BIM4Ren

TRAINING

Digital Twins for nZEB Renovation

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This project has received funding from the H2020 programme under Grant Agreement No. 820773

IES

Outline

Digital Twin key concepts

- Compliance vs performance
- Model calibration
- Worked example

Strategies towards net zero

- Operational improvements
- Shallow retrofit
- Deep renovation
- Integration of RES (towards PEB)

Choosing a renovation scenario

- Optimisation
- LCA + LCC
- Multicriteria scenario comparison

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Digital Twins for renovation

Closing the performance gap

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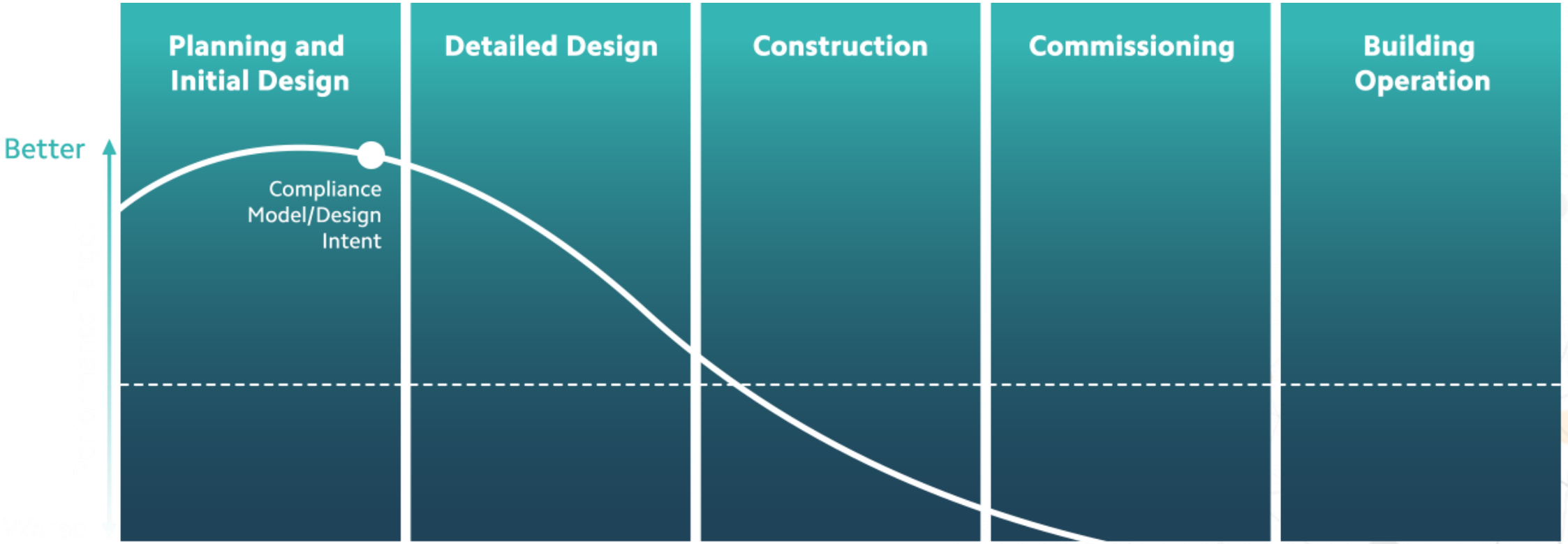
The problem with buildings



Buildings don’t perform to their design intent and typically perform worse than even the minimal targets

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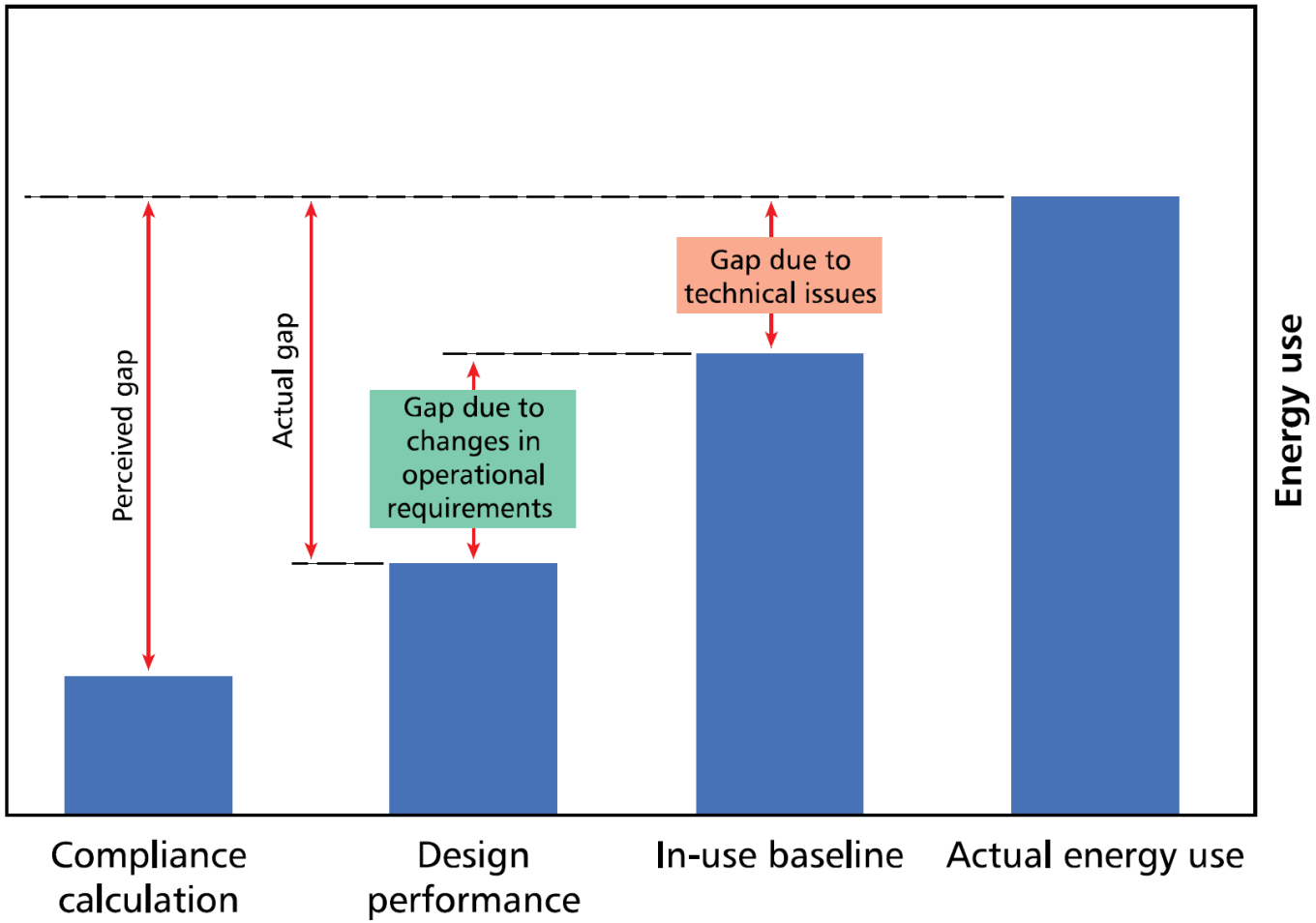
Compliance is not performance



Source: CIBSE TM63:2020 Building performance modelling and calibration for energy in-use

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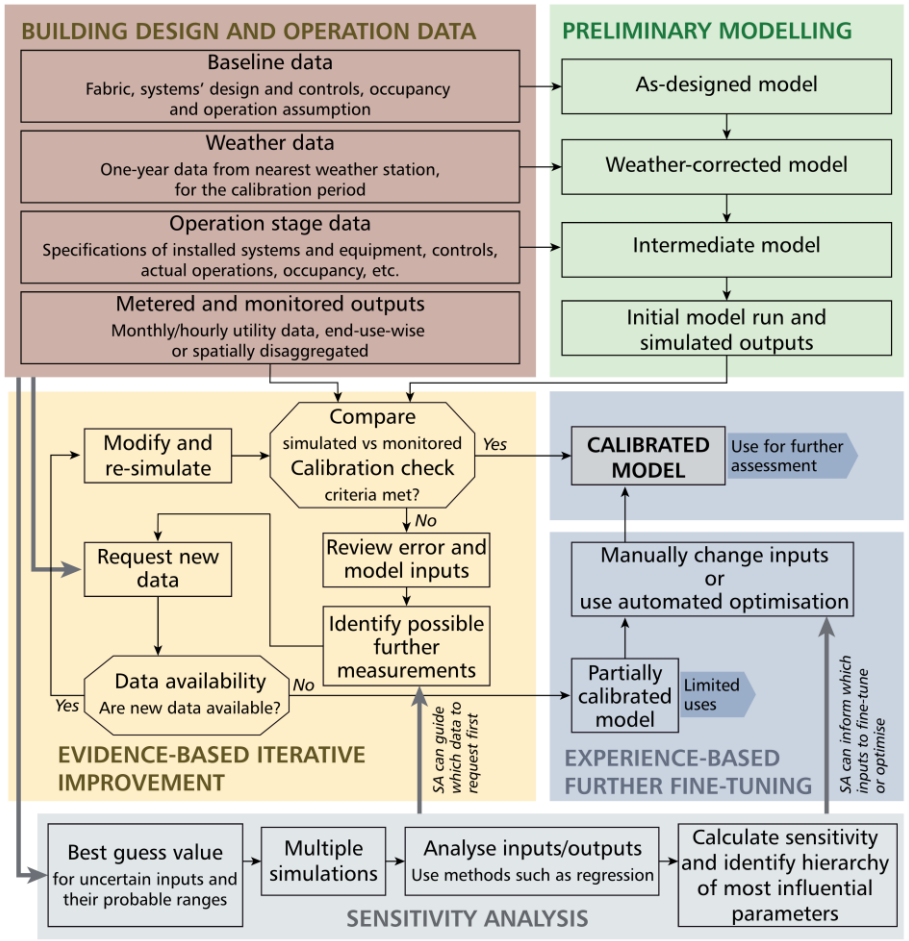
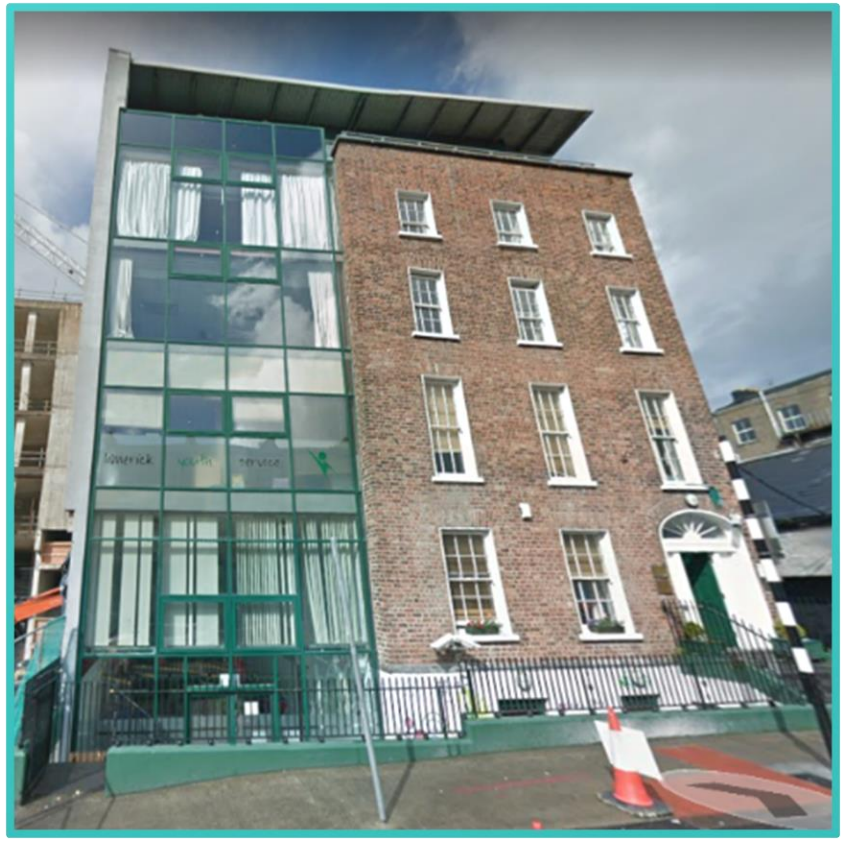
Model calibration for accuracy

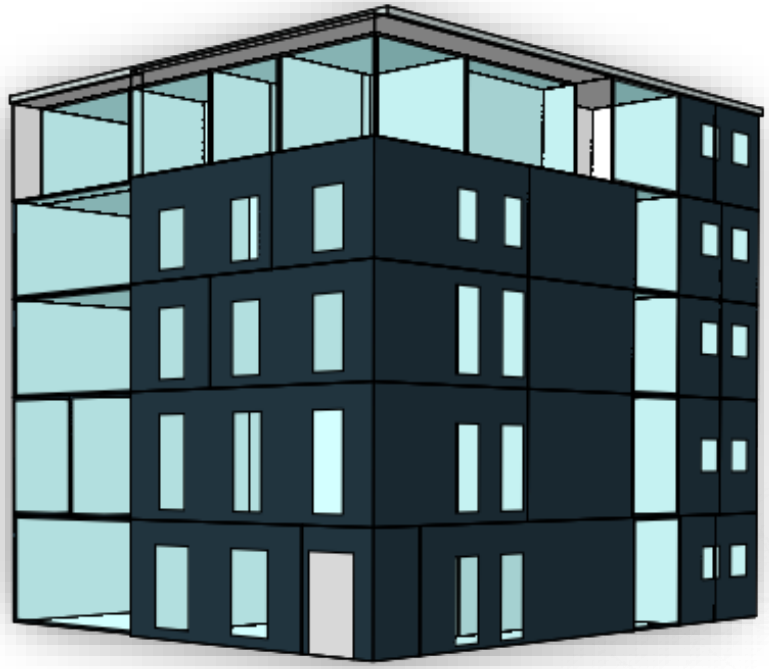


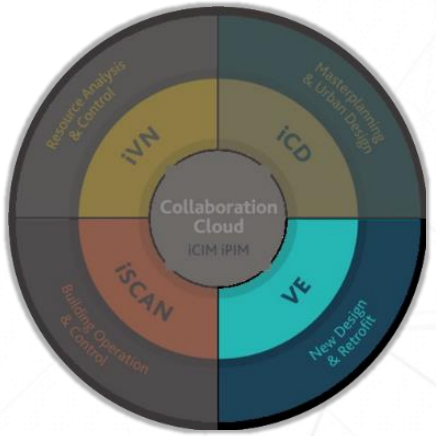
Source: CIBSE TM63:2020 Building performance modelling and calibration for energy in-use

