
Interreg
EUROPEAN UNION
North-West Europe
Housing 4.0 Energy
European Regional Development Fund

TU Delft

Feasibility and Market Potential of H4.0E Small, (Near) Zero-Energy Dwellings

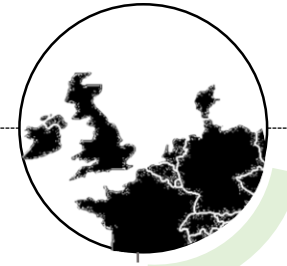
Cynthia Souaid

PhD Researcher

Outline

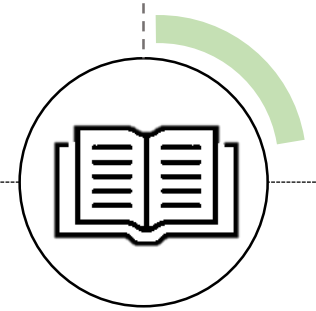
Interreg North-West Europe Housing 4.0 Energy
European Regional Development Fund

General Introduction
Contextual Background
H4.0E Aim & Objectives



Housing Challenge

Affordability

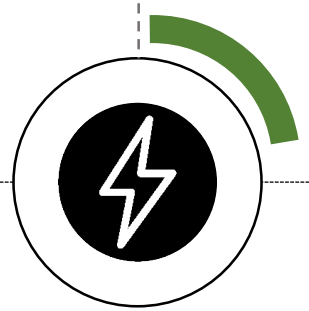


Market Supply
Institutional Barriers

Market Demand
Current Housing Preferences

SMALL

Low Carbon/Zero-Energy



Energy Performance
Embodied Carbon

1

H4.0E: Affordable and Sustainable Housing through Digitization

Why?

Interreg North-West Europe Housing 4.0 Energy
European Regional Development Fund

Size

Composition

Housing Needs

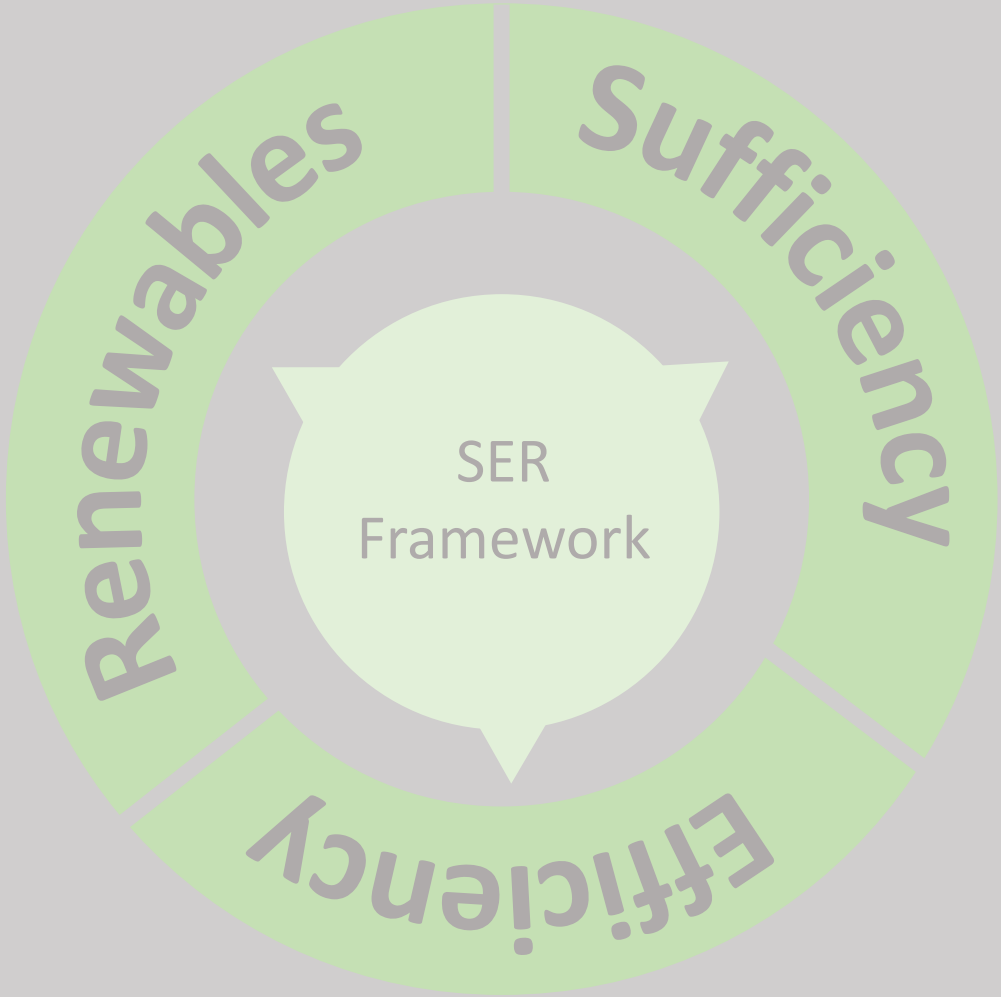
H4.0E Contextual Background

Financial Capacities

Housing Shortage

IPCC 6th Assessment Report

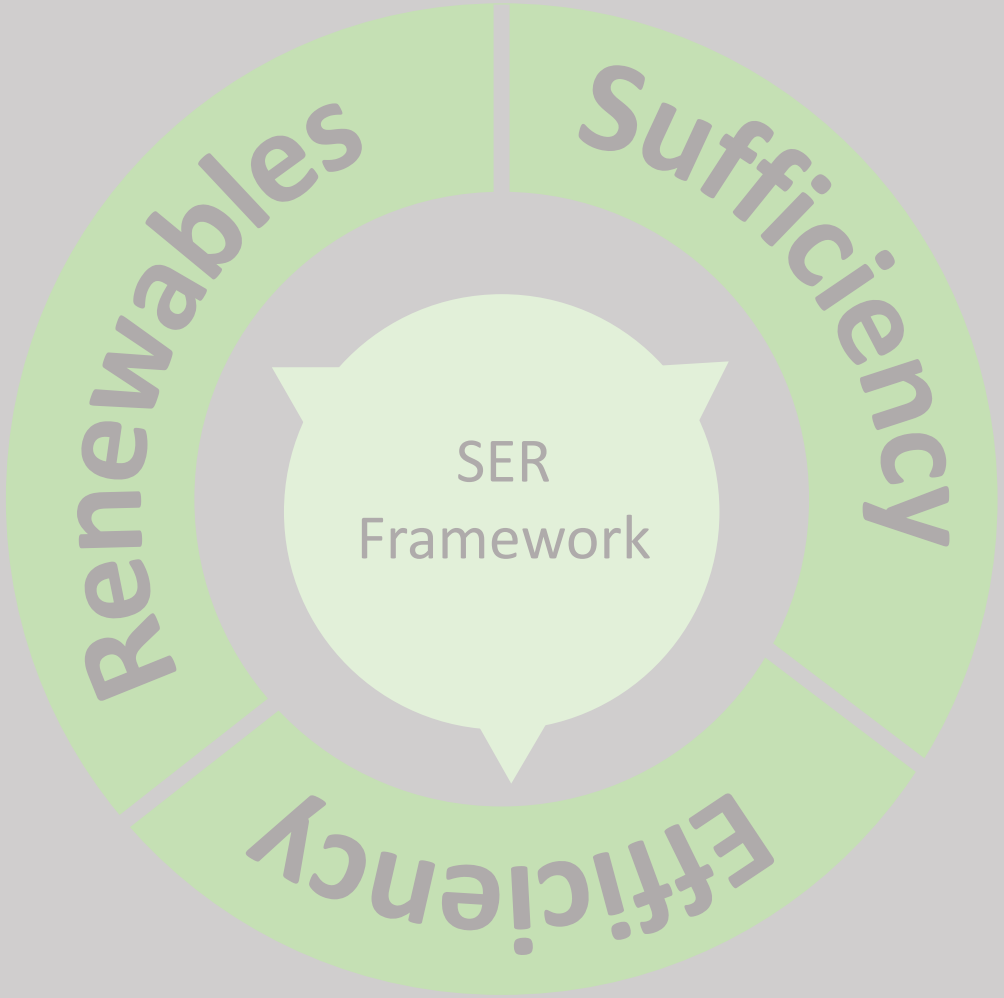
> Evidence of observed impacts, projected risks, levels and trends in vulnerability, and adaptation limits, demonstrate that worldwide climate resilient development action **is more URGENT than previously assessed** in AR5.



Adapted from the IPCC, 6TH Assessment Report

Sufficiency

> “avoiding the demand for […] natural resources while delivering **a decent living standard** […].”



Adapted from the IPCC, 6TH Assessment Report

> Sufficiency interventions in buildings include adjusting the size of buildings to the evolving needs of households by downsizing dwellings.

What?

H4.0E Aim

> Enable a significant **switch** of small households in NWE **to new, affordable, zero-energy homes,** leading to an extensive **reduction of housing related CO_2 emissions.**

H4.0E Objectives

- **REDUCE** both costs and carbon emissions.
- **ASSESS** the selection of techniques, materials and methods.
- **ENABLE** an easy and affordable replicability through a digital platform.

How?

H4.0E Pilots & Partners

NL

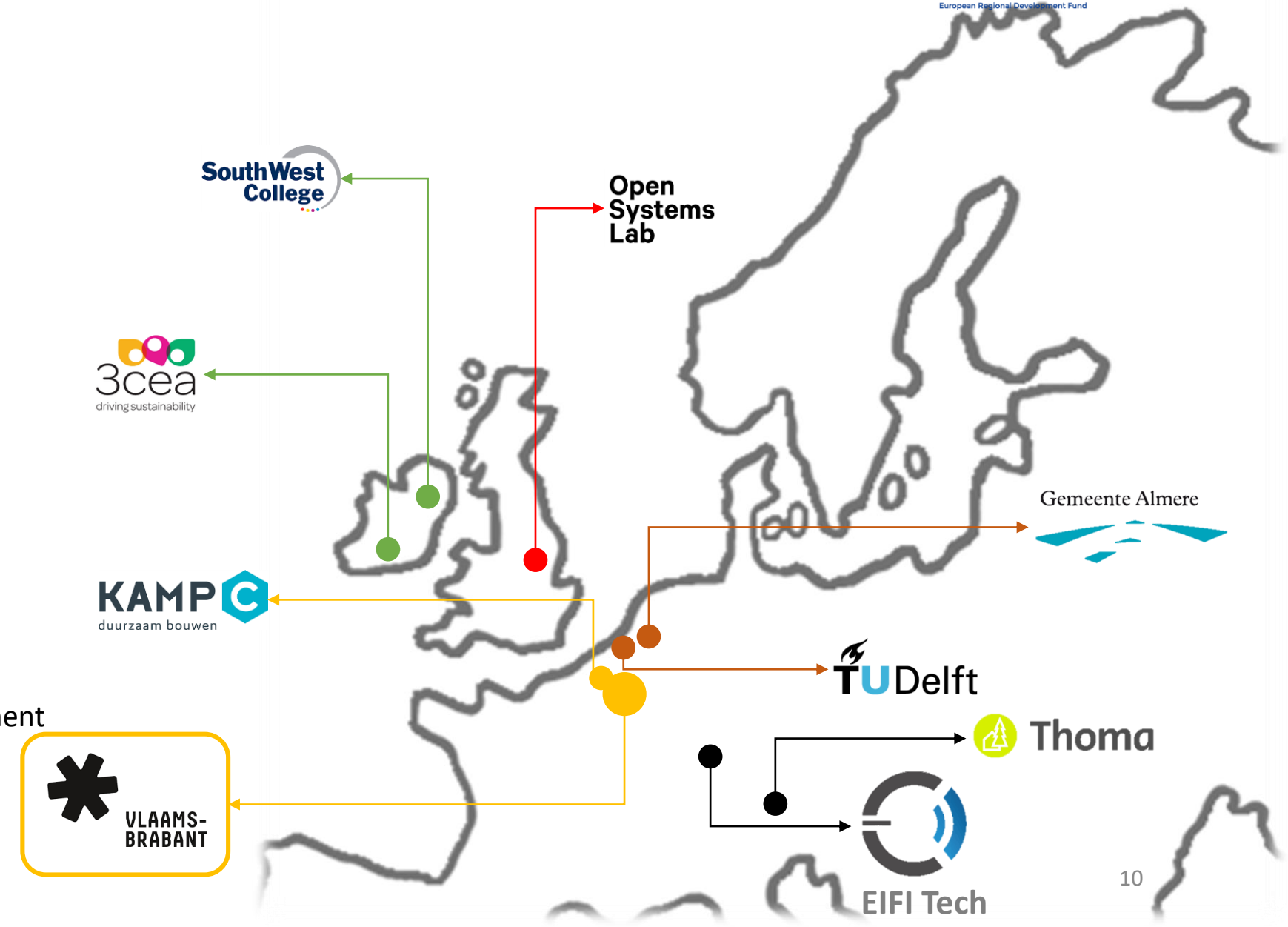
- 27 Dwellings
- Detached, Semi-detached
- Middle-income
- Ownership
- Private Sector
- Self-build

