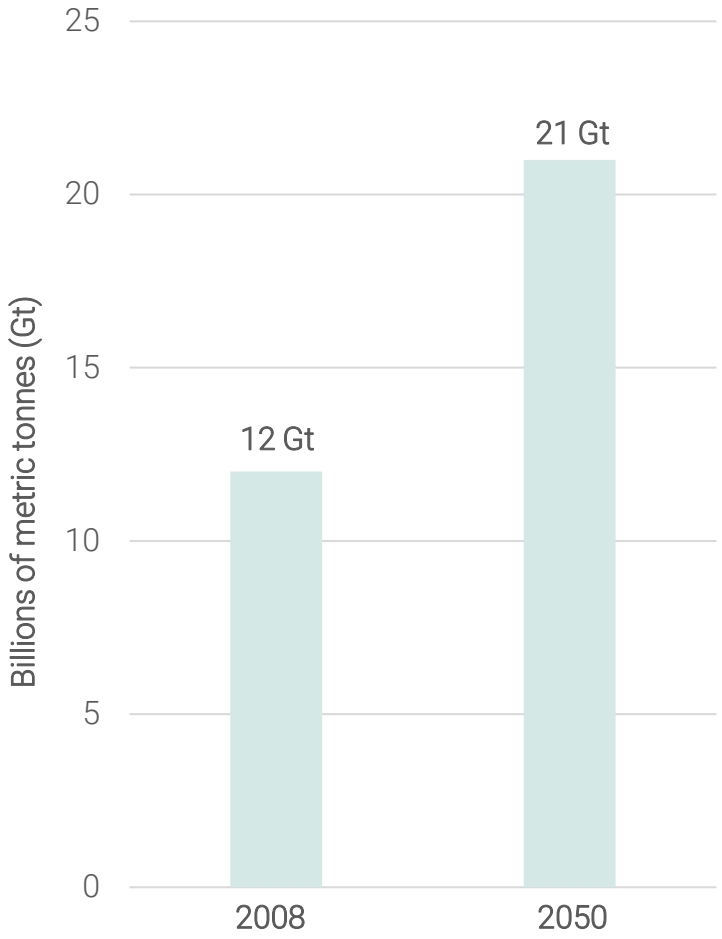
Global Material Resource Extraction



Ref – OECD (2012), OECD (2018)

Global Waste Generation



Ref – OECD (2012), World Bank (2018)

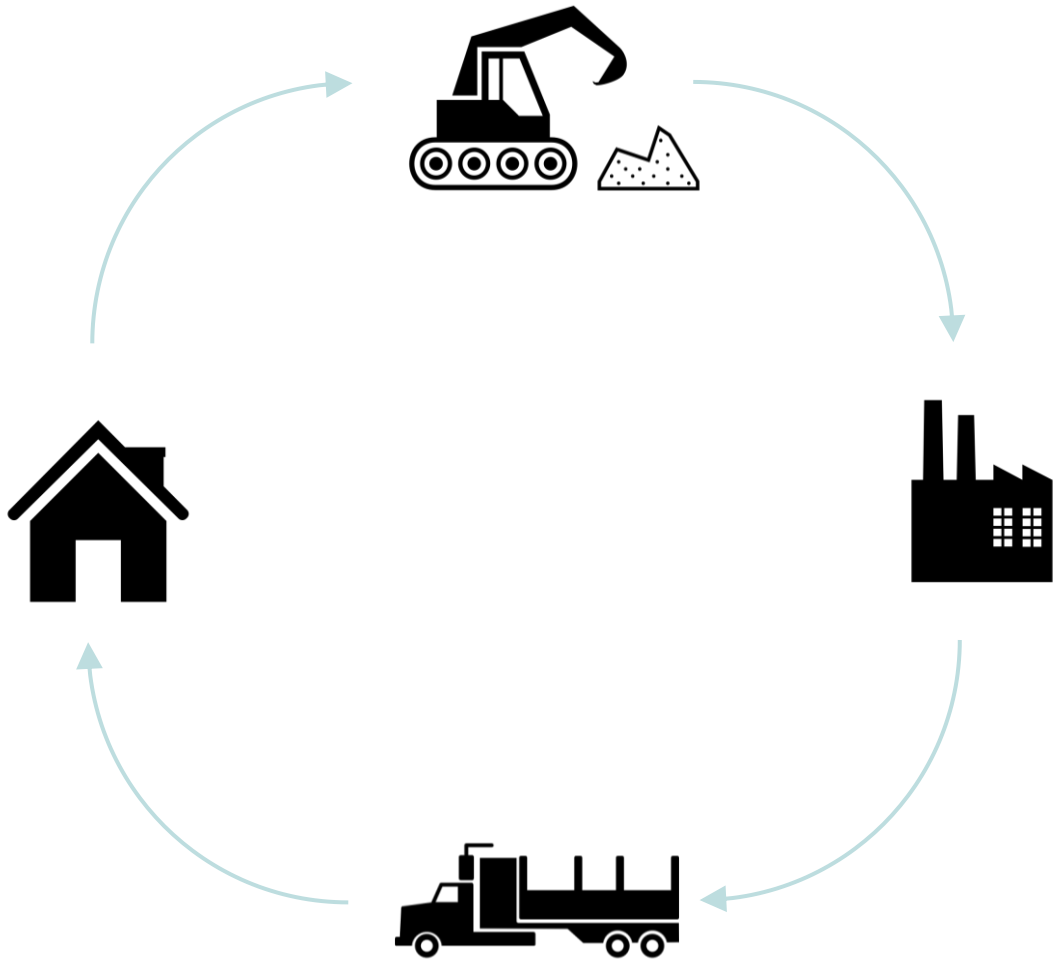
Linear Economy

TAKE

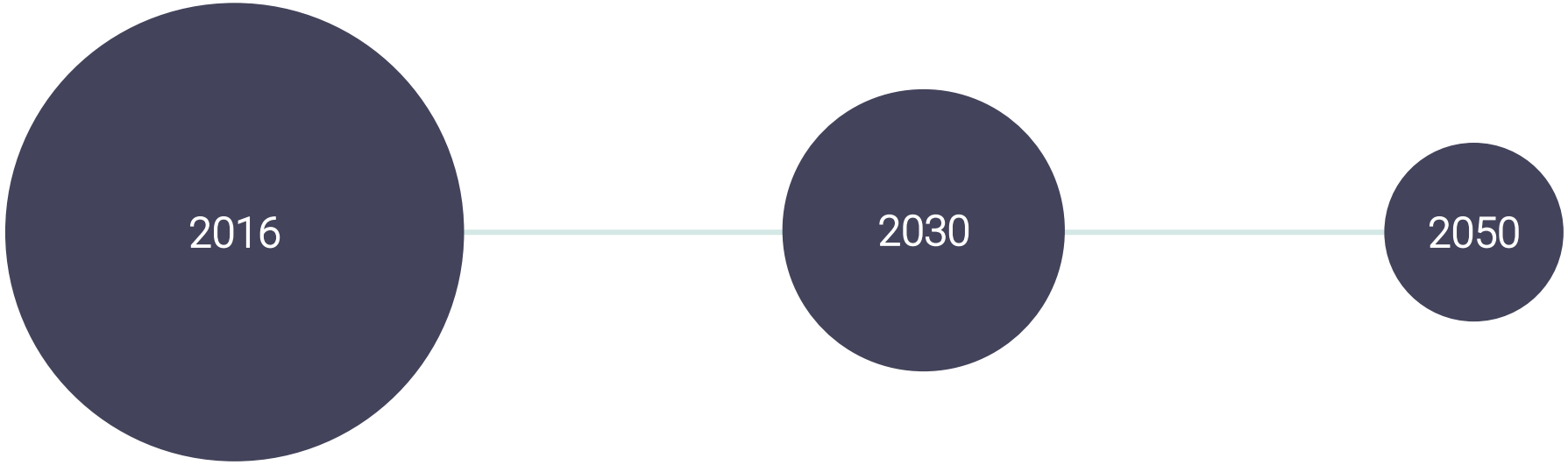
MAKE

DISPOSE

Circular Economy



Circular Netherlands in 2050



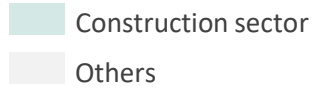
Introduction

50% reduction in raw material consumption

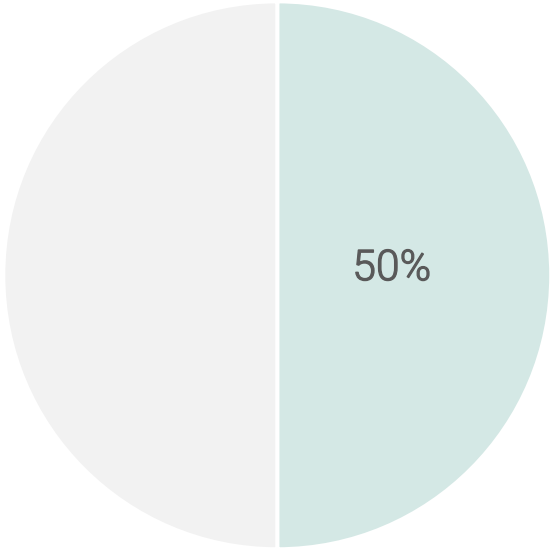
100% waste free economy

Ref – Government of Netherlands (2016)

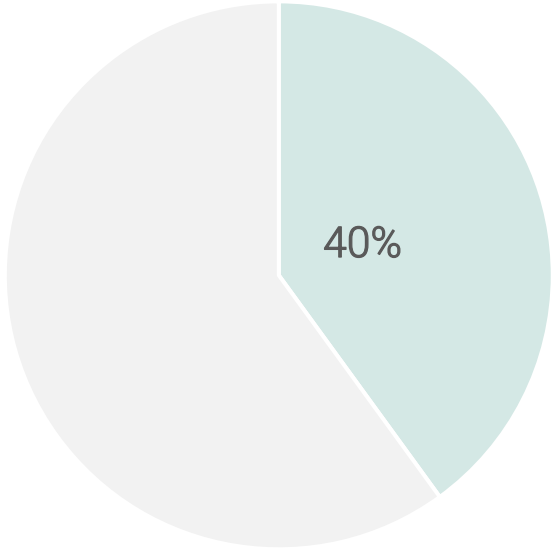
Construction Sector in the Netherlands



Raw material consumption



Energy consumption



Ref – Ministry of Infrastructure and the Environment and Ministry of Economic Affairs (2016)

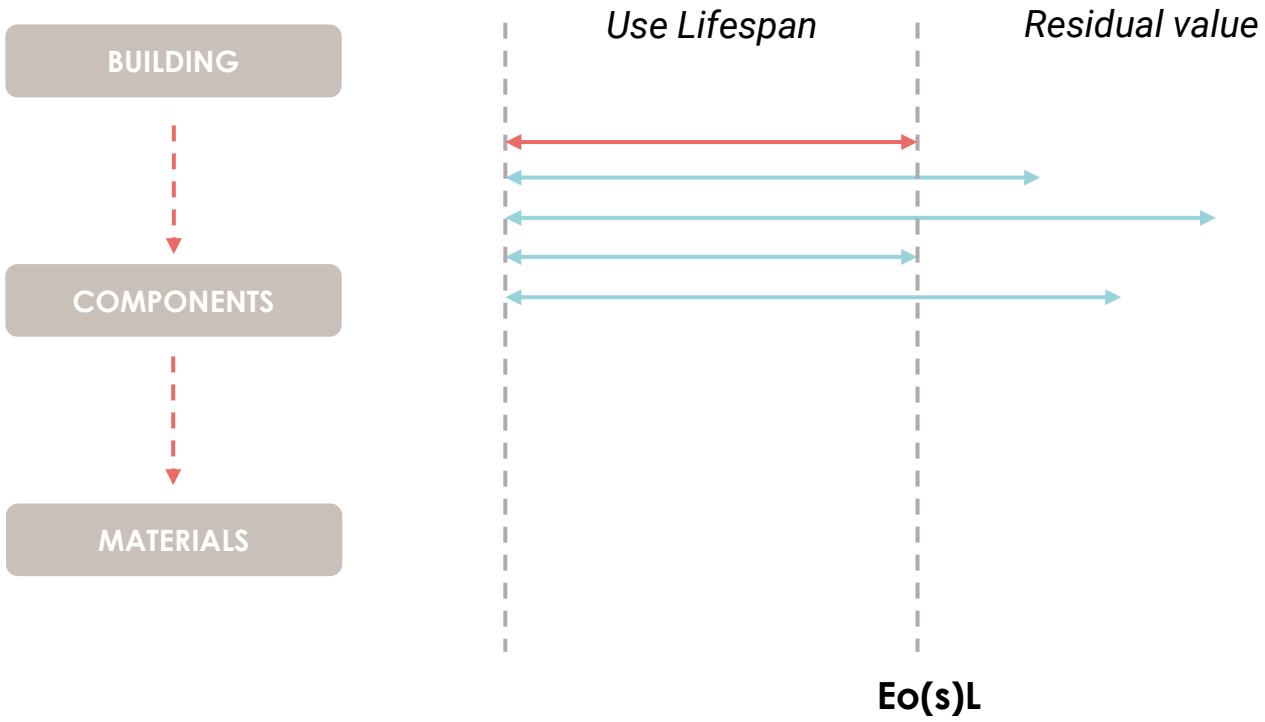
Ref – Bio by Deloitte (2017), Ministry of Infrastructure and Environment (2016)

Value Retention >>>

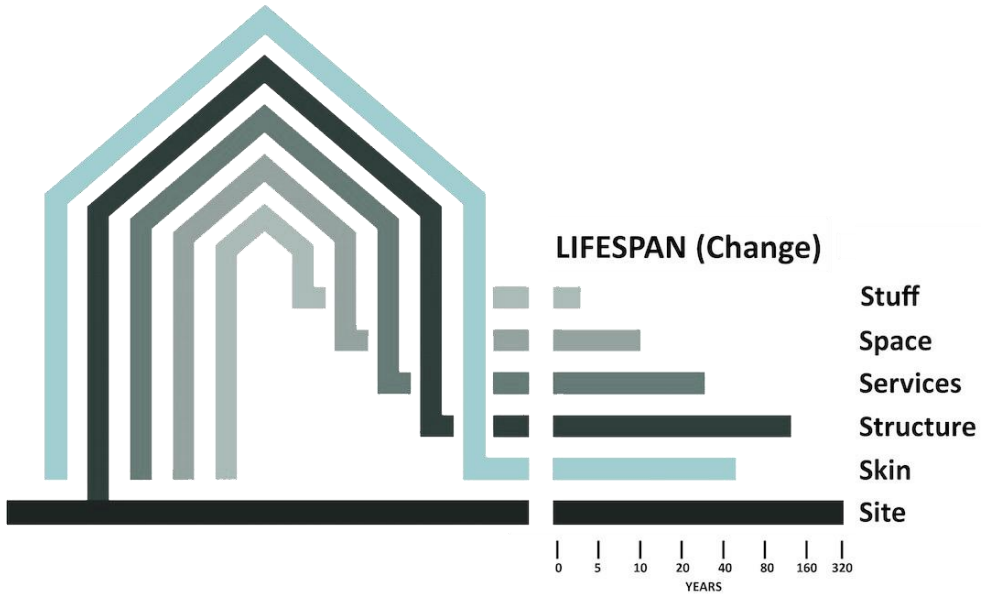
- REFUSE
- REDUCE
- REUSE
- REPAIR
- REFURBISH
- REMANUFACTURE
- REPURPOSE
- RECYCLE
- RECOVER
- REMINE

Building Lifecycle

Building as a system of lifecycles



Building Layers



Ref – Shearing Layers by Steward Brand (1994), Gorgolewski and Morettin (2009)

Research Question

How can **secondary materials** from **construction and demolition processes** be **reused** in the **facade industry**? Can a reuse process contribute to create a **circular value** and **reduce negative environmental impacts** for facades?

Design Question

How can a **circular hybrid steel curtain wall** be designed by **facade companies** reusing the **secondary material stream** for office buildings in the **Netherlands**?

Secondary Materials

Inventorying

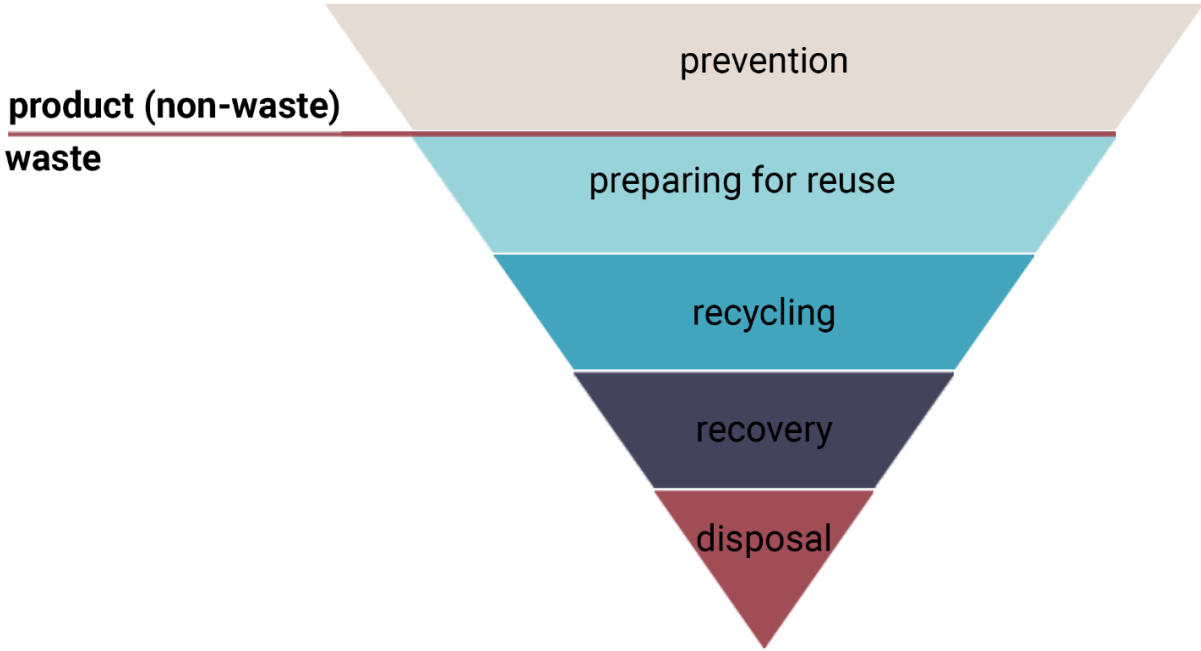
Selective Demolition

Distribution

Reuse of Secondary Materials

According to **EU Waste Framework Directive** (2008/98/EC),

"*reuse is any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.*"

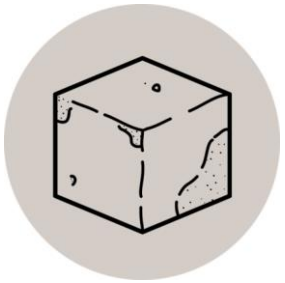


EU Waste Hierarchy Model

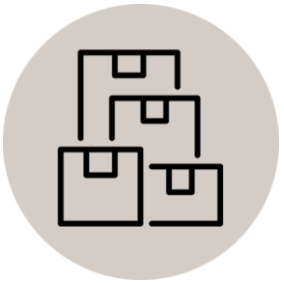
Ref – WFD (2008/98/EC)

Barriers to Direct Reuse of Secondary Materials for Facades

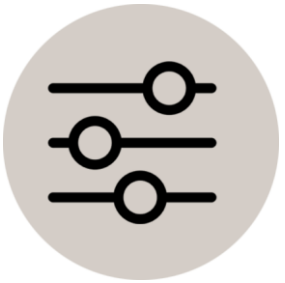
Lack of Information about previous condition



Wear and tear affecting safety of facade



Inconsistency in quality and quantity of supply



Customization in facades

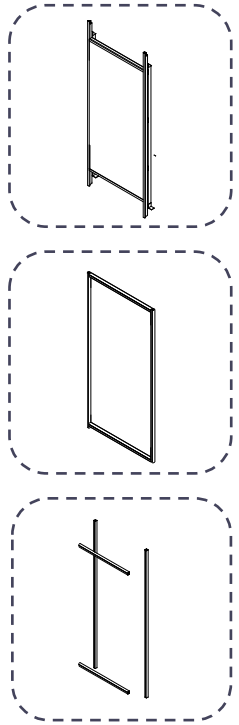
Obsolete Performance

If direct reuse is not possible, how can secondary materials still be reused?