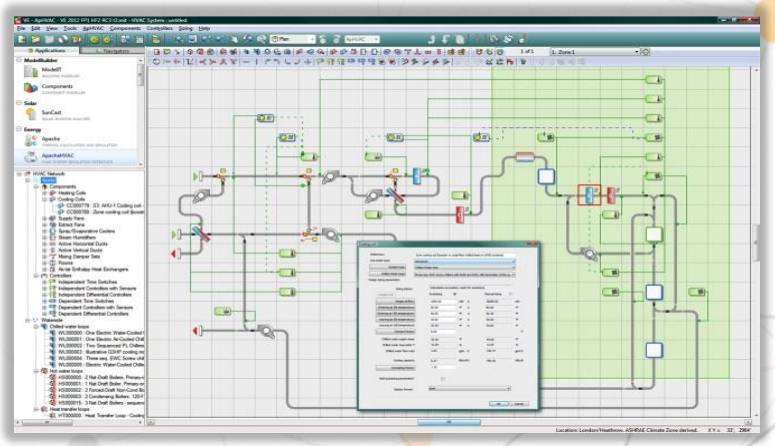
- TM63 (2020) Methodology
- Guidance for energy model calibration
- Evidence and experience based approach

Worked example









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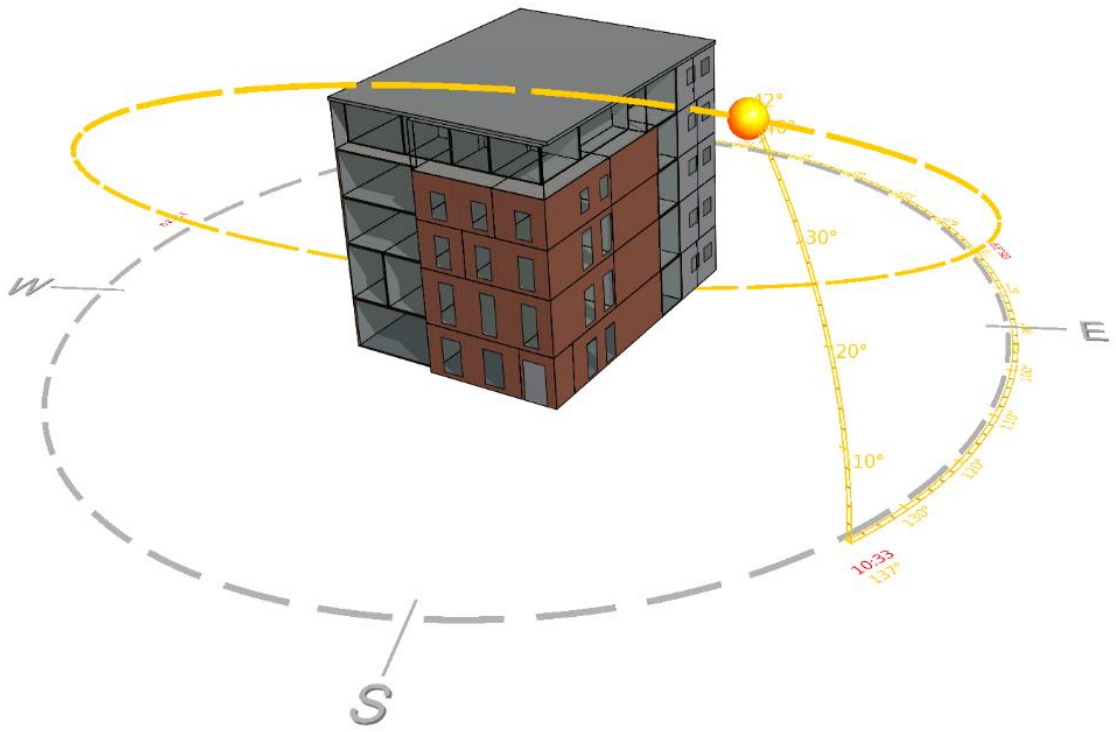
Building Location & Climate Analysis



Site Data
Location: *Example St.,* Shannon, Ireland
Latitude: **.661392
Longitude: -*.630491
Orientation: 202° clockwise from North
Weather Station: Shannon Airport, IE
Cooling Degree Days: 0
Heating Degree Days: 3374
Yearly Global Solar Radiation: 944 kWh/m^2

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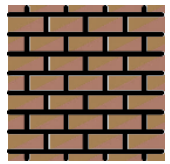
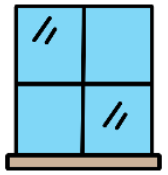
Model Inputs – Building Envelope

- Input
- *Source*
- *Assumption*



External walls

- Solid wall (40 – 60 cm); U-value: 1.97 W/m^{2}K
- *Site visit & SEAI average values by location and construction date*



External windows

- Single/Double glazing; U-value: 2.7-3.8 W/m^{2}K
- *Site visit & SEAI average values by location and construction date*

Ground exposed floor

- Cast concrete (100 cm); U-Value: 0.89 W/m^{2}K
- *SEAI average values by location and constr. date*

Roof

- Concrete deck; U-value: 2.3 W/m^{2}K
- *Average SEAI average values by location and construction date*

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Model Inputs - Systems

- Input
- *Source*
- *Assumption*

Lighting

- Fluorescent bulbs (~95%) & LED bulbs (~5%)
- *Site visit & CIBSE guidelines by space type*

Heating System

- Underfloor heating
- *Site Visit*

Ventilation System

- Mechanical/natural ventilation
- *Site Visit*

Heating Source

- 2 Gas Boilers (DHW & Space heating)
- *Site Visit*

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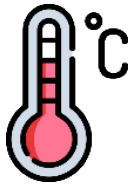
Model Inputs – Building Operation

- Input
- *Source*
- *Assumption*

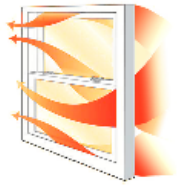
Ventilation rate

- Default air changes / hour
- *CIBSE standards per space type & No. of people*



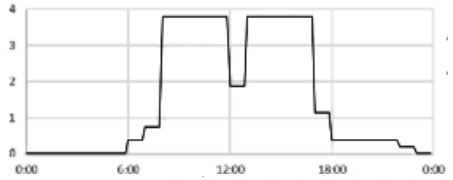
Thermal set points & Schedule

- Heating: 23°C; Cooling: N/A
- *Site Visit*



Infiltrations & Heat losses

- 0.21 air changes / hour
- *Construction year*



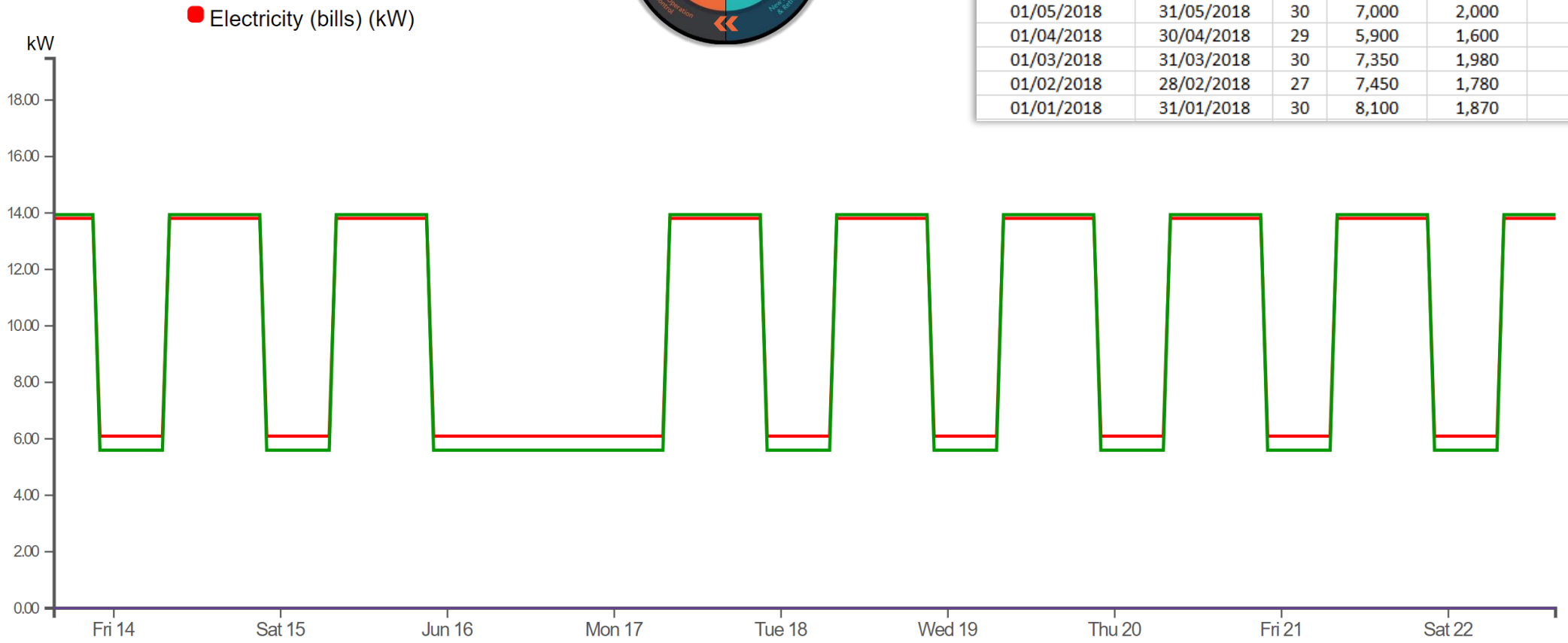
Profiles of use

- Weekly (Mon-Sat): 8:00 – 22:00 (morning peak occupancy)
- Thursday evening: event in Hall room > peak of occupancy
- Sundays: closed
- *Site Visit*

Calibration: Electricity consumption

CSV

Period start	Period end	Days	kWh Day	kWh night	Total kWh
01/10/2018	31/10/2018	30	6,000	2,000	8,000
01/09/2018	30/09/2018	29	6,000	2,400	8,400
01/08/2018	31/08/2018	30	5,560	1,600	7,160
01/07/2018	31/07/2018	30	5,900	1,500	7,400
01/06/2018	30/06/2018	29	5,600	1,450	7,050
01/05/2018	31/05/2018	30	7,000	2,000	9,000
01/04/2018	30/04/2018	29	5,900	1,600	7,500
01/03/2018	31/03/2018	30	7,350	1,980	9,330
01/02/2018	28/02/2018	27	7,450	1,780	9,230
01/01/2018	31/01/2018	30	8,100	1,870	9,970



June 14th – June 22nd

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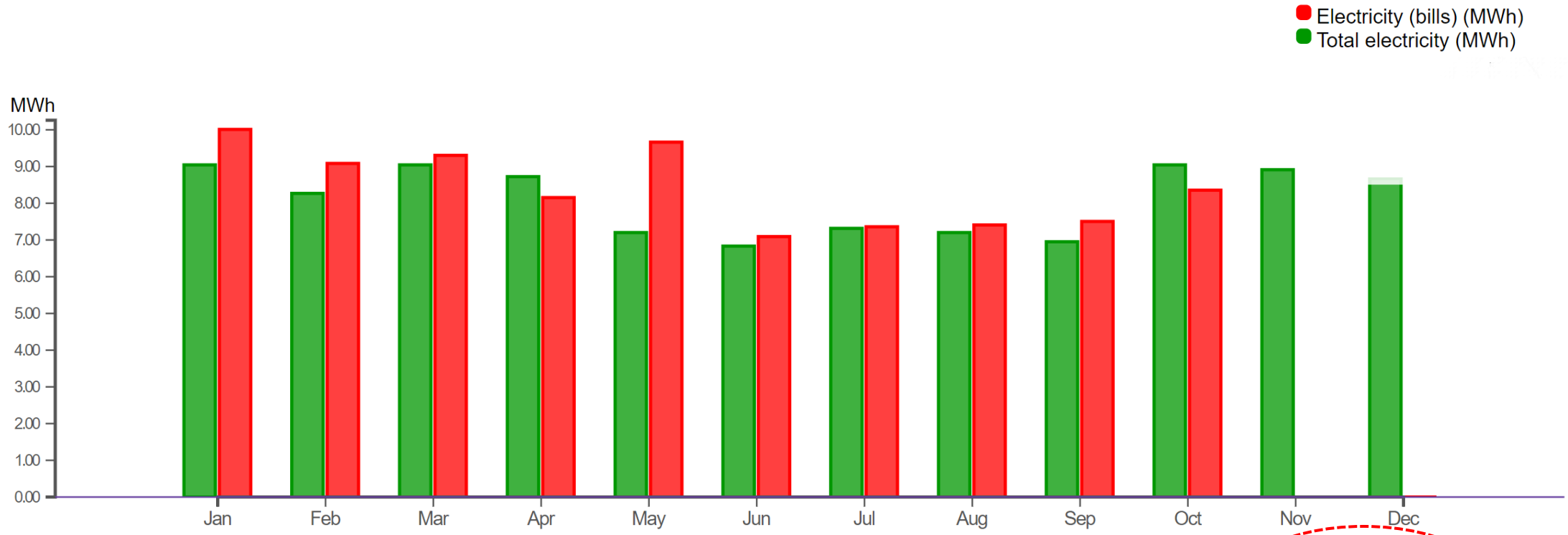
Accuracy of the Model