BE

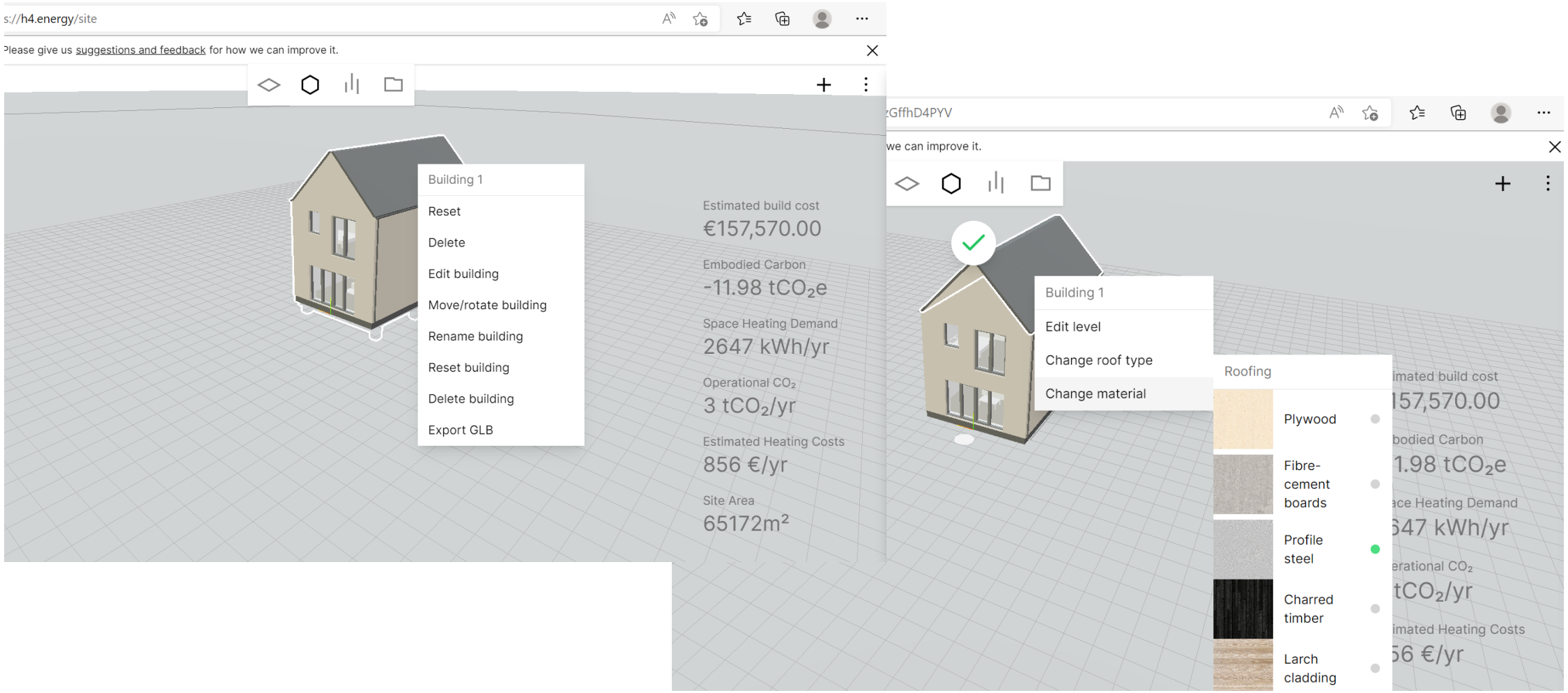
- 6 Dwellings
- Detached, Semi-detached,
- Low-income
- Social Letting Agency waiting list
- Rental
- Private Sector, partially subsidized

IE

- 12 Dwellings
- Detached, Semi-detached, Apartment
- Low-income
- Social Housing Waiting list
- Rental
- Social Housing sector



h4.energy


s://h4.energy/site
Please give us suggestions and feedback for how we can improve it.
Building 1
Reset
Delete
Edit building
Move/rotate building
Rename building
Reset building
Delete building
Export GLB
Estimated build cost
€157,570.00
Embodied Carbon
-11.98 tCO2e
Space Heating Demand
2647 kWh/yr
Operational CO2
3 tCO2/yr
Estimated Heating Costs
856 €/yr
Site Area
65172m²
GffhD4PYV
we can improve it.
Building 1
Edit level
Change roof type
Change material
Roofing
Plywood
Fibre-cement boards
Profile steel
Charred timber
Larch cladding

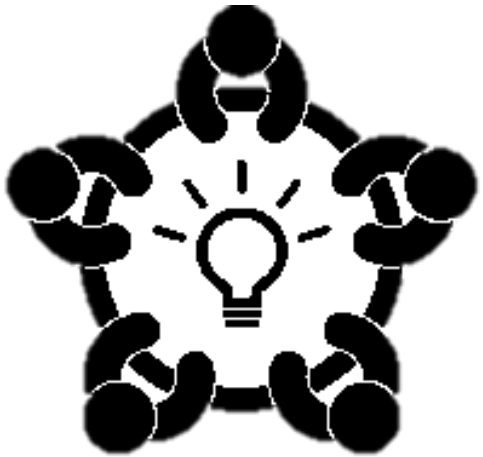
2

Market Supply: Barriers to Implementation and Uptake

> The decarbonisation of buildings is constrained by multiple barriers and obstacles […].

IPCC, 6TH Assessment Report

Institutional Context



METHOD

Focus group discussions

Focus Group Content

Financial

Technical

Legislative

Cultural

Institutional Context

METHOD

Semi-structured Interviews

GENERAL

CONTEXT SPECIFIC

Context Specific Barriers

Netherlands

✖ Residual counting

Land price determination based on market value and residual counting: most cost savings from self-building go into the residual land price

✖ Testing period

Long periods of testing and development for national building regulations for future concepts and upscaling*

Belgium

✖ Number of dwellings per plot

Often it is limited to one house per a relatively large plot which was perceived to discourage the uptake of smaller dwellings

✖ Restrictive building regulations

Current building and planning regulations pose minimum living area requirements often exceeding the largest H4.0E dwelling design

Ireland

✖ Accessibility and fire requirements

Lack of information/experience of professionals when it comes to compliance of innovative dwelling designs or materials

✖ Individual certification

Each certification needed requires an individual application and pre-certification is not possible even if dwelling designs are being replicated

Recommended Suggestions

Examples

Netherlands

- **Need to take into account the land price determination** that is based on market value and the residual counting especially **when it comes to the determination of the affordability of a dwelling.**

Belgium

- Need to **promote small scale living** that would lead to the reconsideration of the building regulations that restrict it.
- Need to **promote clustered construction** by giving **precedence to area development** rather than parcel-based land subdivision.

Ireland

- Need to **promote the performance of** zero-energy, **low carbon dwellings** such as H4.0E dwellings **with a focus on their compliance to fire and accessibility requirements.**
- Need to take into account the **time** required within the individual scheme of certification **throughout the replication of H4.0E dwellings**.

General Barriers

Perception of higher costs

A better energy performance is linked to higher initial costs and potentially higher maintenance costs.

Trade-off between energy efficiency and affordability

The current priority leans towards providing more dwellings at potentially the same cost.

Uncertainty and risks of innovation

Reluctance of housing professionals and local authorities to implement innovative building materials and construction methods

General Barriers

Perception of higher costs
A better energy performance is linked to higher initial costs and potentially higher maintenance costs.

Trade-off between energy efficiency and affordability
The current priority leans towards providing more dwellings at potentially the same cost.

Uncertainty and risks of innovation
Reluctance of housing professionals and local authorities to implement innovative building materials and construction methods

BUSINESS

AS

USUAL

Recommendations

INNOVATION IN INFORMATION DISSEMINATION

REAL

CHANGE

APPROACH

Recommendations

INTEGRATE information provision in the housing provision process
Trained experts should be incorporated at key decision making moments that local authorities, social housing associations, private developers, encounter throughout the process of housing provision.

REAL

TRAIN key intermediaries
Training of intermediaries would not only cover NZEB related information and regulation but also communication skills to develop the ability to address different housing professionals according to their different interests and goals

CHANGE

TAILOR NZEB information to the professional field it is addressing
NZEB information should be personalized to the situational context of its targeted audience for a more impactful dissemination

APPROACH

3 Market Demand: Housing Preferences of Small Households

Fulfilling current housing preferences

Downsizing for the sake of sufficiency and the environment

To what extent do smaller dwelling sizes fulfil the housing preferences of small households?

Current Housing Preferences

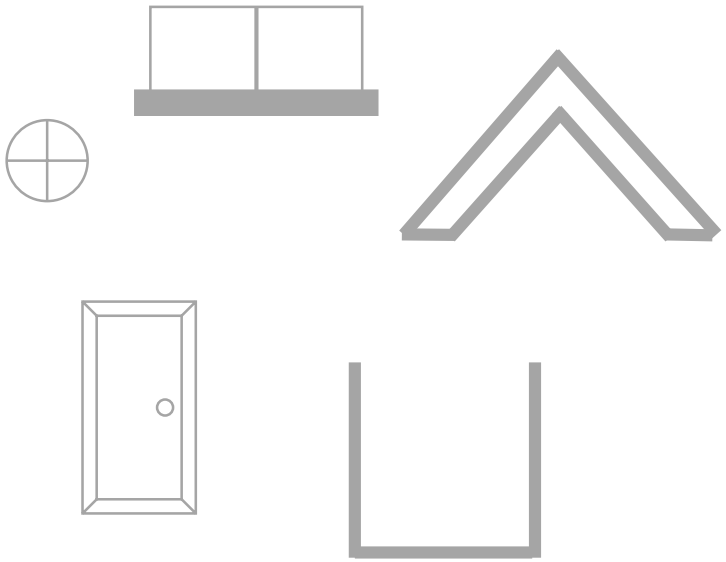
METHOD

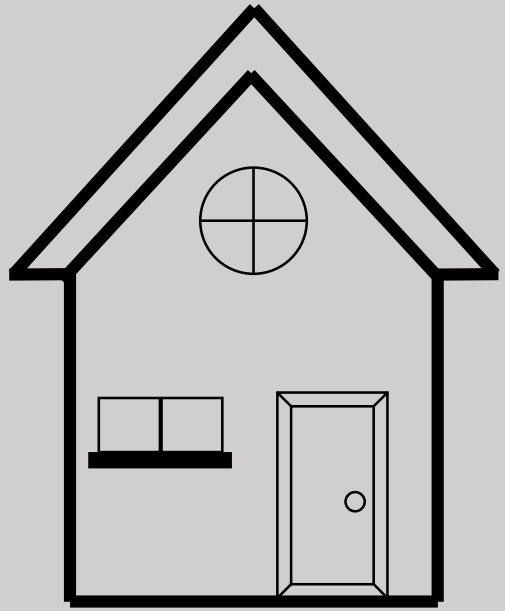
Housing preferences questionnaire

MAUT Method

A compositional Approach

Individual attributes → **Complete profiles**





Housing Attributes

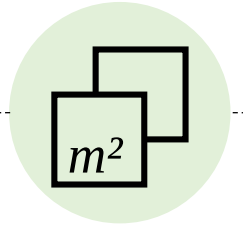
Dwelling Type

Detached
Semi-detached
Terraced
Apartment

Dwelling Location

City
Suburbs
Rural

Dwelling Size

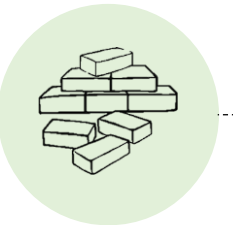


≤50 m^2
51 to 80 m^2
81 to 100 m^2
> 100 m^2

Number of Bedrooms

One
Two
Three
Four

Building Materials



Timber
Concrete
Bricks

Housing Preferences Survey

Interreg North-West Europe Housing 4.0 Energy
European Regional Development Fund

Attribute **Importance**

Wanneer je nadenkt over hoe je graag woont: hoe belangrijk zijn de volgende kenmerken dan voor jou op een schaal van 0 (niet belangrijk) tot 10 (zeer belangrijk)?