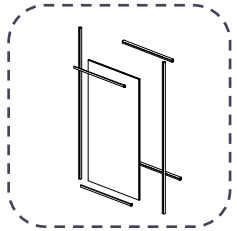
Residual Value of Material

Source of Harvest

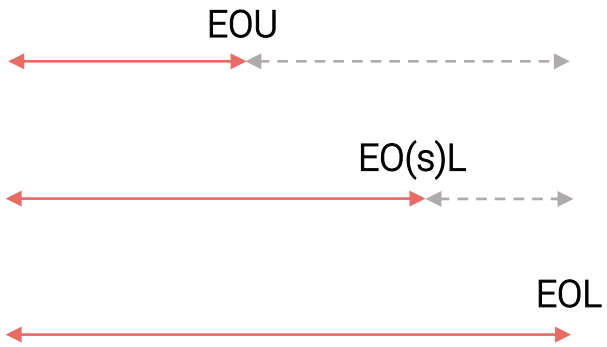
Form of Harvest



Extraction Process

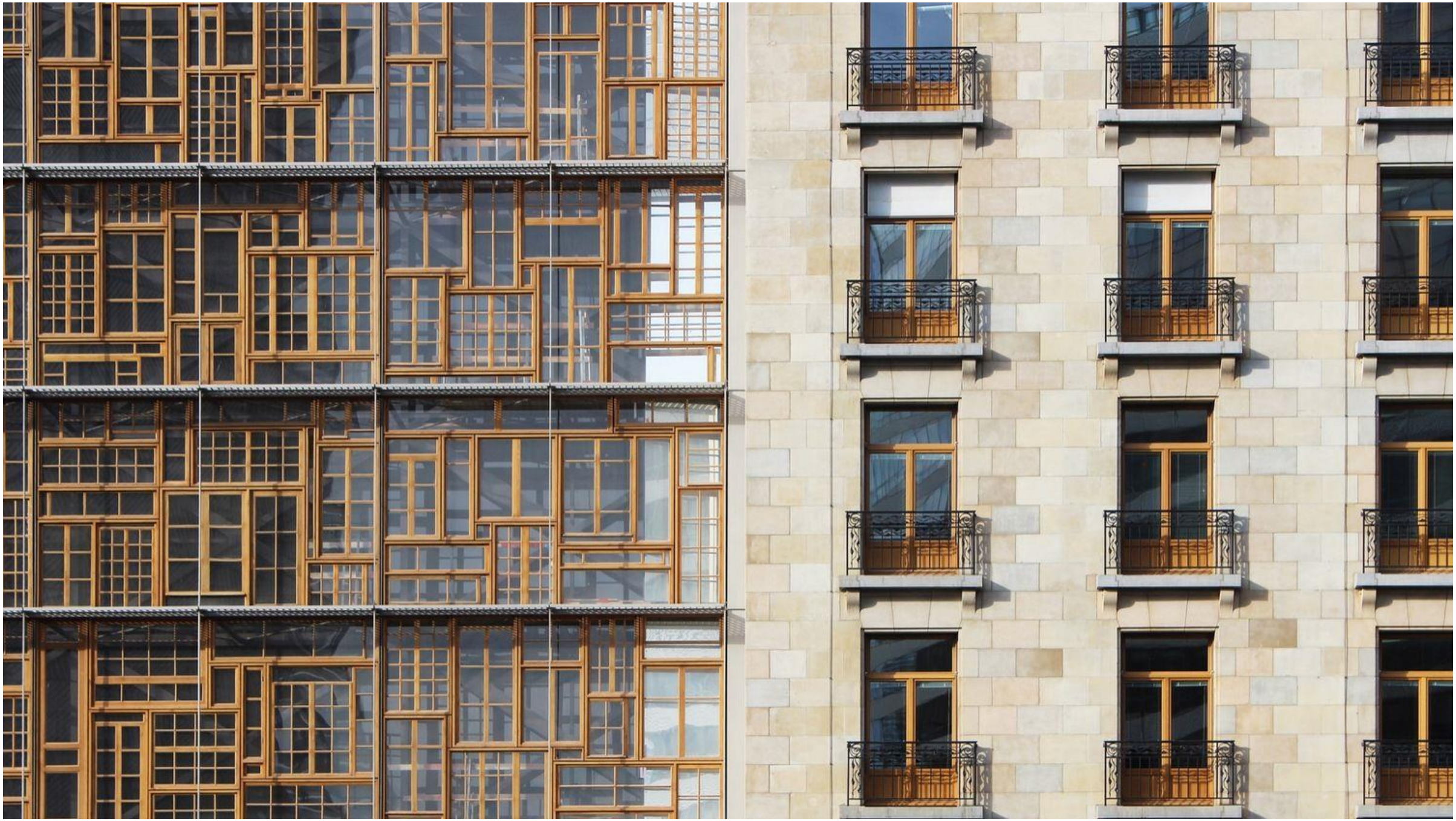


Use Life Span



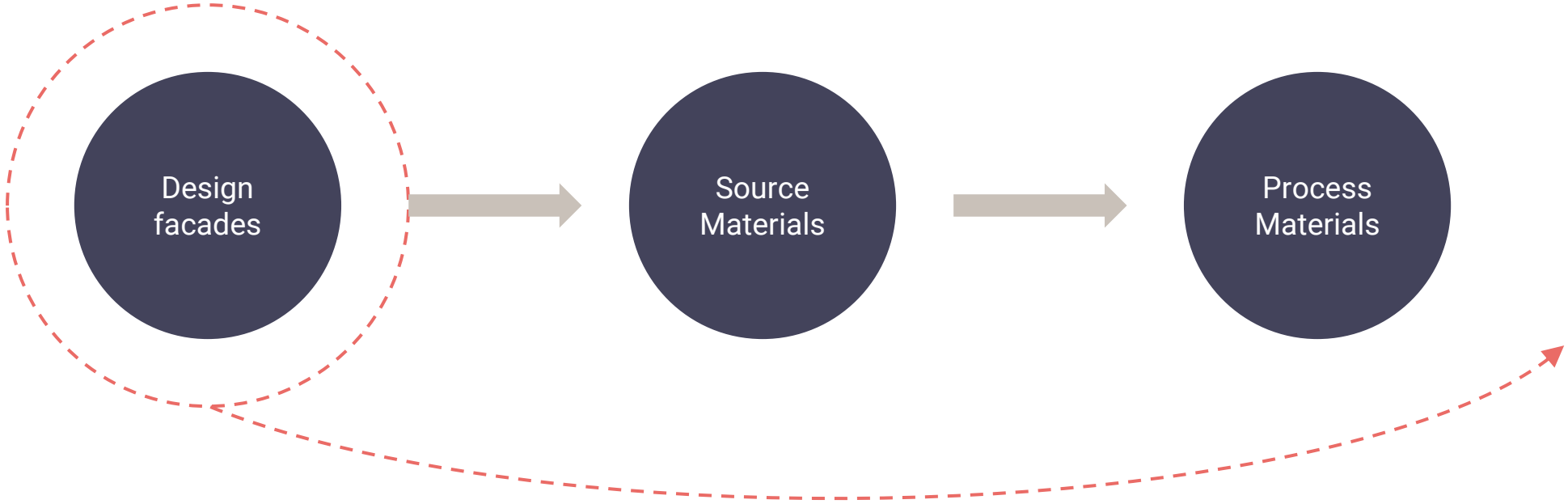
EOU = End of Use
EOL = End of Life
EO(s)L = End of Service Life

Reuse Strategy



How does the Residual Material Value apply to the Design Process?


