Improving Efficiency in Energy Renovations:
A Decision Support Tool for
Residential Buildings

Using a Multi-Criteria Approach to Balance Environmental, Social, and Economic Factors

Evanthia Soumelidou

5933552

Mentors:
1st mentor | Thaleia Konstantinou
2nd mentor | Michela Turrin
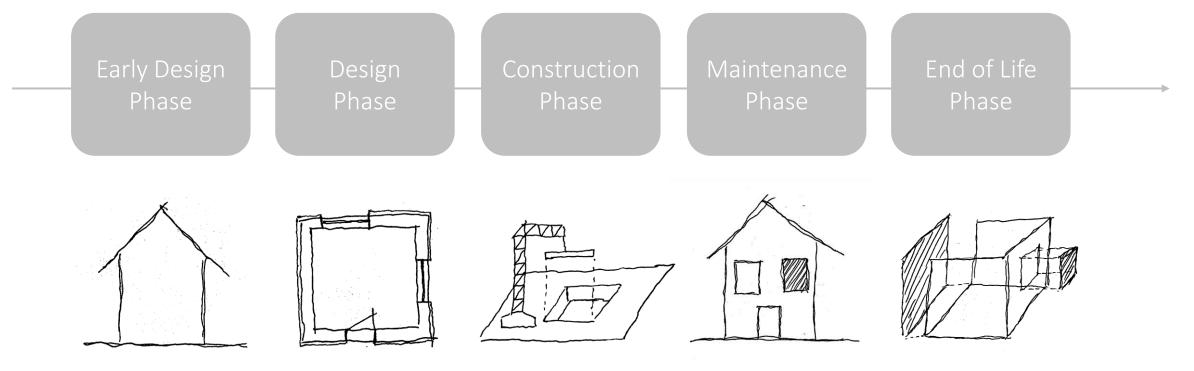PhD Consultant | Diletta Ricci

BOLD

TUDelft

2030

Reduce emissions
by at least 55%

2040

70-80% reduction
in emissions

2050

net-zero emissions
and climate
neutrality

Europe retrofitting 1-1.5% every year

NL

80% residential

Early Design Phase → Design Phase → Construction Phase → Maintenance Phase → End of Life Phase
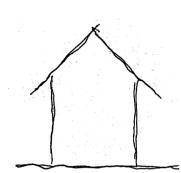
Early Design Phase
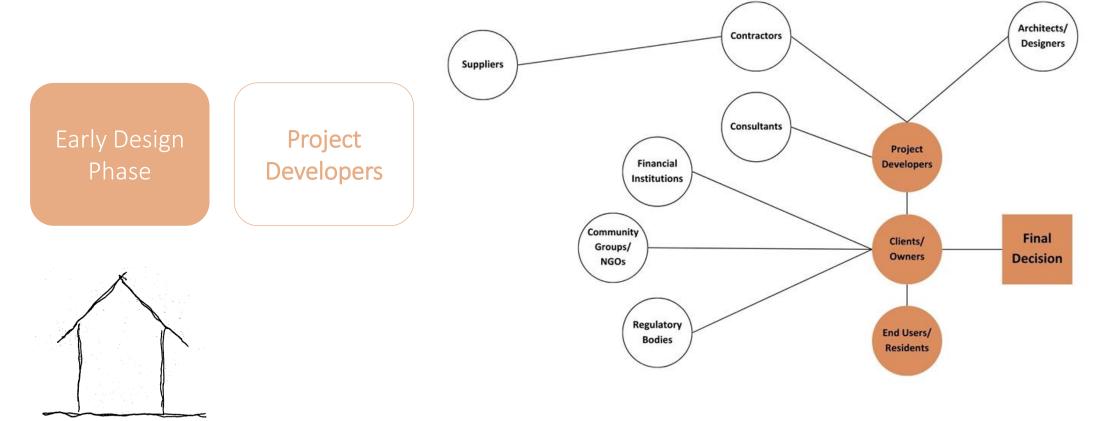
Efficiently and Economically

Clear Objective Definition

Optimal Solution Selection

Risk Minimization

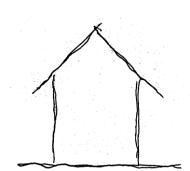# The critical role of project developers and end users

Early Design Phase

Project Developers

Stakeholder Decision-Making Flow in Renovation Projects

Early Design Phase

Project Developers

Energy Performance

Payback Periods

Increased property value

Unawareness
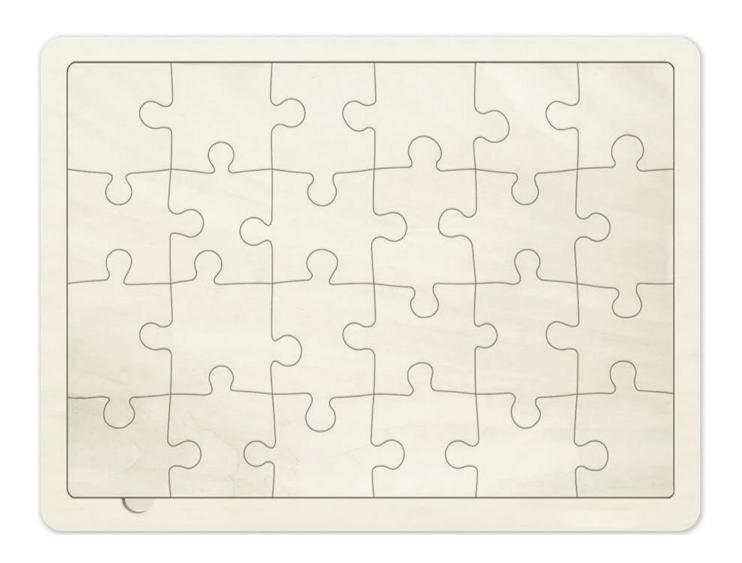
Early Design Phase

Energy Savings

Rental-cost factors
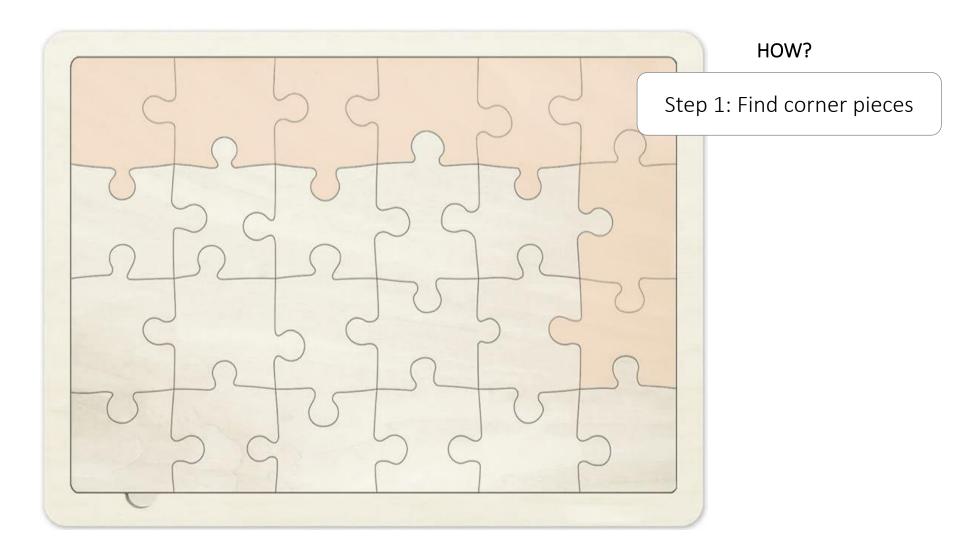
Various Technological Solutions
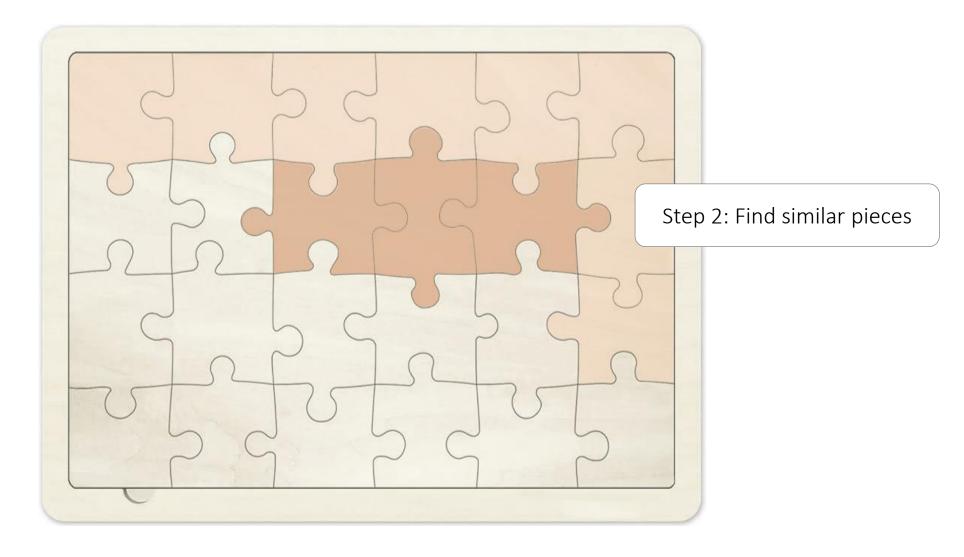
Financial pay-offs

Required levels of renovation

Successful

renovation project

HOW?