	niet belangrijk 0	1	2	2	3	4	5	6	7	8	9	zeer belangrijk 10
Type woning	○	○	○	○	○	○	○	○	○	○	○	○
Ligging/Locatie	○	○	○	○	○	○	○	○	○	○	○	○
Of je eigenaar dan wel huurder bent van je woning	○	○	○	○	○	○	○	○	○	○	○	○
Grootte van de woning	○	○	○	○	○	○	○	○	○	○	○	○
Aantal slaapkamers	○	○	○	○	○	○	○	○	○	○	○	○
Materiaal waaruit de woning is opgetrokken	○	○	○	○	○	○	○	○	○	○	○	○
Woonkost (huur of afbetaling)	○	○	○	○	○	○	○	○	○	○	○	○
Energiekost (verwarming en elektriciteit)	○	○	○	○	○	○	○	○	○	○	○	○

Attribute **Preference**

Als je nadenkt over hoe je graag woont, in welke mate hebben de volgende woningtypen jouw voorkeur op een schaal van 0 (laagste voorkeur) tot 10 (hoogste voorkeur)?

Woningtype

	Laagste voorkeur 0	1	2	3	4	5	6	7	8	9	Hoogste voorkeur 10
Vrijstaand	○	○	○	○	○	○	○	○	○	○	○
Halfopen	○	○	○	○	○	○	○	○	○	○	○
Rijwoning	○	○	○	○	○	○	○	○	○	○	○
Appartement	○	○	○	○	○	○	○	○	○	○	○
Studio/Kamer	○	○	○	○	○	○	○	○	○	○	○

Als je nadenkt over hoe je graag woont, in welke mate hebben de volgende locaties jouw voorkeur op een schaal van 0 (laagste voorkeur) tot 10 (hoogste voorkeur)?

Ligging/Locatie

	Laagste voorkeur 0	1	2	3	4	5	6	7	8	9	Hoogste voorkeur 10
In de stad	○	○	○	○	○	○	○	○	○	○	○
In de stadsrand	○	○	○	○	○	○	○	○	○	○	○
Landelijk, in/nabij de dorpskern	○	○	○	○	○	○	○	○	○	○	○
Landelijk, buiten de dorpskern	○	○	○	○	○	○	○	○	○	○	○

Survey

Outcomes

Survey Outcomes

Sample Characteristics

	Age			Household Size			Income			
	Y	M	S	1	2	3+	€	€€	€€€	⊙
NL	9%	40%	**51%**	**82%**	11%	7%	**31%**	**34%**	25%	10%
BE	17%	27%	**56%**	**78%**	15%	7%	**10%**	**38%**	41%	11%
IR	12%	80%	8%	33%	21%	46%	**16%**	**56%**	24%	4%

((o)) Average Response Rate 10%

Survey Outcomes

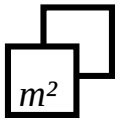
Current Housing Situation

Interreg North-West Europe Housing 4.0 Energy
European Regional Development Fund

TENURE TYPE

Owner Occupation

70%



DWELLING SIZE

Larger than 100 m²

60%

DWELLING TYPE

Terraced Dwelling	Detached Dwelling
60%	65%
NL	BE/IR

BUILDING MATERIAL

Bricks	Concrete
60%	60%
NL/BE	IR

((o)) Average Response Rate 10%

Survey Outcomes

Current Comfort & Satisfaction Ratings

Very uncomfortable

Very comfortable

NL	86%	
BE	77%	
IR	70%	

Very dissatisfied

Very satisfied

NL	87%	
BE	77%	
IR	67%	

Survey Outcomes

Willingness to move

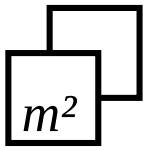
60%

NO

66% 59% 54%

Survey Outcomes

Housing Attributes Importance Scores

Dwelling Type	Dwelling Location	Dwelling Size	Number of Bedrooms	Building Materials
				
79	87	78	71	72
76	87	75	70	71
73	87	81	68	69

Survey Outcomes

Housing Attributes Importance Scores

Dwelling Type	Dwelling Location	Dwelling Size	Number of Bedrooms	Building Materials
79	87	78	71	72
76	87	75	70	71
73	87	81	68	69

Survey Outcomes

Housing Attributes Levels Preference Scores – *Dwelling Type*

	DD	SD	TD	AD	S
NL	60	56.5	57	53	-
BE	82.5	53	30	34	7.5
IR	90	56	32	24	-

100

Survey Outcomes

Housing Attributes Levels Preference Scores – *Dwelling Size*

	DD	SD	TD	AD	S	50	80	100	>
NL	60	56.5	57	53	-	15	39.5	65	62
BE	82.5	53	30	34	7.5	11	27	48	62
IR	90	56	32	24	-	14	30	47	77

100

Survey Outcomes

Housing Attributes Levels Preference Scores – *Number of Bedrooms*

	DD	SD	TD	AD	S
NL	60	56.5	57	53	-
BE	82.5	53	30	34	7.5
IR	90	56	32	24	-

	50	80	100	>
NL	15	39.5	65	62
BE	11	27	48	62
IR	14	30	47	77

	1	2	3	4
NL	17	57	63	41.5
BE	16	52.5	65	42
IR	12	30	65	68.5

100

Survey Outcomes

Housing Attributes Levels Preference Scores - *Location*

	DD	SD	TD	AD	S
NL	60	56.5	57	53	-
BE	82.5	53	30	34	7.5
IR	90	56	32	24	-

	50	80	100	>
NL	15	39.5	65	62
BE	11	27	48	62
IR	14	30	47	77

	U	SU	R
NL	58	63	54
BE	26.5	42	70.5
IR	43	56	71

	1	2	3	4
NL	17	57	63	41.5
BE	16	52.5	65	42
IR	12	30	65	68.5

	C	W	B
NL	61	37	81
BE	50	45	81
IR	69.5	62	61

100

Survey Outcomes

Housing Attributes Levels Preference Scores – *Building Materials*

	DD	SD	TD	AD	S
NL	**60**	56.5	57	53	-
BE	**82.5**	53	30	34	7.5
IR	90	56	32	24	-

	50	80	100	>
NL	15	39.5	**65**	62
BE	11	27	48	**62**
IR	14	30	47	77

	U	SU	R
NL	58	**63**	54
BE	26.5	42	**70.5**
IR	43	56	71

	1	2	3	4
NL	17	57	**63**	41.5
BE	16	52.5	**65**	42
IR	12	30	65	68.5

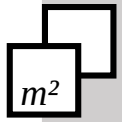
	C	W	B
NL	61	37	**81**
BE	50	45	**81**
IR	69.5	62	61

100

Survey Outcomes

Most & Least Preferred Dwelling Profiles

APARTMENT DWELLING



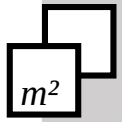
50 m² OR LESS

1 BEDROOM

TIMBER

Survey Outcomes

Most & Least Preferred Dwelling Profiles

DETACHED DWELLING		APARTMENT DWELLING
80 m² to 100 m² /OR MORE		50 m² OR LESS
3 BEDROOMS /OR MORE		1 BEDROOM
BRICKS /OR CONCRETE		TIMBER

Survey Outcomes

Averagely Attractive Dwelling Profile

51

NL

48

BE

53

IR

Survey Outcomes

H4.0E Dwelling Profiles

	H4.0E Profile #1		H4.0E Profile #2		H4.0E Profile #3
 **NL**	Semi-detached dwelling in a suburban location of a size of **80 to 100** m² with two bedroom and timber as a main building material.	<	Detached dwelling in a suburban location of a size of **80 to 100** m² with two bedroom and timber as a main building material.		-
 **BE**	Semi-detached dwelling in a rural location of a size of less than **50 m²** with one bedroom and timber as a main building material.	<	Detached dwelling in a rural location of a size of **50 to 80 m²** with one bedroom and timber as a main building material.		-
 **IR**	Apartment dwelling in a rural location of a size between **50 and 80 m²** with one bedroom and timber as a main building material.	<	Apartment dwelling in a rural location of a size between **80 and 100 m²** with one bedroom and timber as a main building material.	<	Semi-detached dwelling in a rural location of a size between 50 and **80 m²** with two bedrooms and concrete/timber as a main building material.

Survey Outcomes

H4.0E Dwelling Profiles

	H4.0E Profile #1		H4.0E Profile #2		H4.0E Profile #3
NL	55.9	<	56.6		-
BE	40.9	<	49.5		-
IR	40.5	<	47.2	<	50.4

Semi-detached dwelling in suburban location of a size of **80 to 100 m²** with two bedroom and timber as a main building material.

Detached dwelling in suburban location of a size of **80 to 100 m²** with two bedroom and timber as a main building material.

Semi-detached dwelling in a rural location of a size of less than **50 m²** with one bedroom and timber as a main building material.

Detached dwelling in a rural location of a size of **50 to 80 m²** with one bedroom and timber as a main building material.

Apartment dwelling in a rural location of a size between **50 and 80 m²** with one bedroom and timber as a main building material.

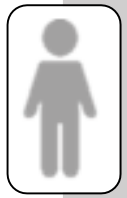
Apartment dwelling in a rural location of a size between **80 and 100 m²** with one bedroom and timber as a main building material.

Semi-detached dwelling in a rural location of a size between 50 and **80 m²** with two bedrooms and concrete/timber as a main building material.

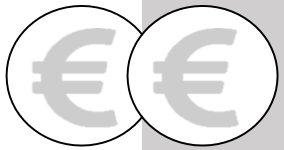
Survey Outcomes

Sensitivity Analysis

Stricter Target Group



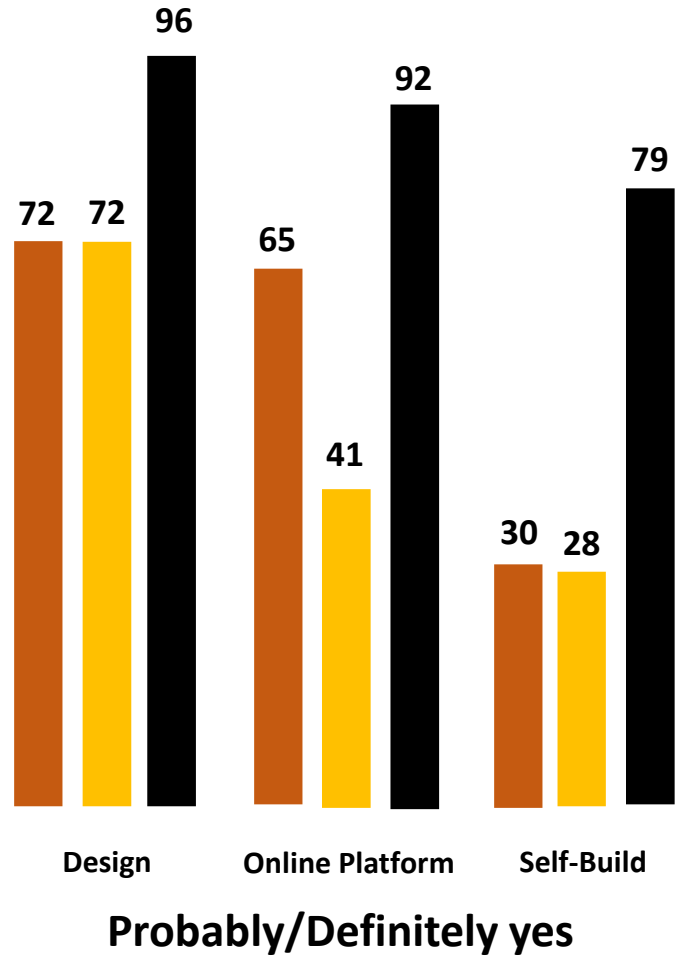
Similar Housing Preferences



Survey Outcomes

Design, Online Platform, Self-build

	Design	Online Platform	Self-Build
NL	72%	65%	30%
BE	72%	41%	28%
IR	**96%**	**92%**	**79%**



Survey Outcomes

Main Conclusions

There is a market potential for H4.0E dwellings

Although H4.0E dwelling profiles did not score very high, the study of people's trade-offs showed that several housing characteristics would make them more appealing if provided.