Monthly total	2019-01-01	2019-02-01	2019-03-01	2019-04-01	2019-05-01	2019-06-01	2019-07-01	2019-08-01	2019-09-01	2019-10-01	2019-11-01	2019-12-01
Total electricity (MWh)	9.0487	8.2700	9.0487	8.7265	7.2000	6.8321	7.3167	7.2000	6.9489	9.0487	8.9144	8.6730
Electricity (bills) (MWh)	10.0112	9.0854	9.3038	8.1570	9.6660	7.0905	7.3589	7.4080	7.5035	8.3595	0.0000	0.0000

missing bills

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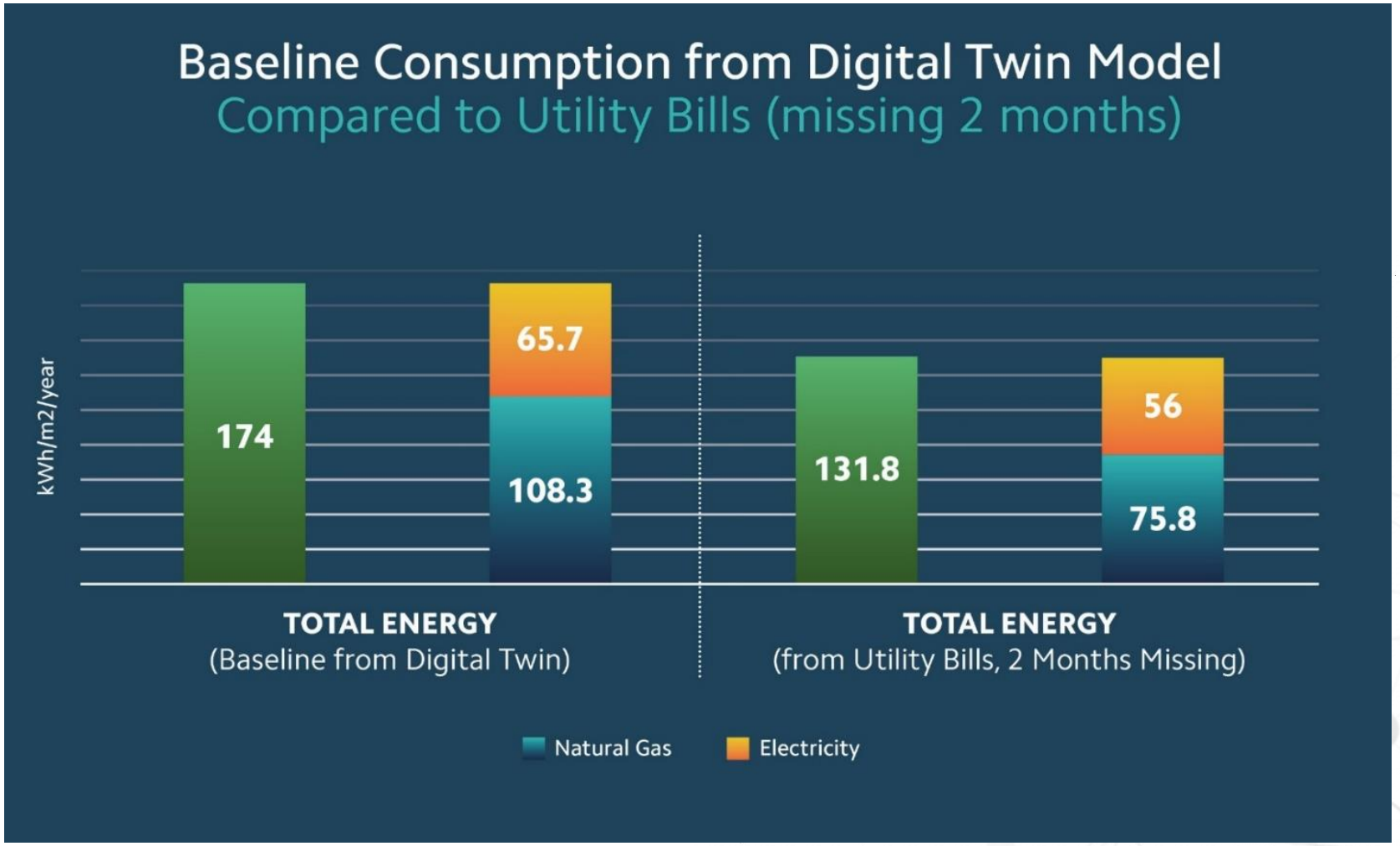
Accuracy of the Model



***-2.1%** compared to the extrapolated bills*

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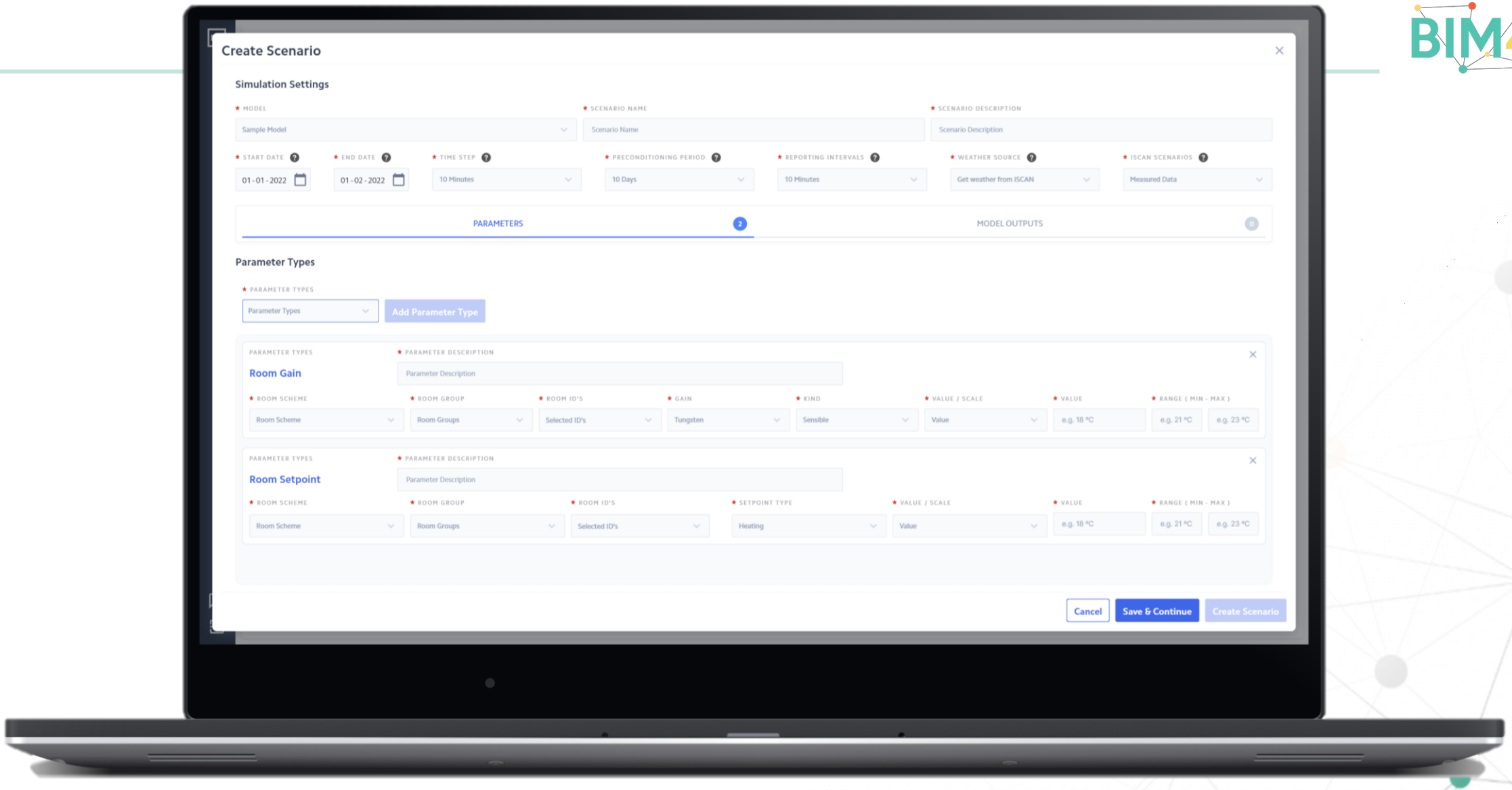

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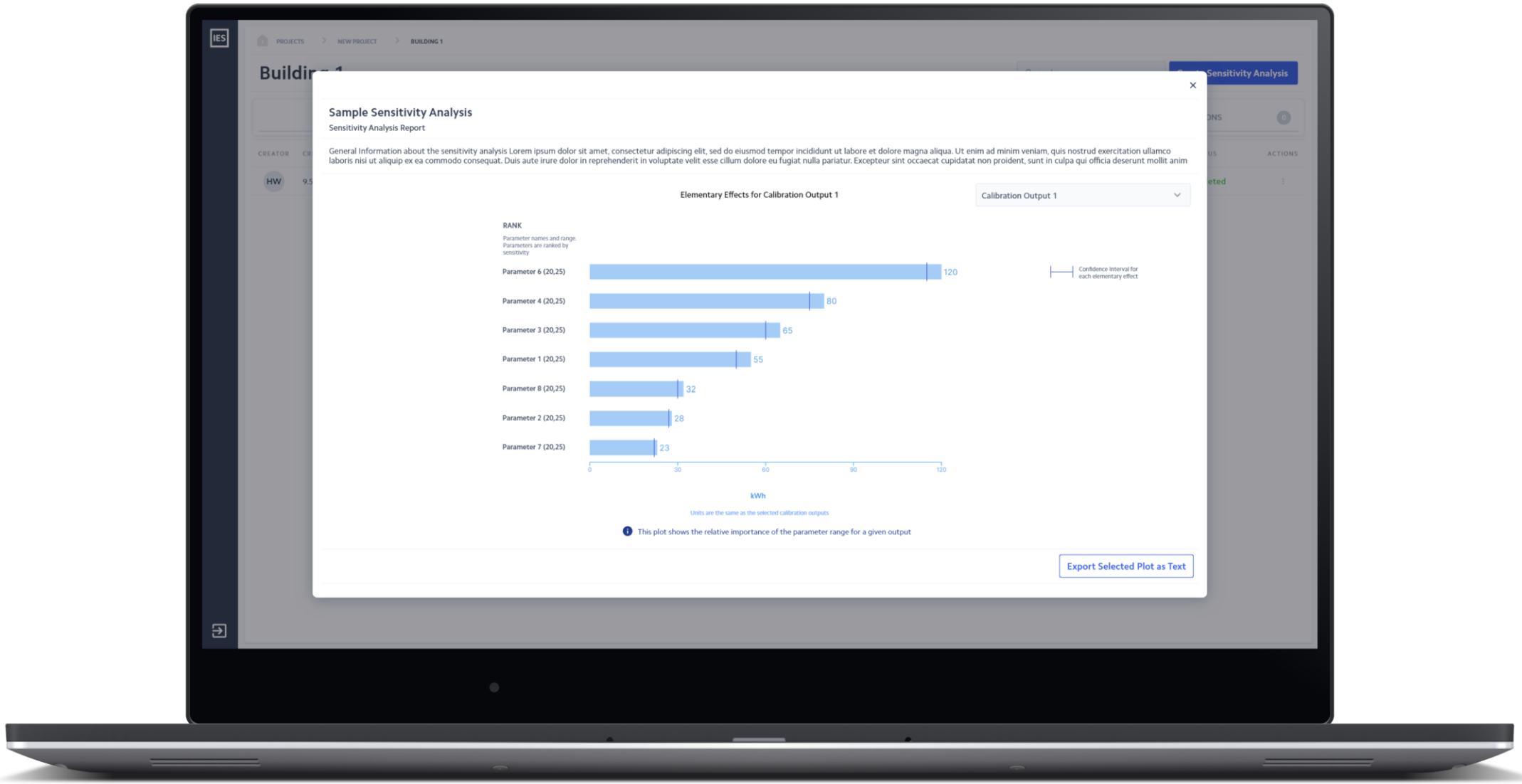

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Strategies towards neat zero