Step 1: Find corner pieces

Step 2: Find similar pieces

Reality of a
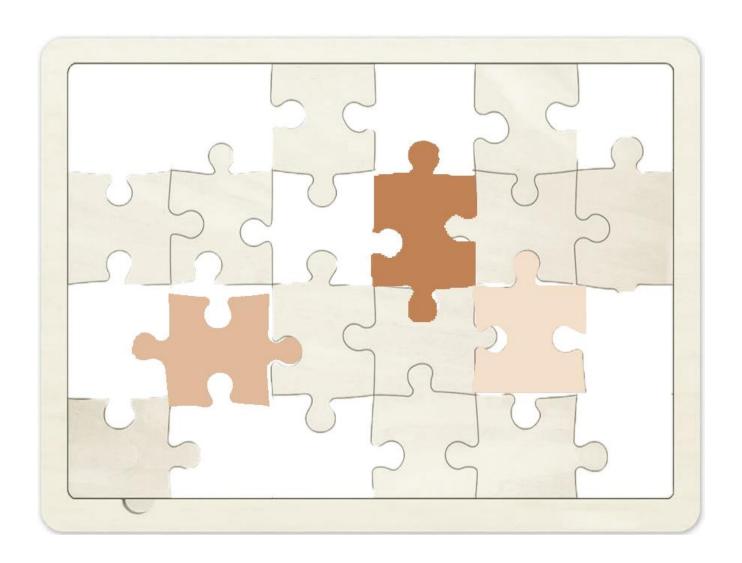
renovation project

Reality of a

renovation project

Early Design Decision-Making Inefficiencies
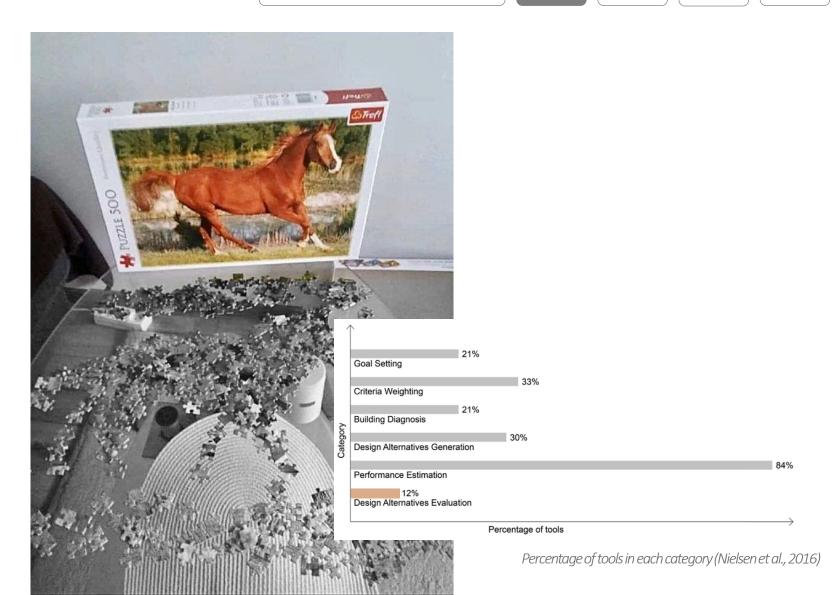
Stakeholder Misalignment and Information Asymmetry

Stakeholder Misalignment and Information Asymmetry

Need for Standardized and Adaptive Tools

Percentage of tools in each category (Nielsen et al., 2016)

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Main research question

*How can the **decision-making process** in the **early design phase** of **energy***

*renovations in **residential buildings** be improved to enable **project***

***developers** to make* efficient decisions *that consider environmental,*
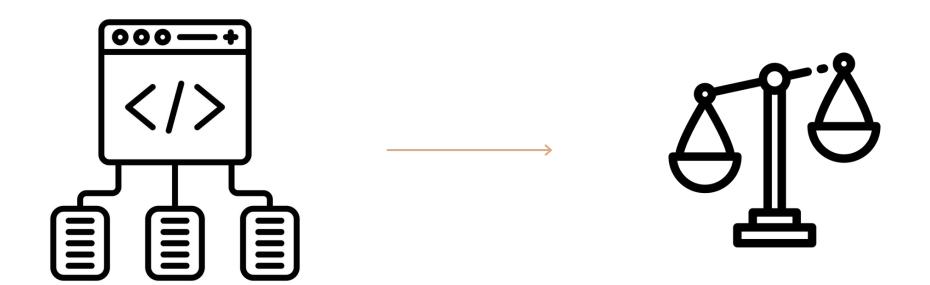
economic, and social factors?

Core Objective
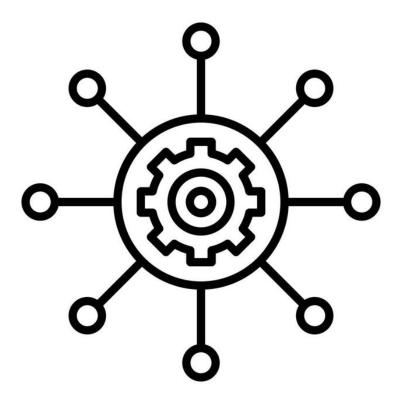
decision-making framework

Novelty
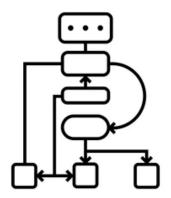
Integration process

Boundary Conditions

Scope of
Decision-Making
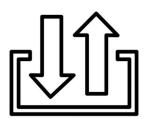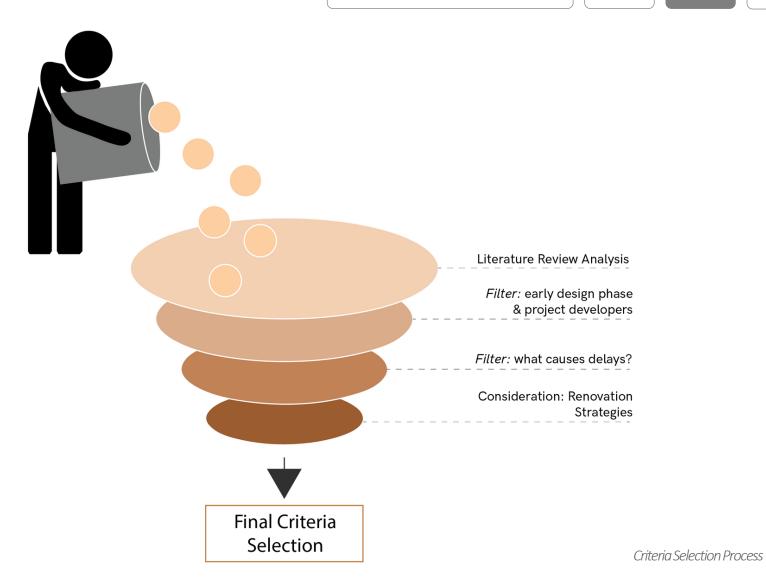
Methodological
Constraints

Automation &
Computation

Input & Output
Constraints

Literature Review Analysis

Filter: early design phase & project developers

Filter: what causes delays?