Design facades
Source Materials
Process Materials


Design facades
Source Materials
Process Materials

Material Sourcing

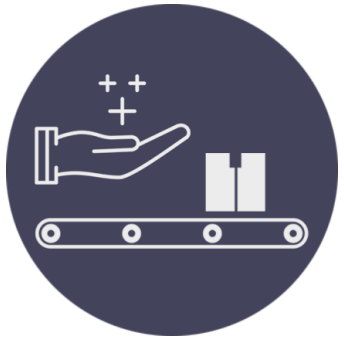
Material Processing

Material Reuse

Material Sourcing

Material Identification
Material Extraction

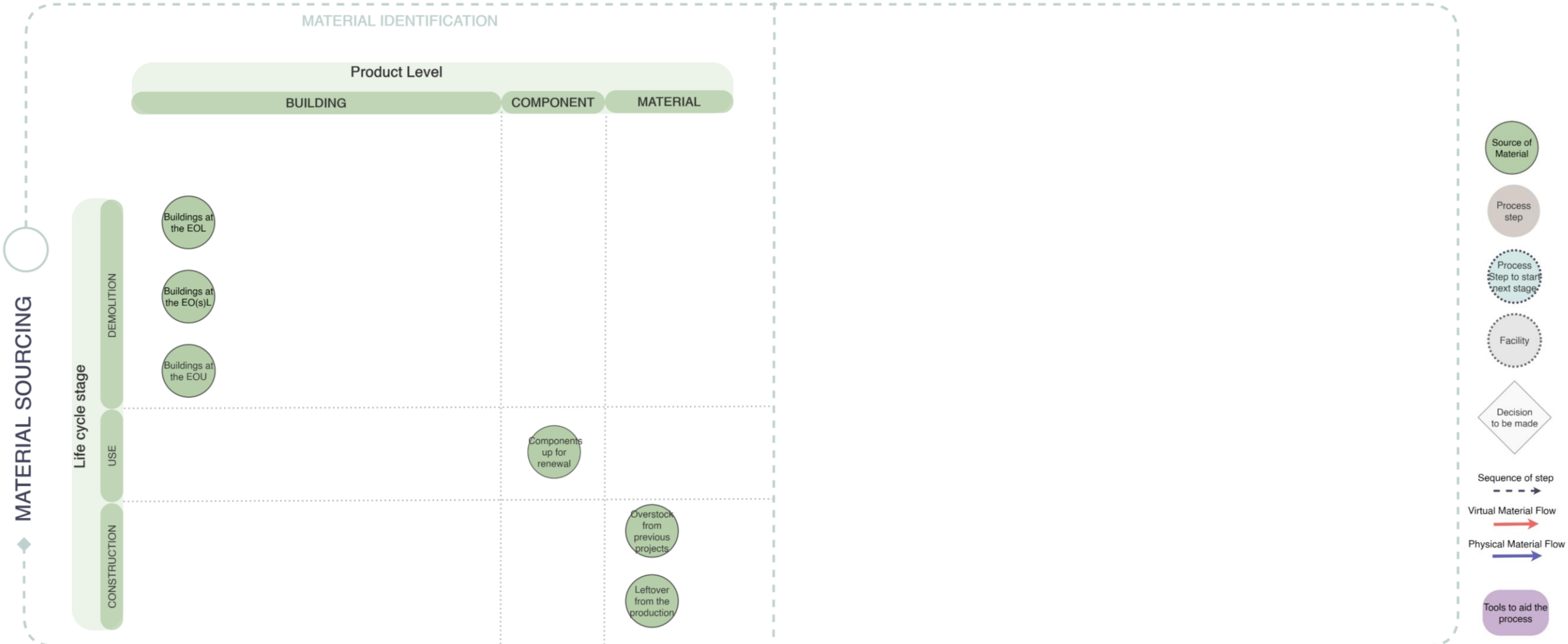
Material Processing

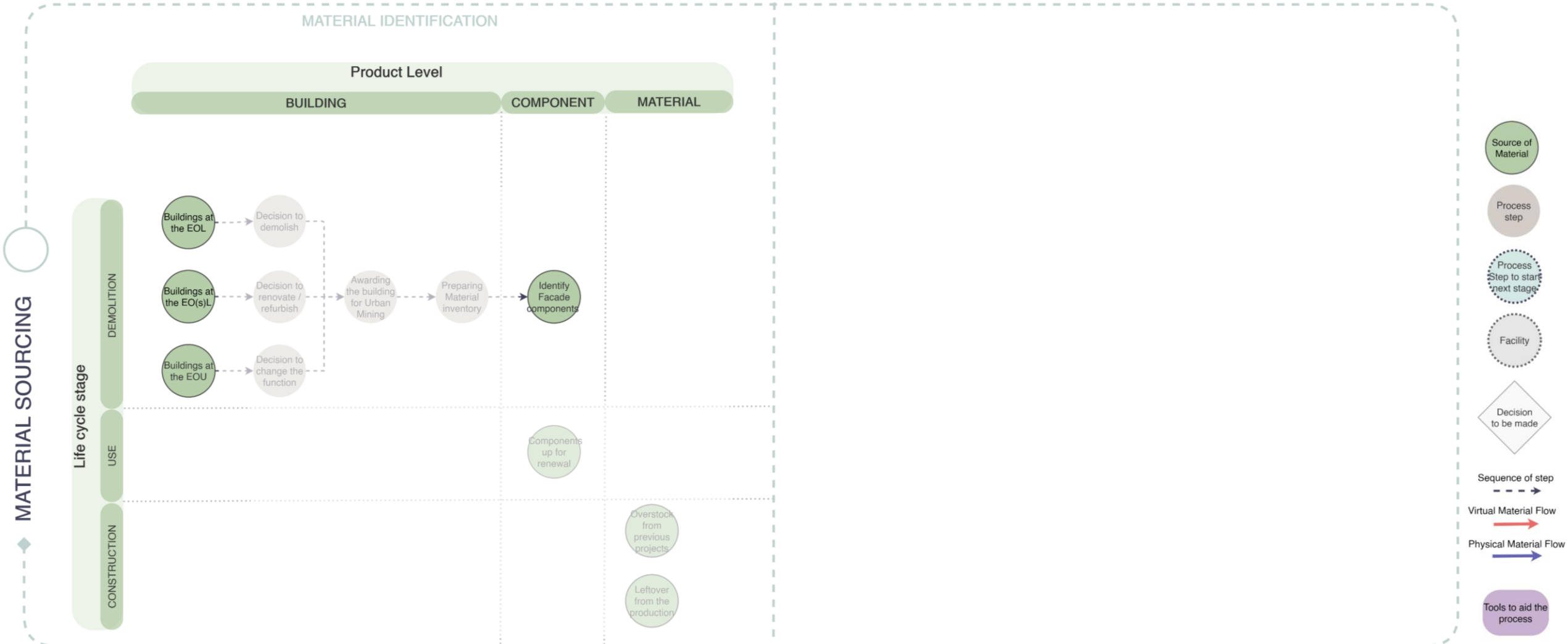


Preliminary Processing
Material Valuation

Material Reuse

Design Methodology
Façade Manufacturing


MATERIAL SOURCING
MATERIAL IDENTIFICATION
Product Level
BUILDING
COMPONENT
MATERIAL
Life cycle stage
DEMOLITION
USE
CONSTRUCTION
Buildings at the EOL
Buildings at the EO(s)L
Buildings at the EOU
Components up for renewal
Overstock from previous projects
Leftover from the production
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process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Product Level
BUILDING
COMPONENT
MATERIAL
Life cycle stage
DEMOLITION
USE
CONSTRUCTION
Buildings at the EOL
Buildings at the EO(s)L
Buildings at the EOU
Decision to demolish
Decision to renovate / refurbish
Decision to change the function
Awarding the building for Urban Mining
Preparing Material inventory
Identify Facade components
Components up for renewal
Overstock from previous projects
Leftover from the production
Source of Material
Process step
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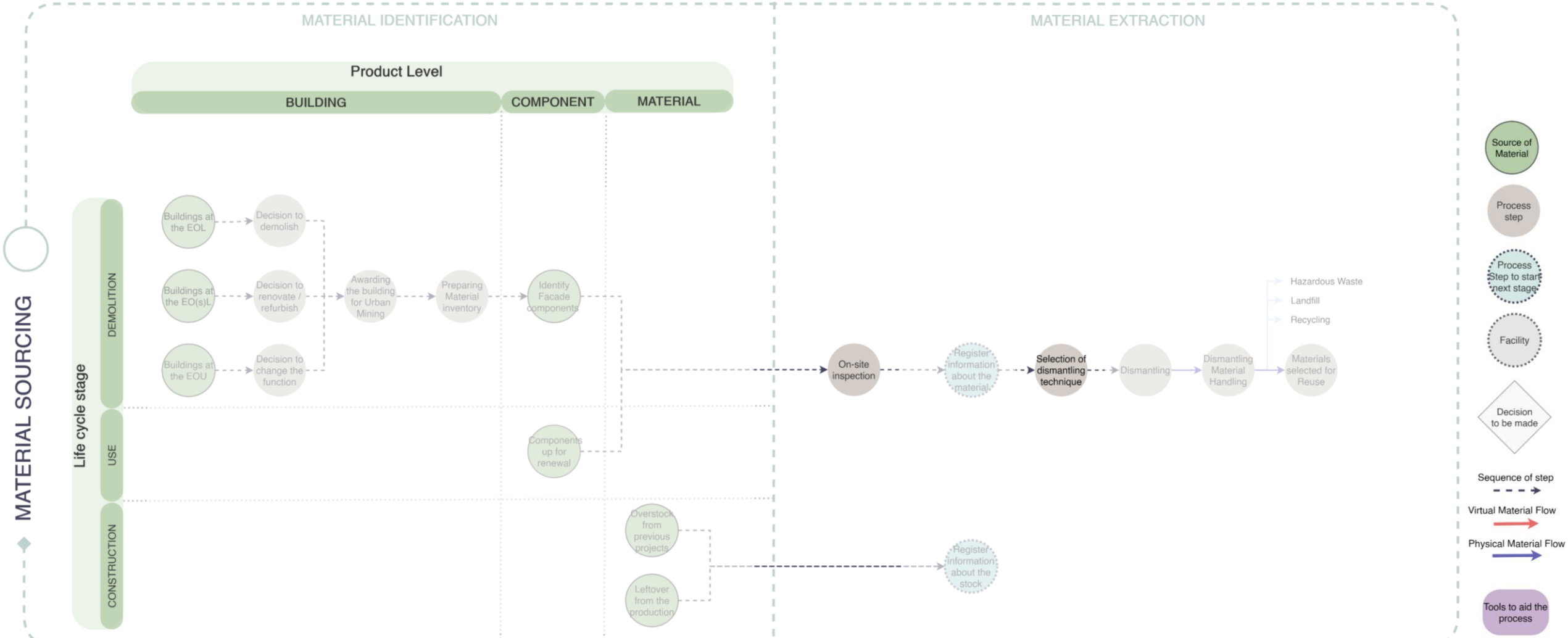
Physical Material Flow
Tools to aid the process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MATERIAL EXTRACTION
Product Level
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COMPONENT
MATERIAL
Life cycle stage
DEMOLITION
USE
CONSTRUCTION
Buildings at the EOL
Buildings at the EO(s)L
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Identify Facade components
Components up for renewal
Overstock from previous projects
Leftover from the production
On-site inspection
Register information about the material
Selection of dismantling technique
Dismantling
Dismantling Material Handling
Hazardous Waste
Landfill
Recycling
Materials selected for Reuse
Register information about the stock
Source of Material
Process step
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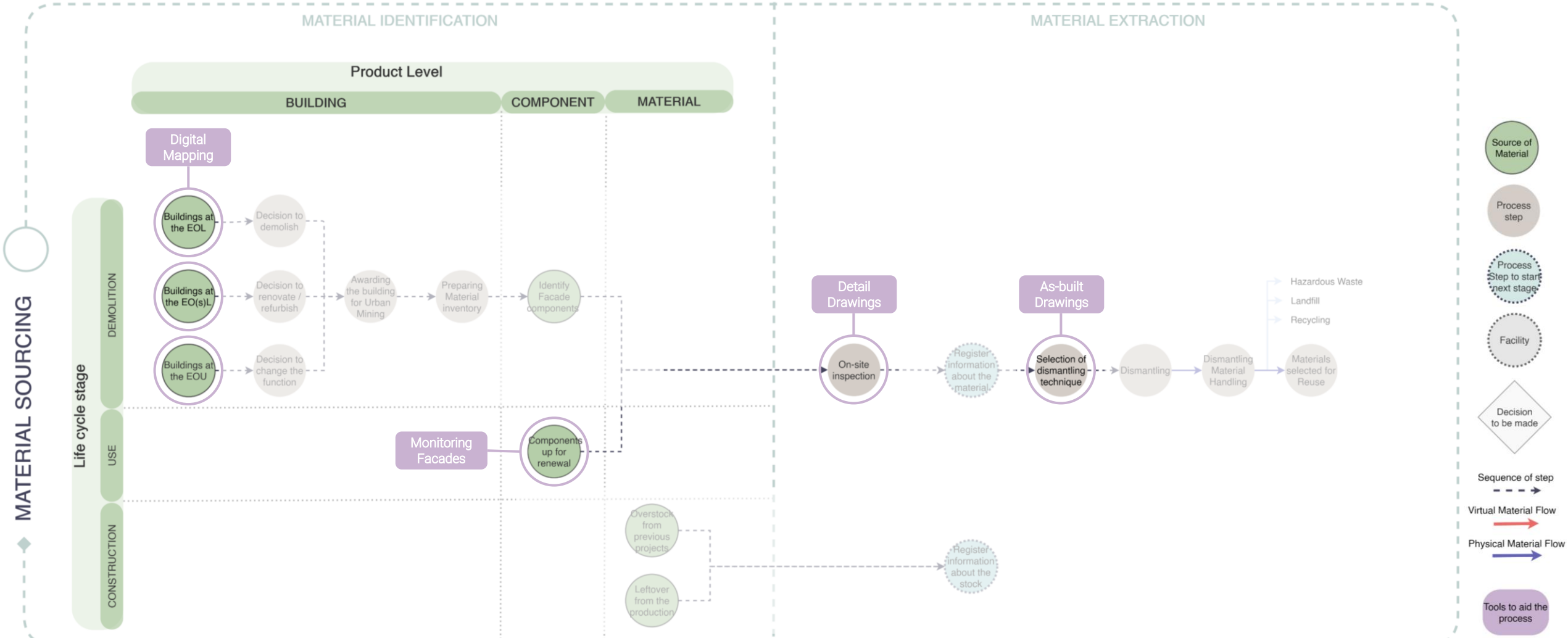
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Life cycle stage
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USE
CONSTRUCTION
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Detail Drawings
On-site inspection
Register information about the material
As-built Drawings
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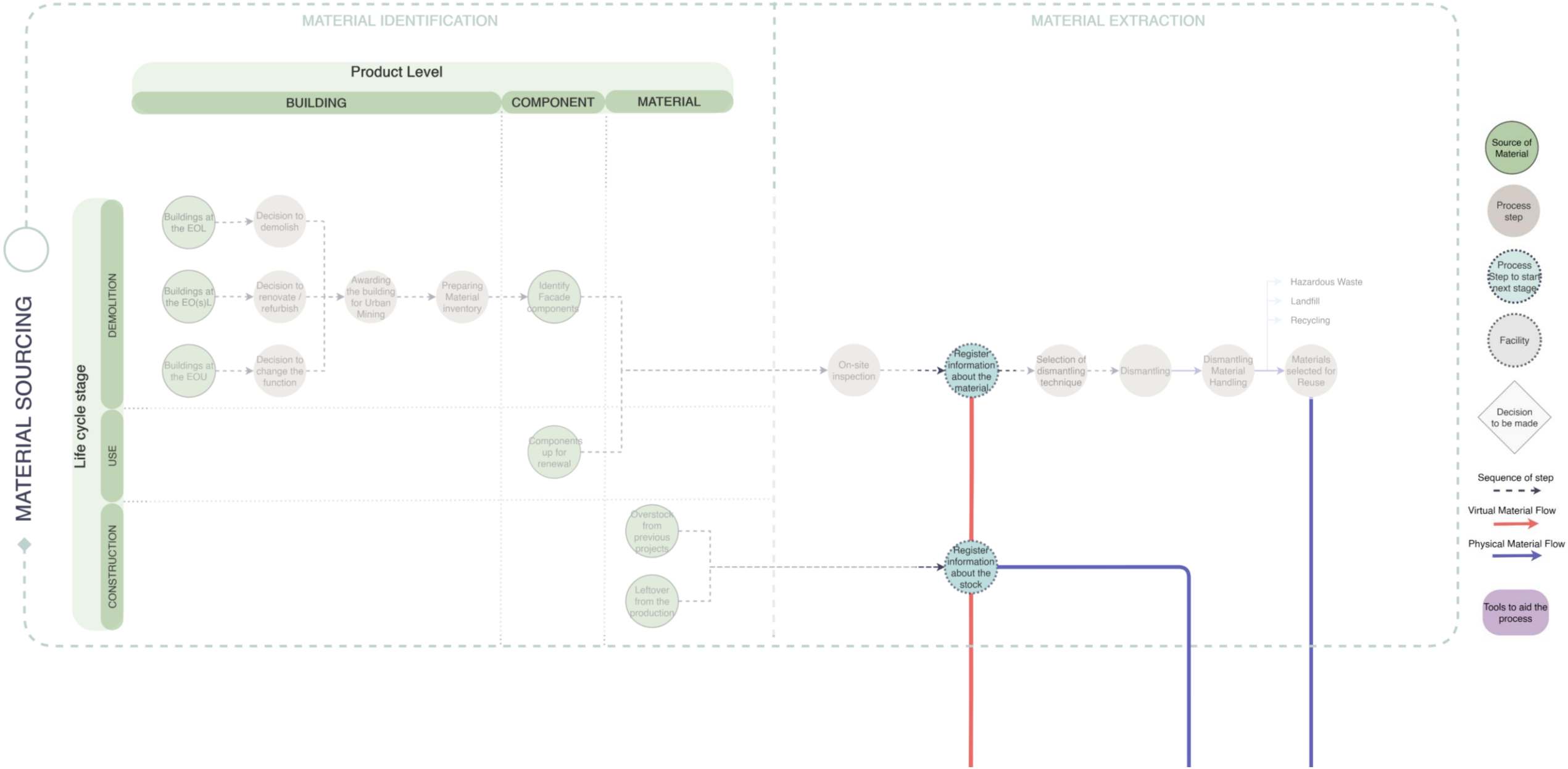
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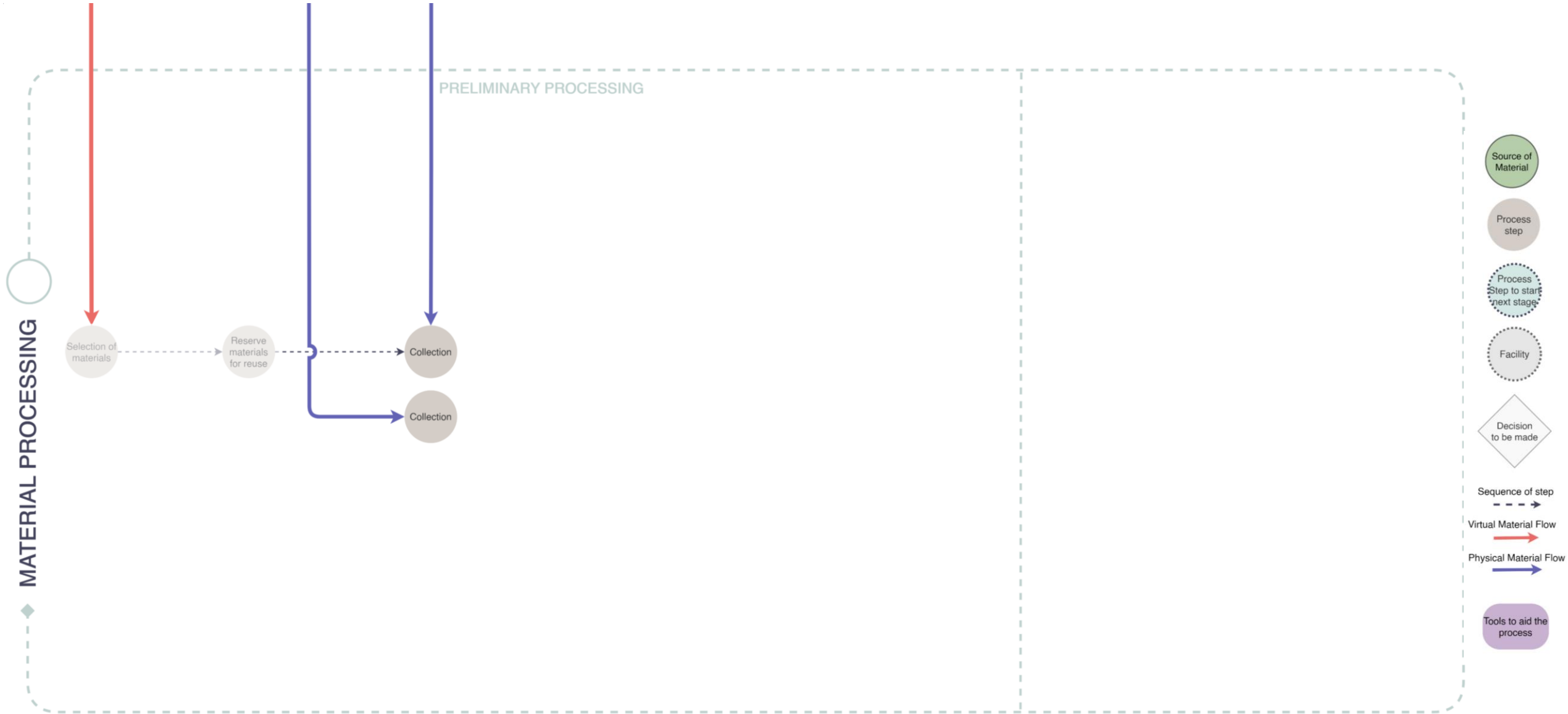
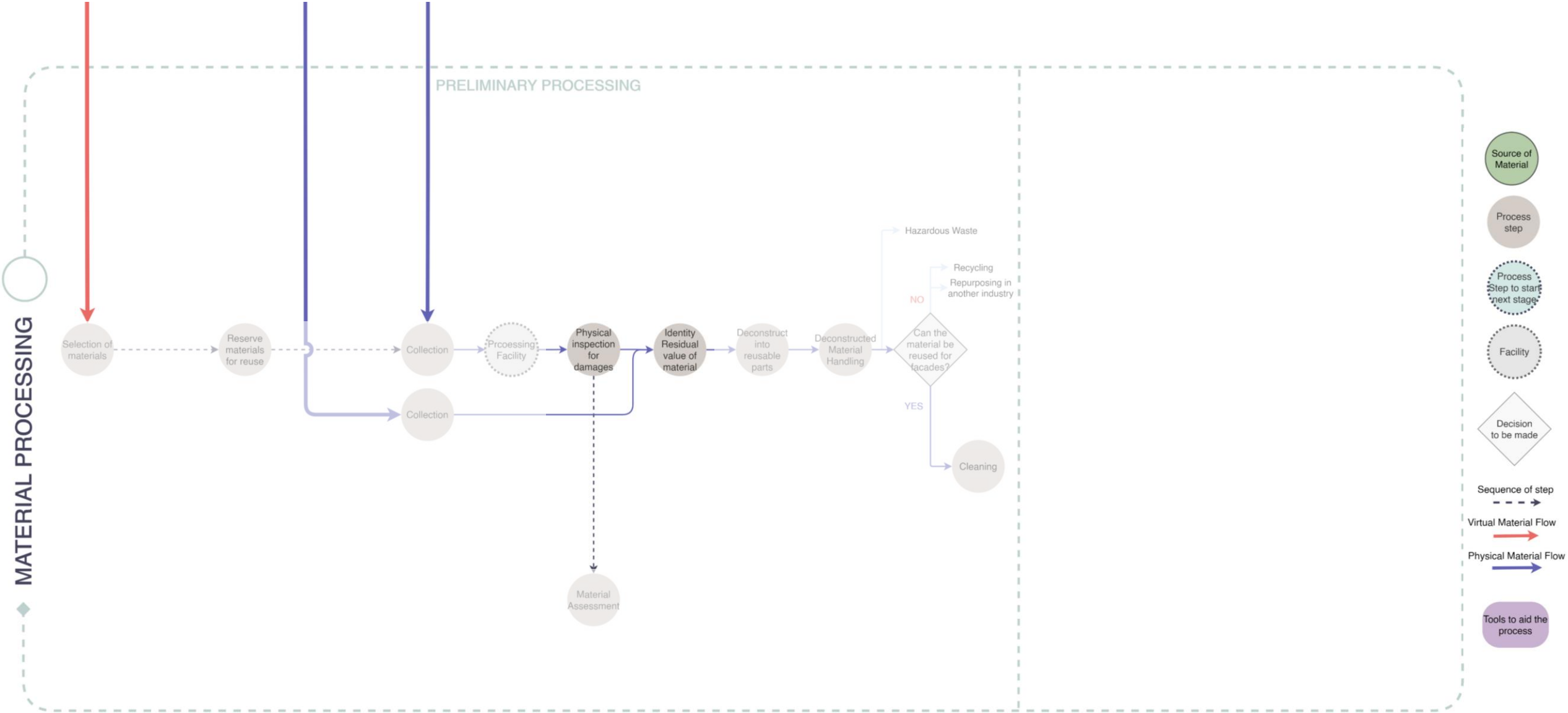
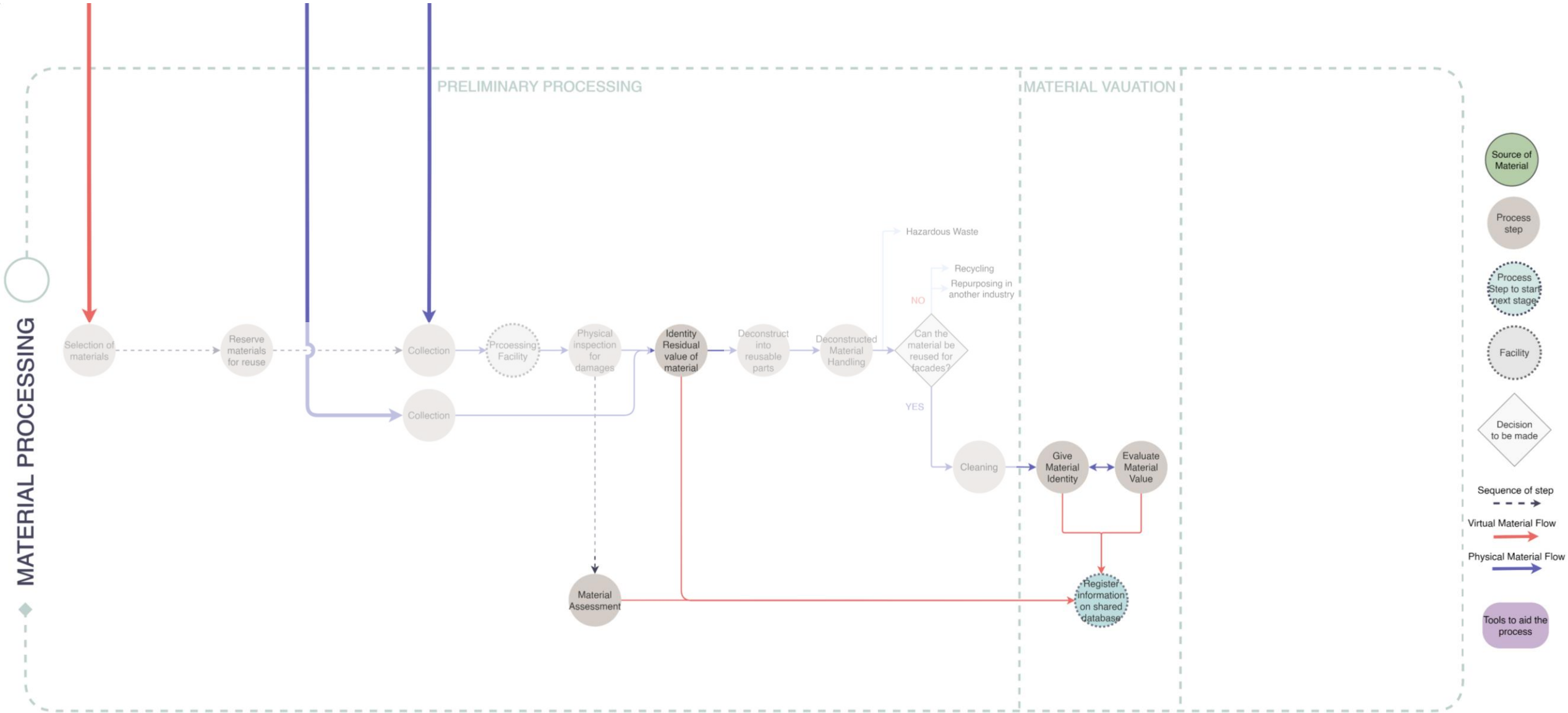
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process


MATERIAL PROCESSING
PRELIMINARY PROCESSING
Selection of materials
Reserve materials for reuse
Collection
Collection
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process