Using a Digital Twin to roadmap building decarbonisation

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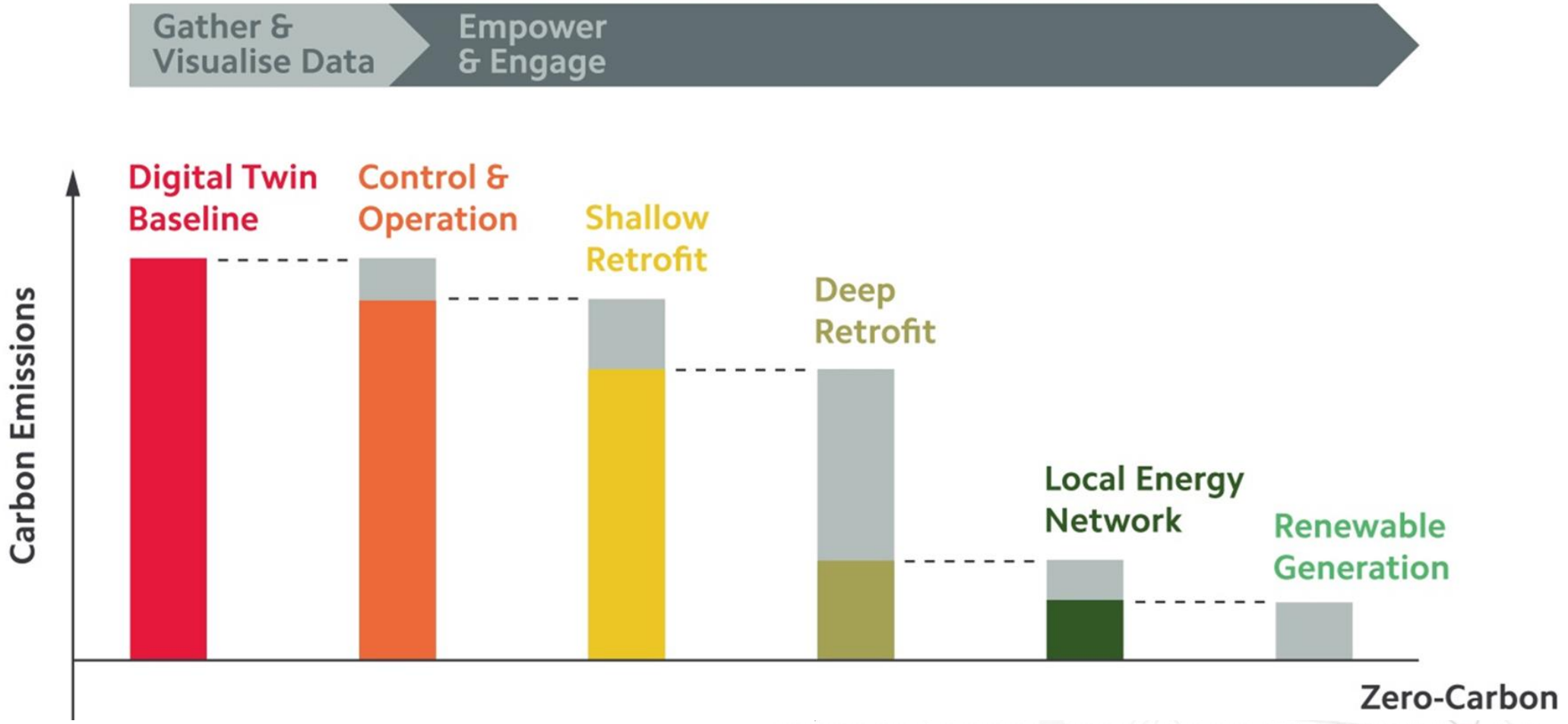
Digital Twin for nZEB renovation



Evaluate the impact of different renewable energy generators to achieve operational zero carbon

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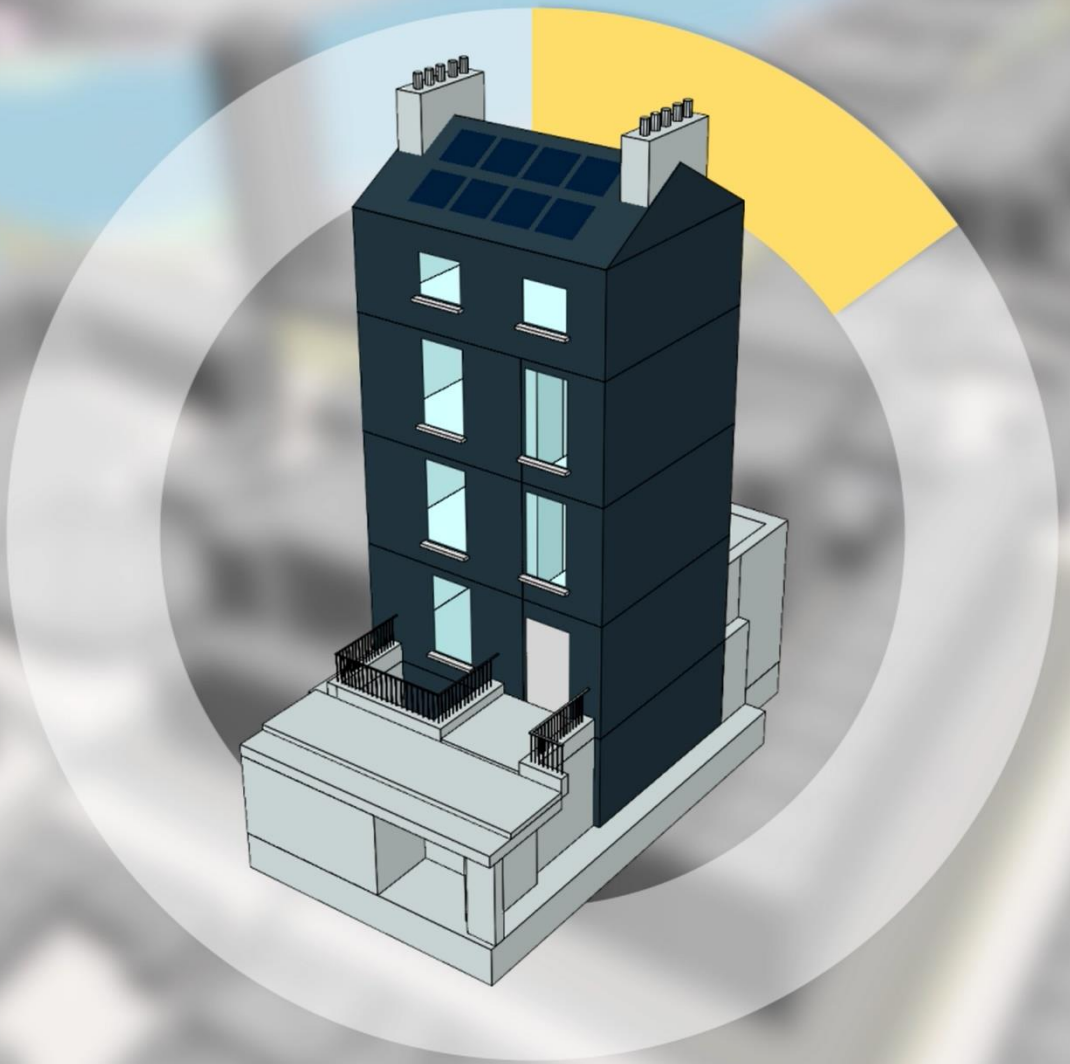
AREA OF INTEREST – RESIDENTIAL BUILDING ON LOWER HARSTONGE STREET



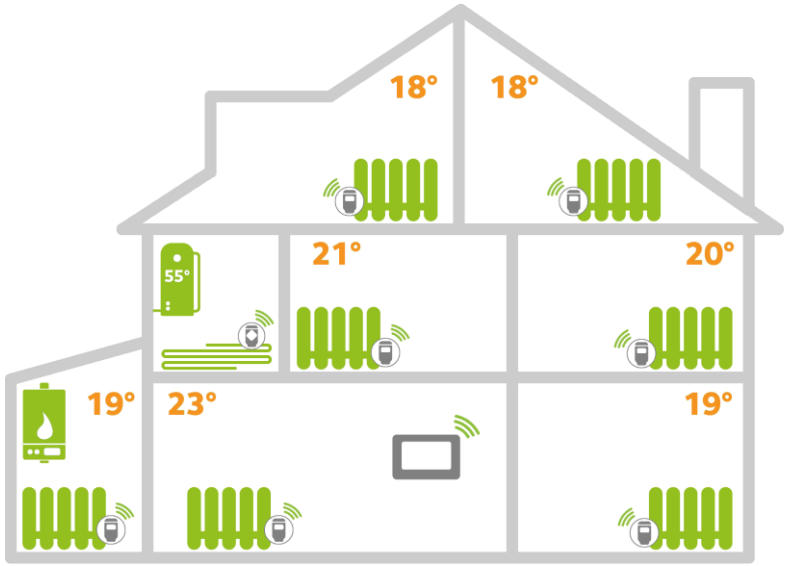
- POTENTIAL ENERGY EFFICIENCY STRATEGIES

- OPERATIONAL MEASURES

- HEATING CONTROL UPGRADES AND ZONING: 15% SAVING

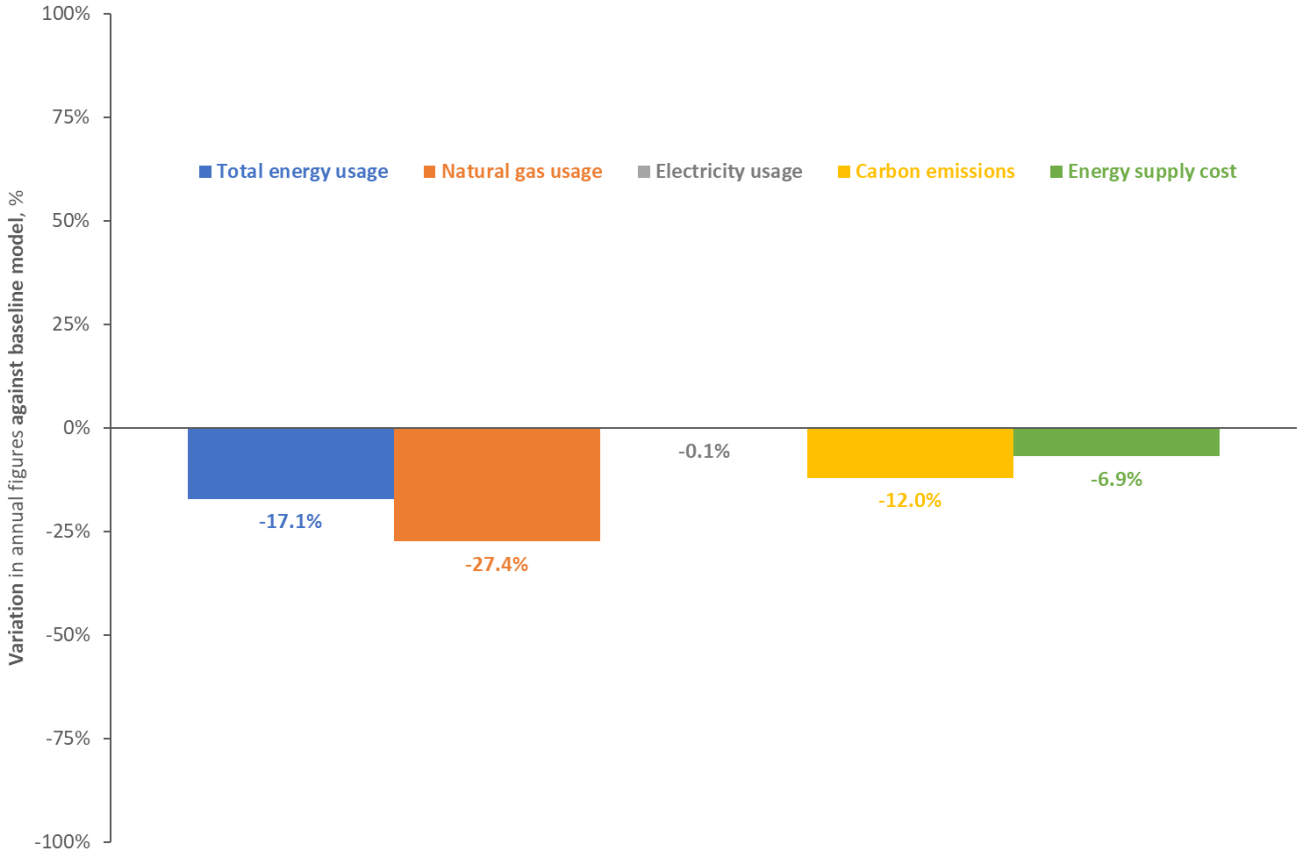
Operational Measures

1. Zone heating controls



Heating control improvements:

- *Individual room thermostats and HSP based on activity and occupancy*
- *Setback value of 16° C for unoccupied rooms*



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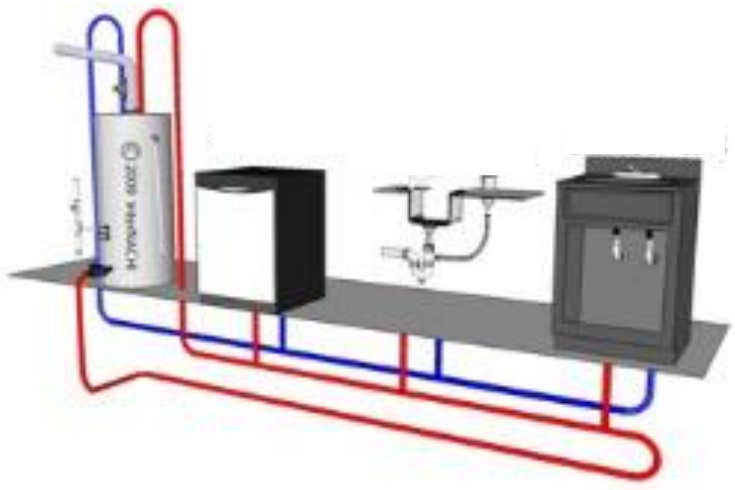
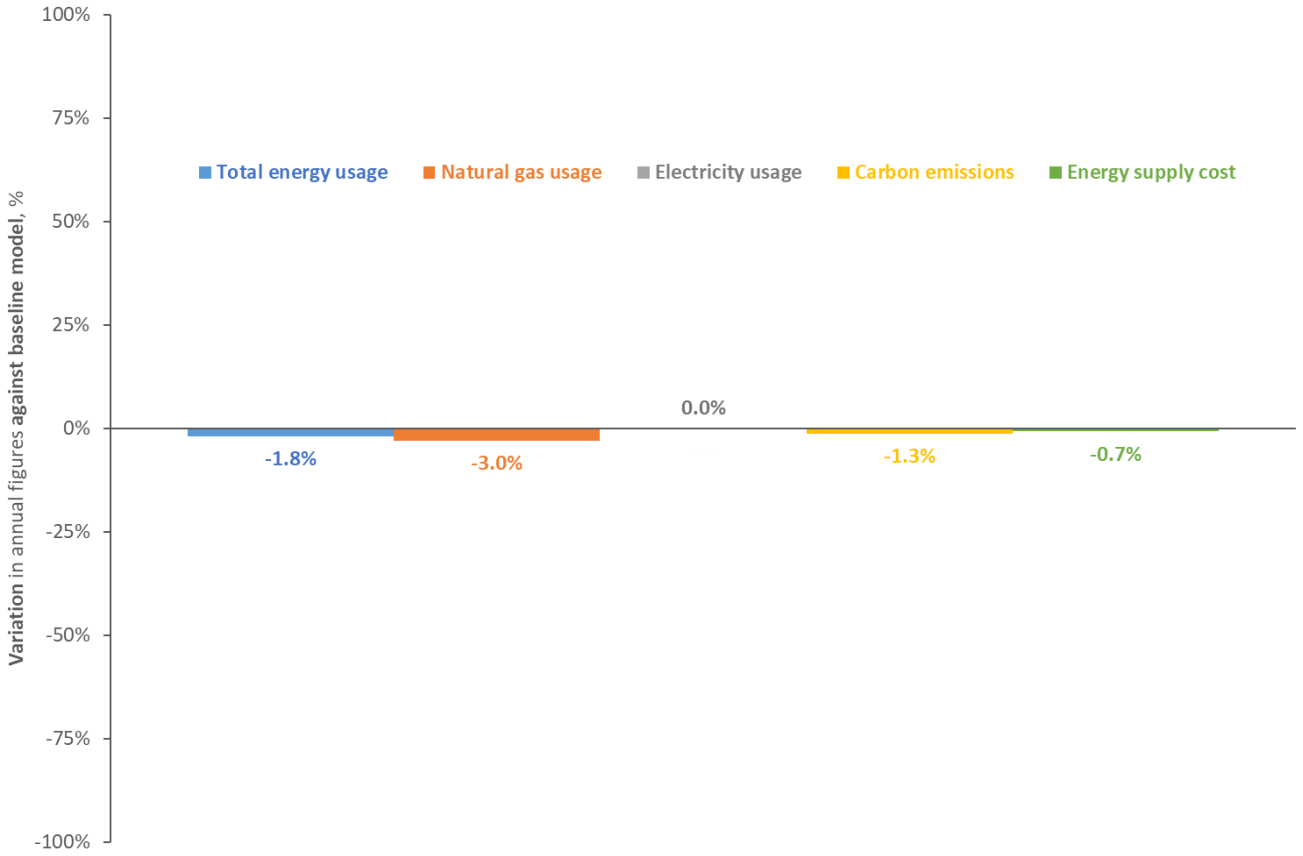
Operational Measures