Consideration: Renovation Strategies

Final Criteria Selection

Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — MCDM Methods selection
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

Criteria Selection Process

Economic

EC_C1_Investment Cost

EC_C2_Operational Cost

EC_C3_Payback Period

EC_C4_Net Present Value

Social

S_C5_Renovation Duration

S_C6_Renovation Nuisance

S_C7_Energy Affordability Index (EAI)

Environmental

EN_C8_Heating Demand

EN_C9_Cooling Demand

EN_C10_Embodied Carbon

EN_C11_Share of Renewable energy generation

Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — MCDM Methods selection
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

Building Envelope

Building Systems/Services

Step 1	Goal identification
Step 2	Criteria definition
Step 3	**Alternatives selection**
Step 4	MCDM Methods selection
Step 5	Criteria weighting
Step 6	Prioritization
Step 7	Case Study Validation
Step 8	Sensitivity analysis
Step 9	Final decision

Wall and/or roof insulation
Energy-efficient windows
Fixed/adjustable shading

Heating upgrade

Upgraded Ventilation

Renewables addition

Main Principle Definition

Building Envelope	Building Systems/Services		
Wall and/or roof insulation Energy-efficient windows Fixed/adjustable shading	Heating upgrade	Upgraded Ventilation	Renewables addition
Building Envelope Upgrade	**Heating System Upgrade**	**Advanced Ventilation**	**Renewable Energy Integration**

Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — MCDM Methods selection
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

CATEGORY

Building Envelope	Building Systems/Services

MAIN PRINCIPLE

Building Envelope Upgrade | Heating System Upgrade | Advanced Ventilation | Renewable Energy Integration
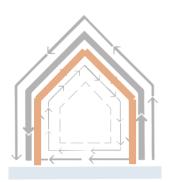
AVAILABLE OPTIONS

Building Envelope Upgrade	Heating System Upgrade	Advanced Ventilation	Renewable Energy Integration
1. Insulation(Façade and/or Roof) External/Internal EPS, Wood fiber, PIR 2. Window Replacement DB + AL /Wood frame TG + AL/Wood Framed 3. Shading Solar Blinds(adjustable)	District Heating Heat pump	Natural Inlet and Mechanical Exhaust (Type C) Mechanical Inlet and Mechanical Exhaust (Type D)	PV (electricity) PVT (electricity + hot water) BIPV(optional)
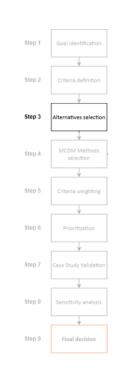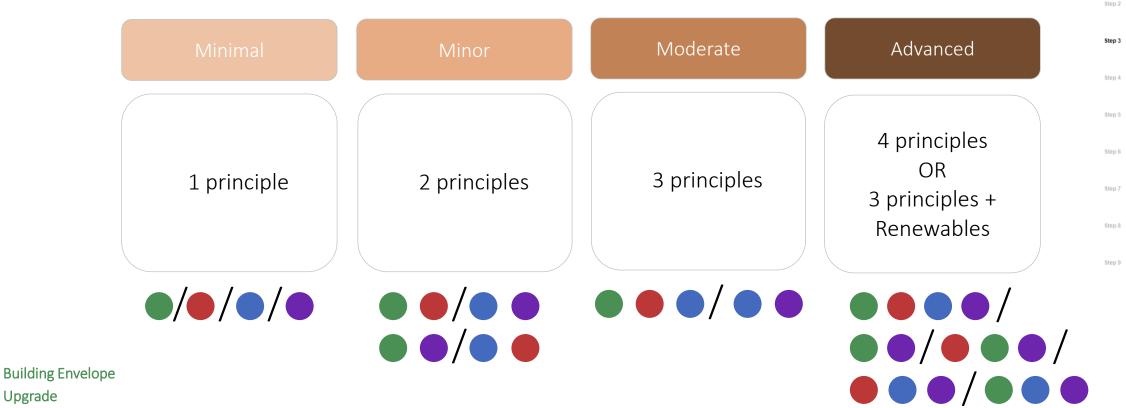
Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — MCDM Methods selection
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

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Minimal	Minor	Moderate	Advanced
1 principle	2 principles	3 principles	4 principles OR 3 principles + Renewables

Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — MCDM Methods selection
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

Building Envelope Upgrade

Heating System Upgrade

Advanced Ventilation

Renewable energy integration

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TOPSIS

AHP

Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — **MCDM Methods selection**
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

MCDM Methods Selection

Step 1 — Goal identification
Step 2 — Criteria definition
Step 3 — Alternatives selection
Step 4 — MCDM Methods selection
Step 5 — Criteria weighting
Step 6 — Prioritization
Step 7 — Case Study Validation
Step 8 — Sensitivity analysis
Step 9 — Final decision

AHP

General Workflow

Detailed Workflow

STEP 1: INPUTS

Fixed Inputs

Local Industry Data — Regulations — demographics — Financial Data — climate data — building Technology data

EPDs
Prices per renovation measure
Datasheets of components

subsidies for energy renovations(if available)
Relocation requirements

annual household income

Percentage of Loan
Loan Interest
Loan Payback Period
Rent Pricing

Location
weather data
hourly input data

Building Volume
Floor Height
Number of people
RE percentage covered
Surface areas(roof,walls,opening)
Existing Rvalues
New Rvalues

EXCEL

RHINO

MULTI-CRITERIA WEIGHTING

economic | social | environmental

EC_C1_investment cost
EC_C2_Operational cost
EC_C3_payback period
EC_C4_NPV

S_C5_renovation duration
S_C6_Renovation Nuisance
S_C7_energy affordability Index(EAI)

EN_C8_heating demand
EN_C9_cooling demand
EN_C10_embodied carbon
EN_C11_share of renewable energy generation

Multi-Criteria Weighting

predefined weights — AHP — pairwise comparisons

USER CUSTOMIZATION

user preferences — re-prioritization — NO — preference order the same?

YES
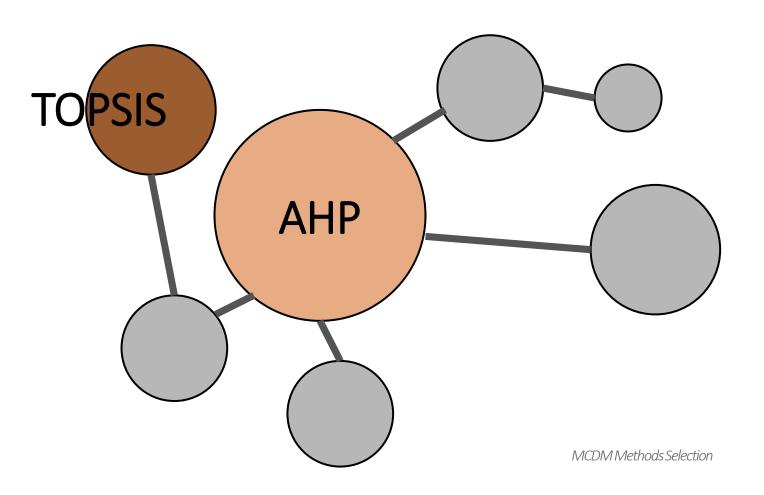
Choose Principle — checkbox — Heating System Upgrade / Building Envelope Upgrade / Advanced Ventilation / Renewable Energy Integration

n Configurations of Scenarios Generation

STEP 2: SURROGATE MODEL

Surrogate Model

Grasshopper Energy Model — Grasshopper Energy Simulations

Surfaces(m2) — Energy Demand(kWh)

EXCEL

OPEX — CAPEX — CO2 — Social

Calculated Financial Data

Result Table

STEP 3: OUTPUT

TOPSIS distance to ideal solution

re-define weights — NO — Is the outcome desirable?

Ranking of generated Scenarios

Bar Graph

Ideal Scenario

Comparison Dashboard

Creating the Tool's Database

Creating the Tool's Database

Creating the Tool's Database

Creating the Tool's Database

Creating the Tool's Database

Creating the Tool's Database

Creating the Tool's Database

Step 1: Inputs

Quick input mode (default):

Building geometry:
total floor area, number of floors, height, area quantities, apartment quantities

Envelope performance:
U-values of walls, roof, windows, etc.