MATERIAL PROCESSING
PRELIMINARY PROCESSING
Selection of materials
Reserve materials for reuse
Collection
Collection
Prcoessing Facility
Physical inspection for damages
Identity Residual value of material
Deconstruct into reusable parts
Deconstructed Material Handling
Can the material be reused for facades?
NO
Hazardous Waste
Recycling
Repurposing in another industry
YES
Cleaning
Material Assessment
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process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Recycling
Repurposing in another industry
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YES
Cleaning
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Evaluate Material Value
Material Assessment
Register information on shared database
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
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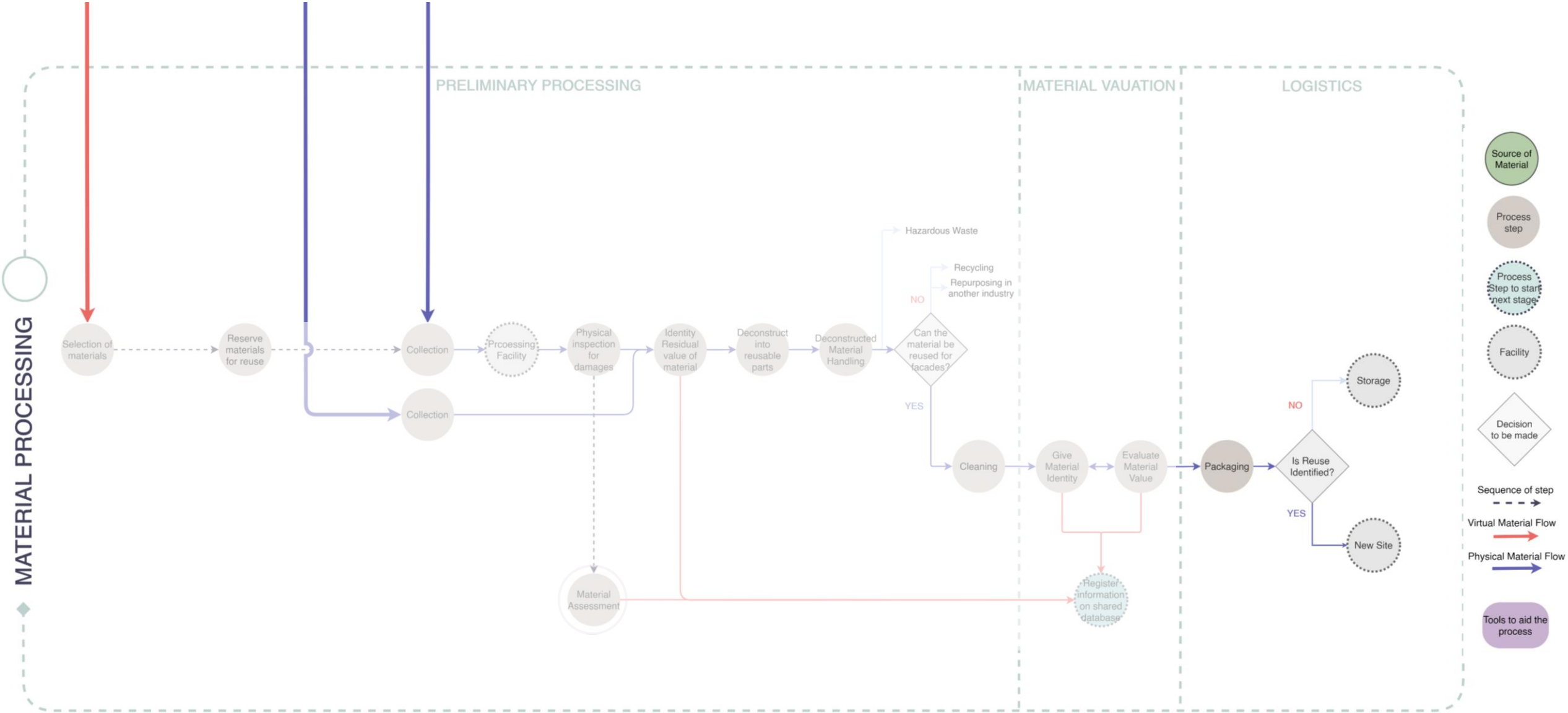
Physical Material Flow
Tools to aid the process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Packaging
Is Reuse Identified?
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Storage
New Site
Material Assessment
Register information on shared database
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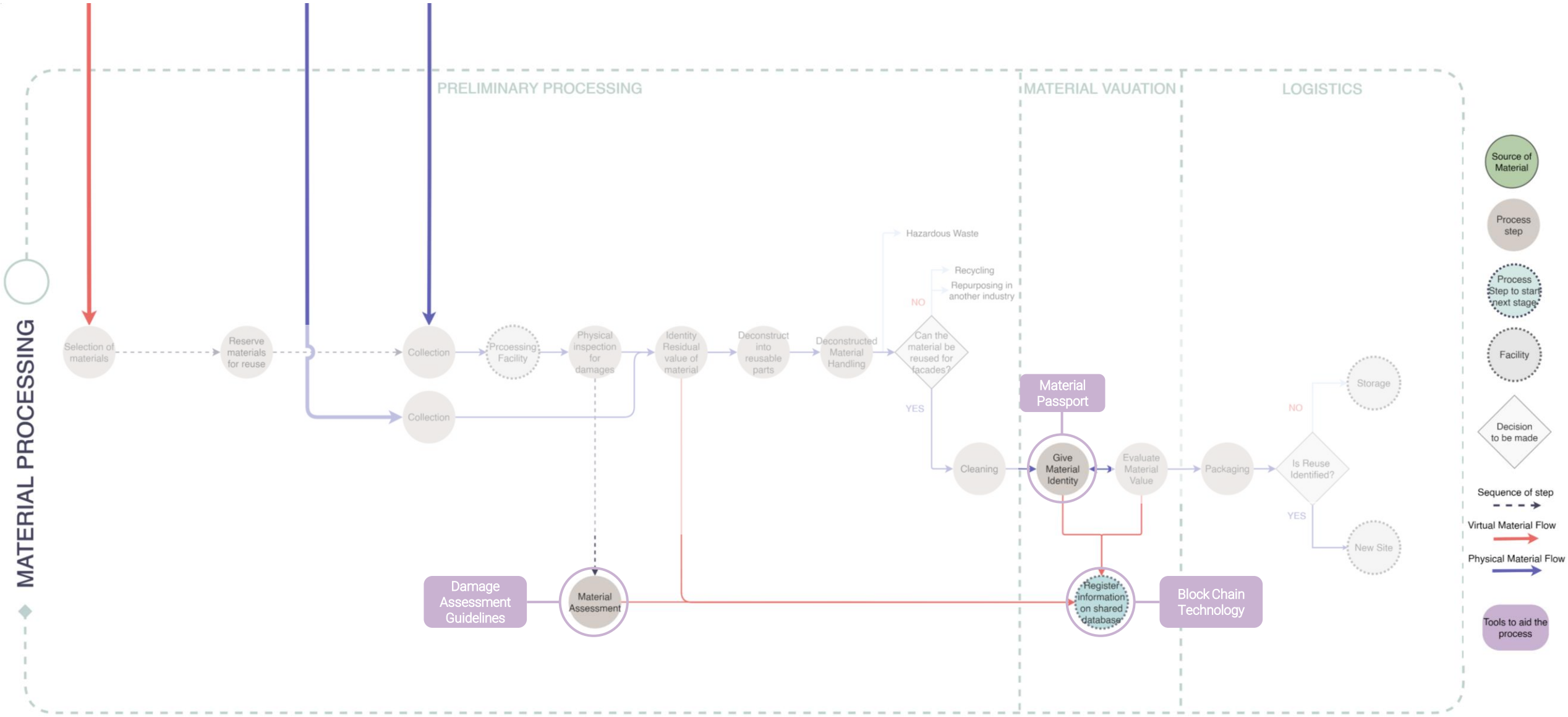
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Material Assessment
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Process step
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Facility
Decision to be made
Sequence of step
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Physical Material Flow
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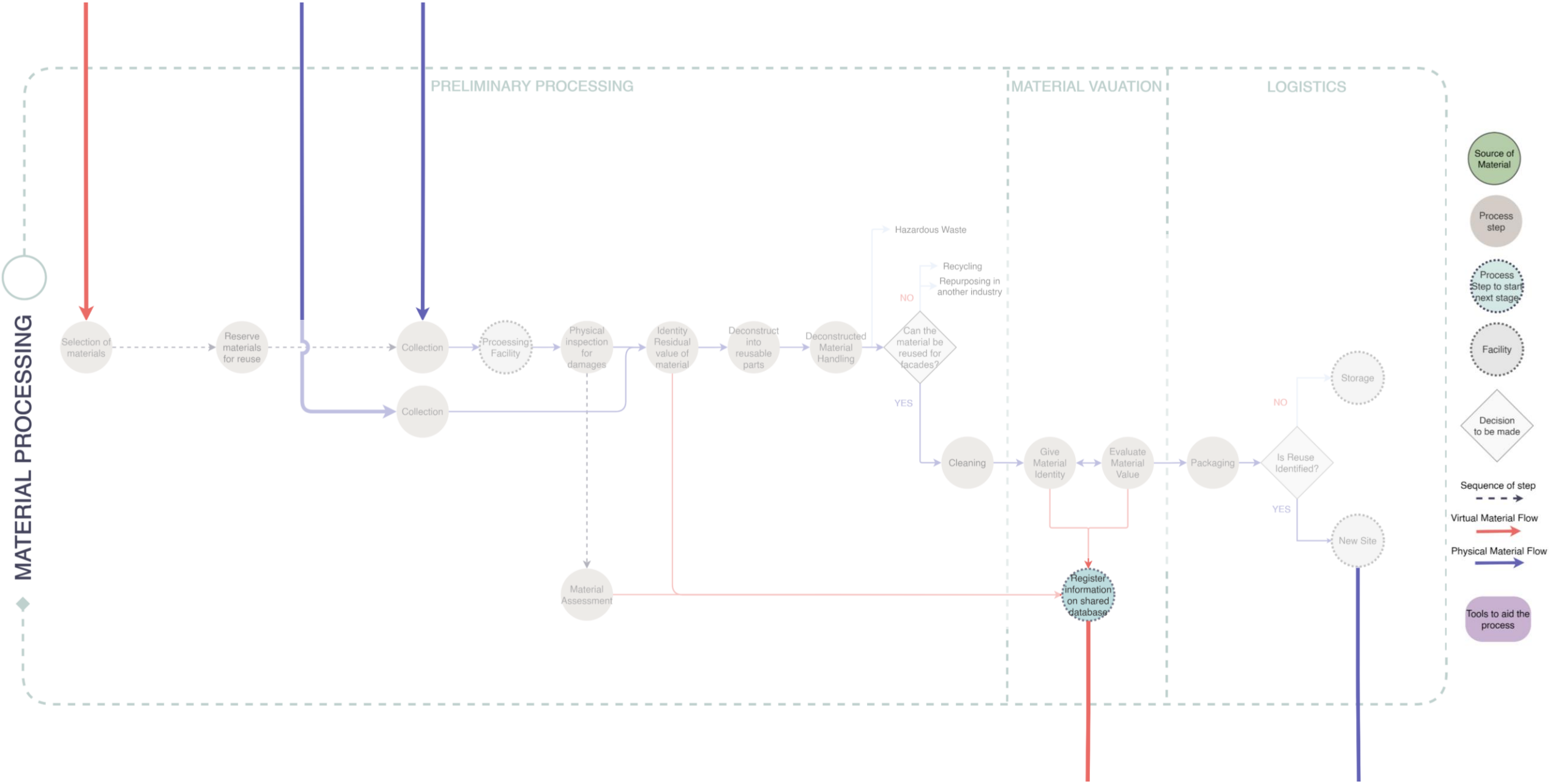
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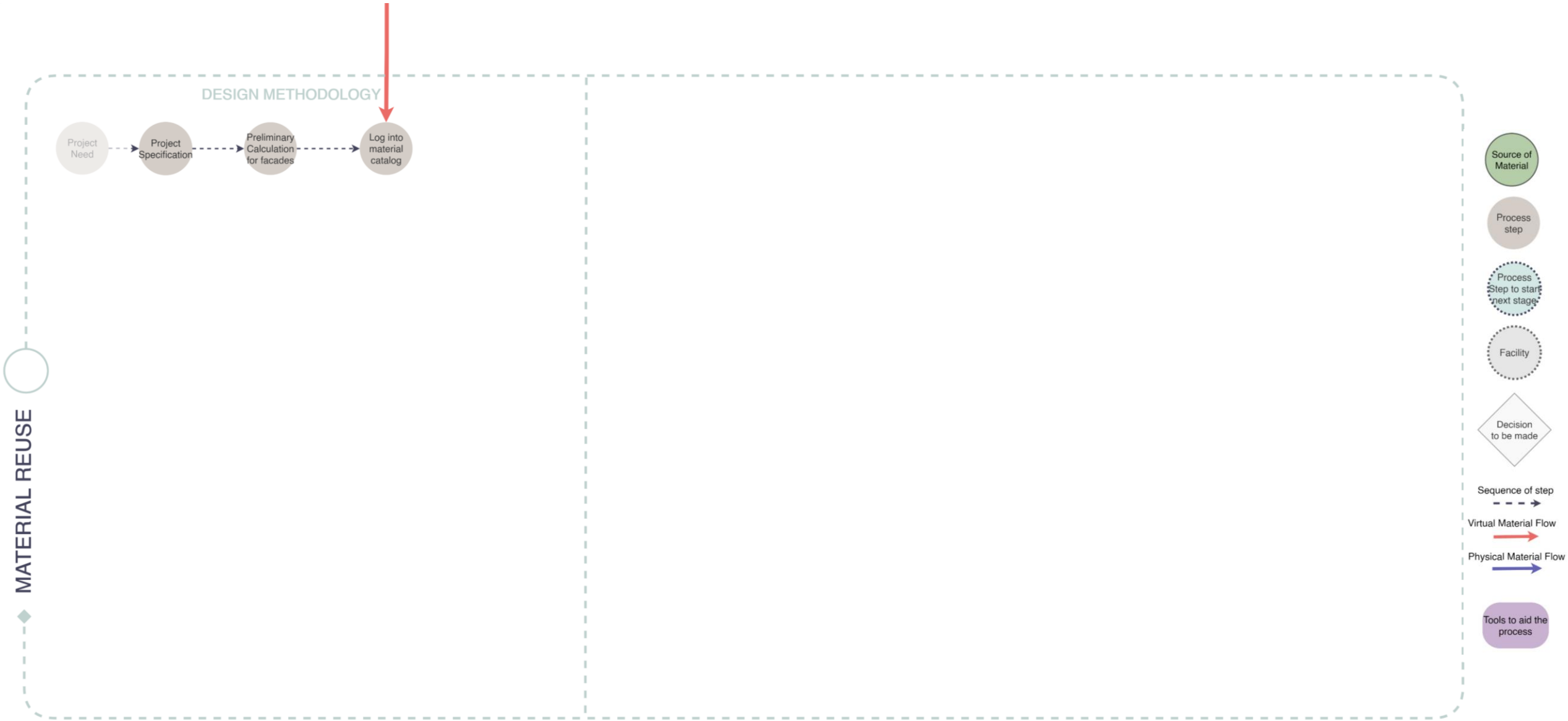
DESIGN METHODOLOGY
Project Need
Project Specification
Preliminary Calculation for facades
Log into material catalog
MATERIAL REUSE
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
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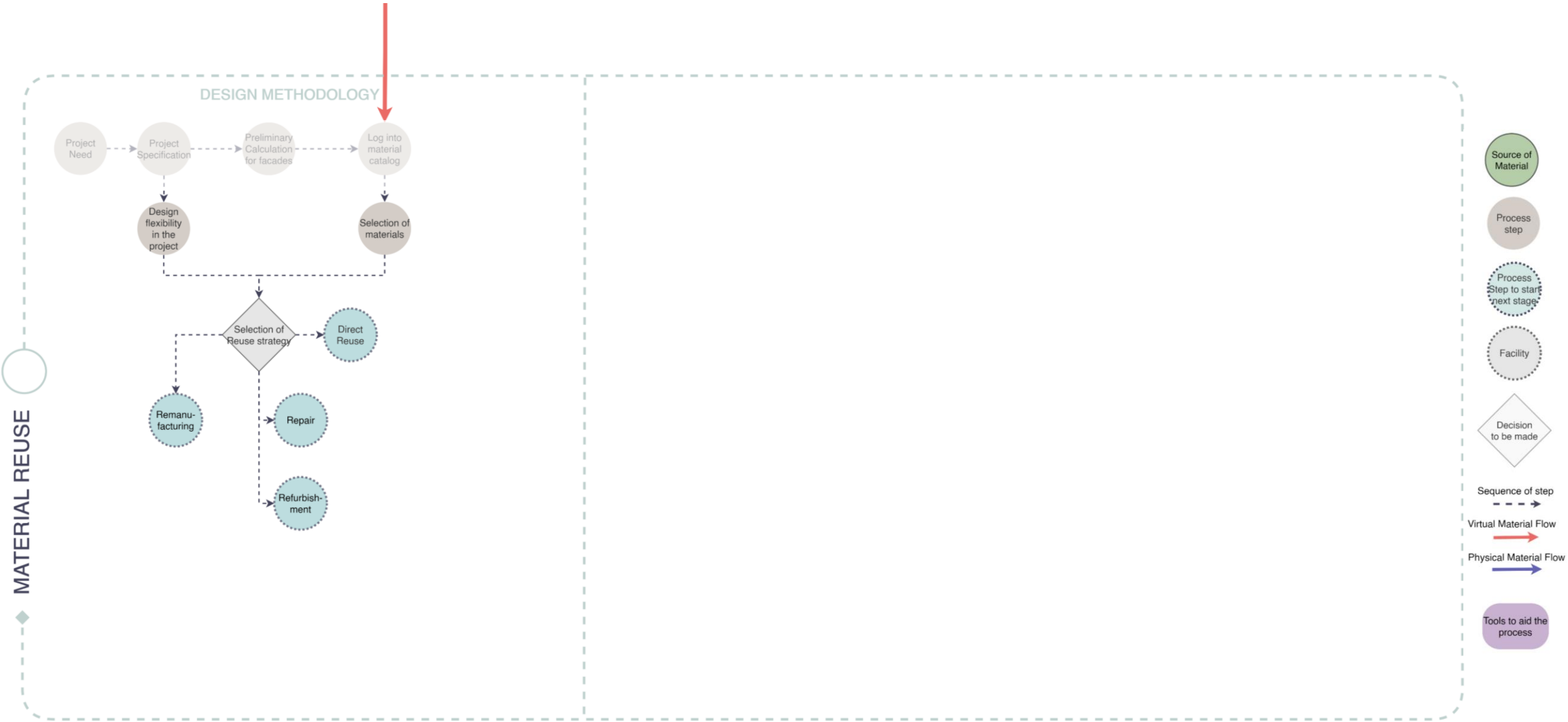
MATERIAL REUSE
DESIGN METHODOLOGY
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Preliminary Calculation for facades
Log into material catalog
Design flexibility in the project
Selection of materials
Selection of Reuse strategy
Direct Reuse
Remanu-facturing
Repair
Refurbish-ment
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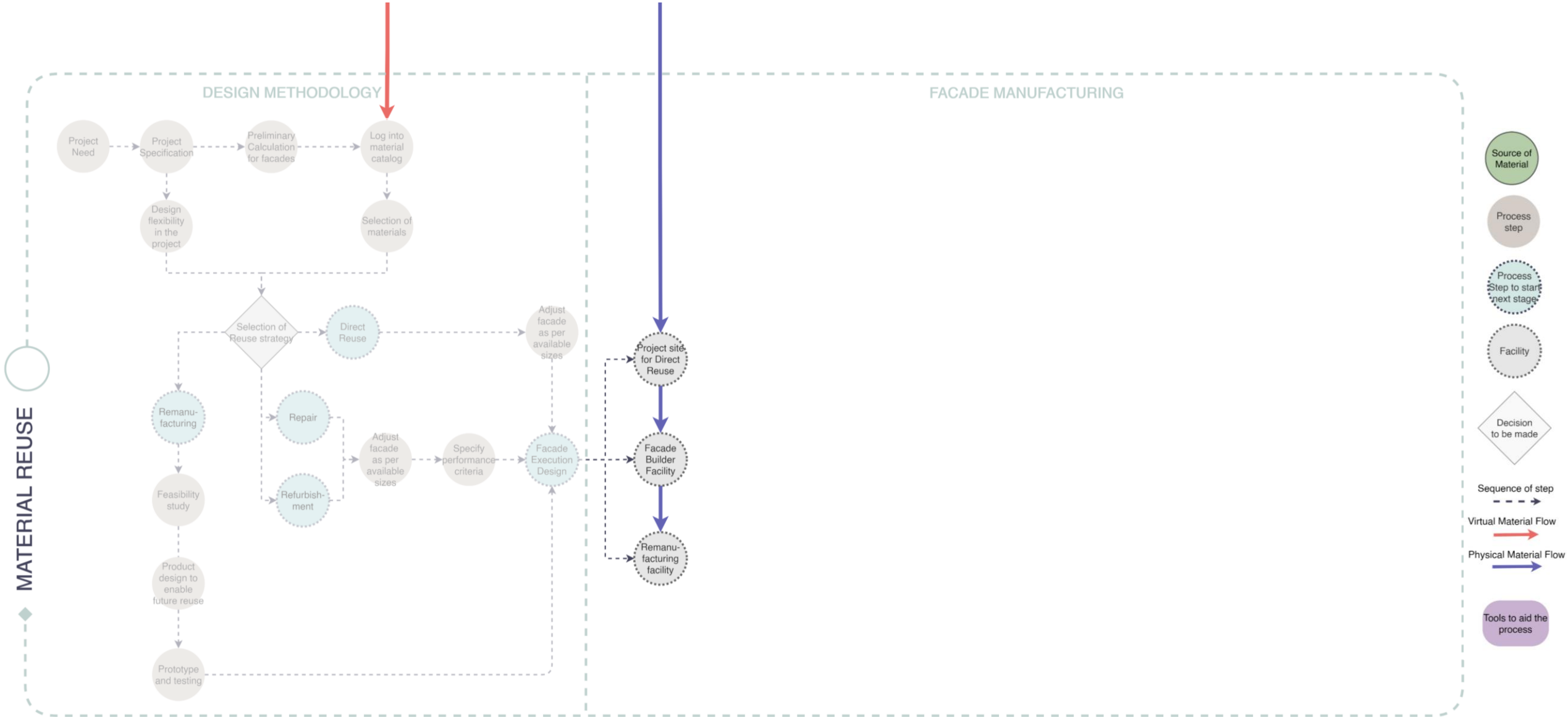
MATERIAL REUSE
DESIGN METHODOLOGY
FACADE MANUFACTURING
Project Need
Project Specification
Preliminary Calculation for facades
Log into material catalog
Design flexibility in the project
Selection of materials
Selection of Reuse strategy
Direct Reuse
Adjust facade as per available sizes
Remanu-facturing
Repair
Adjust facade as per available sizes
Specify performance criteria
Facade Execution Design
Feasibility study
Refurbish-ment
Product design to enable future reuse
Prototype and testing
Project site for Direct Reuse
Facade Builder Facility
Remanu-facturing facility
Source of Material
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Process Step to start next stage
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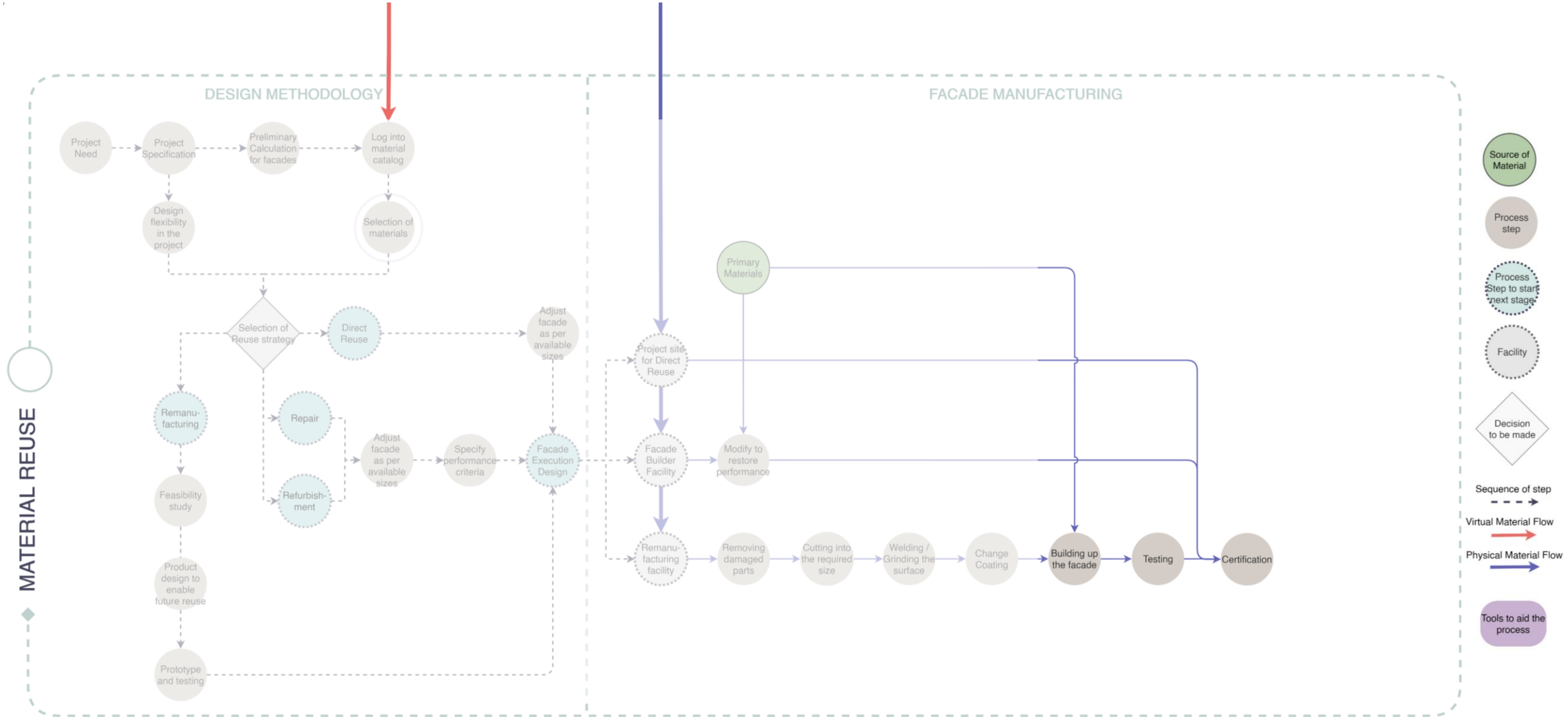
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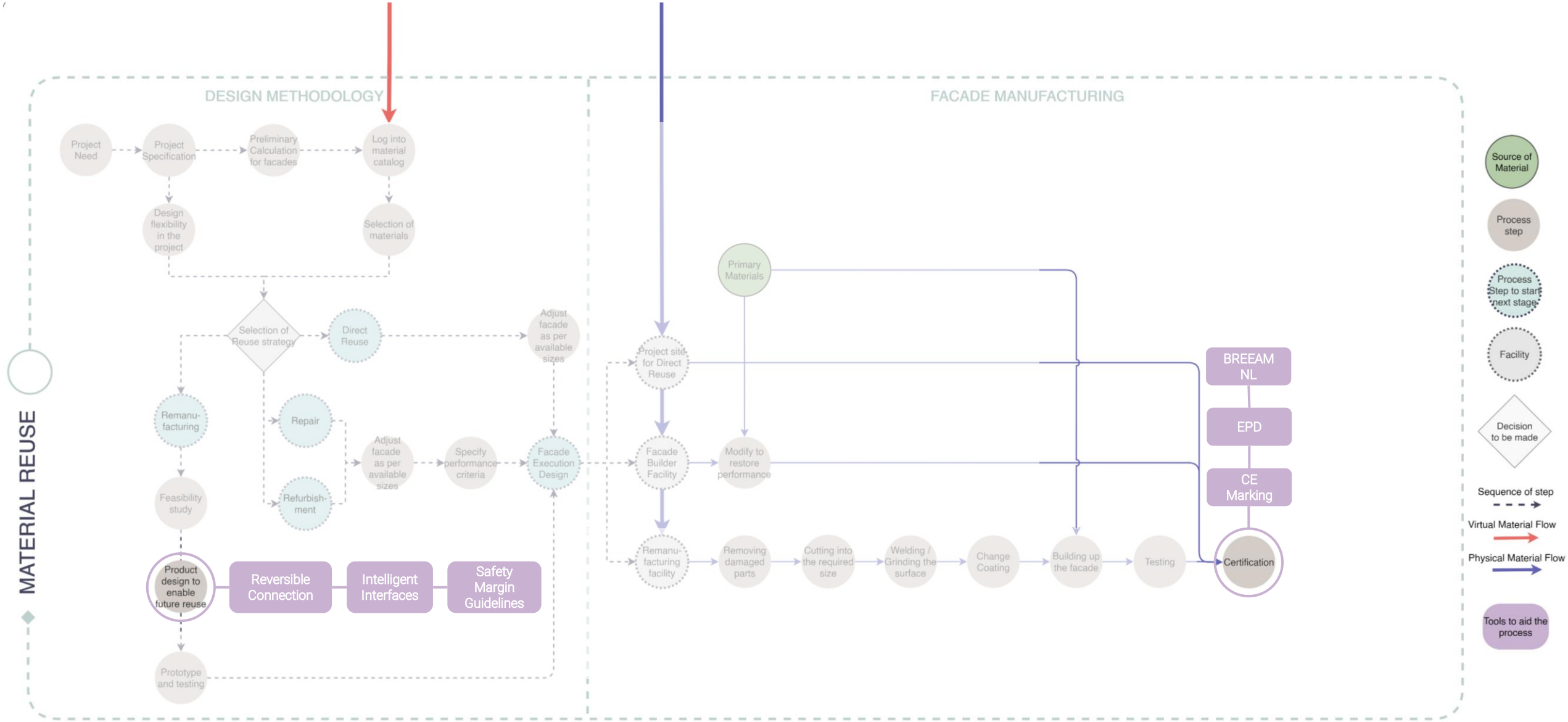
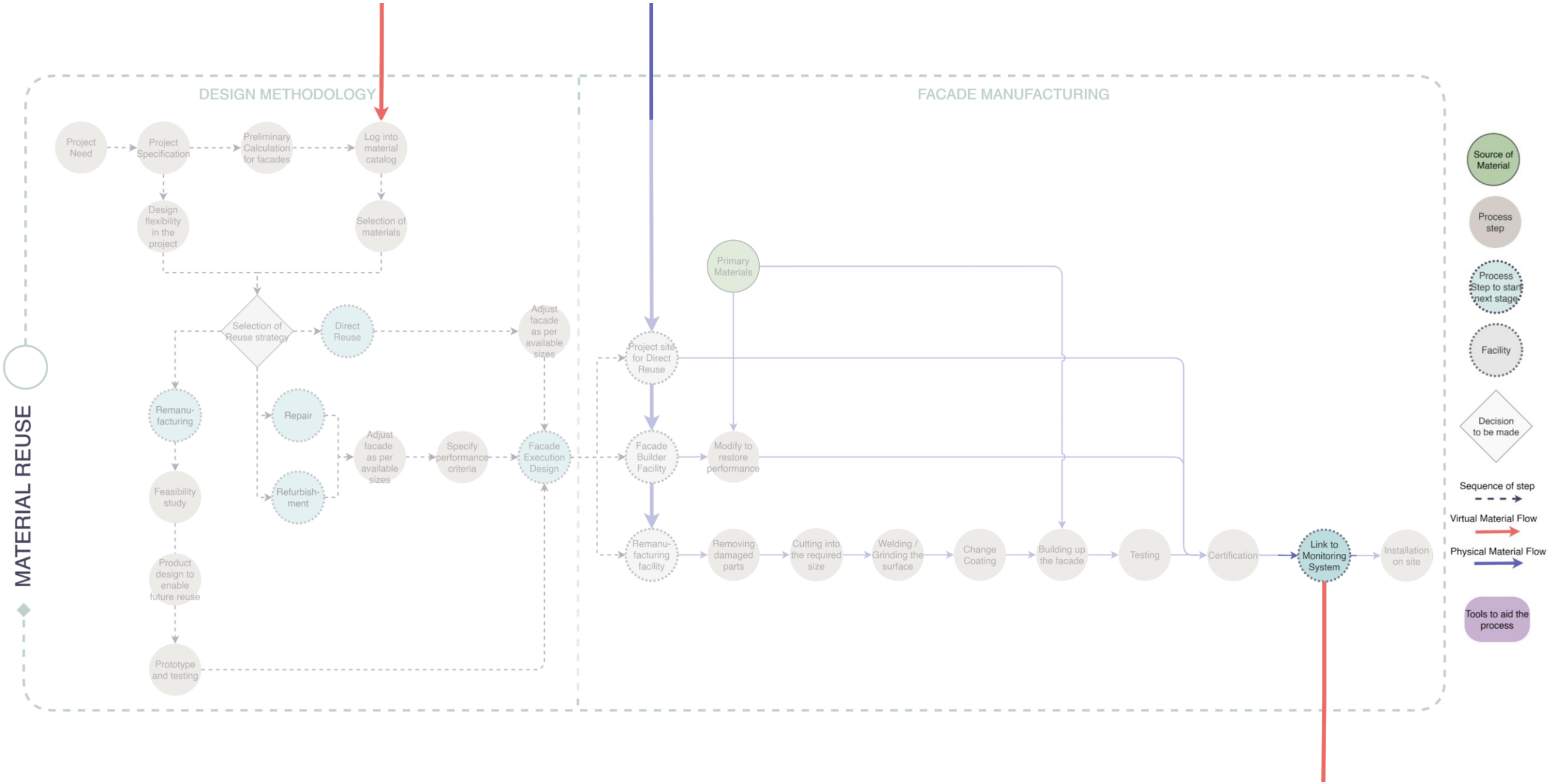
Repair
Adjust facade as per available sizes
Specify performance criteria
Facade Execution Design
Feasibility study
Refurbish-ment
Product design to enable future reuse
Prototype and testing
Primary Materials
Project site for Direct Reuse
Facade Builder Facility
Modify to restore performance
Remanu-facturing facility
Removing damaged parts
Cutting into the required size
Welding / Grinding the surface
Change Coating
Building up the facade
Testing
Certification
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process