2. DHW supply T reduction



Supply T: 60 ° C → Supply T: 45 ° C*



**constrained by Legionellae bacteria regulation*

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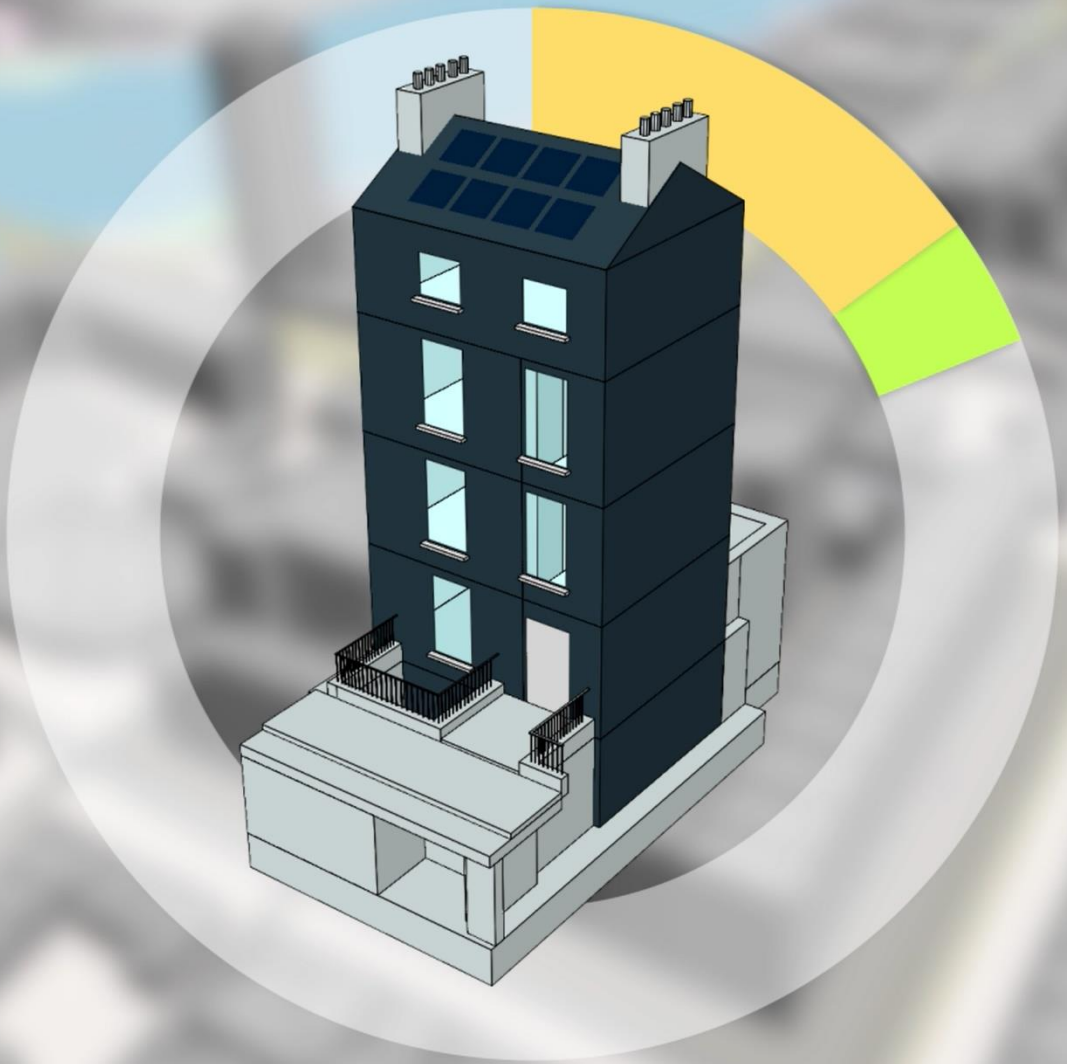
AREA OF INTEREST – RESIDENTIAL BUILDING ON LOWER HARSTONGE STREET



- POTENTIAL ENERGY EFFICIENCY STRATEGIES

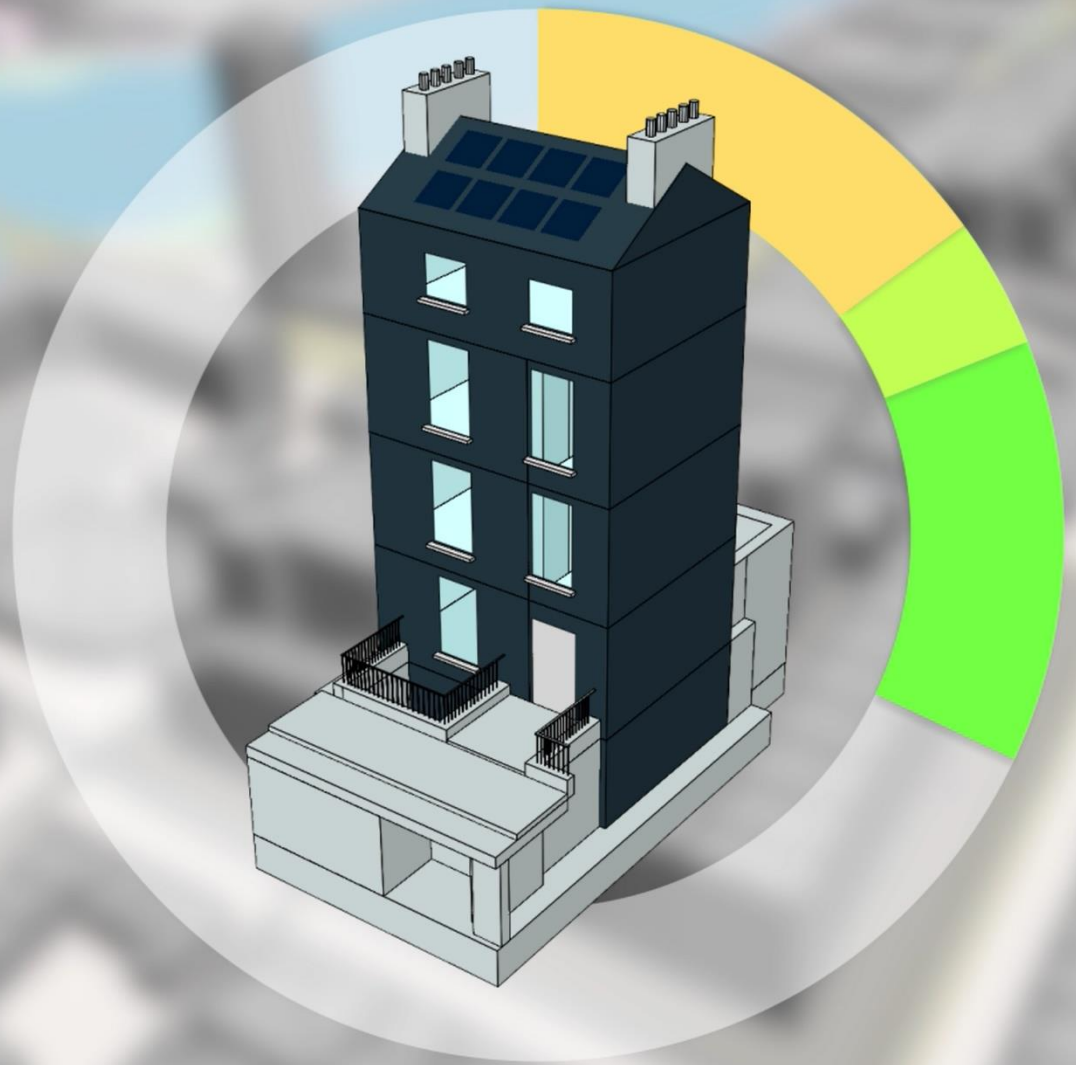
- OPERATIONAL MEASURES

- HEATING CONTROL UPGRADES AND ZONING: 15% SAVING

- SHALLOW RETROFIT MEASURES (I.E. LOW COST)

- WINDOW SEALS REPLACEMENT: 4% SAVING

AREA OF INTEREST – RESIDENTIAL BUILDING ON LOWER HARSTONGE STREET



- POTENTIAL ENERGY EFFICIENCY STRATEGIES

- OPERATIONAL MEASURES

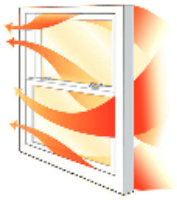
- HEATING CONTROL UPGRADES AND ZONING: 15% SAVING

- SHALLOW RETROFIT MEASURES (I.E. LOW COST)

- WINDOW SEALS REPLACEMENT: 4% SAVING
- REPLACE THE OLD GAS BOILER WITH A NEW ONE: 13% SAVING

Shallow retrofit interventions

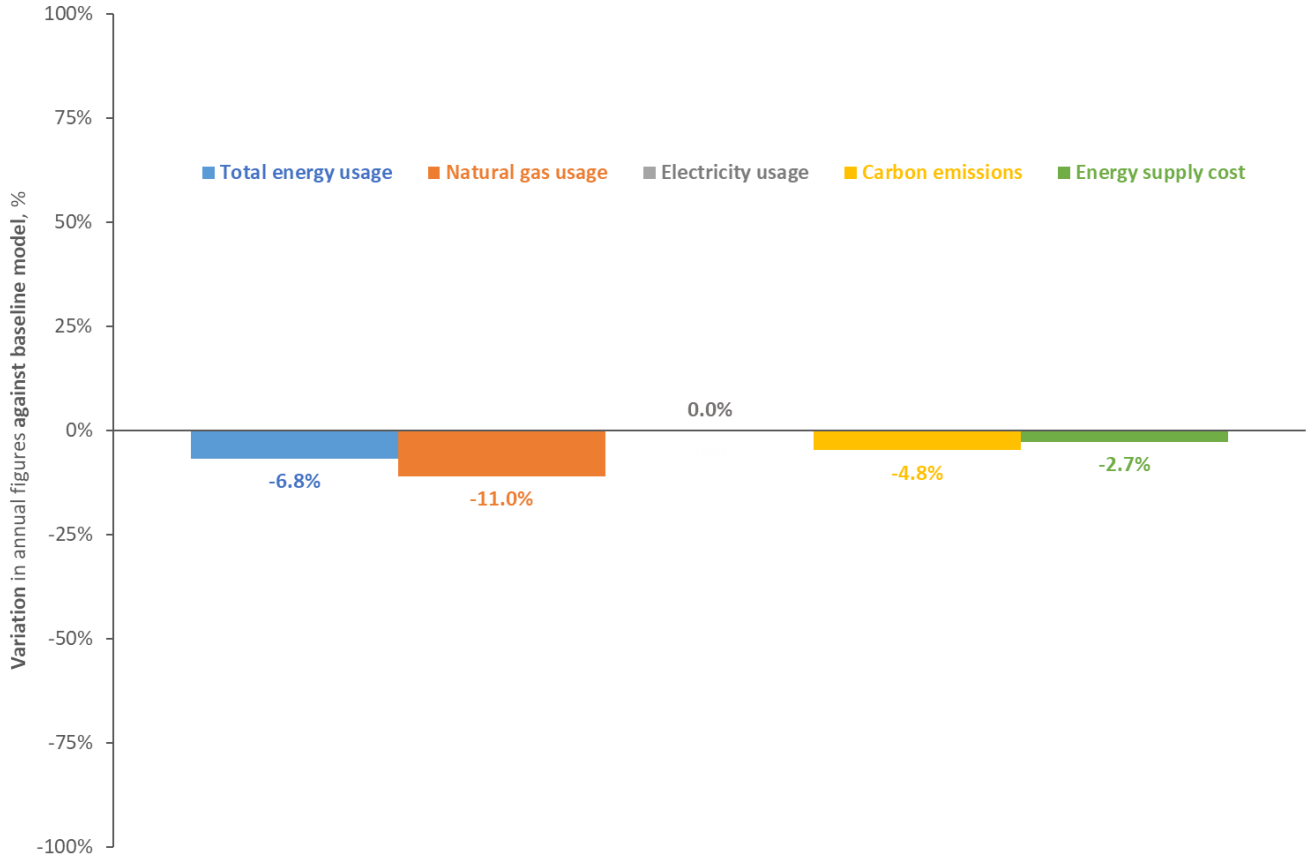
*1. Improving airtightness**



**

Infiltration rate:
0.21 ac/h

Infiltration rate:
0.07 ac/h



**sealing, weather-stripping, and use of door sweeps [ASHRAE Fundamentals Chapter 16 and DHPLG, 2019]*
***EPBD_irish_2019_non-domestic_cost_optimal_report*