System type:
heating/cooling/ventilation systems

Location/climate zone

Financial Data:
Loan Percentage, Interest Rate, Investment Evaluation Period etc.

MVP

Source: Henrik Kniberg, 2016
https://blog.crisp.se/2016/01/25/henrikkniberg/making-sense-of-mvp

Step 1: Inputs

MVP

Quick input mode (default):
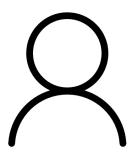
Building geometry:
total floor area, number of floors, height, area quantities, apartment quantities

Envelope performance:
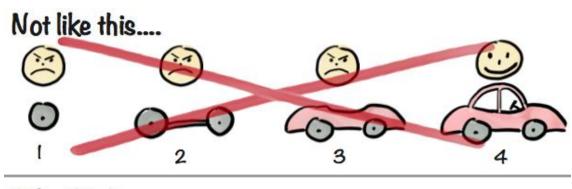U-values of walls, roof, windows, etc.

System type:
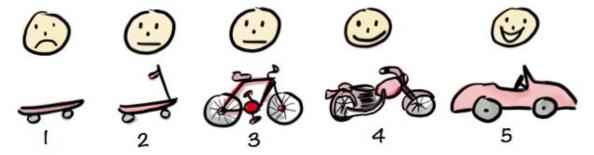heating/cooling/ventilation systems

Location/climate zone

Financial Data:
Loan Percentage, Interest Rate, Investment Evaluation Period etc.

Advanced input mode (future):

Step 2: Multi-Criteria Weighting and Prioritization

Economic €

Criterion A	Importance	Criterion B
C1 (Investment Cost)	6	C2 (Operational Cost)
C1 (Investment Cost)	2	C3 (Payback Period)
C1 (Investment Cost)	2	C4 (NPV)
C2 (Operational Cost)	4	C3 (Payback Period)
C2 (Operational Cost)	2	C4 (NPV)
C3 (Payback Period)	5	C4 (NPV)

Social

Criterion A	Importance	Criterion B
C5 (Renovation Duration)	4	C6 (Nuisance)
C5 (Renovation Duration)	3	C7 (Energy Affordability Index)
C6 (Nuisance)	4	C7 (Energy Affordability Index)

Environmental

Criterion A	Importance	Criterion B
C8 (Heating Demand)	1	C9 (Cooling Demand)
C8 (Heating Demand)	4	C10 (Embodied Carbon)
C8 (Heating Demand)	3	C11 (Share of renewable energy generation)
C9 (Cooling Demand)	3	C10 (Embodied Carbon)
C9 (Cooling Demand)	2	C11 (Share of renewable energy generation)
C10 (Embodied Carbon)	3	C11 (Share of renewable energy generation)

1. Predefined Weights
2. Adjustable Weights

Step 2: Multi-Criteria Weighting and Prioritization

Calculated Criteria Weights

Criterion	Weight (%)
Economic	
EC_C1 investment cost	44.07
EC_C2 Operational cost	10.91
EC_C3 Payback Period	34.21
EC_C4 NPV	10.81
Social	
S_C5 renovation duration	58.95
S_C6 Renovation Nuisance	28.28
S_C7 Energy affordability index (EAI)	12.77
Environmental	
EN_C8 Heating demand	39.43
EN_C9 Cooling demand	33.21
EN_C10 Embodied carbon	8.95
EN_C11 Share of renewable energy generation	18.40

Predefined Weights
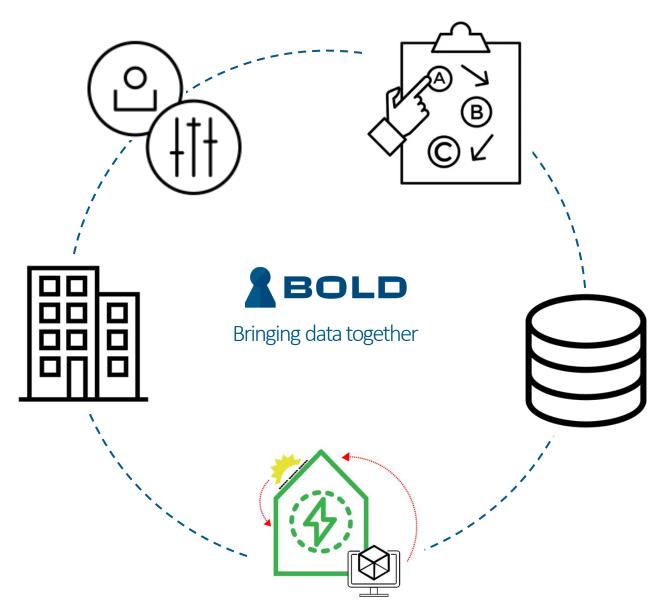
Housing Association Perspective

Step 3: User Customization

Scenario Generation

Total number of combinations: 64

Building Envelope Upgrade [E]

- Wall Insulation [E] ☑
- Roof Insulation [E] ☑
- Openings [E] ☑
- Shading [E] ☐

Heating System Upgrade [H] ☑

Advanced Ventilation [V] ☐

Renewable Energy Integration [R] ☐

[Combine] [Clear]

Generated Scenarios

Scenario 732: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection
Scenario 733: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + Air-to-Water Heat Pump
Scenario 734: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Wooden Frame) + District Heating Connection
Scenario 735: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Wooden Frame) + Air-to-Water Heat

Level of Intervention:	Minor
Subsidy percentage (%):	45

Table of Available Renovation Measures per Main Principle

Show/Hide Available Renovation Measures ▲

| Main Principle	Subcategory	Renovation Measure	Specifications
Building Envelope Upgrade	Wall Insulation	EPS Wood Fiber	External/Internal Location
	Roof Insulation	PIR Wood Fiber	Internal Location
	Openings	double glazing + aluminum frame double glazing + wood frame Triple glazing + aluminum frame Triple glazing + wood frame	
	Shading	Solar Blinds (adjustable)	
Heating System Upgrade	Heating System	District Heating connection Heatpump	
Advanced Ventilation	Ventilation Type	Simple Mechanical Ventilation (Type C)-Central More efficient Mechanical Ventilation (Type D)-Central	
Renewable Energy Integration	PV	Regular PV panels	on the roof assuming 70% coverage
	PVT	PVT Panels	on the roof
	BIPV	BIPV (both facades)	on facades (both facades) assuming 70% coverage