MATERIAL REUSE
DESIGN METHODOLOGY
Project Need
Project Specification
Preliminary Calculation for facades
Log into material catalog
Design flexibility in the project
Selection of materials
Selection of Reuse strategy
Direct Reuse
Adjust facade as per available sizes
Remanu-facturing
Repair
Adjust facade as per available sizes
Specify performance criteria
Facade Execution Design
Feasibility study
Refurbish-ment
Product design to enable future reuse
Reversible Connection
Intelligent Interfaces
Safety Margin Guidelines
Prototype and testing
FACADE MANUFACTURING
Primary Materials
Project site for Direct Reuse
Facade Builder Facility
Modify to restore performance
Remanu-facturing facility
Removing damaged parts
Cutting into the required size
Welding / Grinding the surface
Change Coating
Building up the facade
Testing
Certification
BREEAM NL
EPD
CE Marking
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process


MATERIAL REUSE
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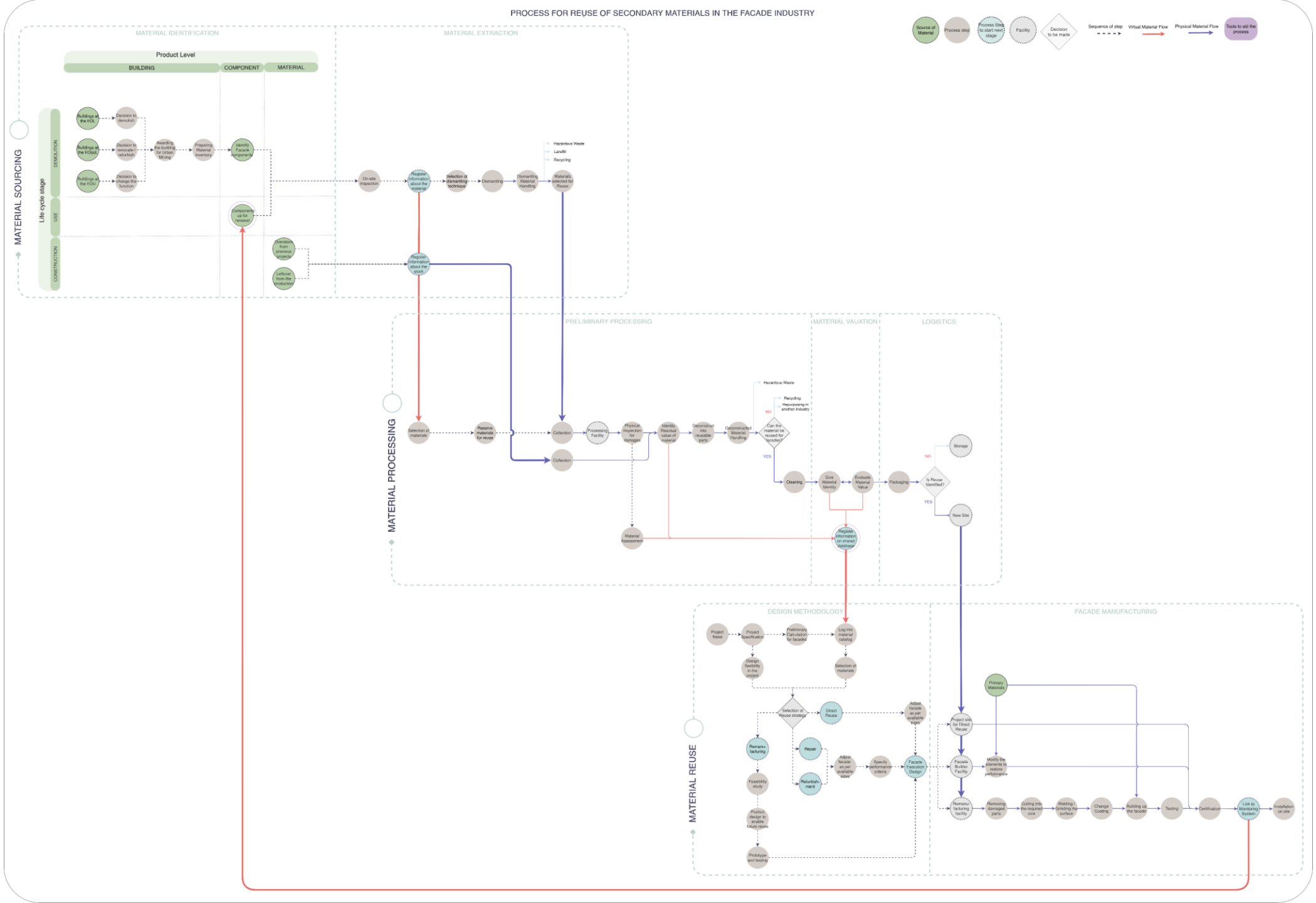
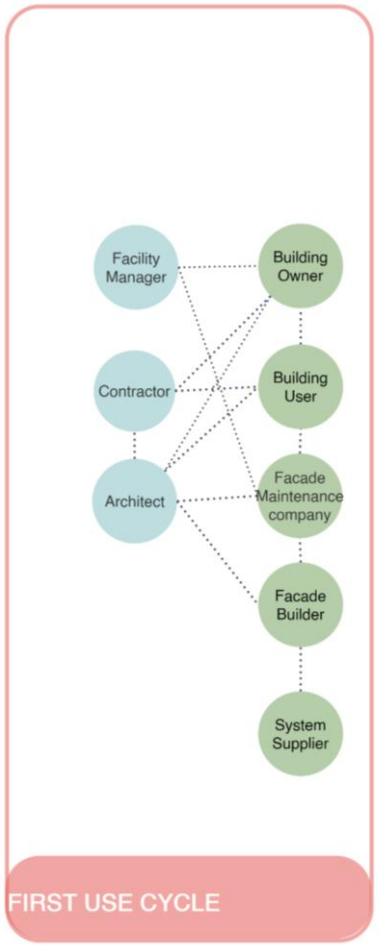
Building up the facade
Testing
Certification
Link to Monitoring System
Installation on site
Source of Material
Process step
Process Step to start next stage
Facility
Decision to be made
Sequence of step
Virtual Material Flow
Physical Material Flow
Tools to aid the process


PROCESS FOR REUSE OF SECONDARY MATERIALS IN THE FACADE INDUSTRY
MATERIAL IDENTIFICATION
MATERIAL EXTRACTION
Product Level
BUILDING
COMPONENT
MATERIAL
MATERIAL SOURCING
Life cycle stage
DEMOLITION
USE
CONSTRUCTION
PRELIMINARY PROCESSING
MATERIAL VAUATION
LOGISTICS
MATERIAL PROCESSING
DESIGN METHODOLOGY
FACADE MANUFACTURING
MATERIAL REUSE

Who all are required to support the reuse process?

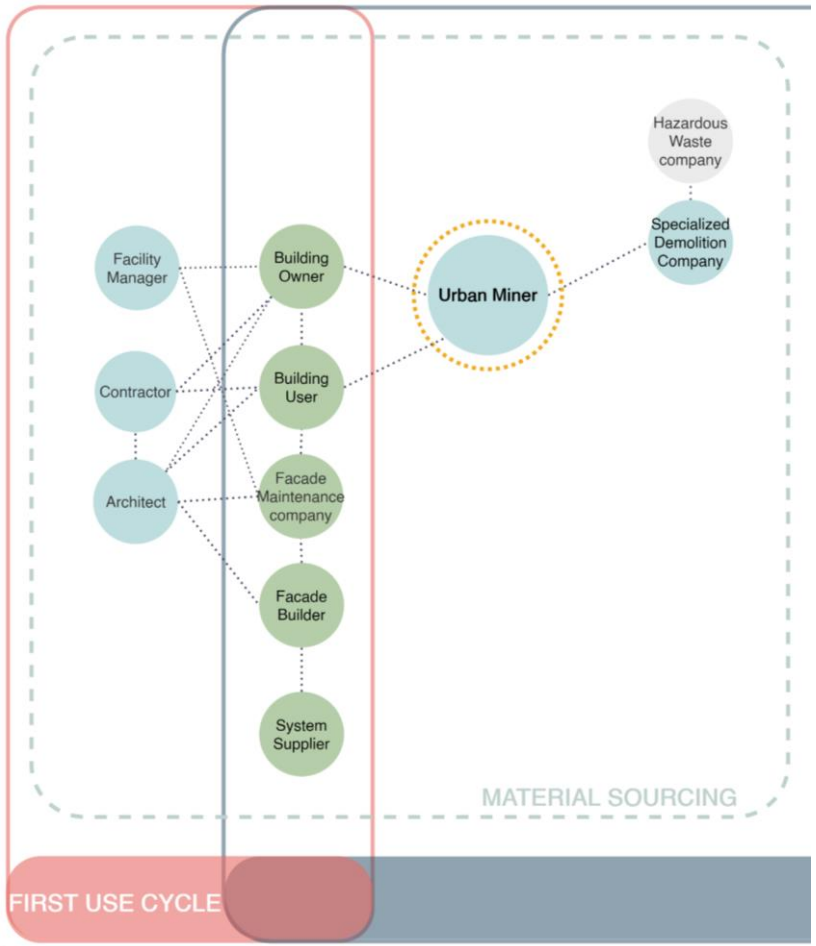
Stakeholders to support the Reuse Process

Start of cycle | Primary | Secondary | Regulatory | New Role



Stakeholders to support the Reuse Process

Start of cycle | Primary | Secondary | Regulatory | New Role



Stakeholders to support the Reuse Process

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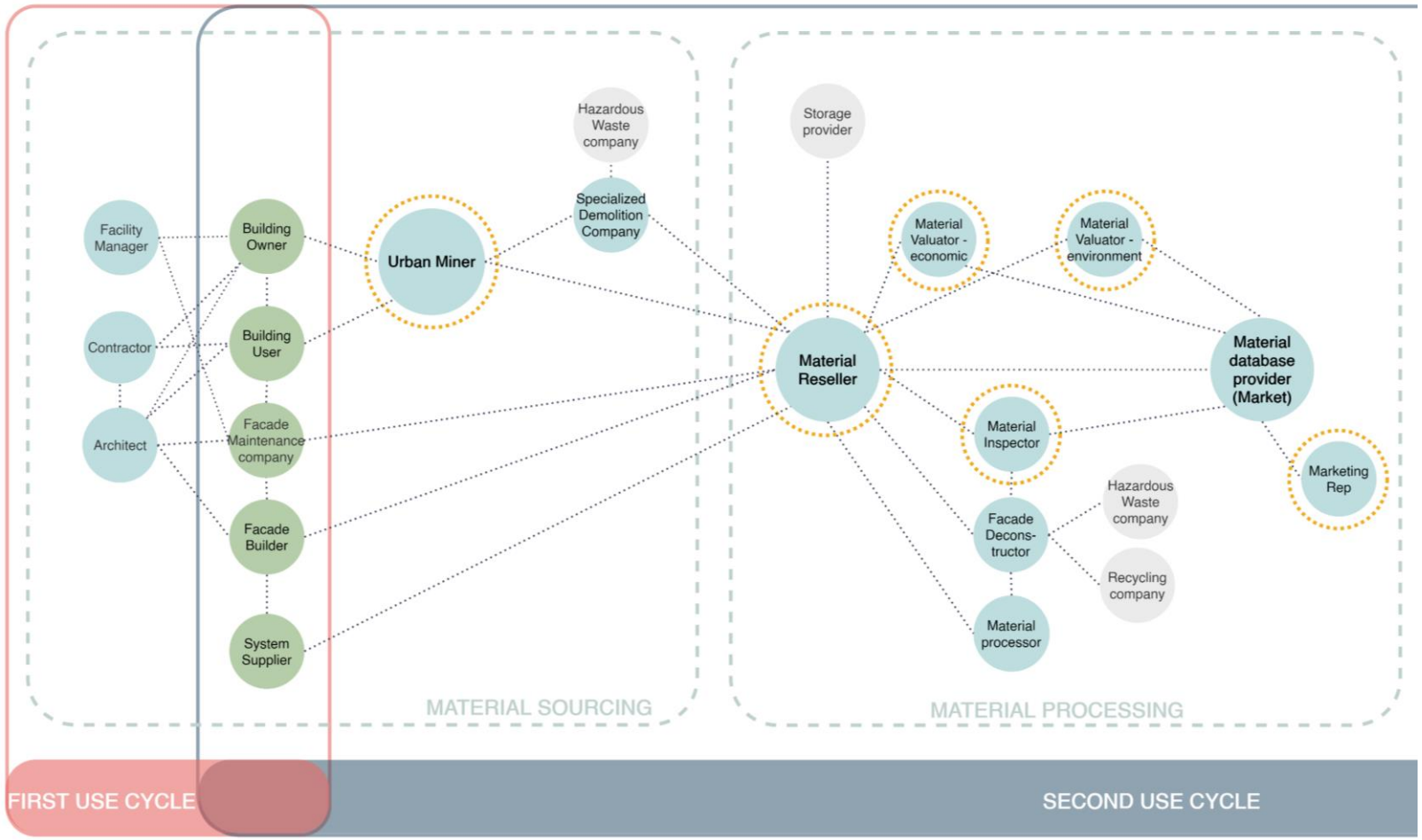

Stakeholders to support the Reuse Process

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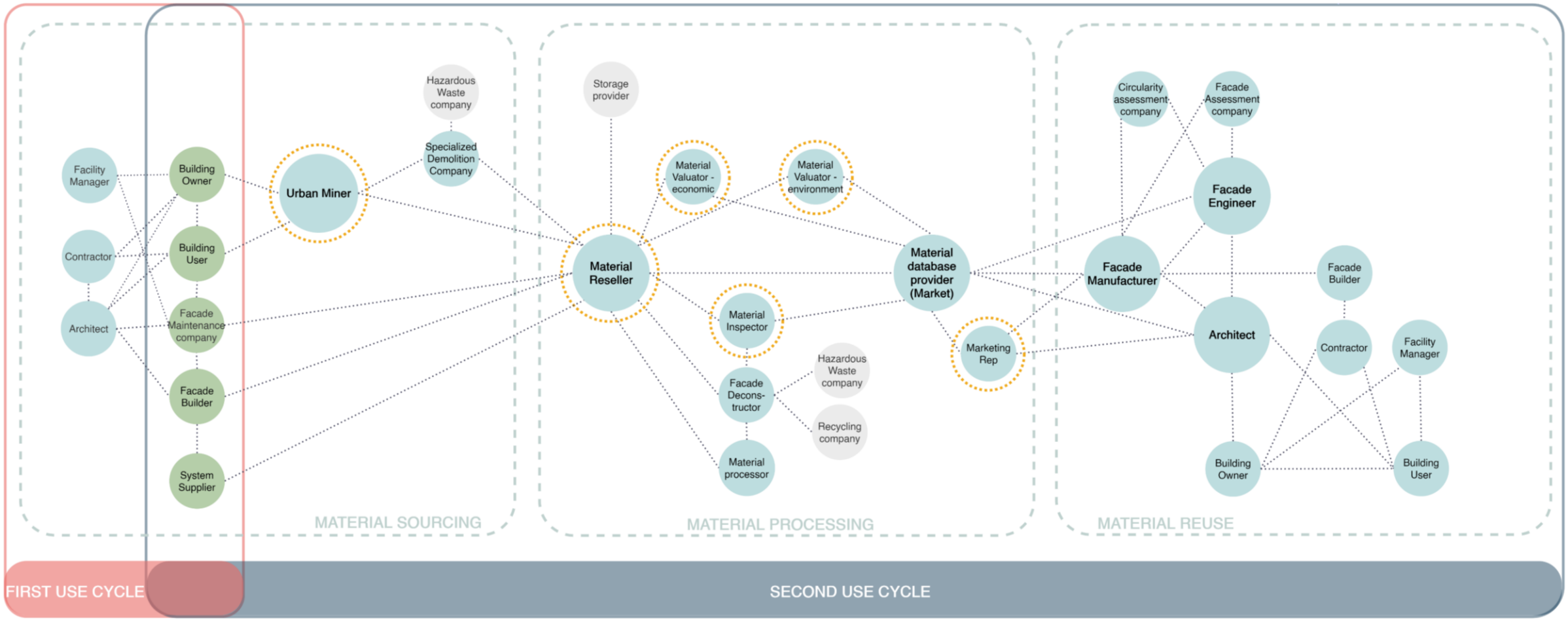
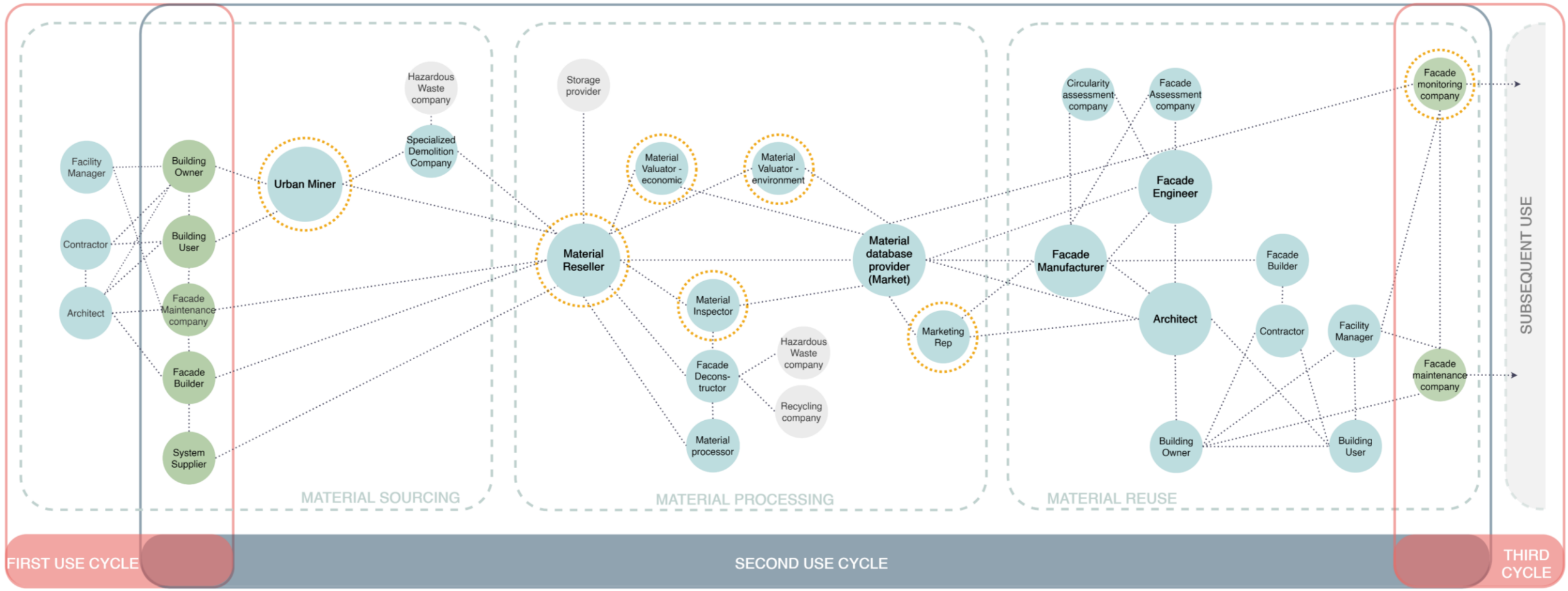
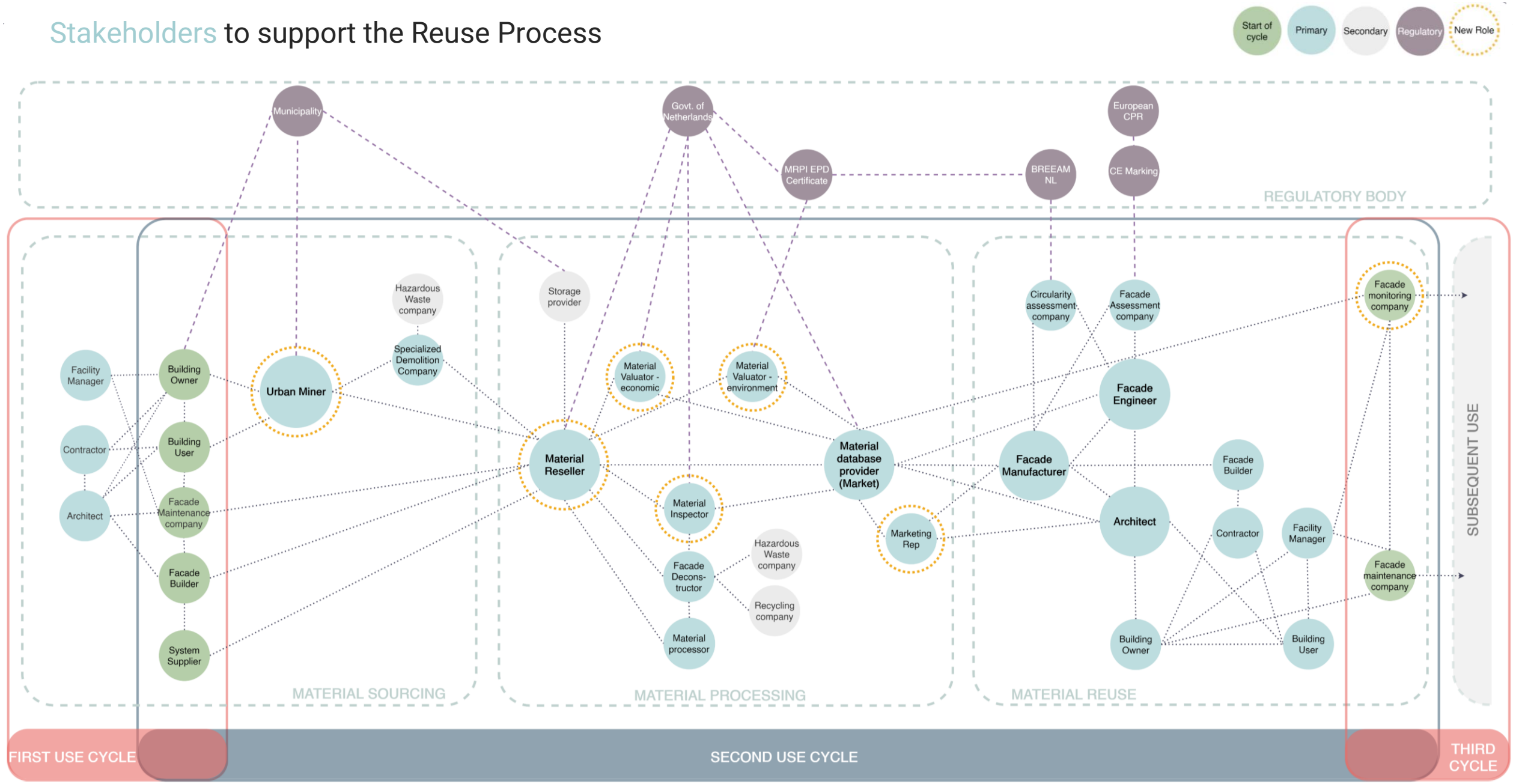