Dwelling type – Detached dwelling
Dwelling location – Rural area, Village centre

Dwelling type – Detached dwelling
Dwelling location – Rural area
Dwelling Size – 80 to 100 m^2

Survey Outcomes

Main Conclusions

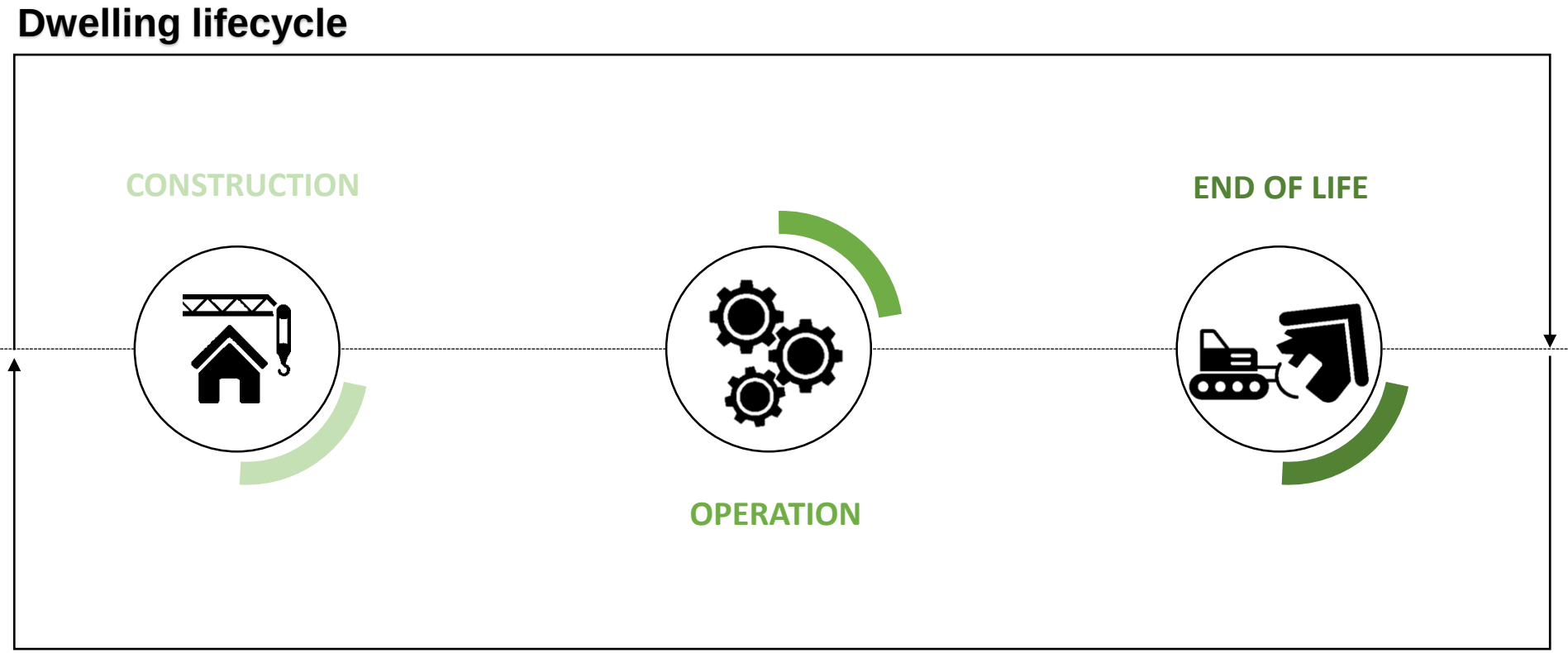
Less than 50 m² is a stretch

Timber

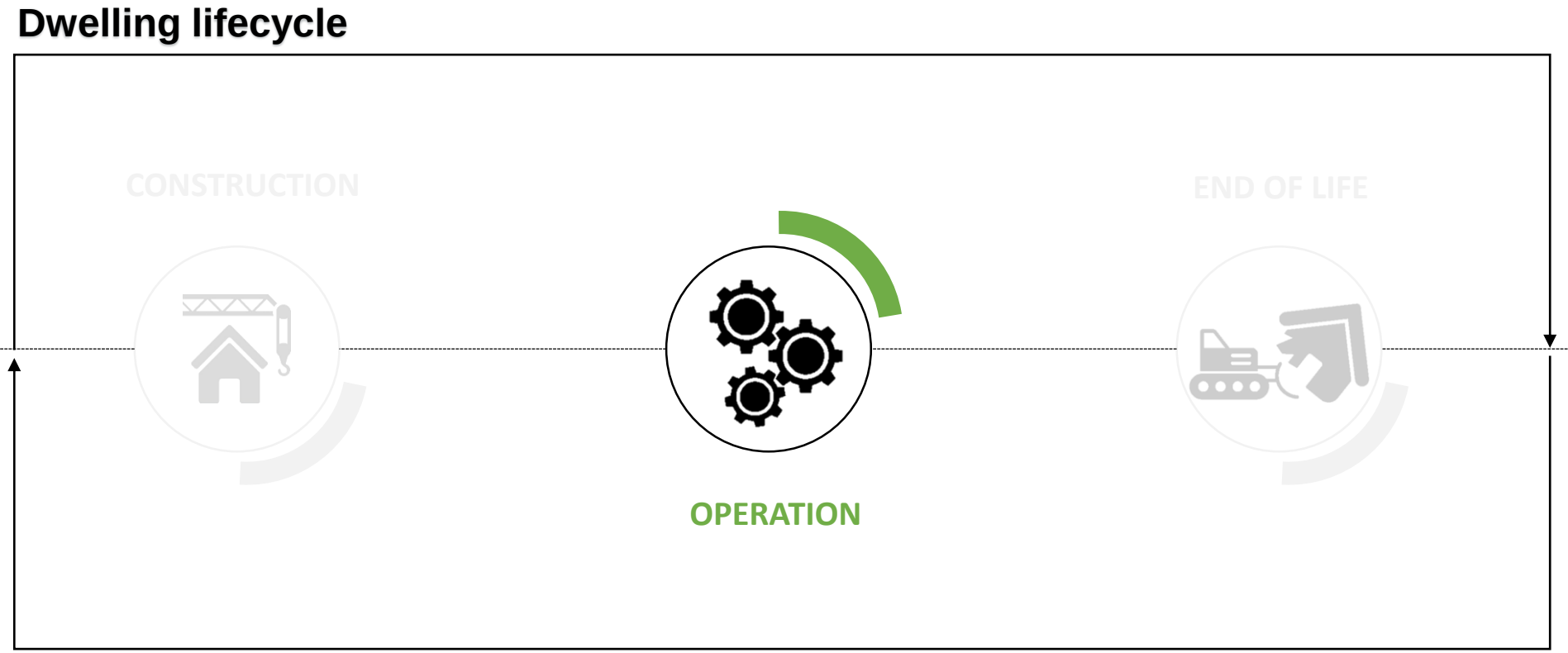
There **is room for change**!