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Step 4: Surrogate Model
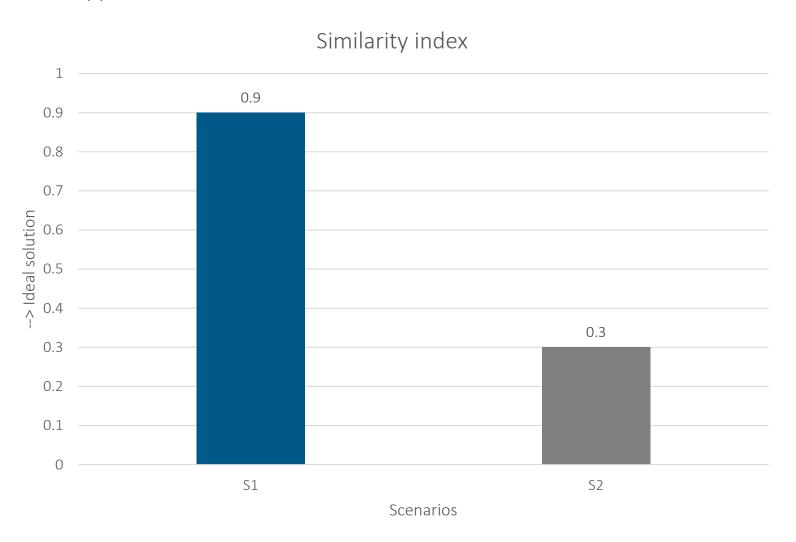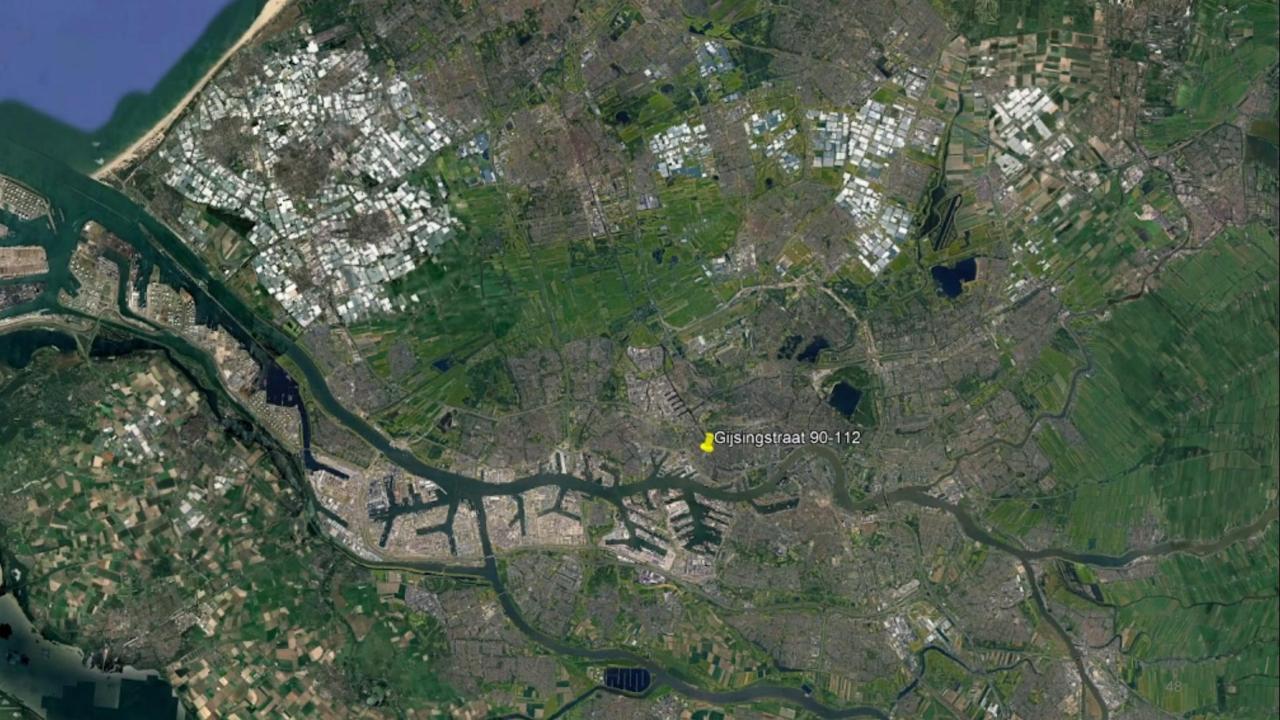
Step 4: Surrogate Model
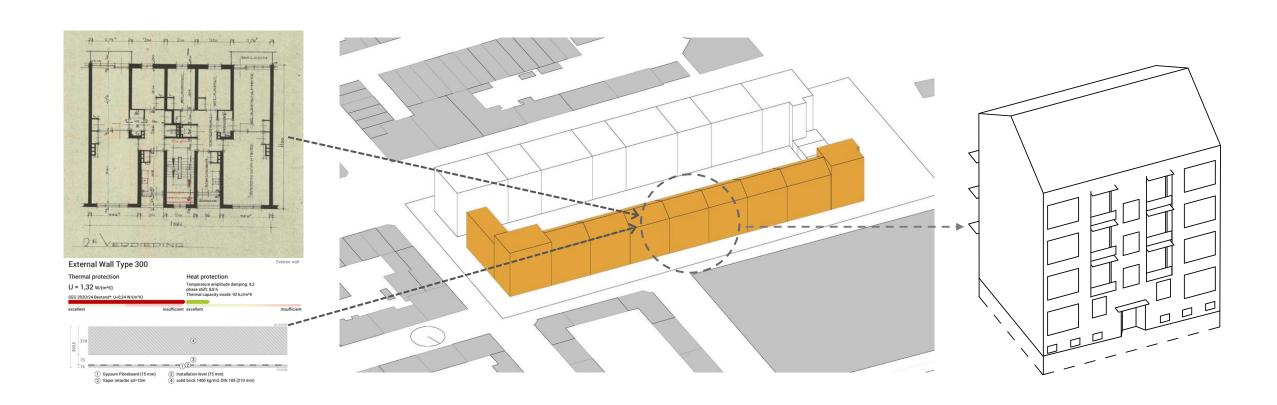
Output of Surrogate Model-Quantified Results Table

Scenarios	EC_C1_ Investment Cost	EC_C2_ Operational Cost	EC_C3_ Payback Period	EC_C4_ Net Present Value	S_C6_ Renovation Duration	S_C7_ Renovation Nuisance	S_C6_ Energy Affordability Index (EAI)	EN_C8_ Heating Demand	EN_C9_ Cooling Demand	EN_C10_ Embodied Carbon	EN_C11_ Share of Renewable energy generation
S1	€	€	Years	€	Weeks	Level	%	kWh/y	kWh/y	kg CO2 eq.	kWh/y
S2	€	€	Years	€	Weeks	Level	%	kWh/y	kWh/y	kg CO2 eq.	kWh/y
...	...	...	...	...	...	...	...	...	...	...	...
Sn	€	€	Years	€	weeks	level	%	kWh/y	kWh/y	kg CO2 eq.	kWh/y

Step 5: Output and Decision Support

Similarity index

Gijsingstraat 90-112

External Wall Type 300

Thermal protection
U = 1,32 W/(m²K)
GEG 2020/24 Bestand*: U<0,24 W/(m²K)
excellent — insufficient

Heat protection
Temperature amplitude damping: 4,3
phase shift: 8,8 h
Thermal capacity inside: 92 kJ/m²K
excellent — insufficient

① Gypsum Fibreboard (15 mm)   ③ Installation level (75 mm)
② Vapor retarder sd=10m   ④ solid brick 1400 kg/m3, DIN 105 (210 mm)

Existing Drawings &
Technical Properties

general 3D Model

One unit modelling including
technical properties
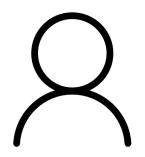
49

Building geometry:
total floor area, number of floors, height, area quantities, apartment quantities

Envelope performance:
U-values of walls, roof, windows, etc.

System type:
heating/cooling/ventilation systems

Location/climate zone

Financial Data:
Loan Percentage, Interest Rate, Investment Evaluation Period etc.

⌂ Building Measurements

Exterior Walls (m²)
0

South Wall (m²)
0

West Wall (m²)
0

Openings (m²)
0

Roof (m²)
0

Standard Apartments
0

Corner Apartments
0

Side Apartments
0

Total Apartments
0

🔧 Technical Properties

U-value Walls (W/m²K)
0.0

U-value Floor (W/m²K)
0.0

U-value Roof (W/m²K)
0.0

U-value Windows (W/m²K)
0.0

Heating System
Select heating system

Hot Water System
Select hot water system

Ventilation System
Select ventilation system

Current Energy Label
e.g., C

Primary Energy Use (kWh/m²/year)
0

Ownership Type
Select ownership type
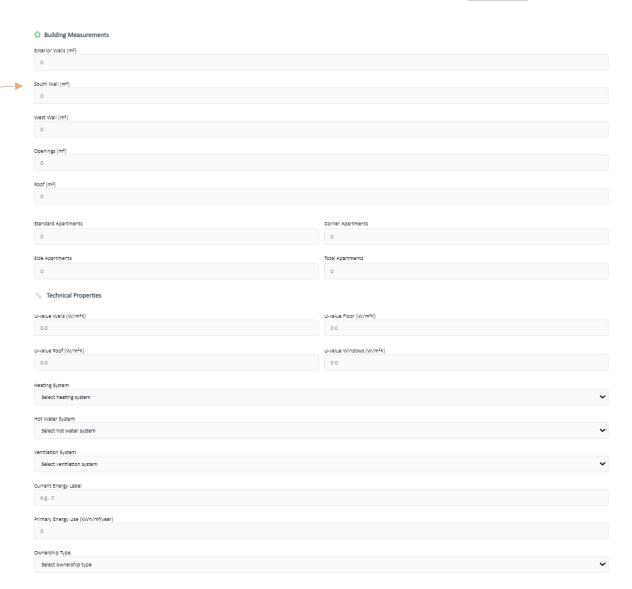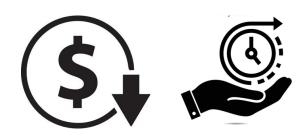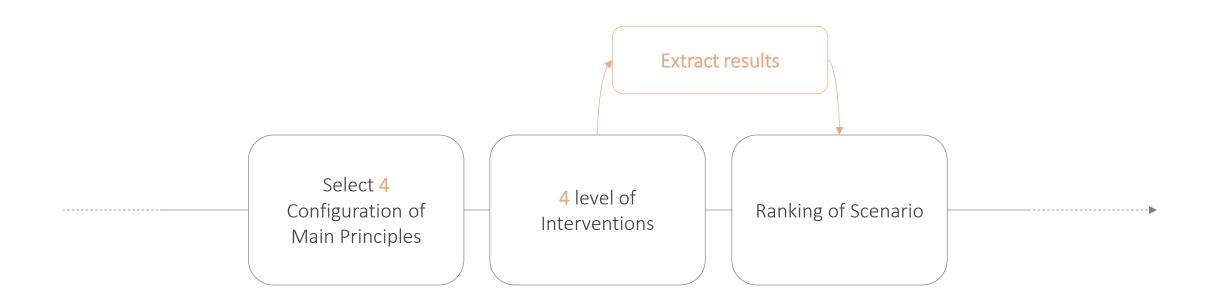
housing association