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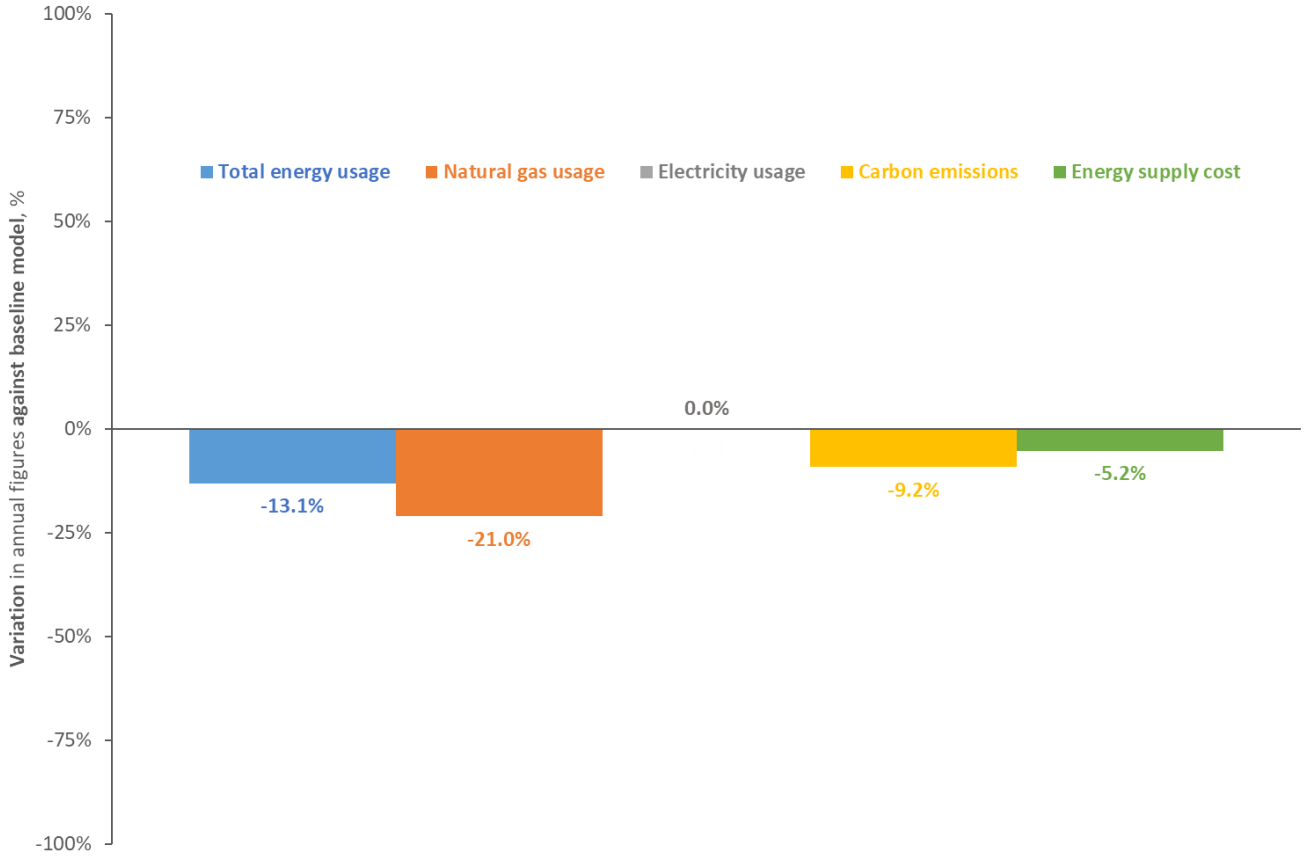
Shallow retrofit interventions

3. Boiler upgrade

Baseline
sCOP: 0.75

New boiler
sCOP: 0.93



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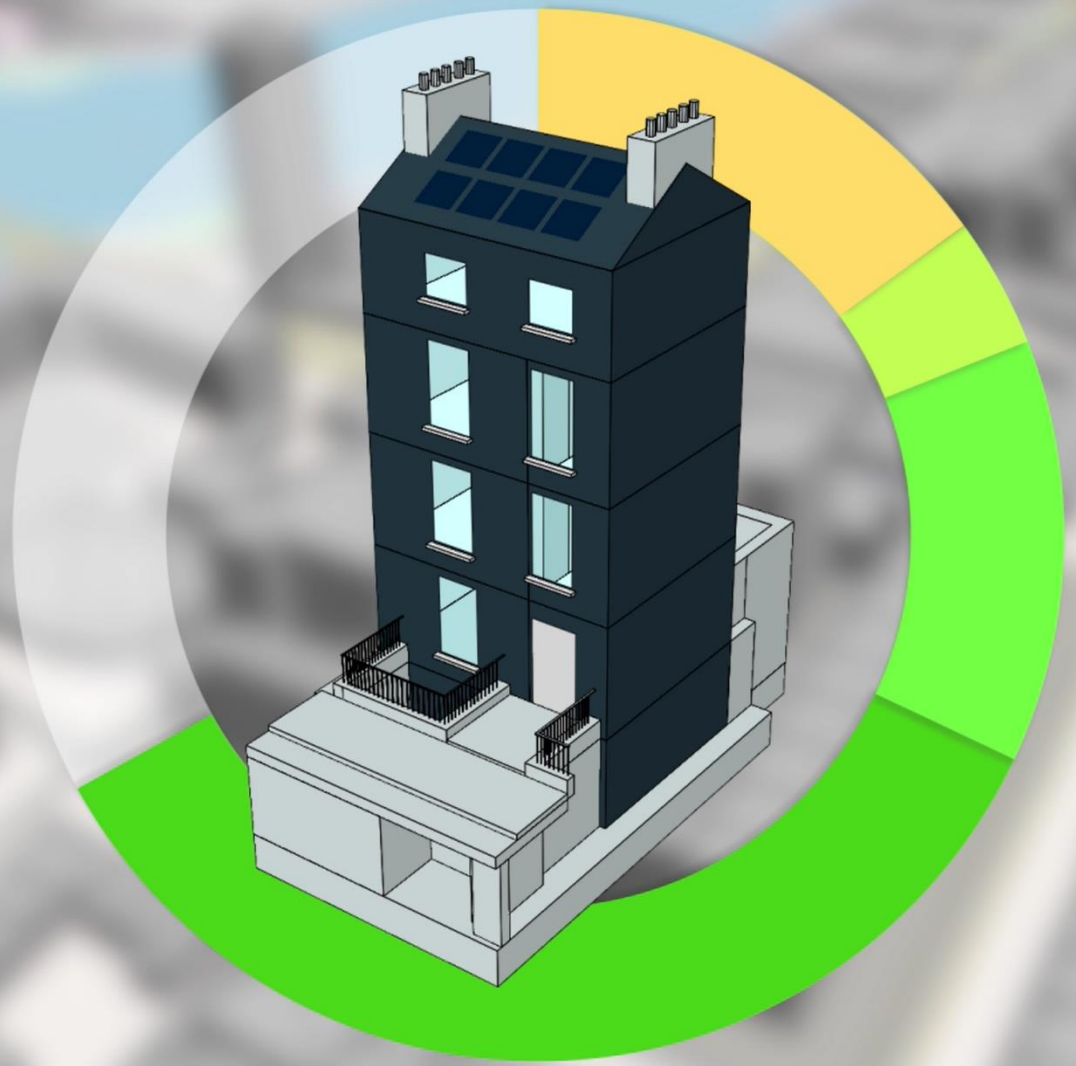
AREA OF INTEREST – RESIDENTIAL BUILDING ON LOWER HARSTONGE STREET



- POTENTIAL ENERGY EFFICIENCY STRATEGIES

- OPERATIONAL MEASURES

- HEATING CONTROL UPGRADES AND ZONING: 15% SAVING

- SHALLOW RETROFIT MEASURES (I.E. LOW COST)

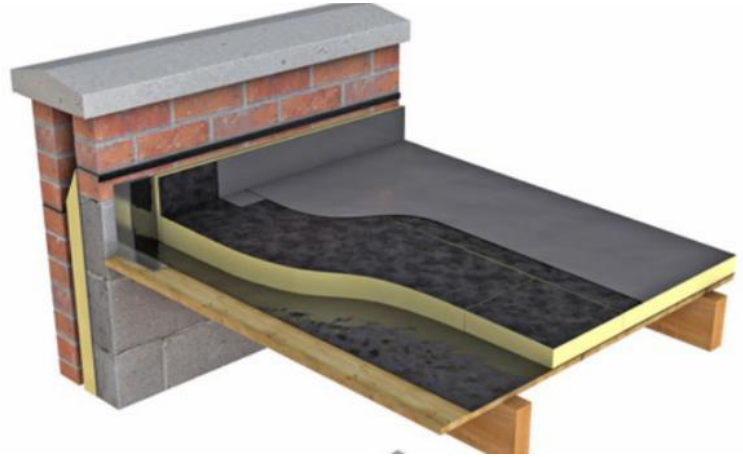
- WINDOW SEALS REPLACEMENT: 4% SAVING
- REPLACE THE OLD GAS BOILER WITH A NEW ONE: 13% SAVING

- DEEP RENOVATION (I.E. INCREASED COST)

- IMPROVING THE BUILDING ENVELOPE: 35% SAVING

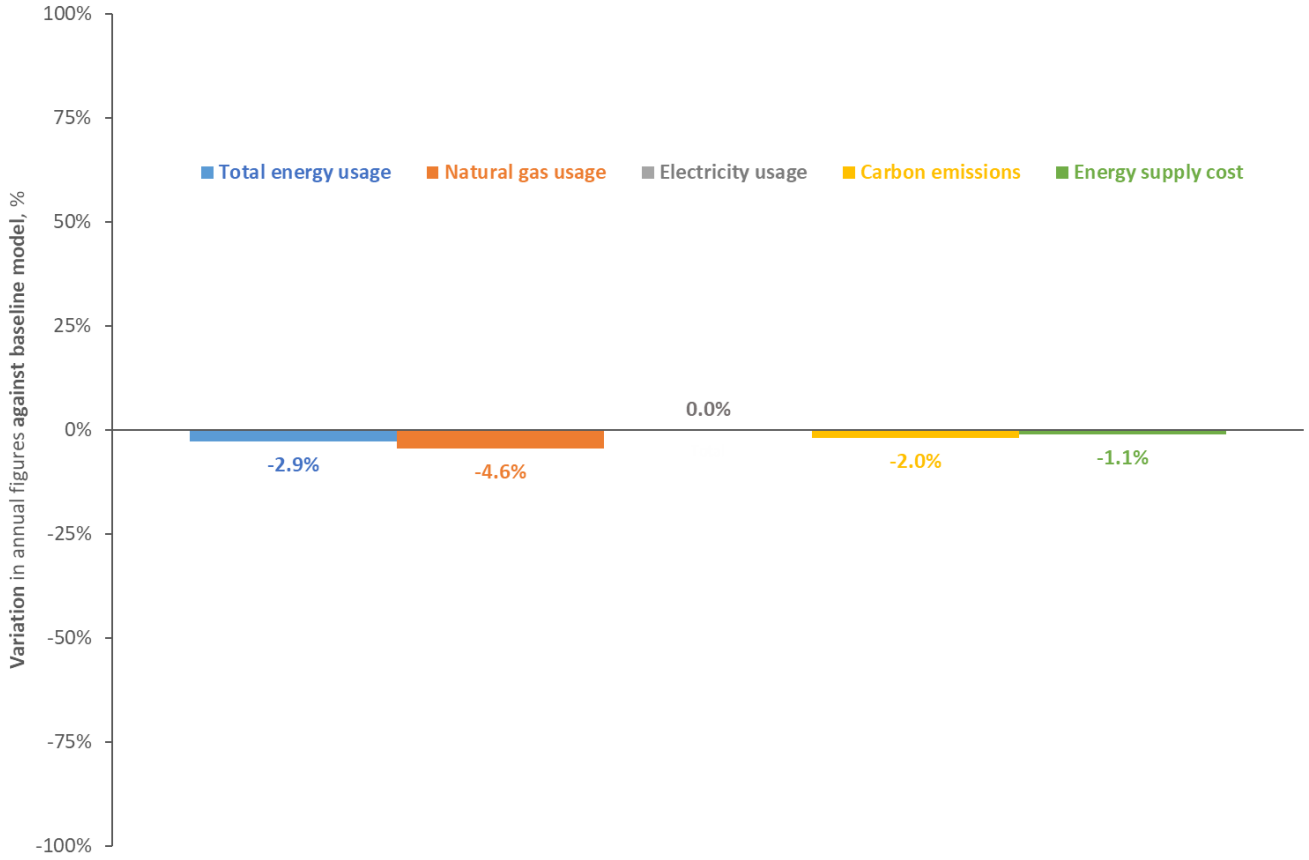
Deep renovation interventions

1. Roof insulation



U-Value improvement:

- *Baseline roof: 2.3 W/(m2)(K)*
- *Roof + aerogel insul. board: 0.6 W/(m2)(K)*
- *Air leakage reduced by 1/4*



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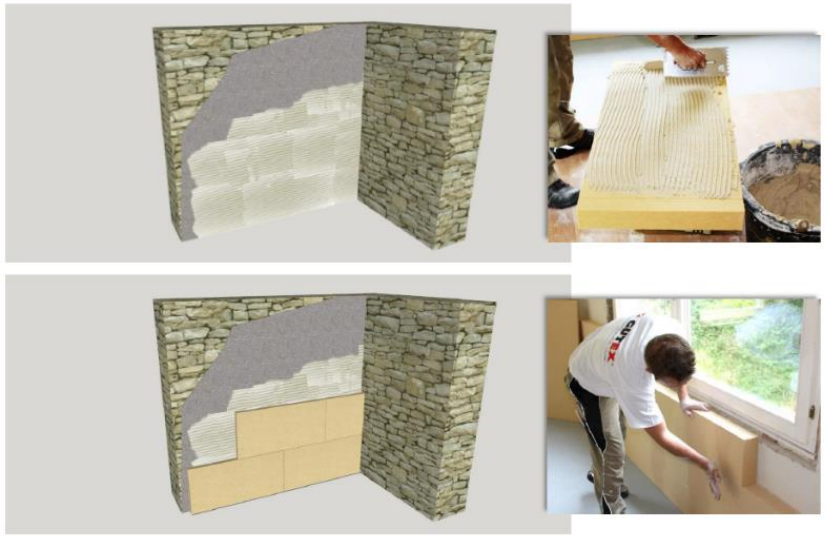
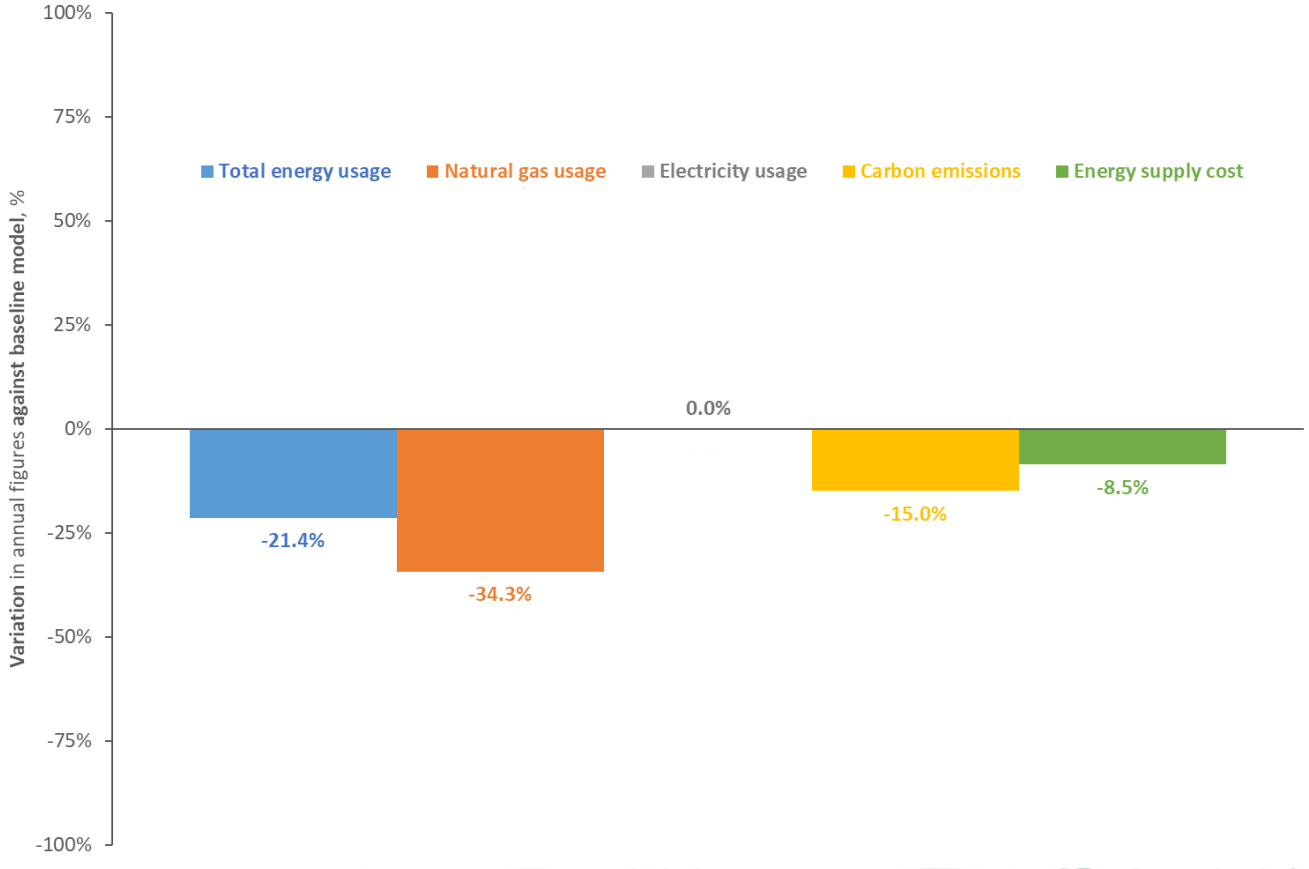
Deep renovation interventions

2. Internal wall insulation



U-Value improvement:

- *Baseline solid wall: 1.97 W/(m2)(K)*
- *Solid wall + aerogel insulation board: 0.58 W/(m2)(K)*



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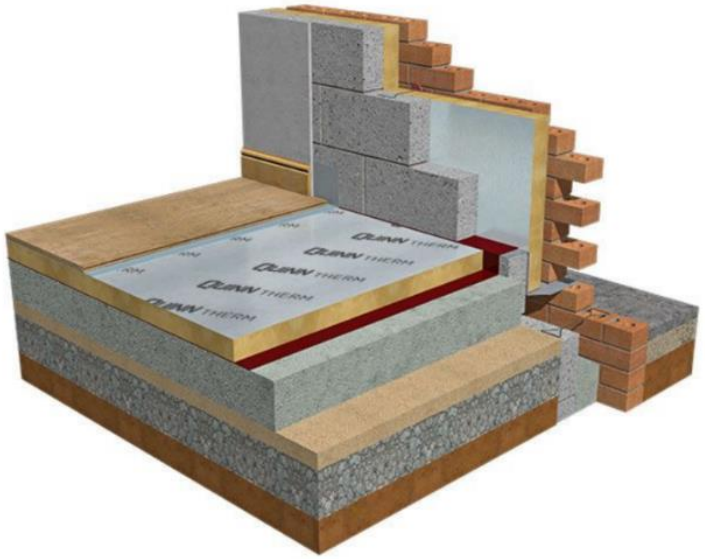
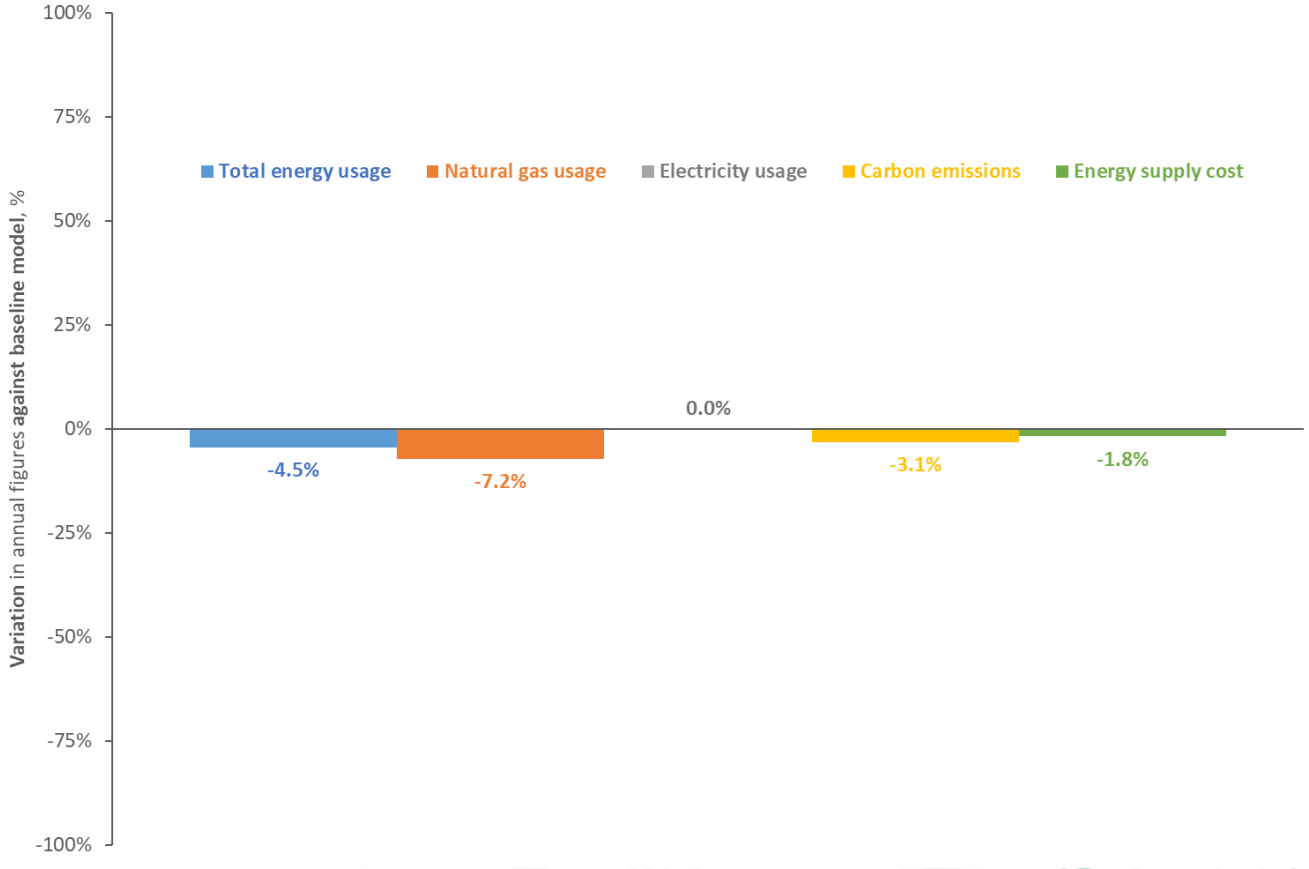
Deep renovation interventions

3. Ground floor insulation



U-Value improvement:

- *Ground Floor: 0.9 W/(m2)(K)*
- *Floating floor + aerogel insulation board: 0.28 W/(m2)(K)*



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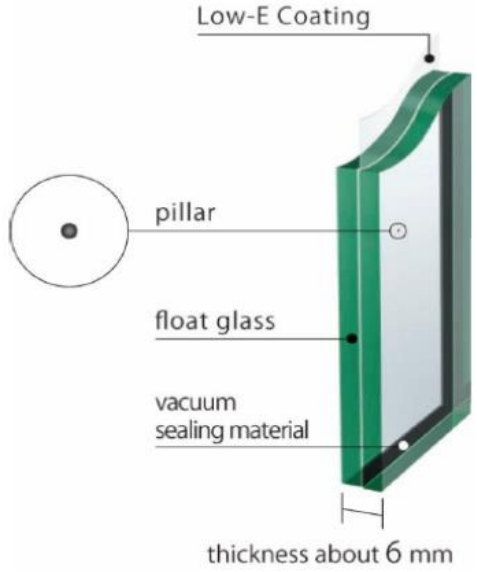
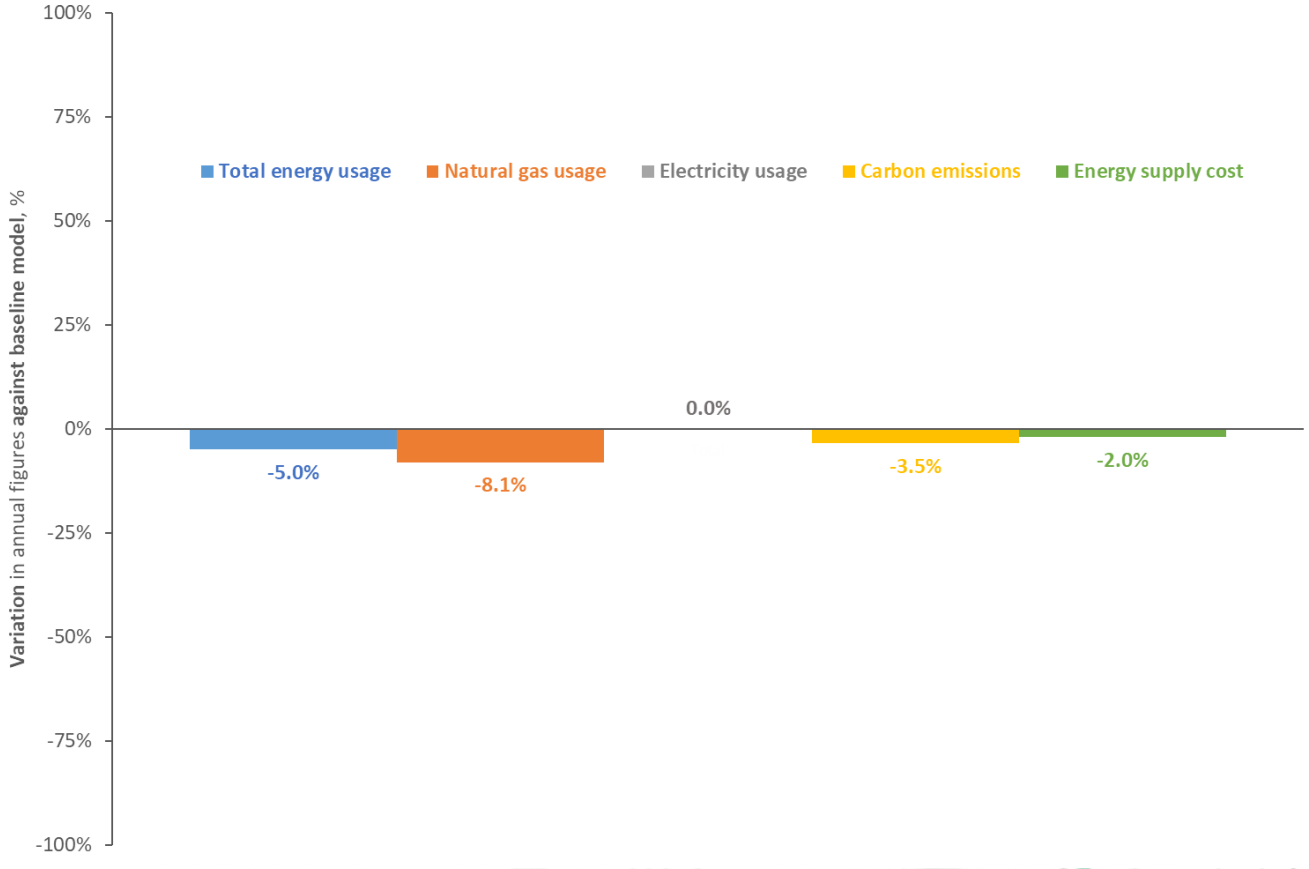
Deep renovation interventions