4 H4.0E Dwelling Design: Embodied Carbon

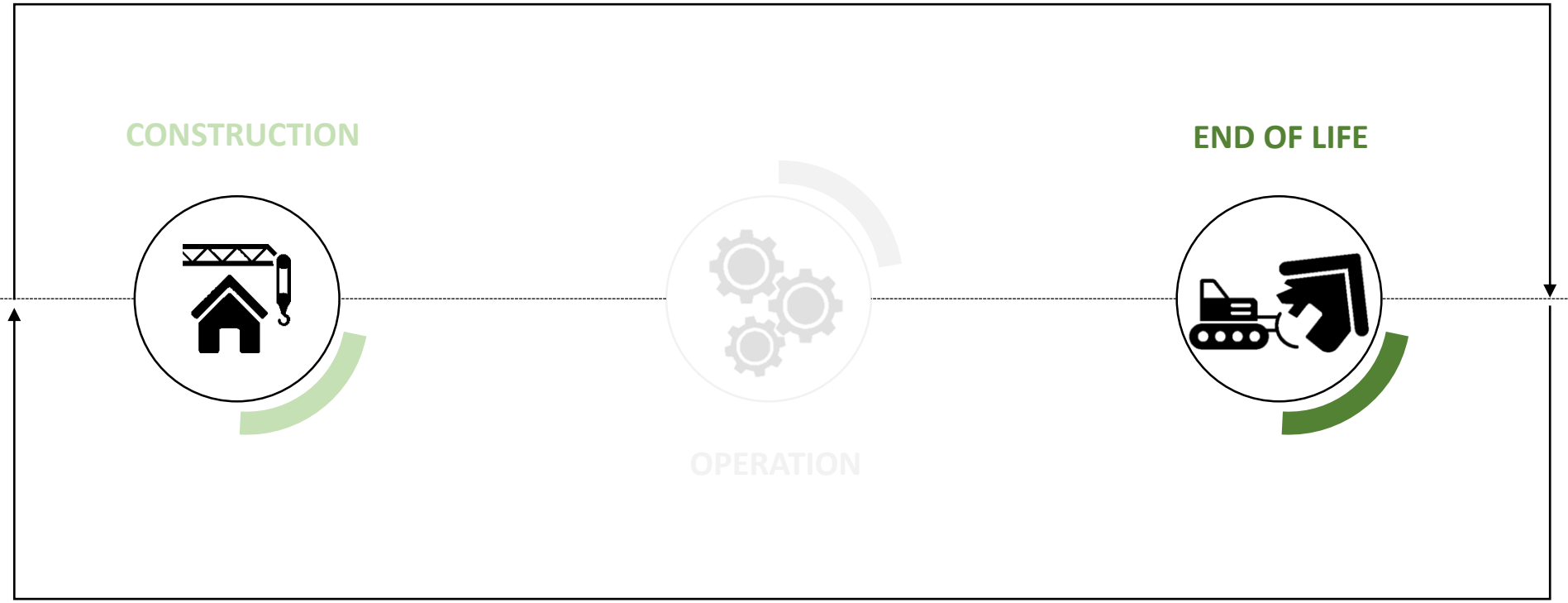
Embodied Carbon



Embodied Carbon

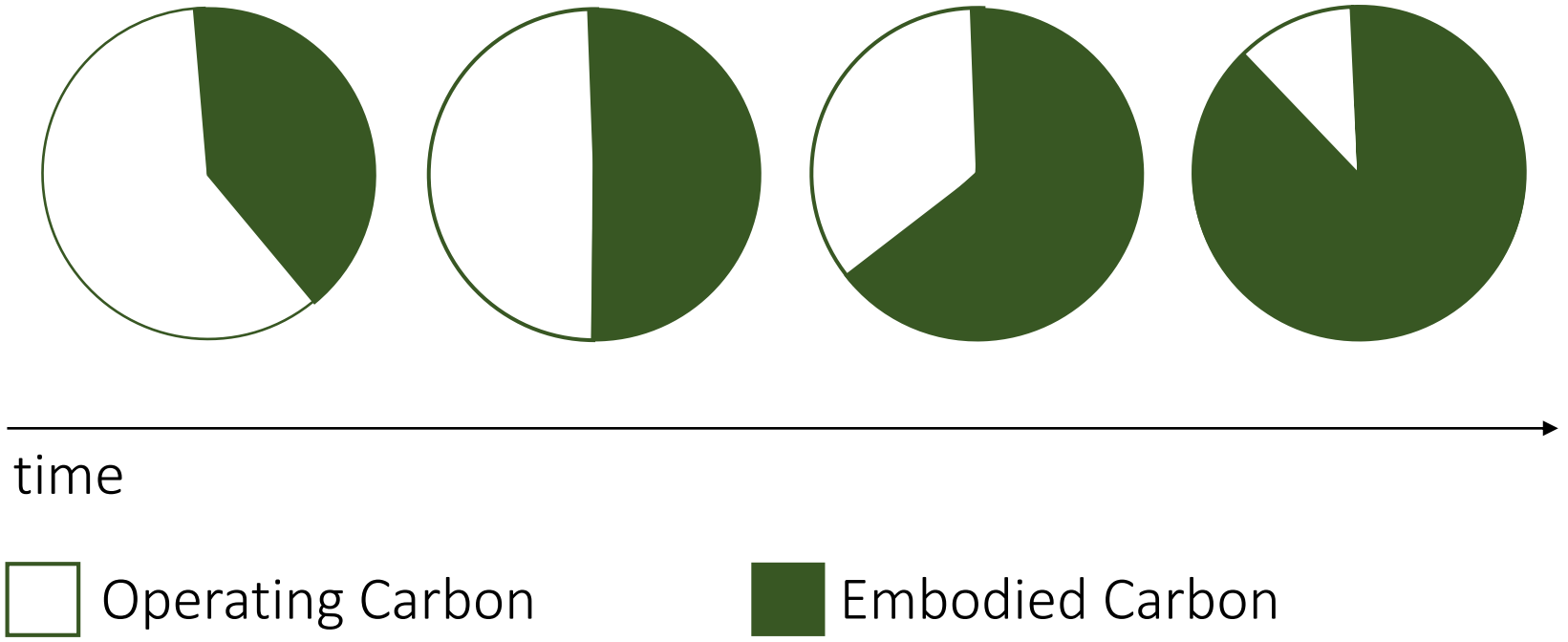


Embodied Carbon



Embodied Carbon

The increasing influence of embodied carbon over time



> The scope of CO_2 emissions has been extended from direct and indirect emissions considered in AR5 to include embodied emissions.

IPCC, 6TH Assessment Report

Embodied Carbon

METHOD

Tool to **O**ptimize the **T**otal **E**nvironmental Impact of **M**aterials

Detailed embodied carbon calculations of H4.0E dwellings using the TOTEM tool

TOTEM and LCA

Material Extraction	Transportation	Production	Construction	De-construction/Demolition	Landfill





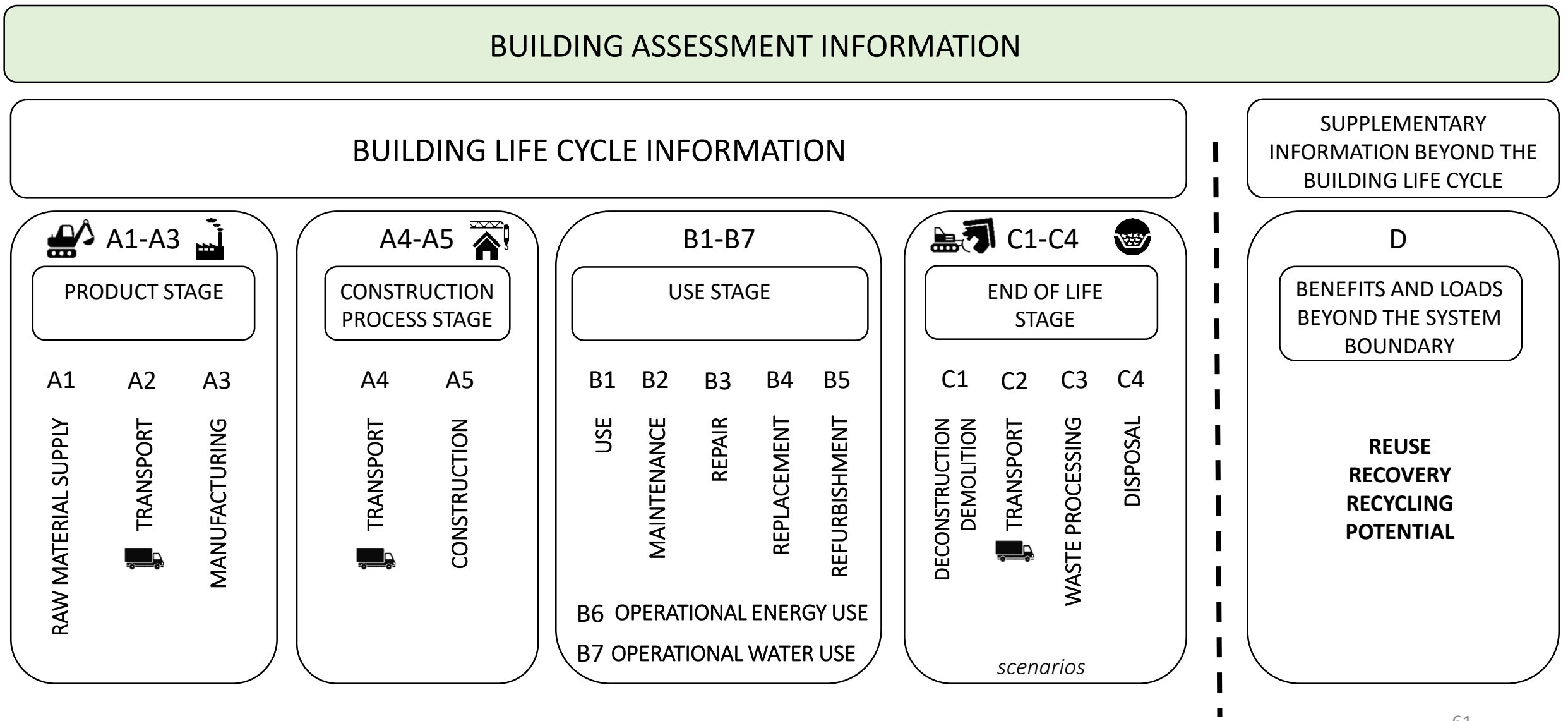

Cradle to Gate

Cradle to Site

Cradle to Cradle

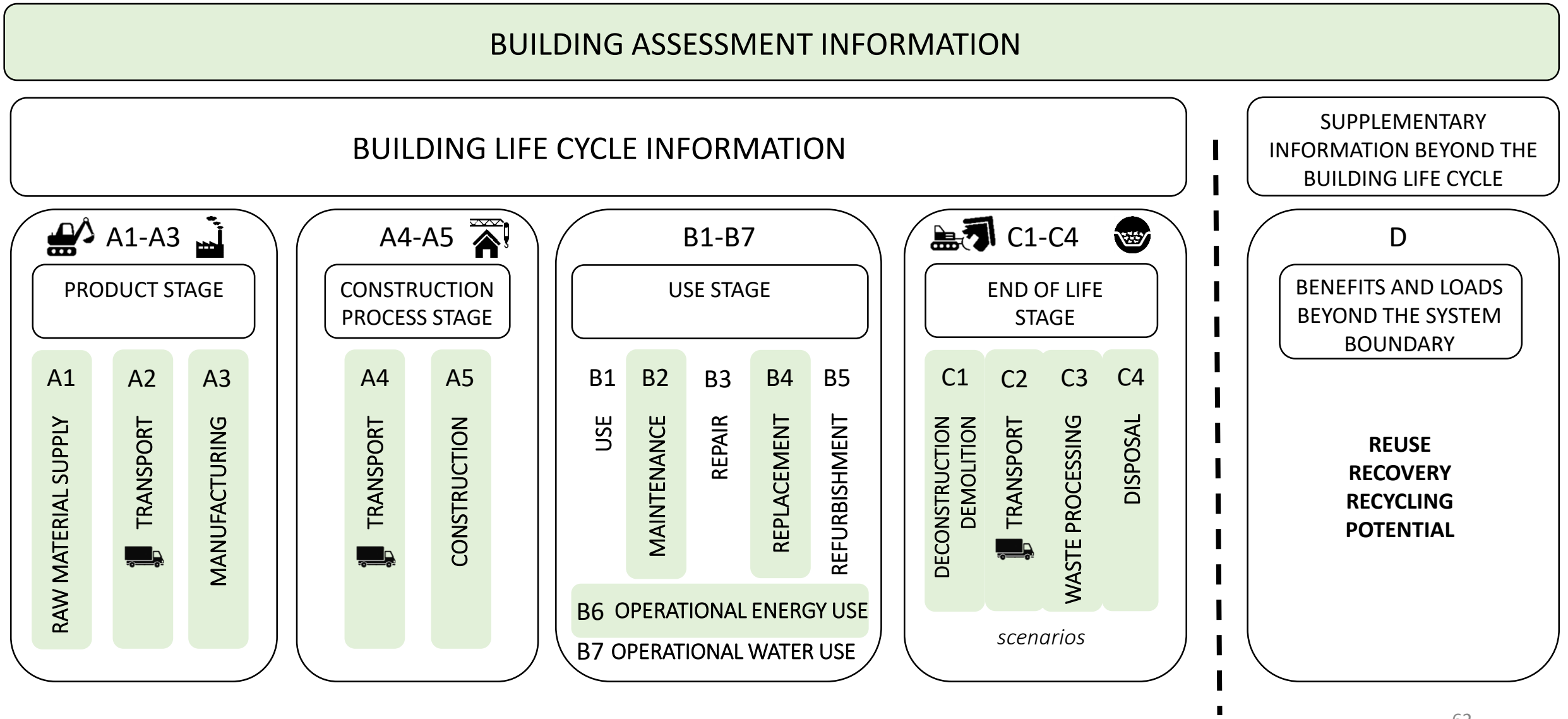
Cradle to Grave

TOTEM and LCA



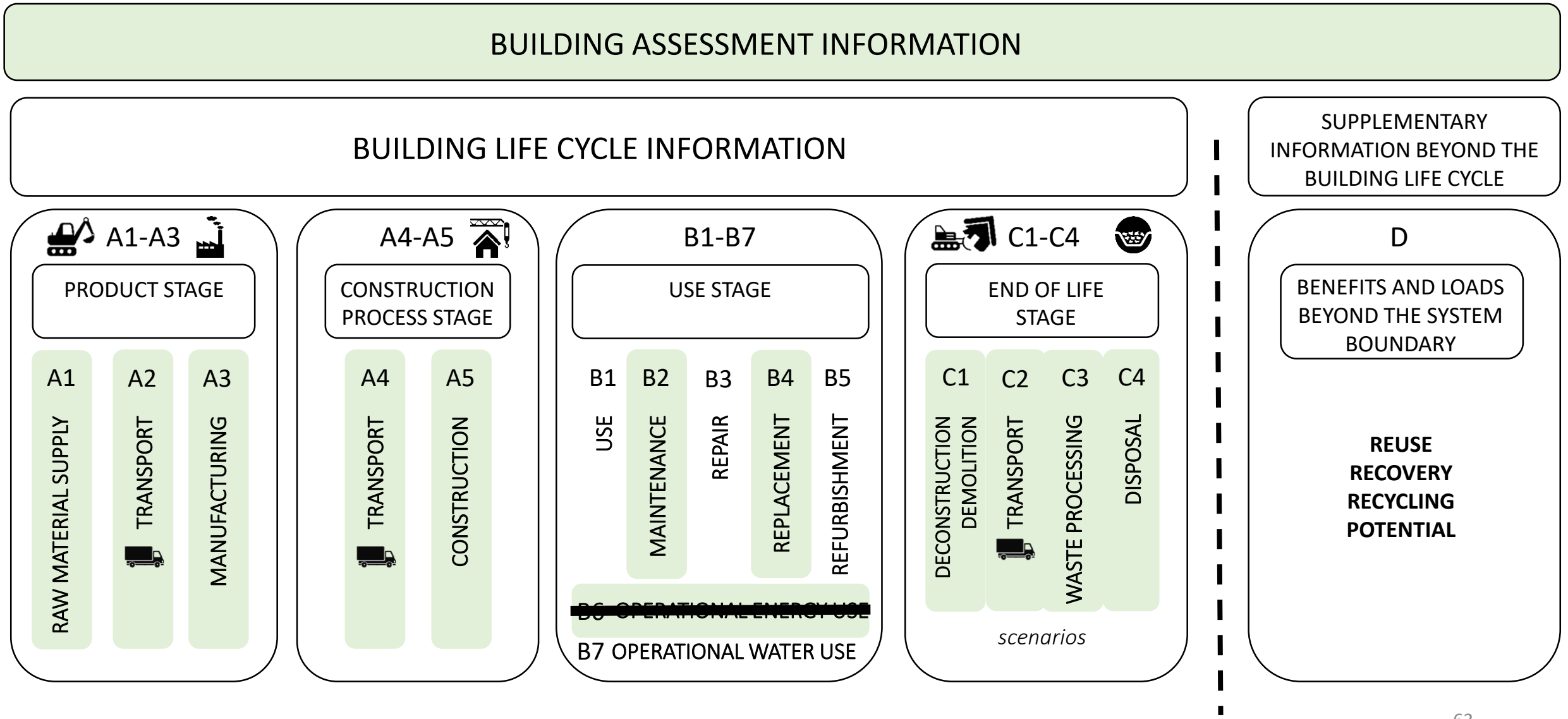
*Overview of the life cycle stages and system boundaries within the European standard EN 15978:2011 (CEN 2011)