Criteria	Final Weights	Specifications		
C1	44%	EC_C1_investment cost		
C2	13%	EC_C2_Operational cost		
C3	33%	EC_C3_payback period		
C4	10%	EC_C4_NPV		
C5	59%	S_C5_renovation duration		
C6	28%	S_C6_Renovation Nuisance		
C7	13%	S_C7_energy affordability index (EAI)		
C8	39%	EN_C8_heating demand		
C9	33%	EN_C9_cooling demand		
C10	9%	EN_C10_embodied carbon		
C11	18%	EN_C11_share of renewable energy generation		

Weights from Housing Association's perspective

Select One Configuration of Main Principles

One level of Intervention

Ranking of Scenario

Extract results

Select **4** Configuration of Main Principles

4 level of Interventions

Ranking of Scenario

WHY?

What affects the results?

Sensitivity Analysis

Ranking of Scenario

Input Parameters Change

Weighting	Electricity Price	Financial Data	Pricing Strategy

Scenario Generation

Total number of combinations: 32

Building Envelope Upgrade [E]

- Wall Insulation [E] ☑
- Roof Insulation [E] ☑
- Openings [E] ☑
- Shading [E] ☐

Heating System Upgrade [H] ☐

Advanced Ventilation [V] ☐

Renewable Energy Integration [R] ☐

Combine | **Clear**

Generated Scenarios

Scenario 154: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame)
Scenario 155: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Wooden Frame)
Scenario 156: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Triple Glazing (Aluminum Frame)
Scenario 157: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Triple Glazing (Wooden Frame)
Scenario 158: External Wall Insulation with EPS + Internal Roof Insulation with Wood Fiber + Window Replacement with Double Glazing (Aluminum Frame)
Scenario 159: External Wall Insulation with EPS + Internal Roof Insulation with Wood

Level of Intervention: **Minimal**

Subsidy percentage (%): 25

Scenario Generation

Total number of combinations: 64

Building Envelope Upgrade [E]

- Wall Insulation [E] ☑
- Roof Insulation [E] ☑
- Openings [E] ☑
- Shading [E] ☐

Heating System Upgrade [H] ☑

Advanced Ventilation [V] ☐

Renewable Energy Integration [R] ☐

Combine | **Clear**

Generated Scenarios

Scenario 732: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection
Scenario 733: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + Air-to-Water Heat Pump
Scenario 734: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Wooden Frame) + District Heating Connection
Scenario 735: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Wooden Frame) + Air-to-Water Heat

Level of Intervention: **Minor**

Subsidy percentage (%): 45

Scenario Generation

Total number of combinations: 128

Building Envelope Upgrade [E]

- Wall Insulation [E] ☑
- Roof Insulation [E] ☑
- Openings [E] ☑
- Shading [E] ☐

Heating System Upgrade [H] ☑

Advanced Ventilation [V] ☑

Renewable Energy Integration [R] ☐

Combine | **Clear**

Generated Scenarios

Scenario 2208: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection + Advanced Ventilation Type C
Scenario 2209: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection + Advanced Ventilation Type D
Scenario 2210: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + Air-to-Water Heat Pump + Advanced Ventilation Type C
Scenario 2211: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + Air-to-Water Heat

Level of Intervention: **Moderate**

Subsidy percentage (%): 45

Scenario Generation

Total number of combinations: 192

Building Envelope Upgrade [E]

- Wall Insulation [E] ☑
- Roof Insulation [E] ☑
- Openings [E] ☑
- Shading [E] ☐

Heating System Upgrade [H] ☑

Advanced Ventilation [V] ☐

Renewable Energy Integration [R] ☑

Combine | **Clear**

Generated Scenarios

Scenario 2336: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection + Photovoltaic Panels (PV)
Scenario 2337: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection + Photovoltaic-Thermal Panels (PVT)
Scenario 2338: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + District Heating Connection + Building Integrated Photovoltaic Panels (BIPV)
Scenario 2339: External Wall Insulation with EPS + Internal Roof Insulation with PIR + Window Replacement with Double Glazing (Aluminum Frame) + Air-to-Water Heat

Level of Intervention: **Advanced**

Subsidy percentage (%): 65

Selected Scenarios

Item	Scenario
S1.1	Insulation->wall->external->EPS, Insulation >roof->internal->PIR-> double glazing + aluminum frame
S1.2	Insulation->wall->external->Wood Fiber, Insulation->roof->internal->Wood Fiber-> triple glazing + aluminum frame
S2.1	Insulation->wall->external->EPS, Insulation >roof->internal->PIR, -> double glazing + aluminum frame ->District Heating Connection
S2.2	Insulation->wall->external->Wood Fiber, Insulation->roof->internal->Wood Fiber, -> triple glazing + aluminum frame ->District Heating Connection
S3.1	District Heating Connection-> More efficient Mechanical Ventilation (Type D)-Central-> Insulation->wall->external->EPS, Insulation >roof->internal->PIR-> double glazing + aluminum frame
S3.2	District Heating Connection-> Simple Mechanical Ventilation (Type C)-Central -> Insulation->wall->internal->PIR, Insulation >roof->internal->PIR-> double glazing + timber frame
S4.1	Insulation->wall->external->EPS, Insulation >roof->internal->PIR-> triple glazing + timber frame ->District Heating Connection->Regular PV Panels
S4.2	Insulation->wall->internal->Wood Fiber, Insulation->roof->internal->Wood Fiber-> double glazing + aluminum frame ->District Heating Connection->Regular PV Panels

Weighting

Weighting

S3.2
- District Heating Connection
- Simple mechanical ventilation type C
- Internal PIR Wall and Roof Insulation
- Double glazing with timber frame

S3.2A1
- District Heating Connection
- Simple mechanical ventilation type C
- Internal PIR Wall and Roof Insulation
- Double glazing with timber frame

S4.1A2
- District Heating Connection
- External EPS Wall and Internal PIR Roof Insulation
- Triple glazing with timber frame
- Regular PV Panels

2/8 DISQUALIFIED

Negative NPV

59

Electricity Price
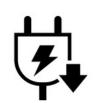
S3.1B1
- District Heating Connection
- More efficient mechanical ventilation type D
- External EPS Wall and Internal PIR Roof Insulation
- Double glazing with aluminum frame

S3.2B2
- District Heating Connection
- More efficient mechanical ventilation type C
- Internal PIR Wall and Roof Insulation
- Double glazing with timber frame

1/8 DISQUALIFIED

SAME BUT 3/8 DISQUALIFIED

Financial Data

S3.1C1
- District Heating Connection
- More efficient mechanical ventilation type D
- External EPS Wall and Internal PIR Roof Insulation
- Double glazing with aluminum frame

S3.1C2.1

S3.2C2.2

S3.2C3.1

S3.2C3.2

2/8 DISQUALIFIED

0/8 DISQUALIFIED

3/8 DISQUALIFIED

3/8 DISQUALIFIED

0/8 DISQUALIFIED

Pricing Strategy

S3.1D1
- District Heating Connection
- More efficient mechanical ventilation type D
- External EPS Wall and Internal PIR Roof Insulation
- Double glazing with aluminum frame

1/8 DISQUALIFIED
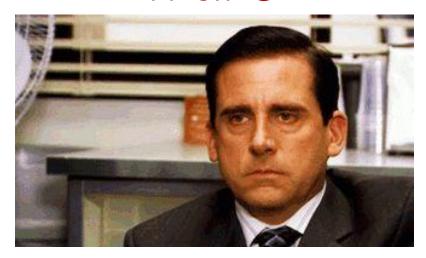
Scenario	Pi	Rank
S3.2	0.826	3
S3.2A1	0.791	7
S4.1A2	0.688	11
S3.1B1	0.790	8
S3.2B2	0.804	6
S3.1C1	0.789	9
S3.1C2.1	0.788	10
S3.2C2.2	0.828	1
S3.2C3.1	0.827	2
S3.2C3.2	0.821	4
S3.1D1	0.805	5

Pi>0.8 ☺

Pi<0.7 ☹

How I know that the results are correct?