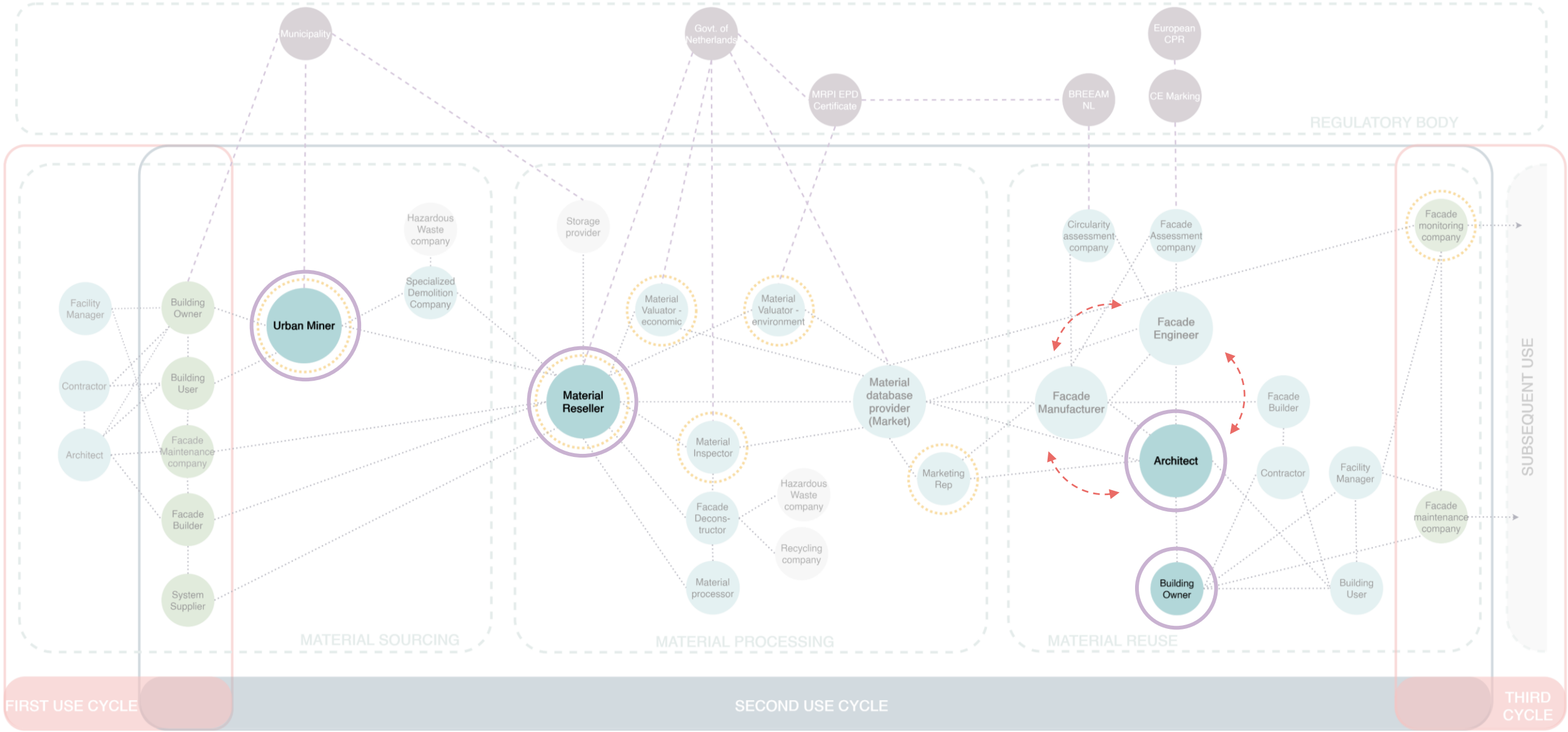
Stakeholders to support the Reuse Process



Stakeholders to support the Reuse Process



Current Market Scenario



Market Challenges and Opportunities

Cost of material

Cost of material handling

Small Scale

Labor Intensive

Ownership

Regulating Cost

Scaling Up

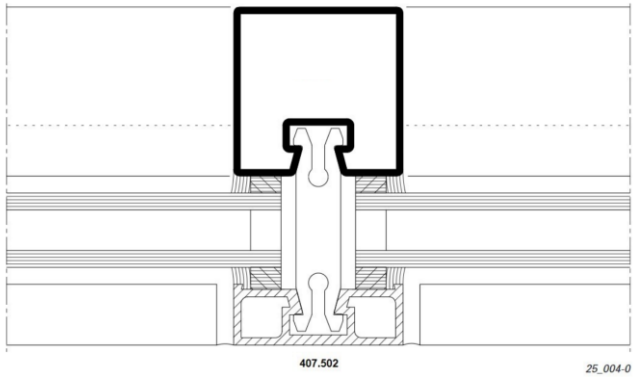
Job Opportunities

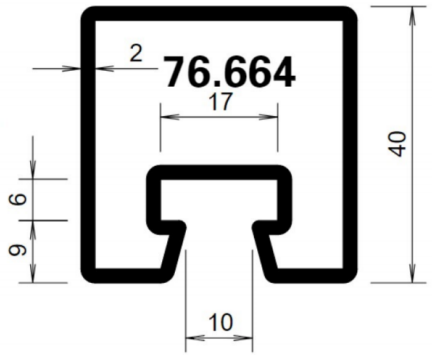
New Business Model

What does it mean for Design?

Scenario 1: Reuse of Construction Stream

- Profiles are not suitable for the new loading condition





Construction Stage

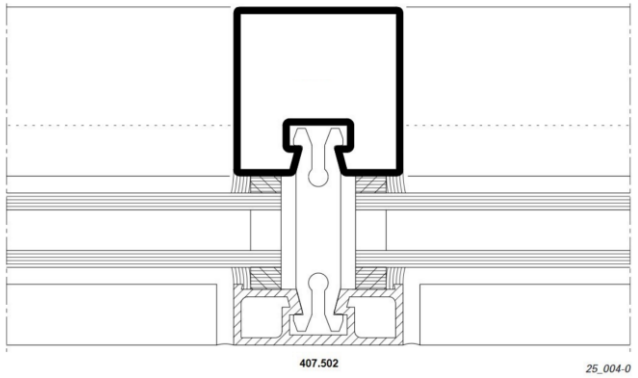
Standard Material

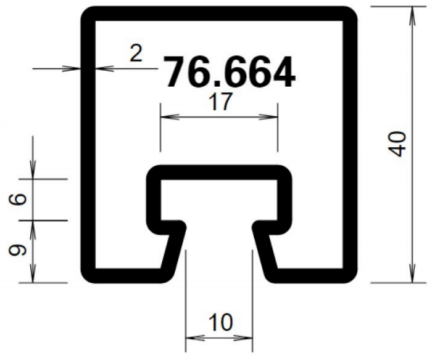
No extraction required

Use Phase never started

Scenario 1: Reuse of Construction Stream

- Strengthening the mullion
- Indirect connection through a bolt



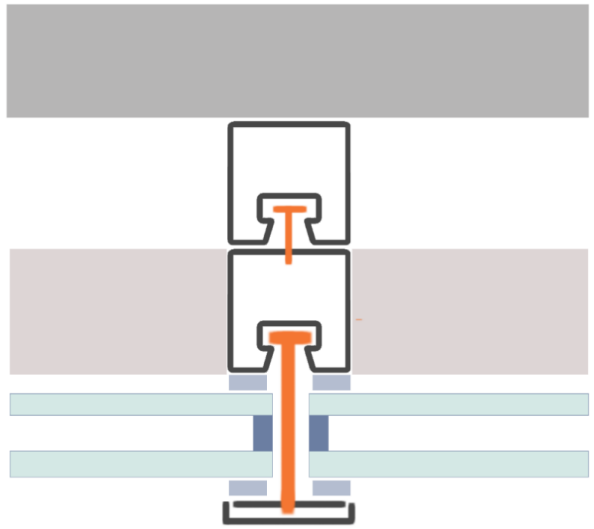


Construction Stage

Standard Material

No extraction required

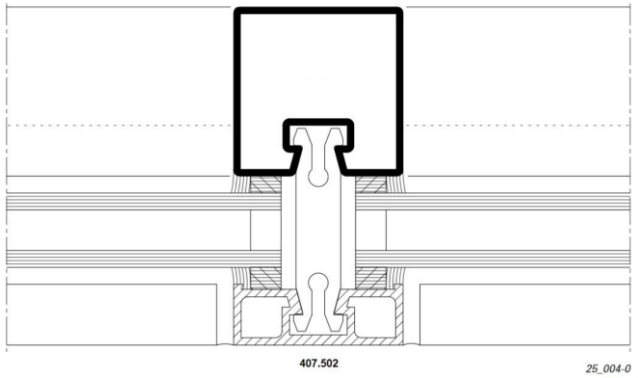
Use Phase never started

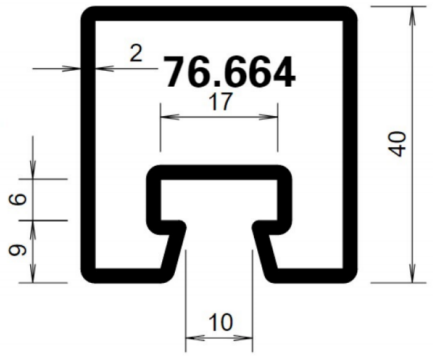


Plan

Scenario 1: Reuse of Construction Stream

- Strengthening the mullion
- Indirect connection through a bolt





Construction Stage

Standard Material

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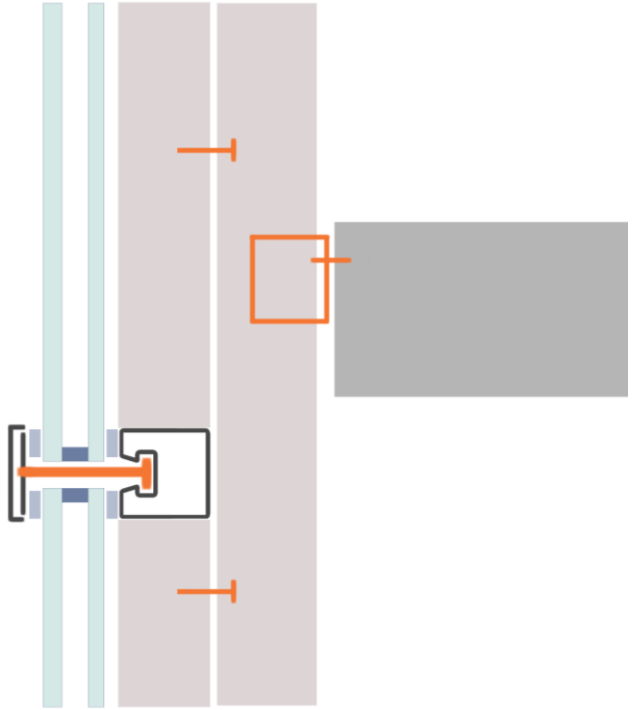
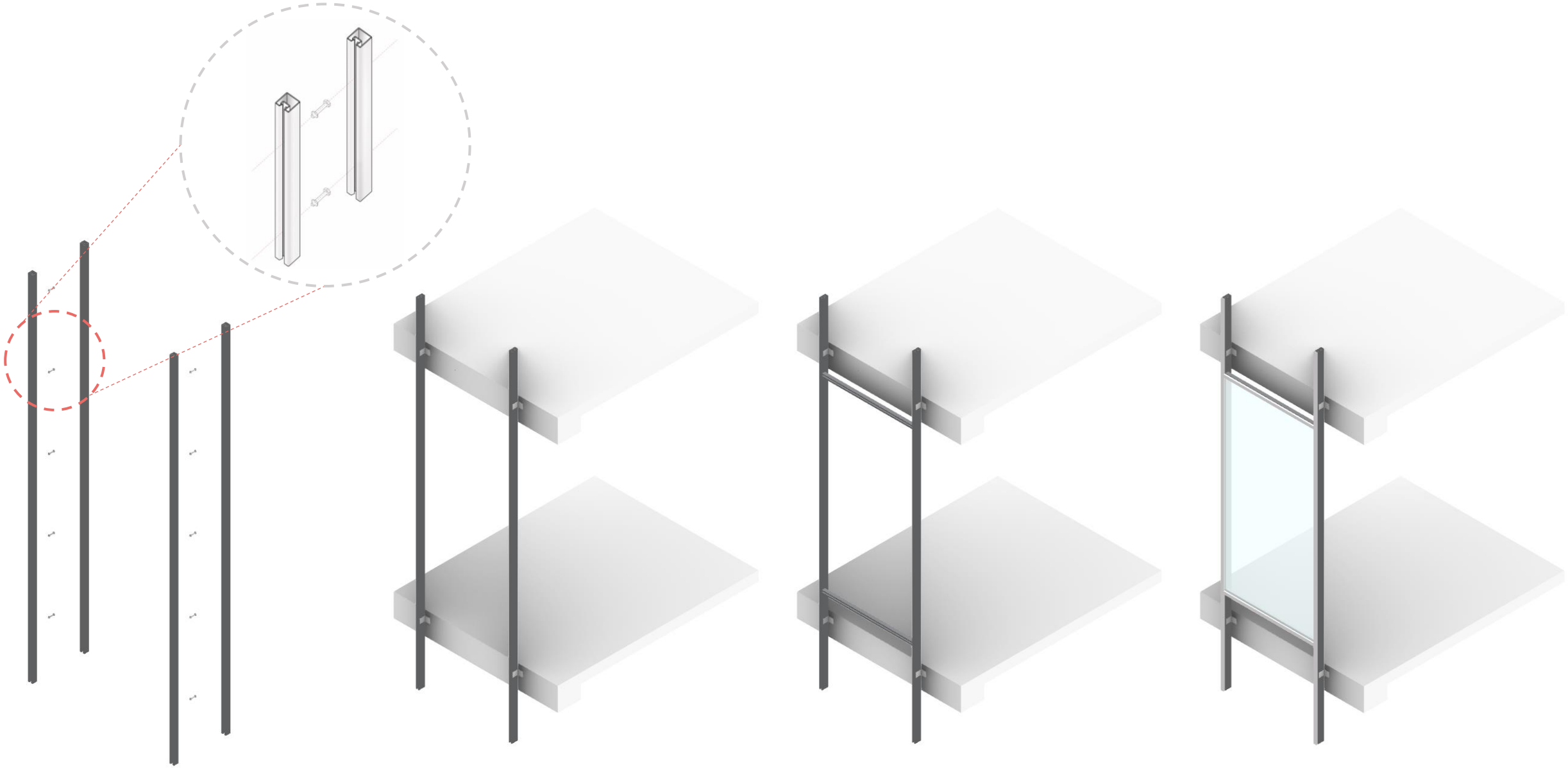


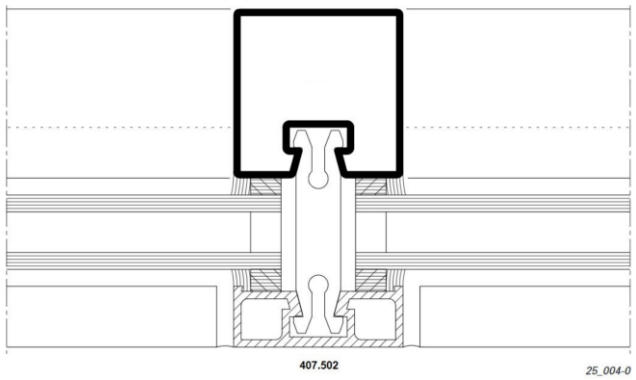
Section

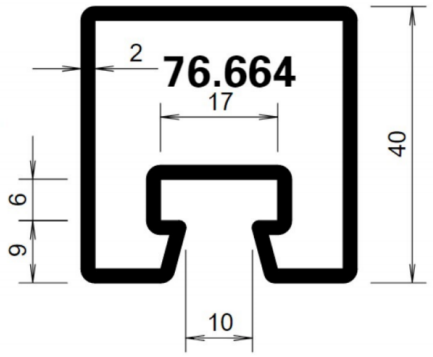
Scenario 1: Reuse of Construction Stream



Scenario 2: Reuse of Demolition Stream

- Smaller profile lengths due to damaged ends of steel mullions
- Material loss during dismantling of aluminum cover caps and pressure plates
- Inadequate performance of glazing unit





Demolition Stage

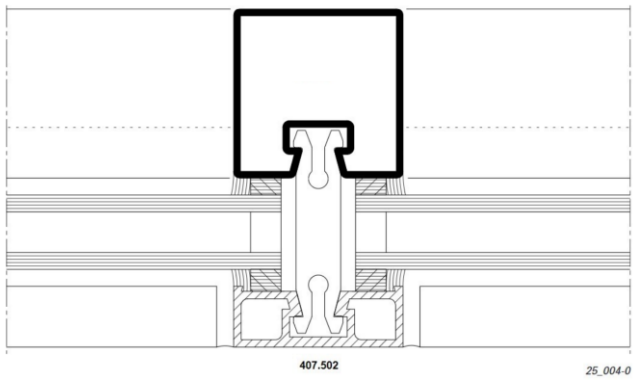
Assembly

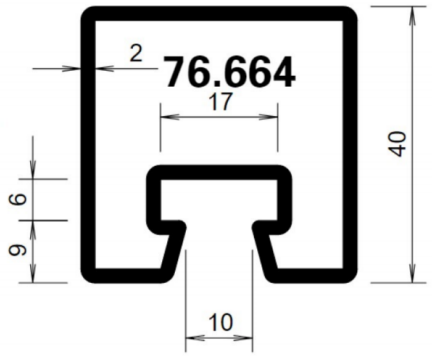
Deconstructed to uncontaminated material

Used for 30 years

Scenario 2: Reuse of Demolition Stream

- Splitting the mullion along the depth to create a substructure
- Primary/Secondary steel or timber base element
- Indirect Connection with independent third component



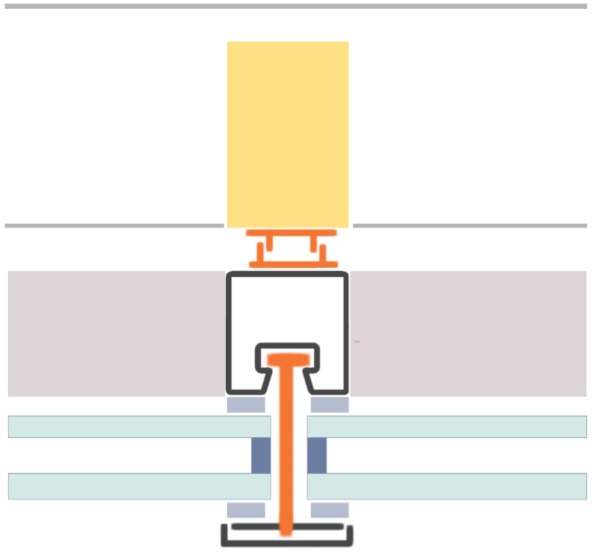


Demolition Stage

Assembly

Deconstructed to uncontaminated material

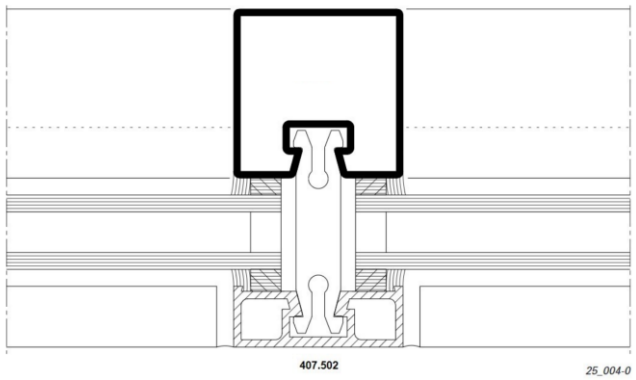
Used for 30 years

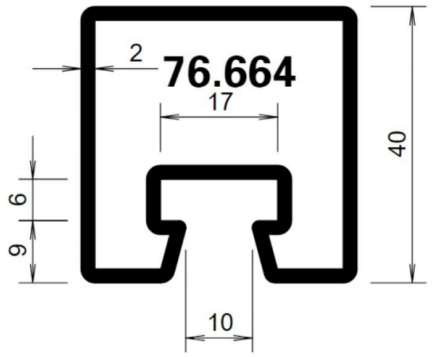


Plan

Scenario 2: Reuse of Demolition Stream

- Splitting the mullion along the depth to create a substructure
- Primary/Secondary steel or timber base element
- Indirect Connection with independent third component