TOTEM and LCA



*Overview of the life cycle stages and system boundaries within the European standard EN 15978:2011 (CEN 2011)

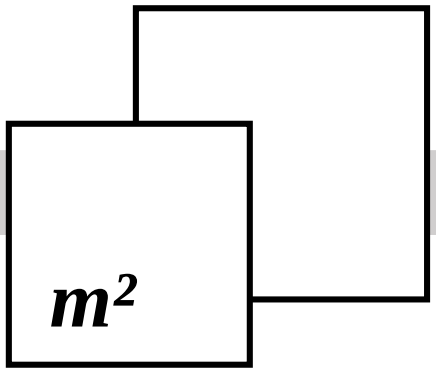
TOTEM and LCA

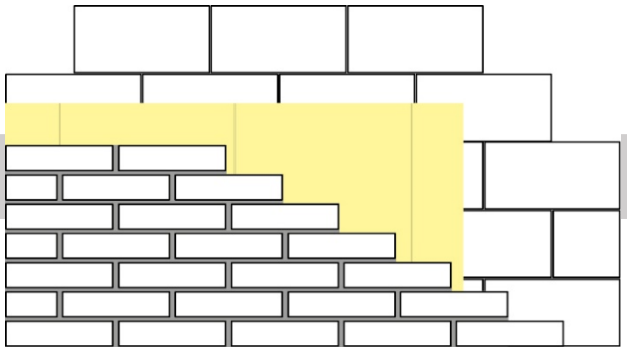


*Overview of the life cycle stages and system boundaries within the European standard EN 15978:2011 (CEN 2011)

Embodied Carbon

Main Dwelling Characteristics





Size

Materials

CO_2

Embodied Carbon

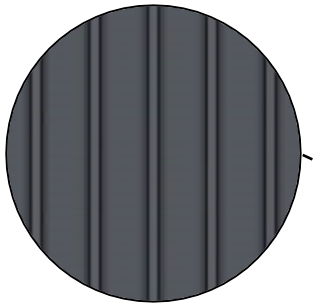
Dwelling Sizes

1	Net Surface Area: 45 m² Gross Surface Area: 59 m²
2	Net Surface Area: 76 m² Gross Surface Area: 103 m²
3	Net Surface Area: 104 m² Gross Surface Area: 137 m²