Manual Calculations

Some weeks

So what affects the results?
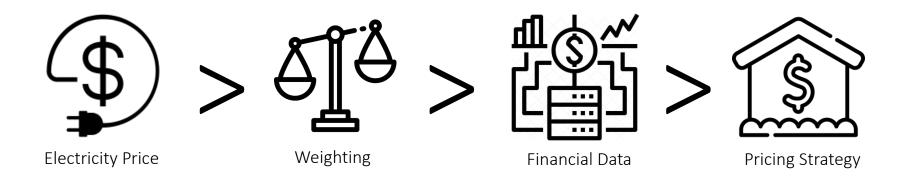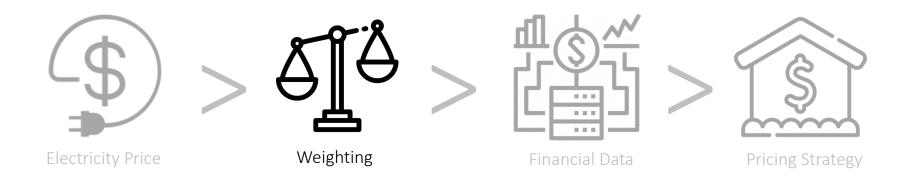
Weighting

Electricity Price

Financial Data

Pricing Strategy

So what affects the results?

Electricity Price > Weighting > Financial Data > Pricing Strategy

So what affects the results?

Electricity Price > Weighting > Financial Data > Pricing Strategy

Which Criteria affect the results?

Weighting

EC_C4_Net Present Value

EN_C8_Heating Demand

EN_C11_Share of Renewable energy generation

So what is the best solution for this case study?

S3.2

- District Heating Connection
- Simple mechanical ventilation type C
- Internal PIR Wall and Roof Insulation
- Double glazing with timber frame

Pi=0.827

9.8% Savings in Heating Demand

+33.6% in Energy Demand-Energy Bill

So what is the best solution for this case study?

S3.2

IRR=7.89%
WACC=7.6%

Do I have to renovate?

What is next?

Early Design Phase

Design Phase

Construction Phase

Maintenance Phase

End of Life Phase

What is next?

Early Design Phase — Design Phase — Construction Phase — Maintenance Phase — End of Life Phase

Exterior wall

Thermal protection
R = 4,94 m²K/W
GEG 2020/24 Bestand*: U<0,24 W/(m²K)
excellent — insufficient

Moisture proofing
Dries 59 days
Condensate: 1,4 g/m²
excellent — insufficient

Heat protection
Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 278 kJ/m²K
excellent — insufficient

Exterior wall
created on 22.6.2025

① Gypsum Fibreboard (15 mm)   ④ solid brick 1400 kg/m3, DIN 105 (210 mm)
② Vapor retarder sd=10m   ⑤ BauderPIR DAL (100 mm)
③ Installation level (75 mm)   ⑥ akurit FP Filzputz (15 mm)

Roof construction

Thermal protection
R = 3,05 m²K/W
DIN 4108*: R>1,75 m²K/W + R_si + R_se
excellent — insufficient

Moisture proofing
No condensate
excellent — insufficient

Heat protection
Temperature amplitude damping: 3,6
phase shift: 7,0 h
Thermal capacity inside: 17,2 kJ/m²K
excellent — insufficient

Roof construction
created on 22.6.2025

① Gypsum board (12,5 mm)   ③ BauderPIR FA (100 mm)   ⑤ Roofing tiles (103 mm)
② Vapor barrier sd=100m   ④ BITUMAT PVC Waterproofing Membrane

Should we apply this scenario to similar typology?