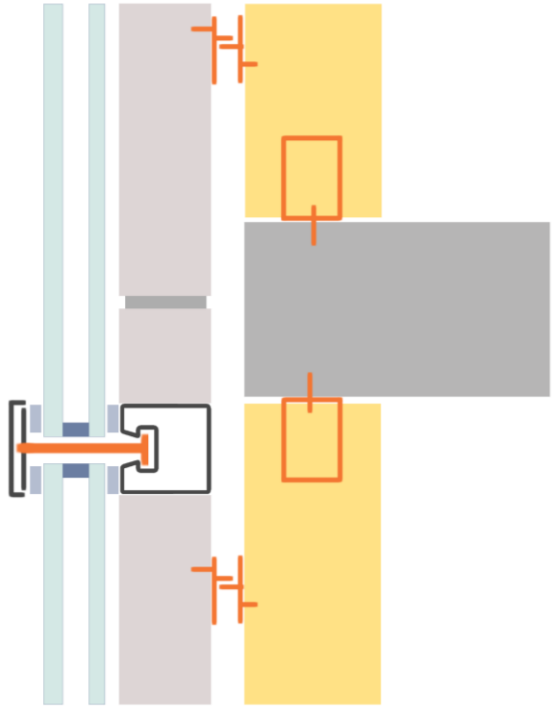


Demolition Stage

Assembly

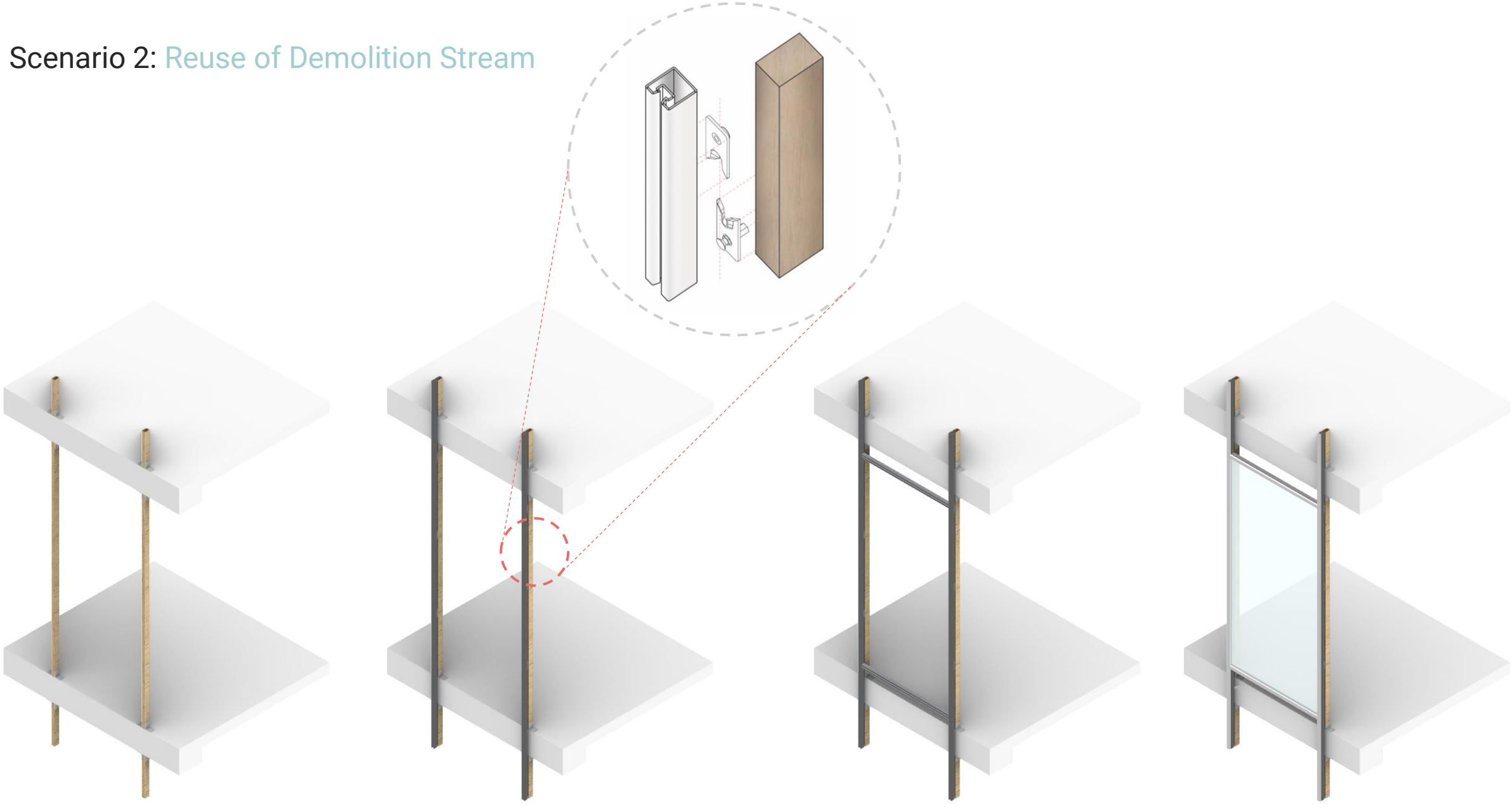
Deconstructed to uncontaminated material

Used for 30 years



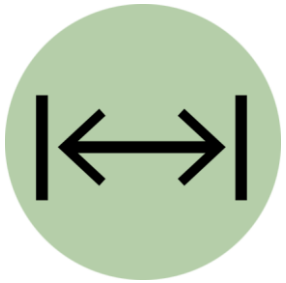
Section

Scenario 2: Reuse of Demolition Stream

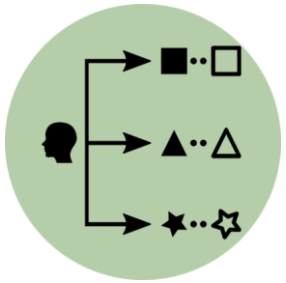


How can design solutions be formulated to overcome the barriers?

Material Inspectors

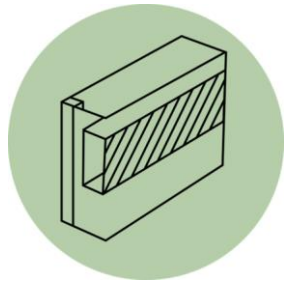


Sufficient Safety Margins



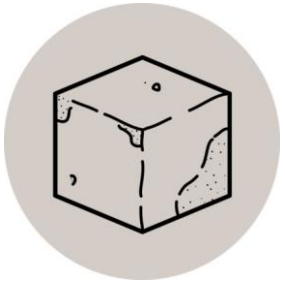
Form of Supply

Changing Design Habits

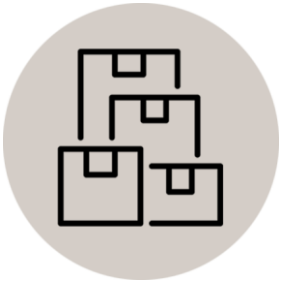


Using Materials Differently

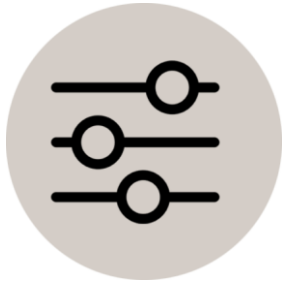
Lack of Information about previous condition



Wear and tear affecting safety of facade



Inconsistency in quality and quantity of supply



Customization in facades

Obsolete Performance

Now that we have the process, people and the design in place, how can we assess reuse?

Parameters for Assessing Reuse

Impact of Reuse

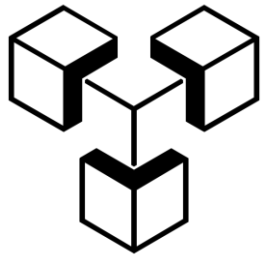
Net Benefits

LCIA

Circular Value of Reuse

Material Flow

MCI

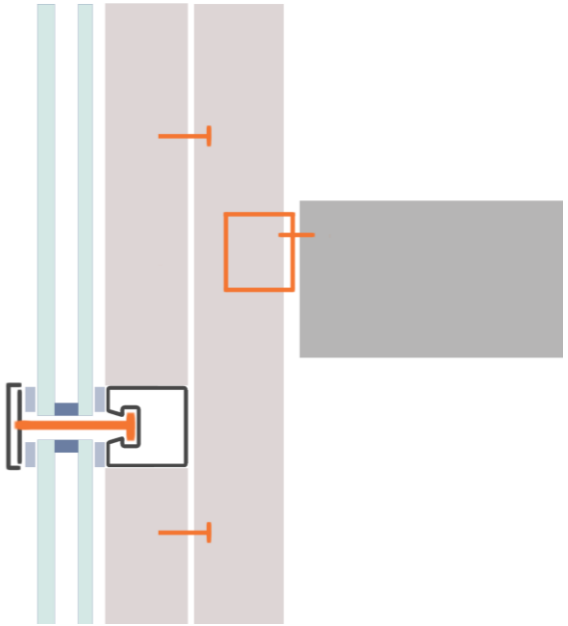


Product Design

Disassembly Potential

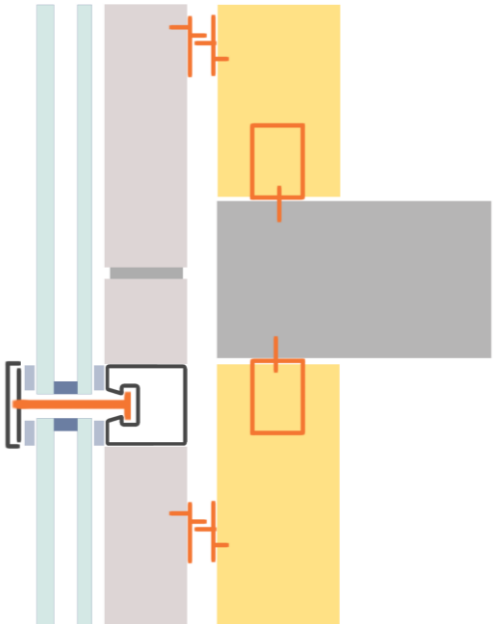
Design Scenarios

Scenario 1 : Reuse of Construction stream



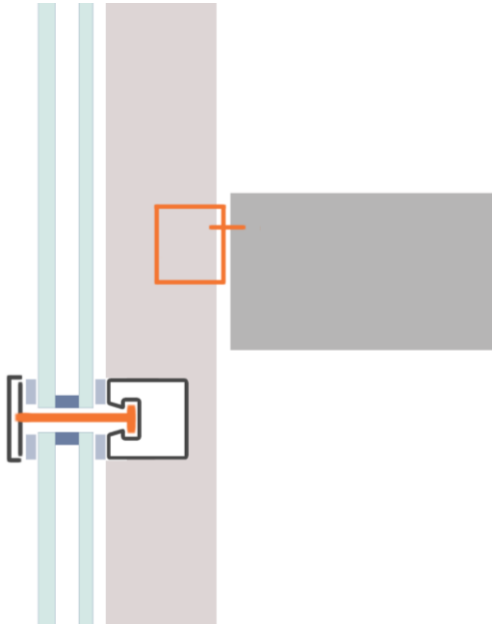
Reuse
100% Steel Mullion and Transom

Scenario 2 : Reuse of Demolition stream



Reuse
100% Steel Mullion and Transom
100% Timber
80% Aluminum pressure plate
60% cover caps

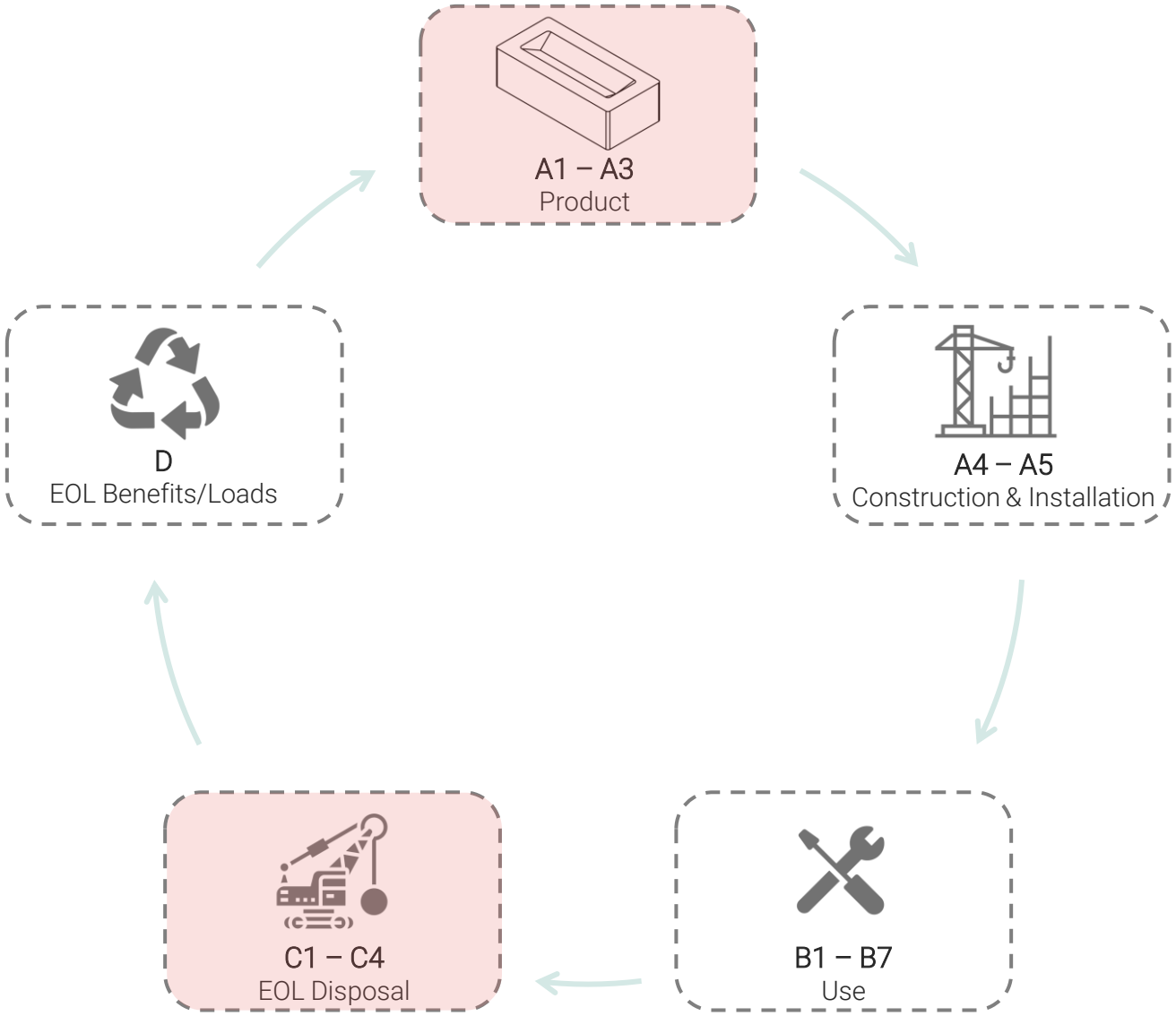
Scenario 3 : Recycling of Demolition stream



Recycled content in Steel and Aluminum supply

Environmental Impact

Lifecycle Assessment Modules

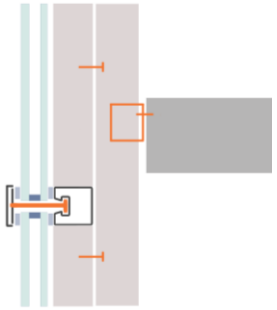


Environmental Impact

Avoided Impact

Added Impact

Scenario 1: Reuse of Construction Stream



C2
Transport to reuse

C3
Processing

C2
Transport to recycling

C3
Recycling

C4
Disposal

A1
Extraction

A2
Transportation

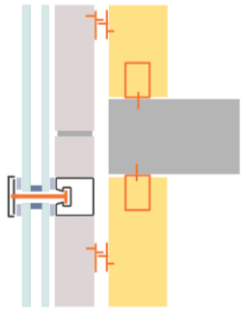
A3
Production

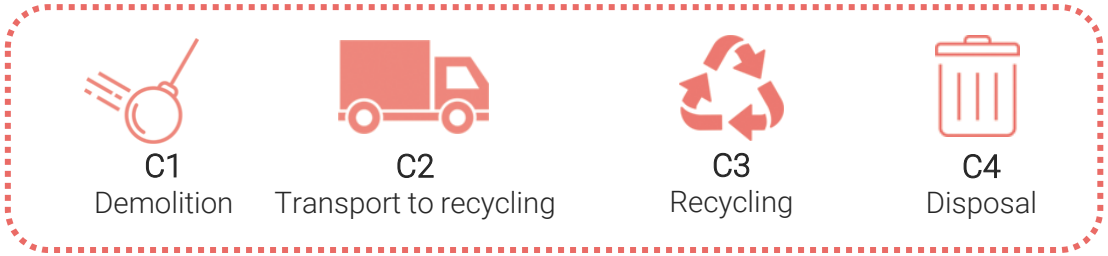
Environmental Impact

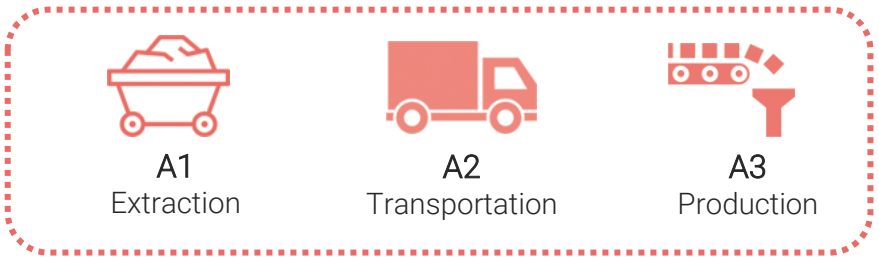
Avoided Impact

Added Impact

Scenario 2: Reuse of Demolition Stream





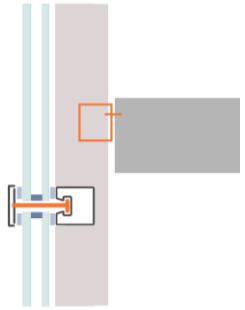


Environmental Impact

Avoided Impact

Added Impact

Scenario 3: Recycling of Demolition Stream



C1
Demolition

C2
Transport to recycling

C3
Recycling

C4
Disposal

A1
Extraction

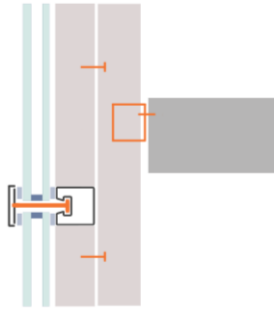
A2
Transportation

A3
Production

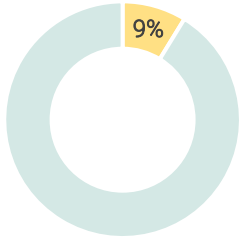
Environmental Impact

Scenario

Scenario 1

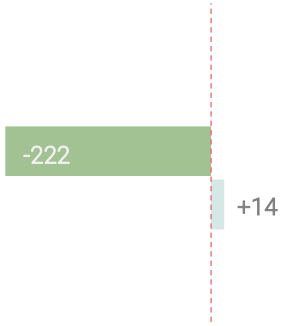


Percentage share of secondary material by volume



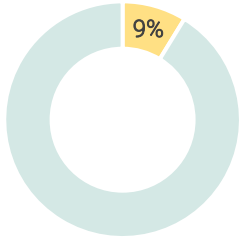
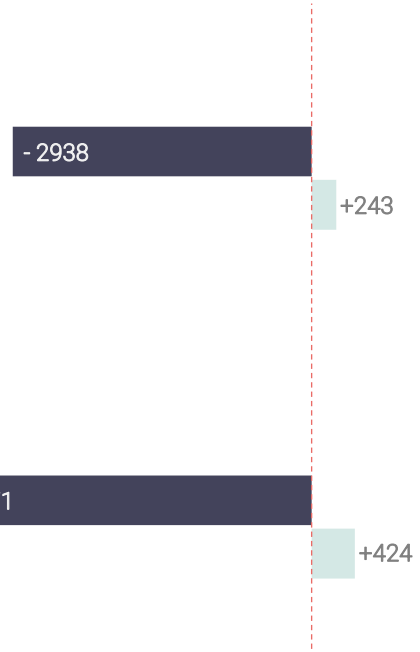
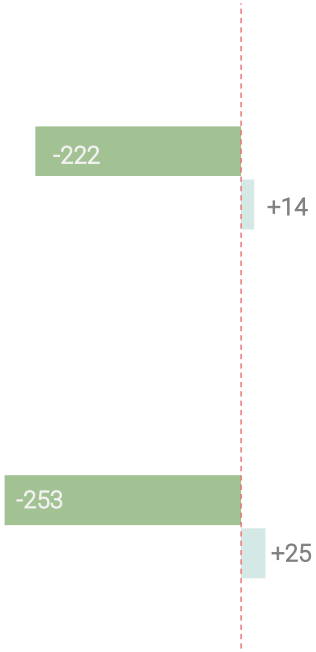
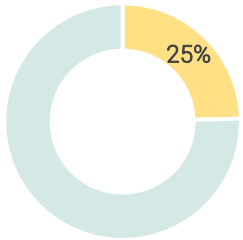
Added/Avoided impact on EE
MJ