Embodied Carbon

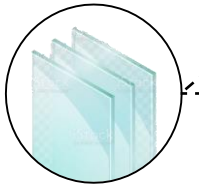
H4.0E Dwellings Materials

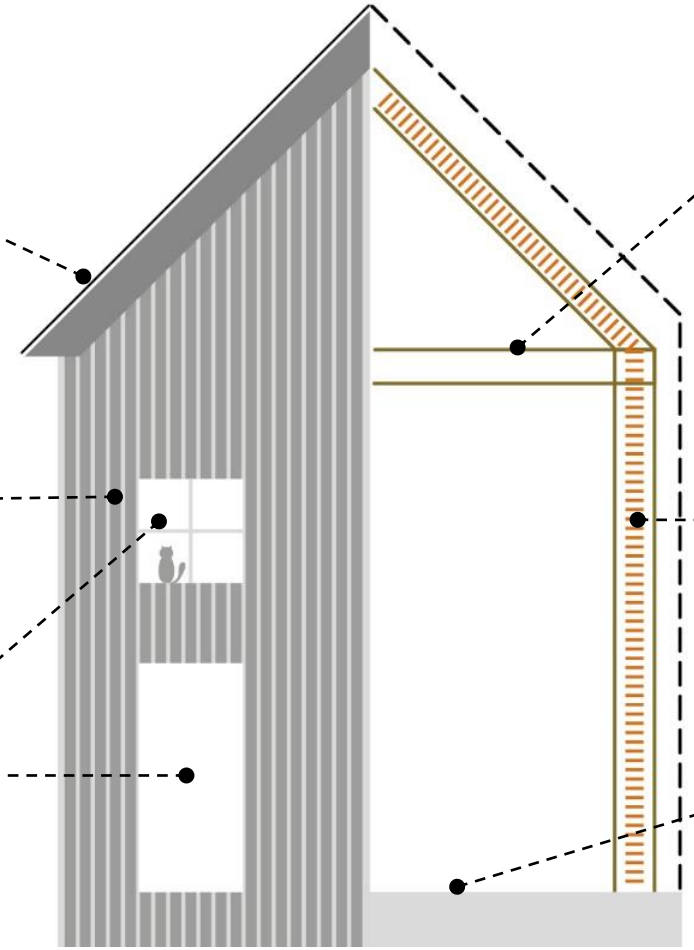
Galvanized corrugated steel roofing



Wooden exterior cladding

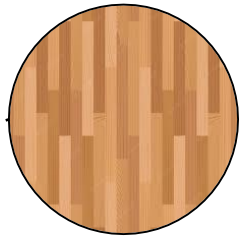
Triple glazing





Wooden structure

Glass wool insulation



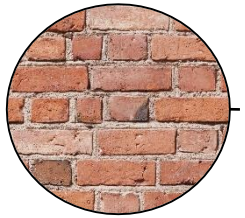
Parquet laminate flooring

Embodied Carbon

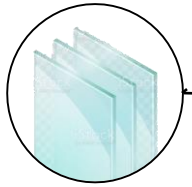
Baseline Dwelling Materials

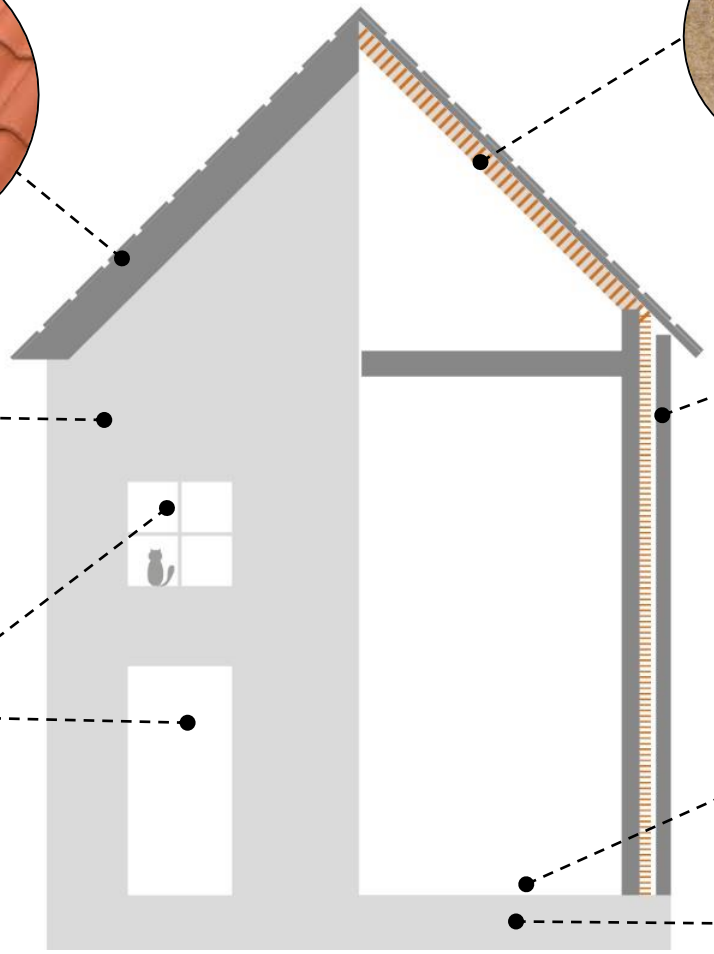
Unglazed ceramic roof tiles

Bricks exterior cladding



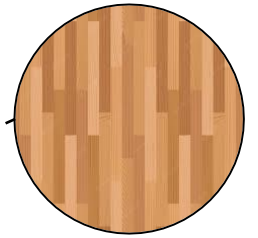
Triple glazing
unchanged





Stone wool insulation

Sand lime hollow bricks structure



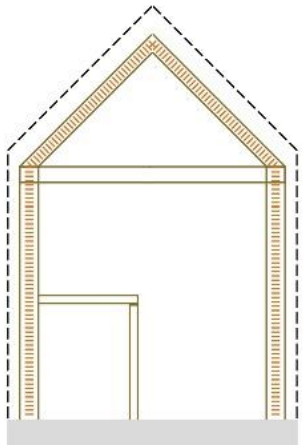
Parquet laminate flooring
unchanged

Pre-stressed concrete beams and EPS block infill

Embodied Carbon

TOTEM Workflow

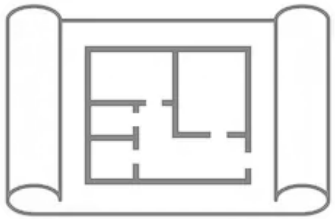
1



Main Building Elements

Building frame, Roof, Wall, Floor, External/Internal opening

2



Quantities

Square meters, Linear meter, Units

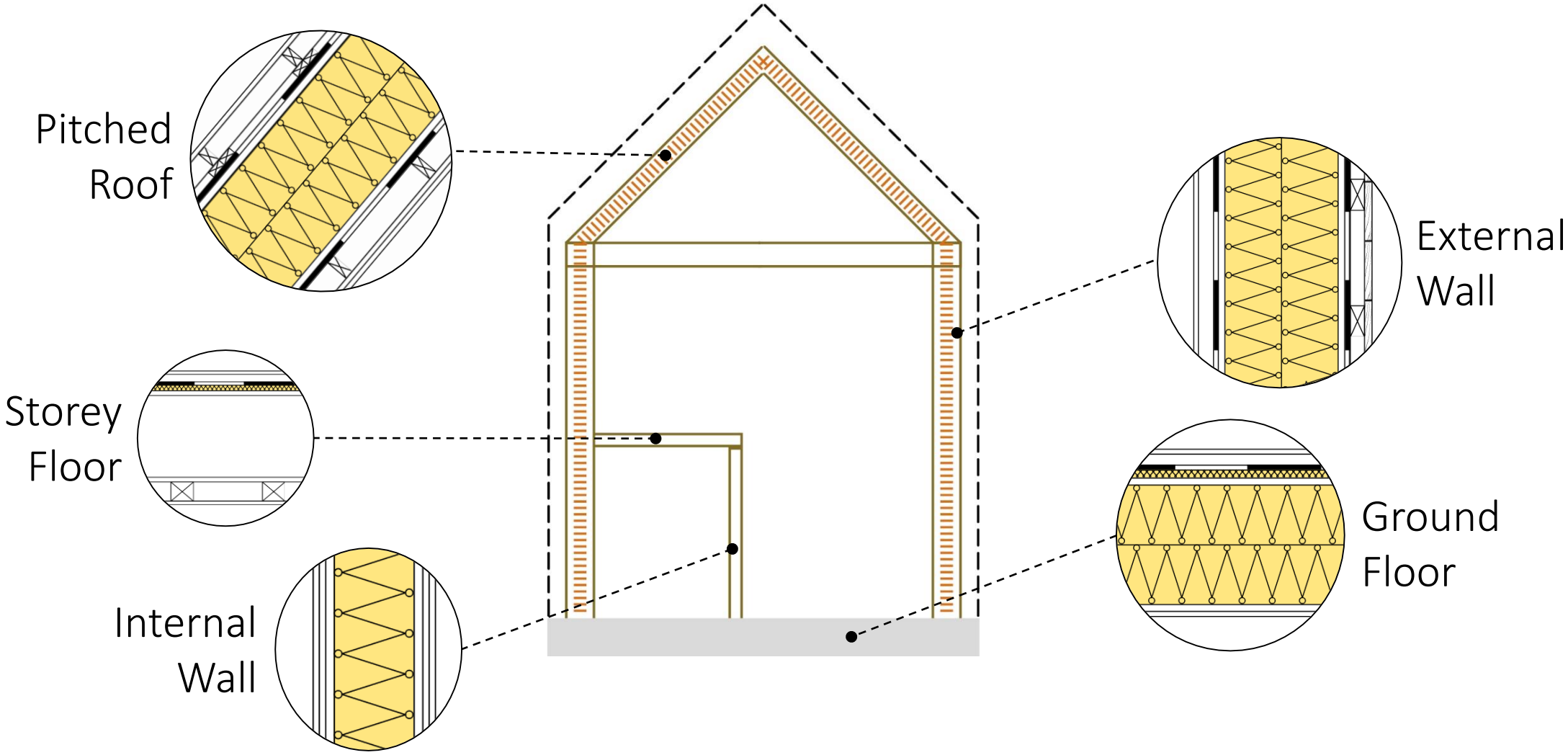
3

Material Composition

External finishing, Internal finishing, Insulation, Proofing sheet

Embodied Carbon

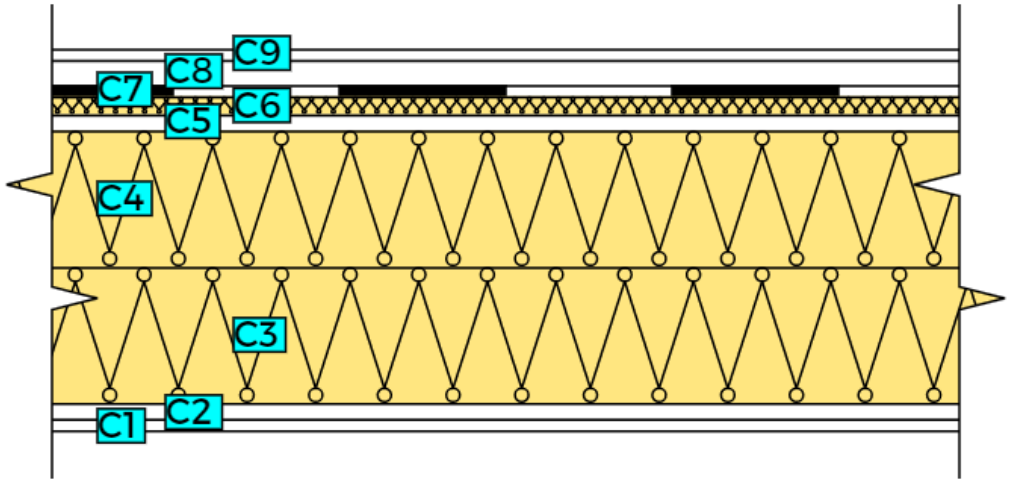
TOTEM Input



Embodied Carbon

TOTEM Input Example

Ground Floor



C9: Parquet | Laminate (7 mm) - XPS (6 mm) | Loose laid

C8: Board | Gypsum fibre (18 mm) - Stone wool (10 mm)

C7: Proofing sheet | PE (0.2 mm) | Loose laid with overlap

C6: Board | EPS (20 mm) | Upon floor slab

C5: Board | Plywood (18 mm) | Nailed

C4: Blanket | Glass wool (150 mm) | For between joists and cross beams | Friction fitted

C3: Blanket | Glass wool (150 mm) | For between joists and cross beams | Friction fitted

C2: Board | Plywood (18 mm) | Nailed

C1: Cavity membrane | PE (0.6 mm) | Taped

Preliminary

Outcomes

Embodied Carbon

Almere Dwellings

	HOUSE 1 – 59 m²	HOUSE 2 – 103 m²	HOUSE 3 – 137 m²
Climate change impact ($KgCO_2eq/m^2$ GFA)	**721**	**502**	**503**
Total Climate change impact ($KgCO_2eq$)	42,563	51,747	68,911
Total Reduction Percentage	13%	24%	13%

Embodied Carbon

Almere Dwellings

	HOUSE 1 – 59 m²	HOUSE 2 – 103 m²	HOUSE 3 – 137 m²
Climate change impact ($KgCO_2eq/m^2$ GFA)	721	502	503
Total Climate change impact ($KgCO_2eq$)	**42,563**	**51,747**	**68,911**
Total Reduction Percentage	13%	24%	13%

Embodied Carbon

Almere Dwellings

	HOUSE 1 – 59 m²	HOUSE 2 – 103 m²	HOUSE 3 – 137 m²
Climate change impact ($KgCO_2eq/m^2$ GFA)	721	502	503
Total Climate change impact ($KgCO_2eq$)	42,563	51,747	68,911
Total Reduction Percentage	**13%**	**24%**	**13%**

Embodied Carbon

Preliminary results – Reduction Percentage

HOUSE 1	HOUSE 2	HOUSE 3
45 m²	76 m²	104 m²
Cradle to Gate	Cradle to Gate	Cradle to Gate
 77%	 87%	 88%

Embodied Carbon

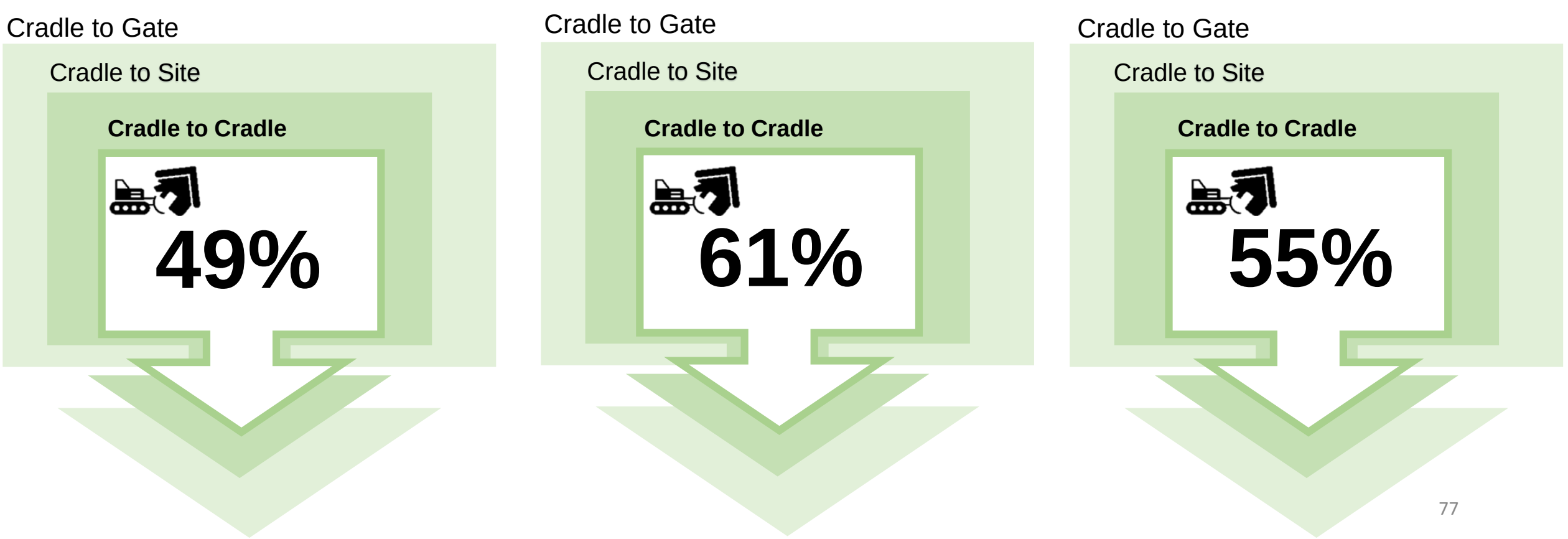
Preliminary results – Reduction Percentage

HOUSE 1	HOUSE 2	HOUSE 3
45 m²	76 m²	104 m²
Cradle to Gate	Cradle to Gate	Cradle to Gate
Cradle to Site	**Cradle to Site**	**Cradle to Site**
71%	**82%**	**82%**

Embodied Carbon

Preliminary results – Reduction Percentage

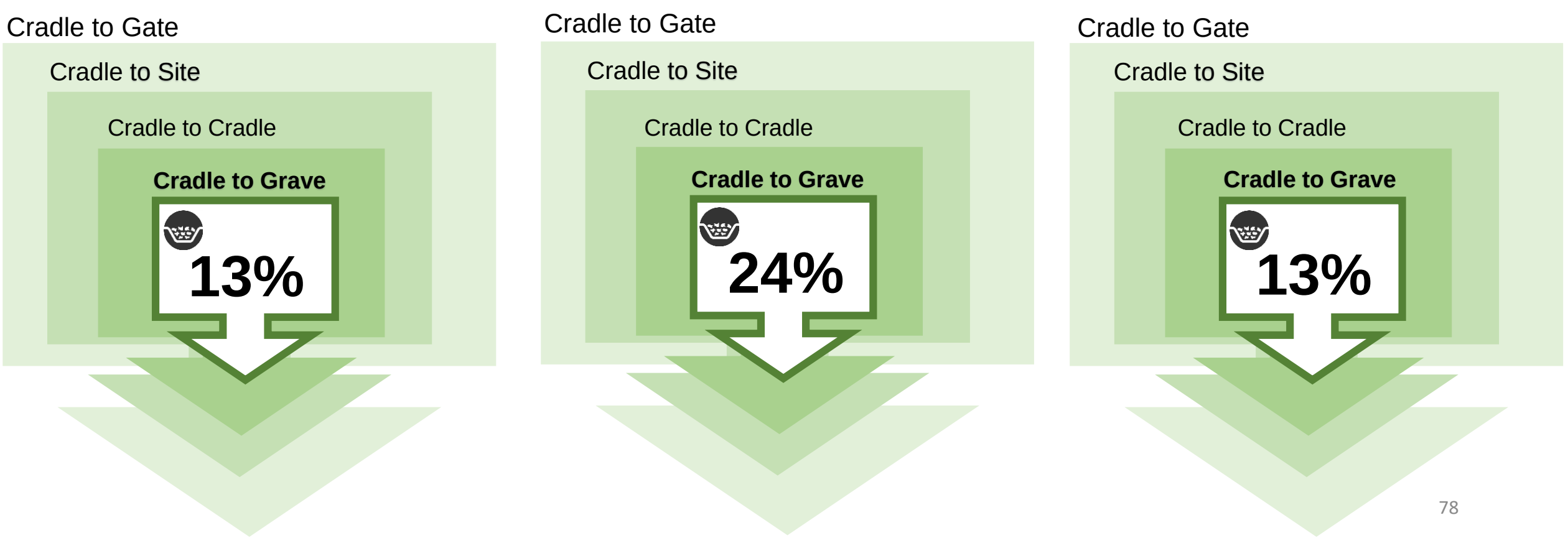
HOUSE 1	HOUSE 2	HOUSE 3
45 m²	76 m²	104 m²



Embodied Carbon

Preliminary results – Reduction Percentage

HOUSE 1	HOUSE 2	HOUSE 3
45 m²	76 m²	104 m²



Embodied Carbon

Preliminary results

Climate Change Impact ($KgCO_{2eq}$ per m^2GFA)

Case	Almere					
GFA	59 m^2		103 m^2		137 m^2	
Scenario	House 1	Baseline	House 2	Baseline	House 3	Baseline
Production	96	415	45	356	35	294
Transportation - to site	18	33	11	26	11	24
Construction + installation	24	28	16	22	16	20
Maintenance	32	34	23	26	24	26
Replacement of components	133	108	102	98	105	99
Replacement of elements	65	103	36	76	43	62
Deconstruction / demolition	2	6	1	5	1.2	4.8
Transportation - end of life	7	10	5	8	5.4	7.4
Waste processing	51	23	39	8	38	11
Disposal	293	74	224	36	231	45
Overal impact - m^2	721	834	502	661	503	581
Overall impact - kg/yr	42563	49177	51747	68114	68911	79597
Difference - %	-13%		-24%		-13%	

Embodied Carbon

Preliminary results

Climate Change Impact ($KgCO_{2eq}$ per m^2GFA)

Case	Almere					
GFA	59 m^2		103 m^2		137 m^2	
Scenario	House 1	Baseline	House 2	Baseline	House 3	Baseline
Production	96	415	45	356	35	294
Transportation - to site	18	33	11	26	11	24
Construction + installation	24	28	16	22	16	20
Maintenance	32	34	23	26	24	26
Replacement of components	133	108	102	98	105	99
Replacement of elements	65	103	36	76	43	62
Deconstruction / demolition	2	6	1	5	1.2	4.8
Transportation - end of life	7	10	5	8	5.4	7.4
Waste processing	51	23	39	8	38	11
Disposal	293	74	224	36	231	45
Overal impact - m^2	721	834	502	661	503	581
Overall impact - kg/yr	42563	49177	51747	68114	68911	79597
Difference - %	-13%		-24%		-13%	

TOTEM Assumptions

End of Life Scenarios

REALITY

✖

TOTEM

=

95%

"The environmental impact of the incineration of construction and demolition waste is attributed in its **ENTIRETY** to the material being incinerated and ***not to the energy produced***."