NO

What should we do?
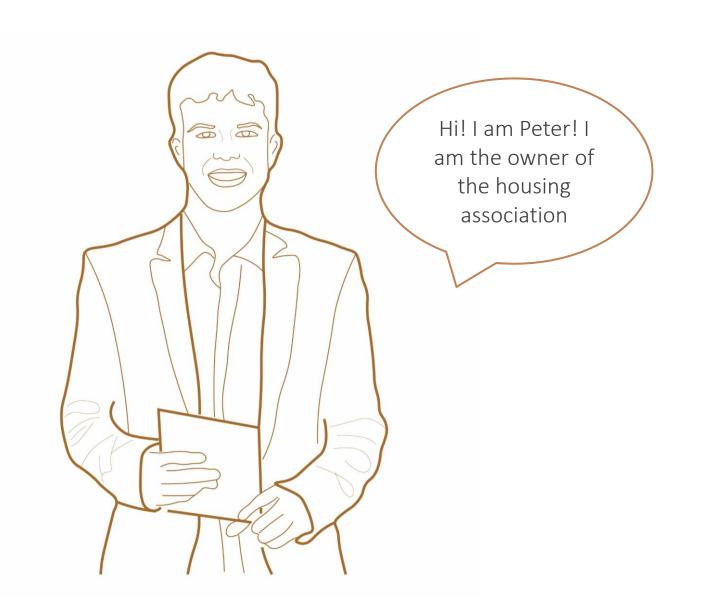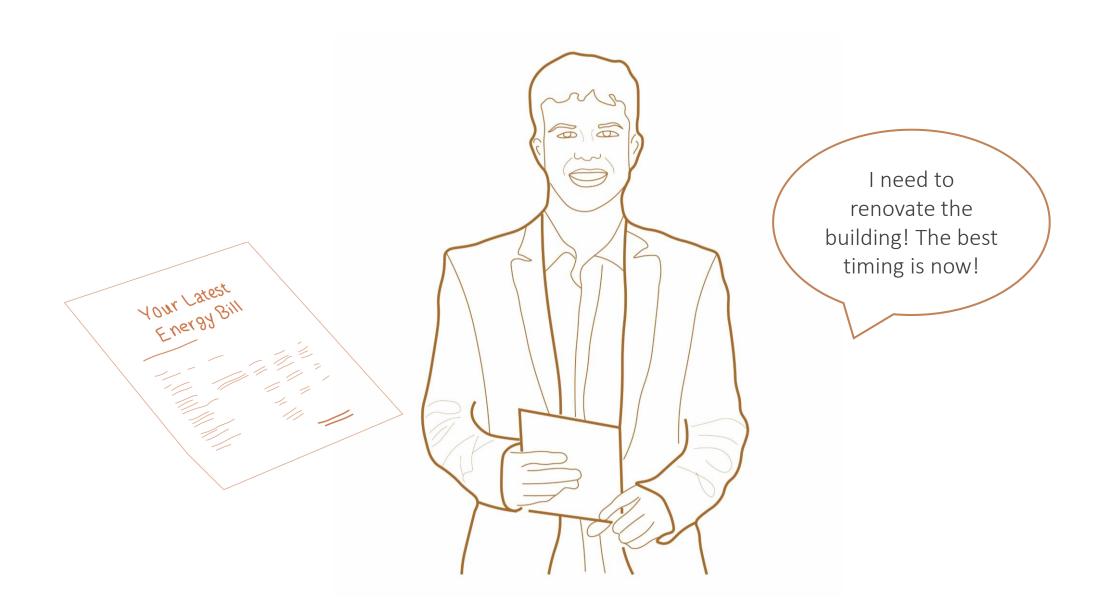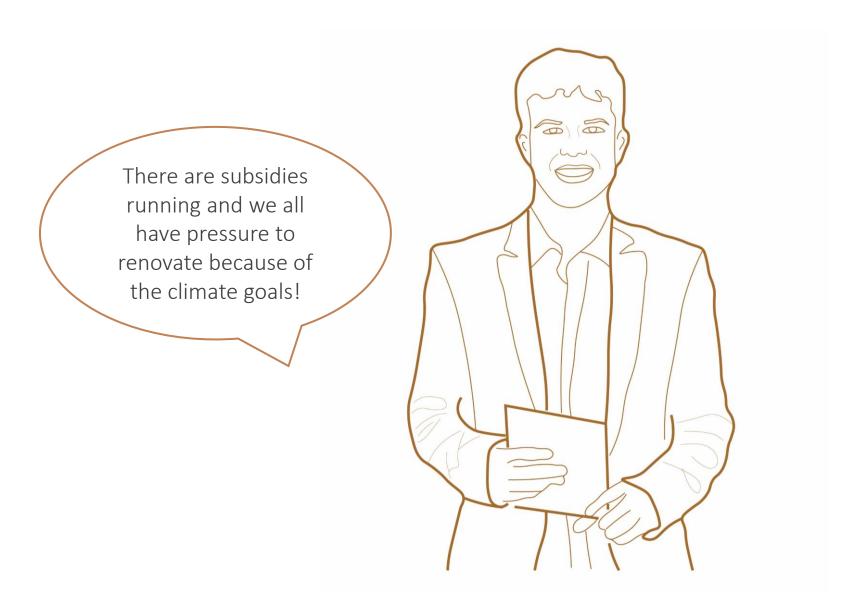
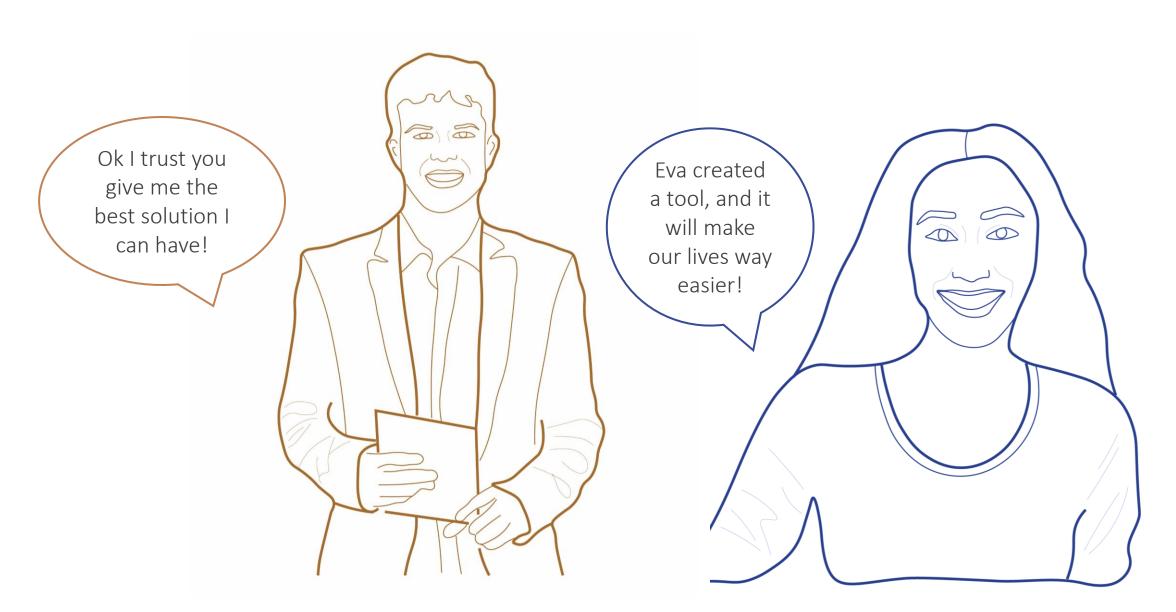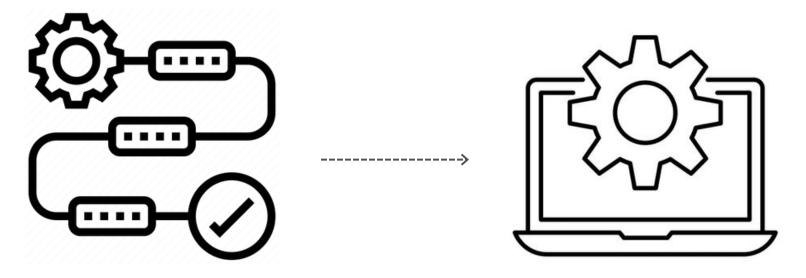# And now the fun part!
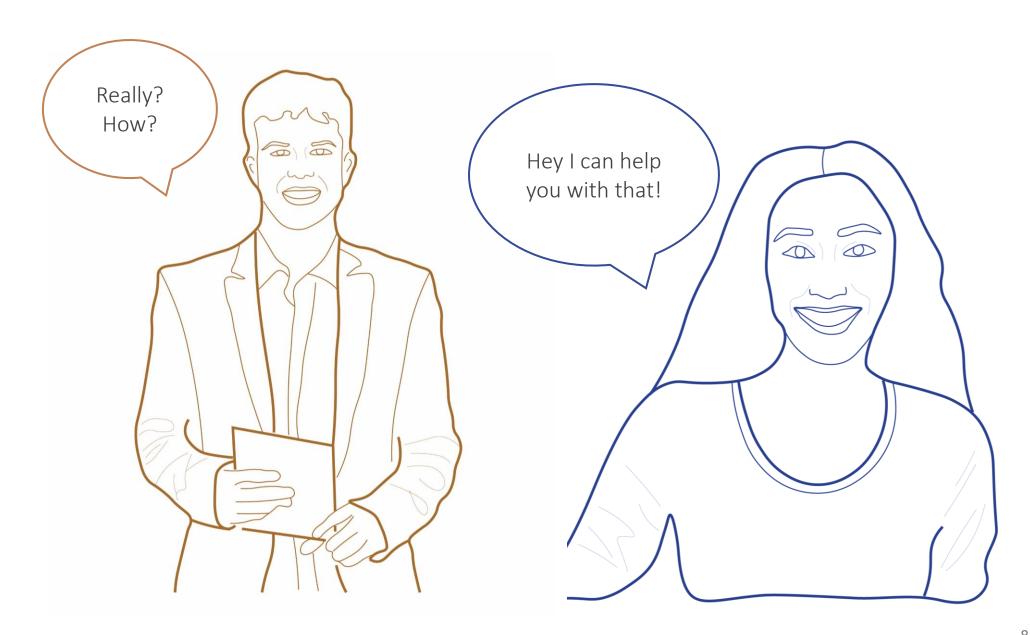
Let's Introduce

User Guidance Workflow

Did I make it?

*How can the **decision-making process** in the **early design phase** of **energy renovations** in **residential buildings** be improved to enable **project developers** to make* *efficient decisions* *that consider environmental, economic, and social factors?*

Did I make it?

Limited Focus on Alternative
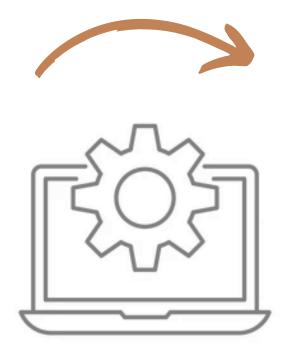
Evaluation

Fragmentation Across Phases

Narrow Scope of Decision Criteria

Complexity and Usability

Lack of Customizability

Focus on Alternatives Evaluation

Holistic Support Across Early Phases

Multi-Criteria Evaluation Framework

Intuitive and User-Friendly Design

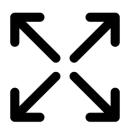Customizability and Adaptability
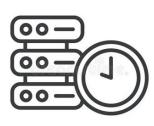
Did I make it?

BEFORE

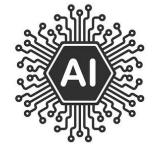Weeks

AFTER

15 minutes

What's next?

Expand   Real time data   Software   AI & ML   Pilots

a BOLD Decision

Thank you!