Added/Avoided impact on GWP
kgCO2

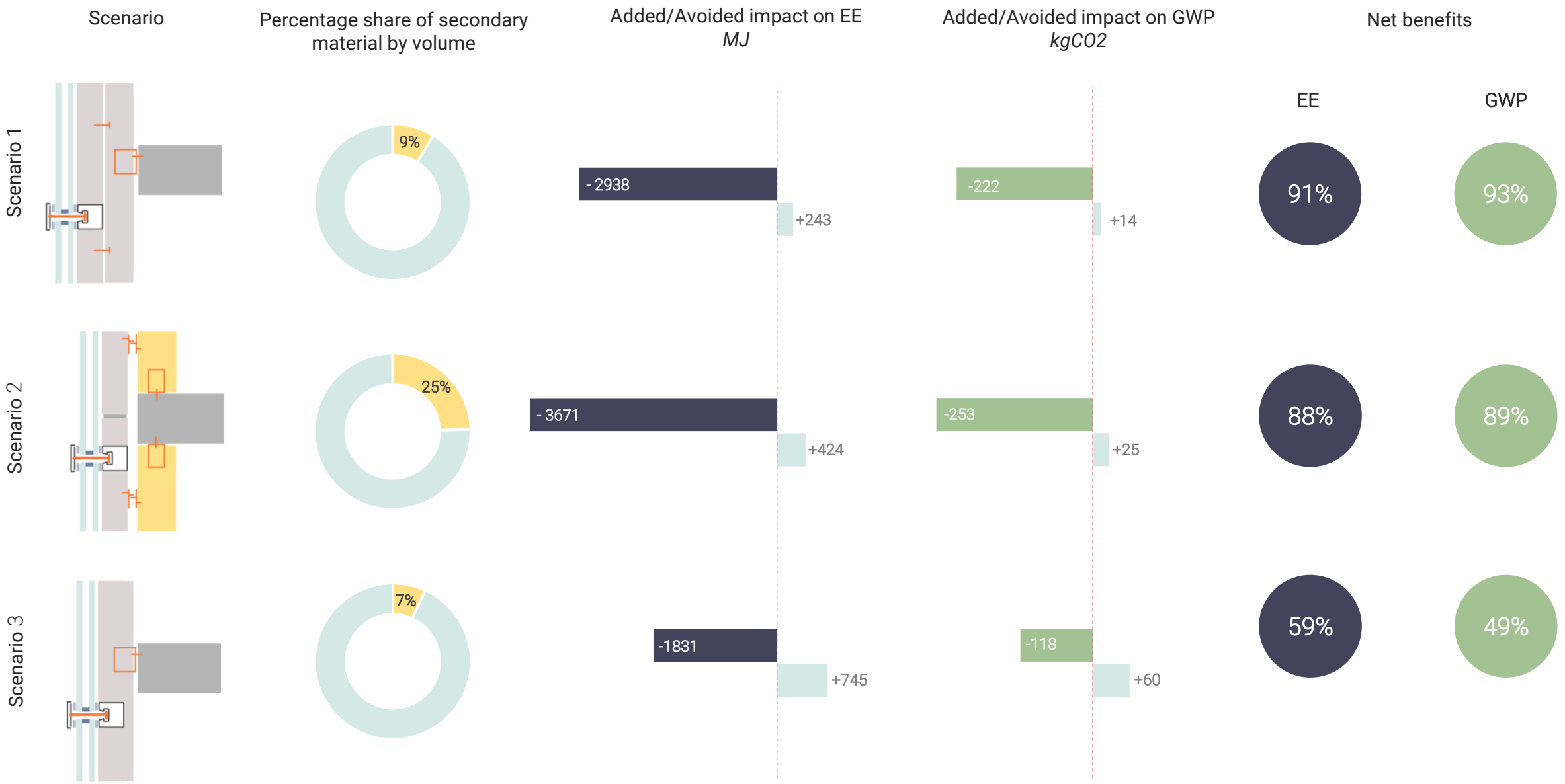


Net benefits

Environmental Impact

Scenario	Percentage share of secondary material by volume	Added/Avoided impact on EE *MJ*	Added/Avoided impact on GWP *kgCO2*	Net benefits
Scenario 1				EE 91% GWP 93%
Scenario 2				EE 88% GWP 89%

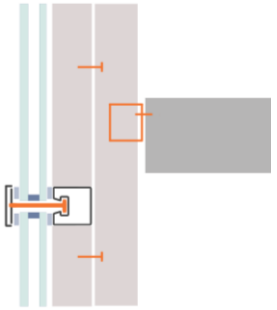
Environmental Impact



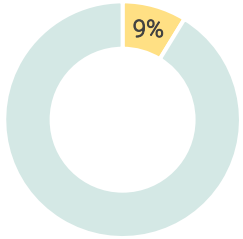
Circular Value

Scenario

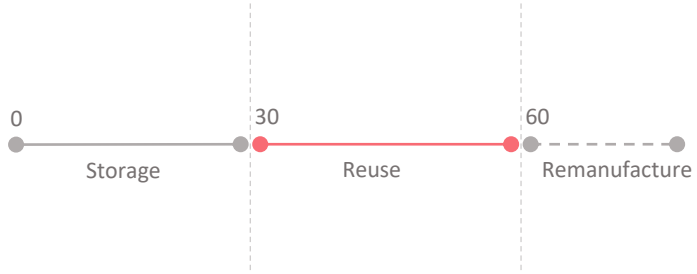
Scenario 1



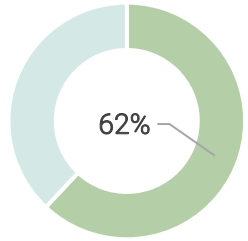
Percentage share of secondary material by volume



Material Use Scenarios



MCI score for 30years of new façade life



Circular Value

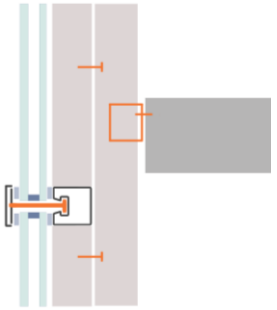
Scenario

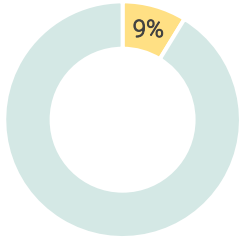
Percentage share of secondary material by volume

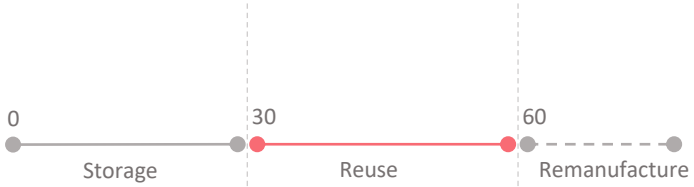
Material Use Scenarios

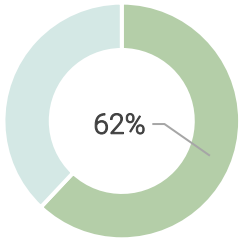
MCI score for 30years of new façade life

Scenario 1

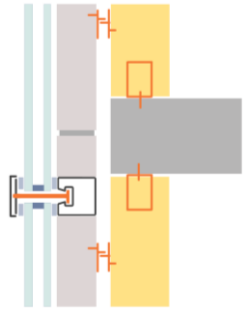


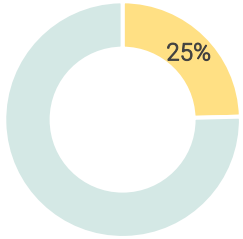


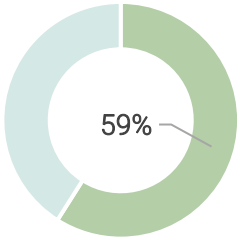




Scenario 2







Circular Value

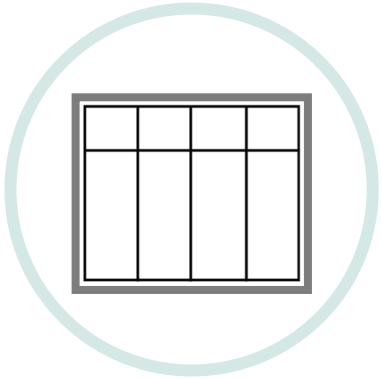
Scenario	Percentage share of secondary material by volume	Material Use Scenarios	MCI score for 30years of new façade life
Scenario 1	9%	0 Storage · 30 Reuse · 60 Remanufacture	62%
Scenario 2	25%	0 In Use · 30 Reuse · 60 Recycle	59%
Scenario 3	7%	0 Recycled content · 30 Recycle	25%

Reuse scenarios have higher net saving for total EE and GWP than recycling

Reuse scenarios have higher restorative material flow than recycling

Value of Reuse

Embodied Value



Functional Value

Economic Value

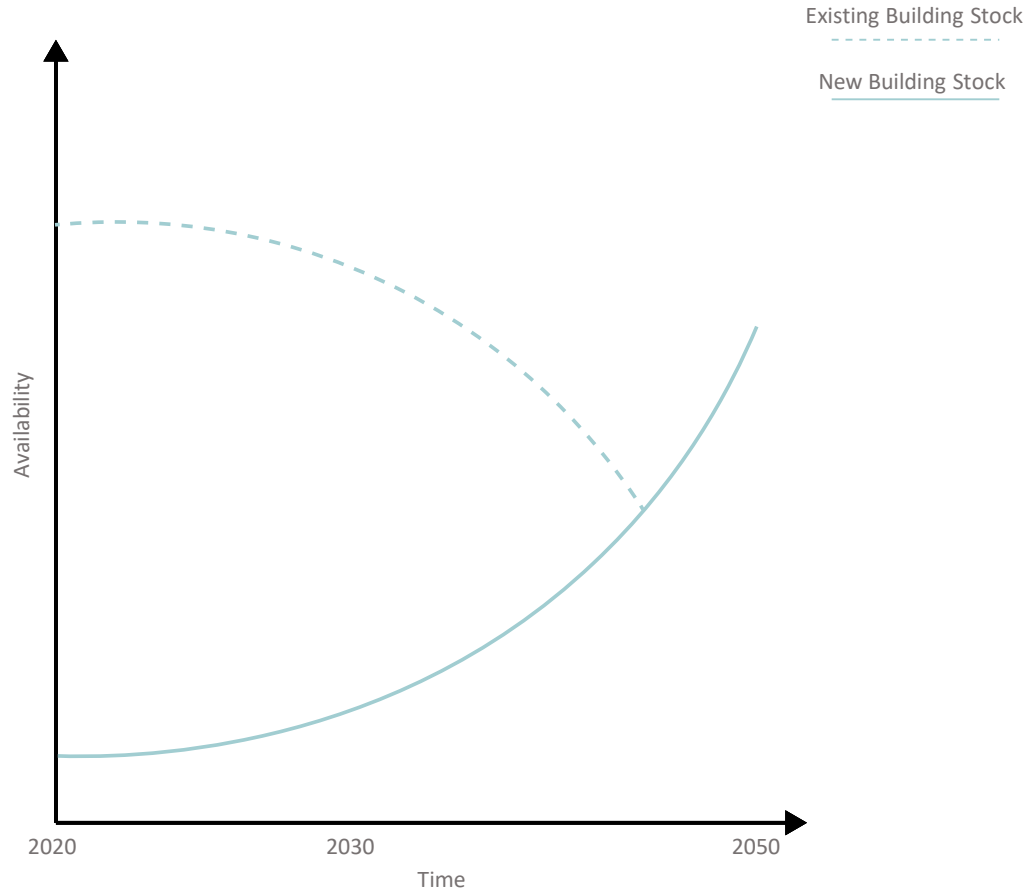
Efforts

Time

Ref – EIB and Metabolic (2020)

Material Trends

- Increasing population resulting in a yearly demand of **17million tonnes** of materials in the construction sector
- Increase in the number of demolition projects to keep up with the building standards



Ref – EIB and Metabolic (2020)

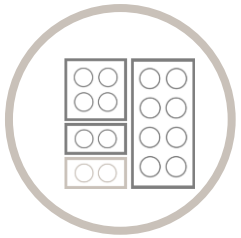
How can we align the practice to safeguard the value of material for reuse?

How can we align the practice to safeguard the value of material for reuse?

For Designers, Architects and Engineers

Transformability

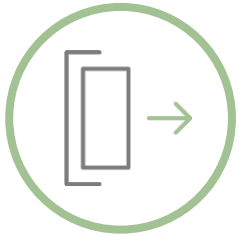
Changing product standards



Changing context

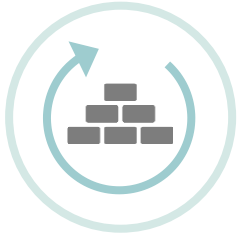
Detachability

External



Internal

Durability



Durable Materials

Maintenance and Repair

How can we align the practice to safeguard the value of material for reuse?

For Raw Material Suppliers

Data

Documenting information

Monitoring the use phase

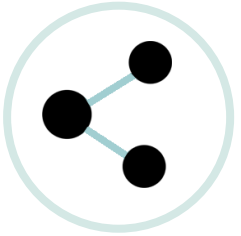
Design

Alternate material options

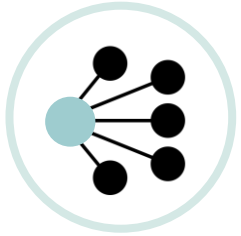
Performance Assessment

Repair service

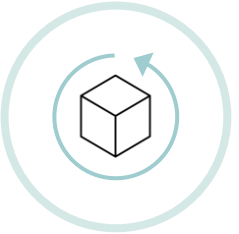
Management



Sharing Information



Extending direct contact



Reverse Supply Chain

How can we align the practice to safeguard the value of material for reuse?

For Raw Material Suppliers and Façade Manufacturers

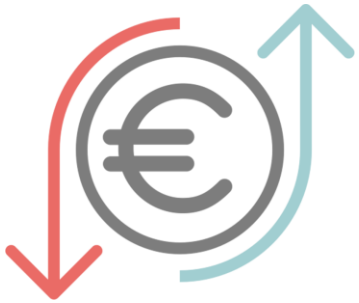
Facade Reuse from Brussels to Leiden by ODS

Philips Circular Lighting Solution

How can we align the practice to safeguard the value of material for reuse?

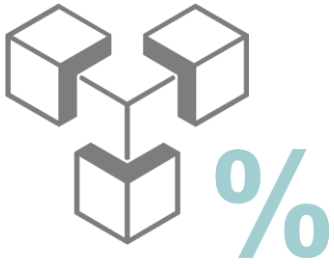
Changing the product assessment methods for Reuse

Dividing impacts over the multiple use cycles



Benefits and burdens added for the stakeholders

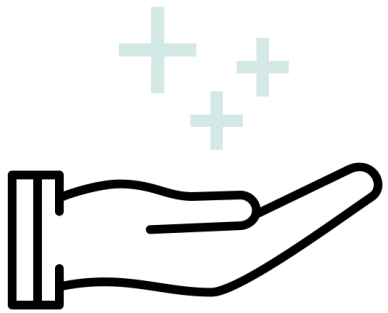
Extended lifespan and added maintenance



Product design for reuse and outflow generated

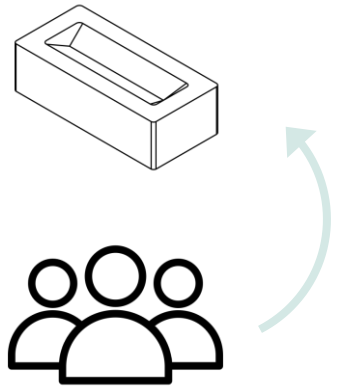
How can we align the practice to safeguard the value of material for reuse?

Regulatory Body



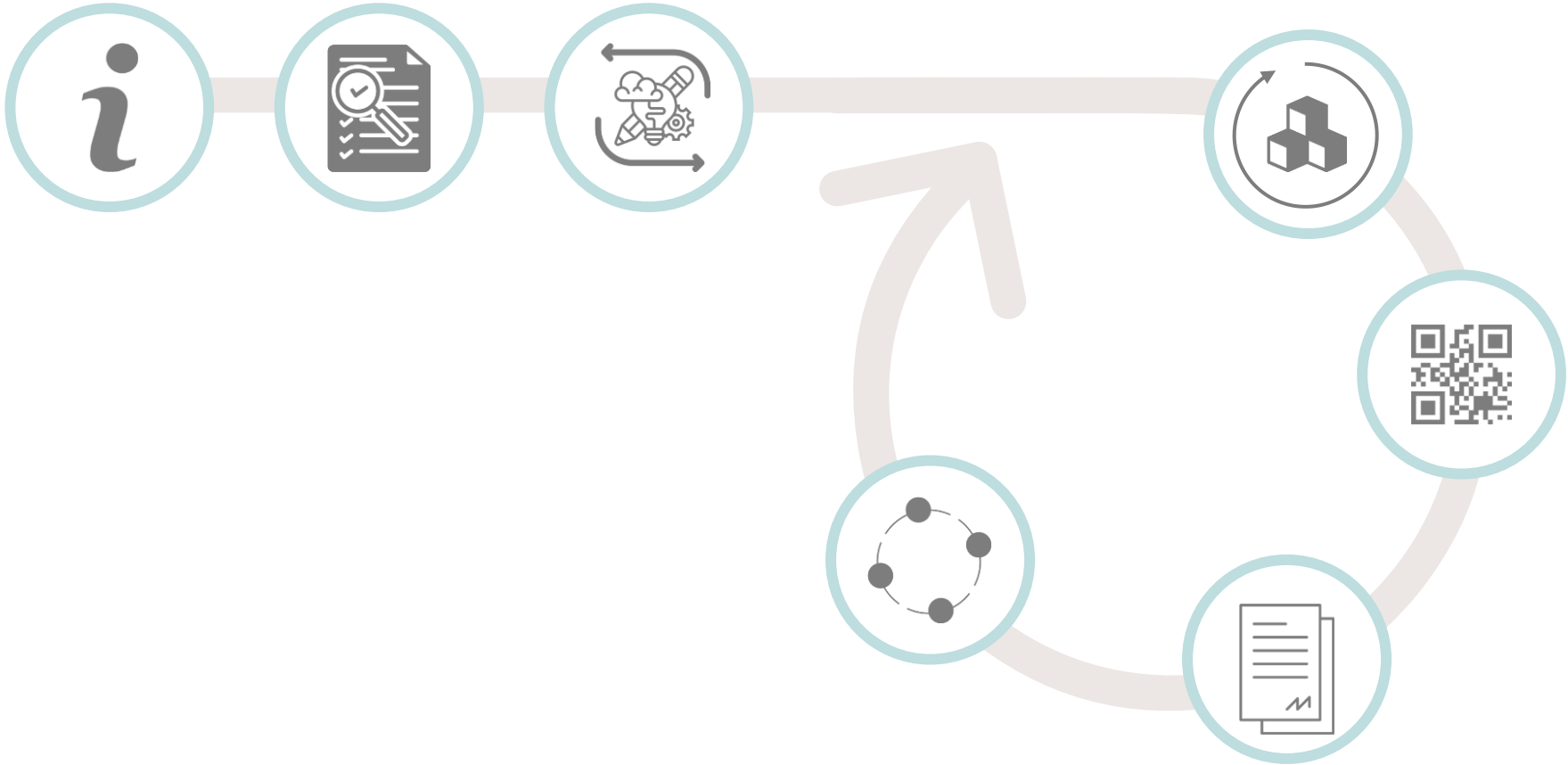
Changing the value **'waste to resource'**

Imposing **carbon tax** on primary material use

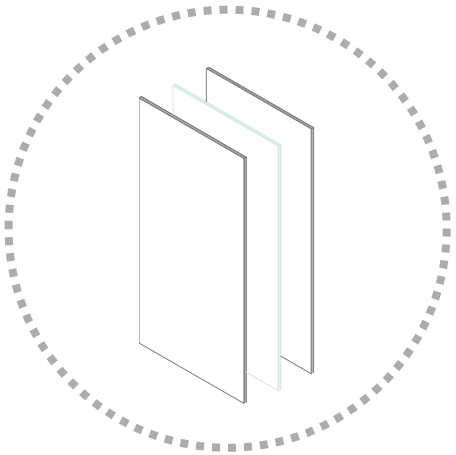


Shifting tax from **infinite resource** to **finite resource**

How can secondary materials from construction and demolition processes be reused in the facade industry? Can a reuse process contribute to create a circular value and reduce negative environmental impacts for facades?

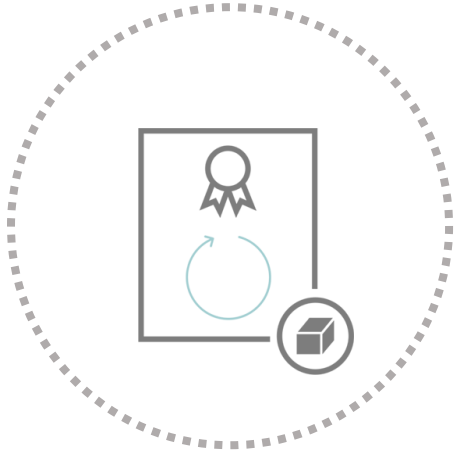


Further Recommendations



Reuse of glazing units

Economic analysis of the Reuse Process



Reuse in Product EPD

Database for Reuse

Circular Economy is not about closing loops of volume, but about closing loops of value.

QUESTIONS

Availability of incoming materials				*Potential Reuse Scenario*			
Source of harvest	**Form of harvest**	**Process for extraction**	**Use Lifespan**	**Residual Material Value (significance)**	**Strategy for reuse**	**Stakeholder**	**Use function**
Demolition Stage of the Building	Standard Material	Deconstructed to disassemble into standard material	EO(s)L	Elements can still perform for their desired function	**Remanufacturing** *processing and treating the material for a new facade*	Raw Material Supplier, Façade Manufacturer	Reuse for the same function
				Elements have been exposed to fatigue loading over their use phase and cannot be reused for the same purpose	**Repurposing** *Defining an alternate function for the material*	Raw material supplier/ Secondary material market	Reuse for a different function/industry
				Extracting maximum value from the element that has developed a very high degree of wear and tear over its use	**Recycling** *Reusing the material in the existing scrap market*	Collection company (on-site), Recycling company	Recycled / downcycled
	Component	Deconstructed to disassemble into components	EO(s)L	The component is uncontaminated and different materials within have a similar technical lifespan	**Remanufacturing** *Processing and treating the component for a new facade*	Component manufacturer, Façade Manufacturer	Reuse for the same function
		Inability to disassemble to uncontaminated material	EO(s)L	Extracting maximum value from components that have been contaminated over the use phase and cannot be disassembled	**Recycling** *Reusing the material in the existing scrap market*	Collection company (on-site), recycling company	Recycled / downcycled if contaminated
	Assembly	Dismantling the system from the building	Reaches EOU prematurely	The facade is in sufficient working condition and is under existing product certification	**Direct reuse** *Reusing for the same purpose without any need for repair or testing*	Original Manufacturer, Façade Consultant, Architect	Reuse for the same function in the same condition
				Enabling product to complete its expected service life	**Repair** *for known product issues*	Repair and maintenance facility - façade builder	Reuse for the same function

	Assembly	Dismantling the system from the building	EO(s)L	Enabling new partial or full-service life for the product for the purpose that was originally intended	**Refurbishing** *Modifying the product to restore its performance and/or functionality or meet technical standards*	Refurbishing facility - façade builder	Reuse for the same function
				Enabling new service life for the product for the purpose that was originally intended	**Remanufacturing** *Disassembling, processing, treating, and reassembling the components or part of a product*	Remanufacturing facility - façade builder	Reuse for the same function
Construction Overstock	Standard Material	Buying back the material at scrap value from façade manufacturer	Use phase never started	Enabling material to utilize the service life it is designed for and reduce the total stock of material at the warehouse	**Direct Reuse** *Reusing the material for the same purpose*	Raw Material Supplier, Façade Manufacturer	Reuse for the same function in a different condition
	Component	Buying back the material at scrap value from façade manufacturer	Use phase never started	Enabling component to utilize the service life it is designed out and reduce the total stock of material at the warehouse	**Direct Reuse** *Reusing the component for the same purpose*	Component manufacturer, Façade Manufacturer	Reuse for the same function in a different condition
Production leftover	Standard Material (Cut pieces)	Buying back the material at scrap value from element producer	Use phase never started	Extracting maximum value from leftovers profiles in varying sizes, shapes, and quantities	**Repurposing** *Defining an alternate function for the element*	Secondary Market	Reuse for a different function/industry