TOTEM Assumptions

End of Life Scenarios

REALITY

✖

TOTEM

=

95%

"For materials that are recycled or reused, it is assumed that 'end of waste' is reached at the exit gate of the sorting facility or collection point. In other words, the impact up to and including the sorting facility is allocated to the waste producing product, but that all subsequent impacts such as **transportation from the sorting facility to the recycling facility or the impact of the recycling process itself fall OUTSIDE of the system boundaries** and are assigned to the next material when the secondary materials are being used."

Embodied Carbon

Lessons Learned

Interreg North-West Europe Housing 4.0 Energy
European Regional Development Fund

E N D O F L I F E

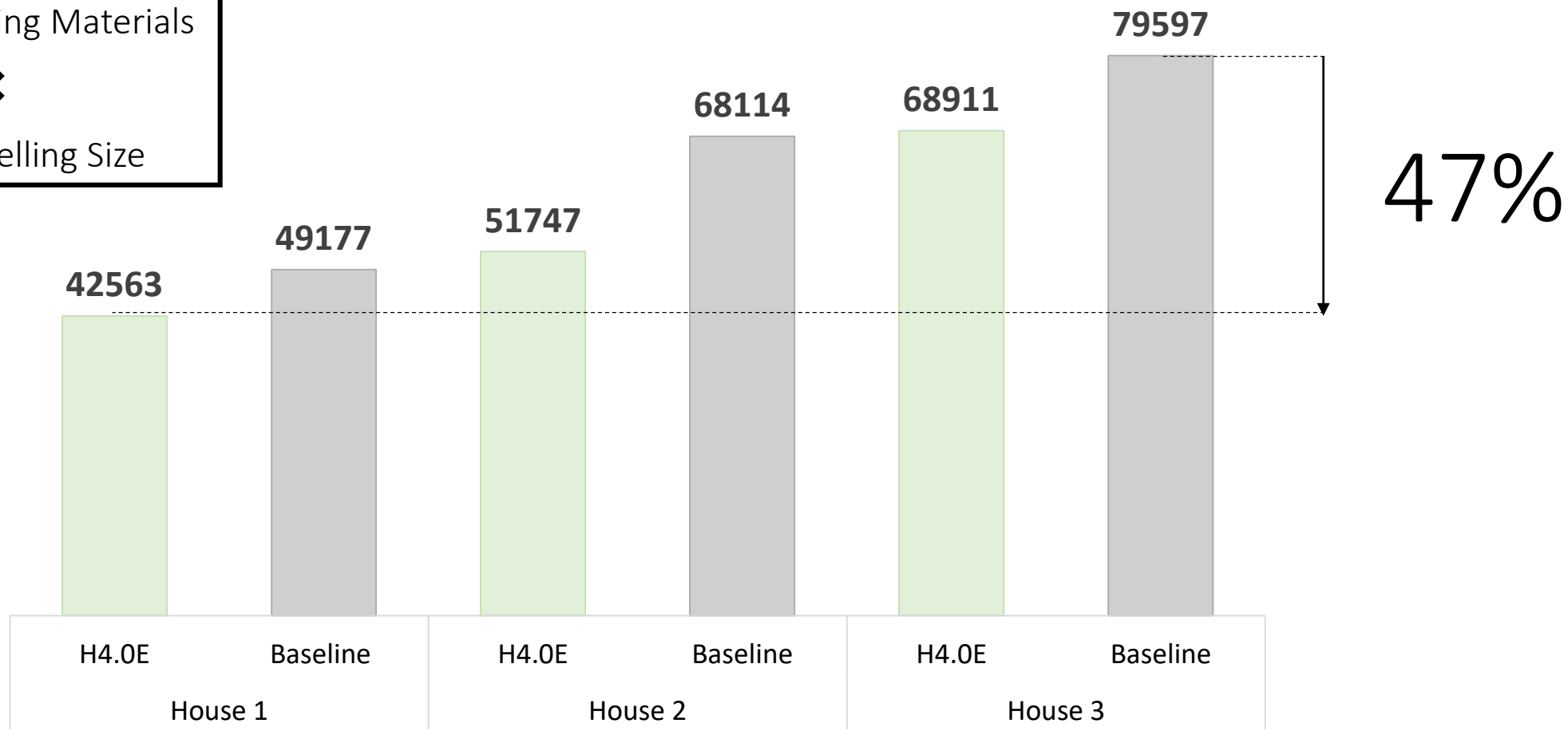
Embodied Carbon

Lessons Learned

Different Building Materials

✖

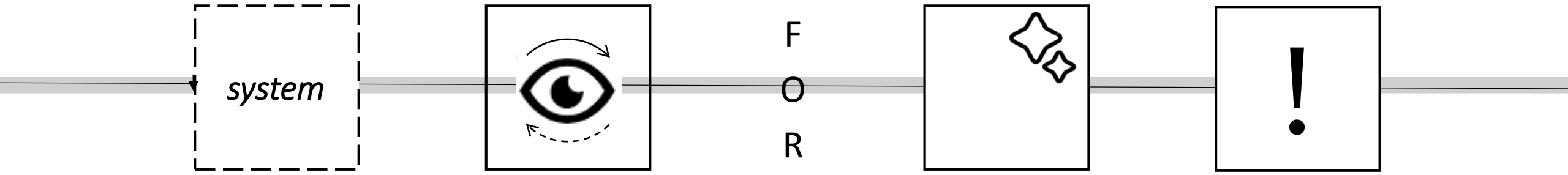
Smaller Dwelling Size



Total Climate Change Impact ($KgCO_2eq$)

Embodied Carbon

What's next?



Clear boundary

Clear assumptions

Full transparency

No green washing

Thank you!

TU Delft Team

Marja Elsinga
Professor of Housing Institutions & Governance
M.G.Elsinga@tudelft.nl

Harry van der Heijden
Associate Professor of Housing Systems
H.M.H.vanderHeijden@tudelft.nl

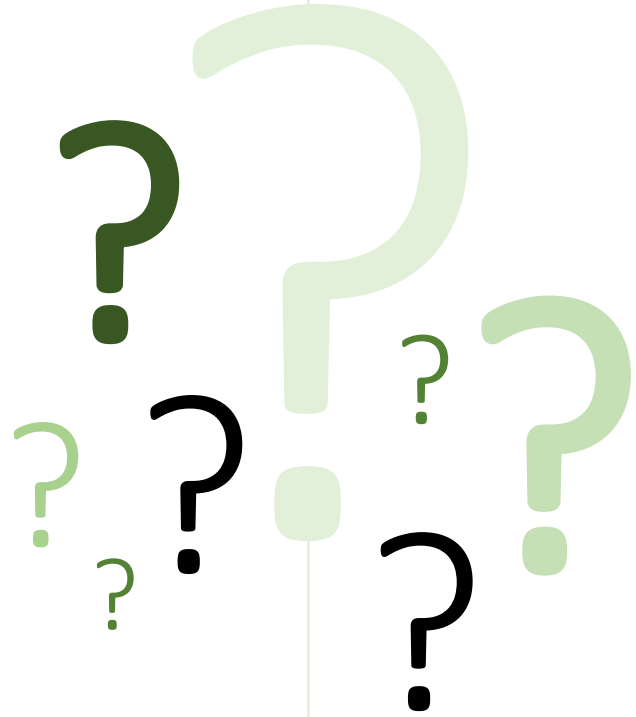
Shima Ebrahimigharehbaghi
PhD researcher, Homeownership, Decision Making, Upscaling
S.Ebrahimigharehbaghi@tudelft.nl

Henk Visscher
Professor of Housing Quality & Process Innovation
H.J.Visscher@tudelft.nl

Arjen Meijer
Assistant Professor, expert in Energy Consumption and Life Cycle Analysis
A.Meijer@tudelft.nl

Cynthia Souaid
PhD research, Energy Transition, (Near) Zero-Energy Housing, Housing Preferences
C.Souaid@tudelft.nl

Questions



Thank you!

Housing 4.0 Energy

European Regional Development Fund

TU Delft

Gemeente Almere

Open Systems Lab

3cea
driving sustainability

VLAAMS-BRABANT

Eifl TECH

SouthWest College

KAMP C

Thoma

Bibliography

- 3cea. (2019, May 3). *3CEA*. Retrieved from 3CEA Three Counties Energy Agency: http://3cea.ie/
- EIfI-Tech. (2019, May 3). *European Institute for Innovation Technology*. Retrieved from European Institute for Innovation Technology: http://tech.eifi.info/
- Factory Zero. (2019, May 3). *Factory Zero*. Retrieved from Factory Zero: https://factoryzero.nl/
- Gemeente Almere. (2019, May 3). *Gemeente Almere*. Retrieved from Gemeente Almere: https://www.almere.nl/
- inhabitat. (2019, May 3). *Inhabitat*. Retrieved from Inhabitat: https://inhabitat.com/the-e-cube-team-belgiums-solar-decathlon-house-is-a-diy-solution-to-housing/
- KAMP C. (2019, May 3). *Kamp C*. Retrieved from Kamp C: https://www.kampc.be/
- NUR-HOLZ. (2019, May 3). *ROMBACH*. Retrieved from NUR-HOLZ: https://www.nur-holz.com/
- nweurope. (2019, May 2). *Interreg North-West Europe*. Retrieved from Affordable & Sustainable Housing through Digitization Housing 4.0 Energy: http://www.nweurope.eu/projects/project-search/h40e-housing-40-energy/
- Open Systems Lab. (2019, May 3). *Open Systems Lab*. Retrieved from Open Systems Lab: https://www.opensystemslab.io/
- Seguin, P. (2019, May 3). *Patrick Seguin*. Retrieved from Galerie Patrick Seguin: https://www.patrickseguin.com/fr/designers/jean-prouve-architecte/inventaire-maison-jean-prouve/maison-demontable-8x8-1945/
- South West College. (2019, May 3). *South West College*. Retrieved from South West College: https://www.swc.ac.uk/
- TU Delft. (2019, May 3). *TU Delft*. Retrieved from TU Delft: https://www.tudelft.nl/en/
- VLAAMS-BRABANT. (2019, May 3). *Vlaams Brabant*. Retrieved from Vlaams Brabant: https://www.vlaamsbrabant.be/index.jsp
- Wikihouse. (2019, May 2). *Wikihouse*. Retrieved from Wikihouse: https://wikihouse.cc/
- European Climate Foundation. (2022). European Climate Foundation. Retrieved April 26, 2022, from https://europeanclimate.org/member/tubiana/
- Intergovernmental Panel on Climate Change. (2022). IPCC. Retrieved April 26, 2022, from https://www.ipcc.ch/assessment-report/ar6/
- Thoma. (2022). Thoma. Retrieved April 26, 2022, from https://www.thoma.at/?lang=en
- Totem. (2018). totem. Retrieved April 26, 2022, from https://www.totem-building.be/pages/welcome.xhtml