4. Windows retrofit



U-Value improvement:

- *Old single glazing: 3.8 W/(m2)(K)*
- *New double glazing with air gap: 0.94 W/(m2)(K)*



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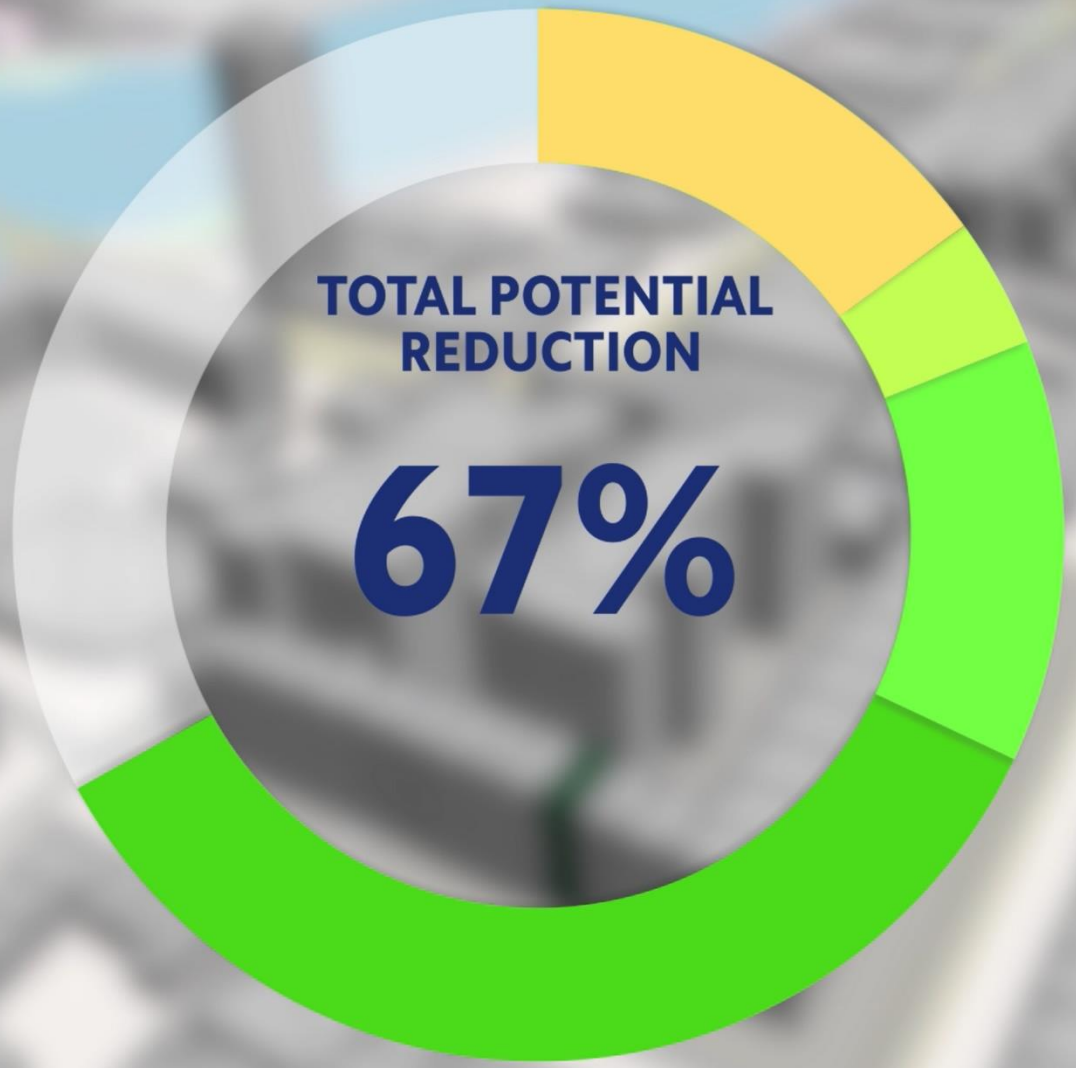
AREA OF INTEREST – RESIDENTIAL BUILDING ON LOWER HARSTONGE STREET



- POTENTIAL ENERGY EFFICIENCY STRATEGIES

- OPERATIONAL MEASURES

- HEATING CONTROL UPGRADES AND ZONING: 15% SAVING

- SHALLOW RETROFIT MEASURES (I.E. LOW COST)

- WINDOW SEALS REPLACEMENT: 4% SAVING
- REPLACE THE OLD GAS BOILER WITH A NEW ONE: 13% SAVING

- DEEP RENOVATION (I.E. INCREASED COST)

- IMPROVING THE BUILDING ENVELOPE: 35% SAVING

Deep renovation interventions

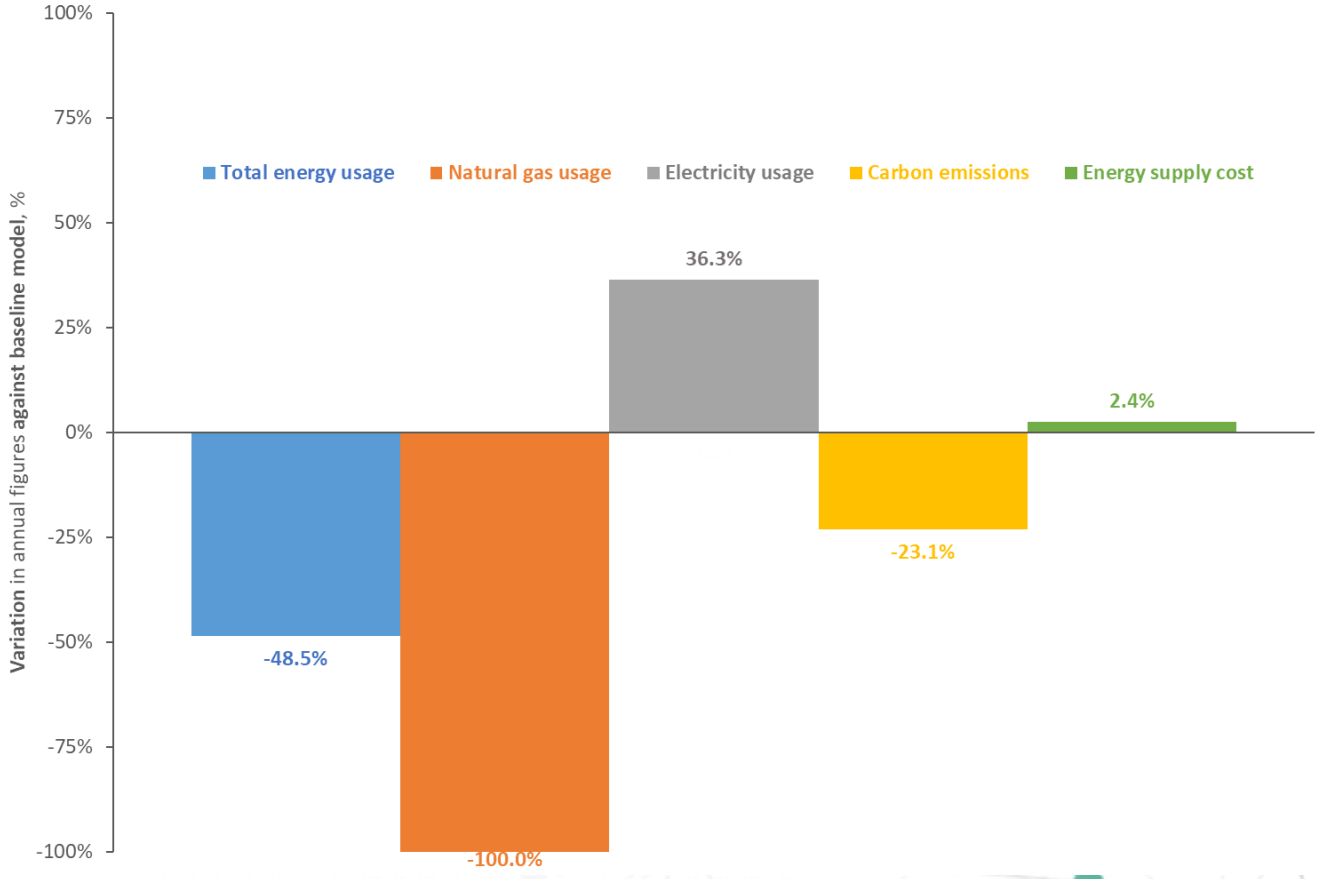
5. Air-to-water heat pump for space heating and DHW

Outdoor units

Indoor units

Improvements:

- *Bring sCOP to 3.25*
- *Can be used for both space heating and DHW*
- *Enables installation of hot water storage tank*



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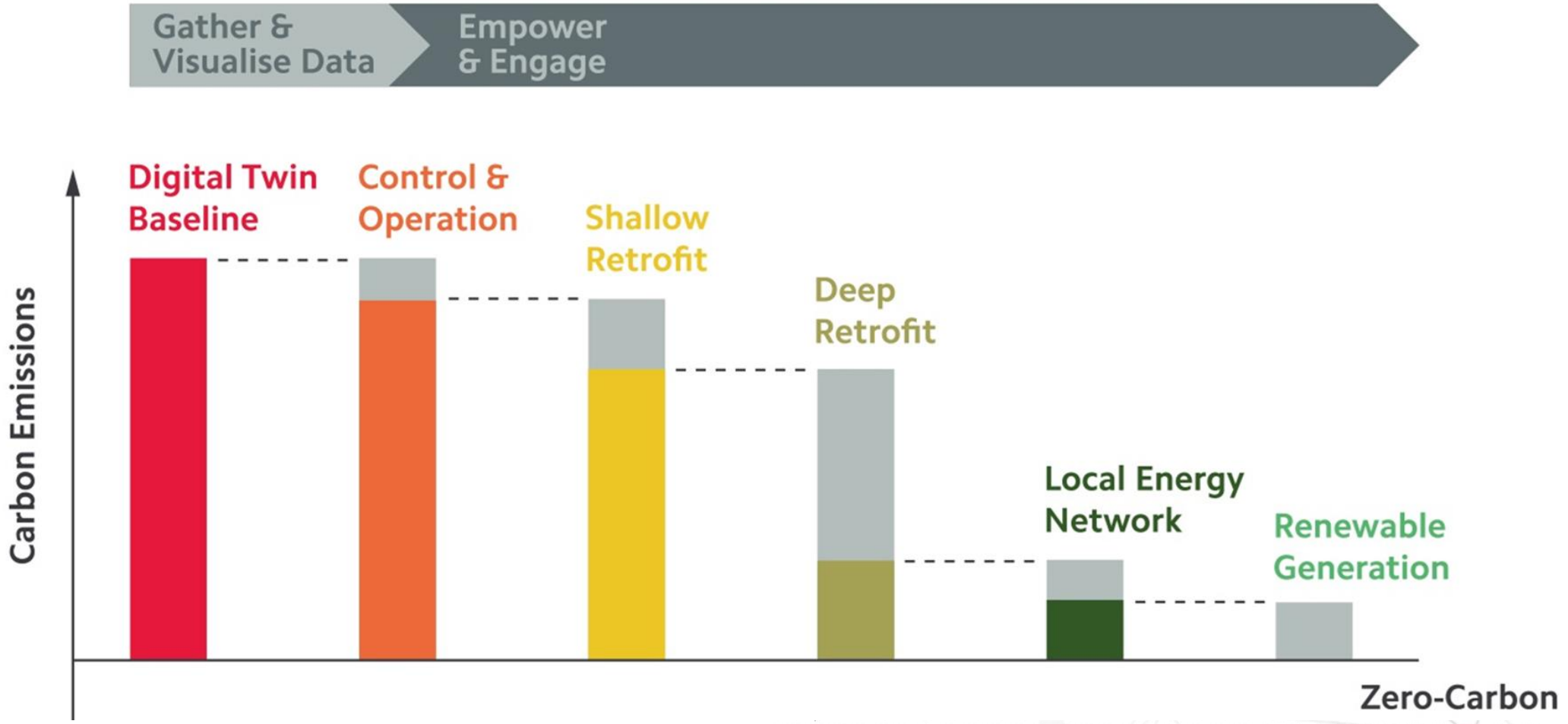
BIM4Ren

TRAINING

Choosing the optimal renovation

This project has received funding from the H2020 programme under Grant Agreement No. 820773

Digital Twin for nZEB renovation



Evaluate the impact of different renewable energy generators to achieve operational zero carbon

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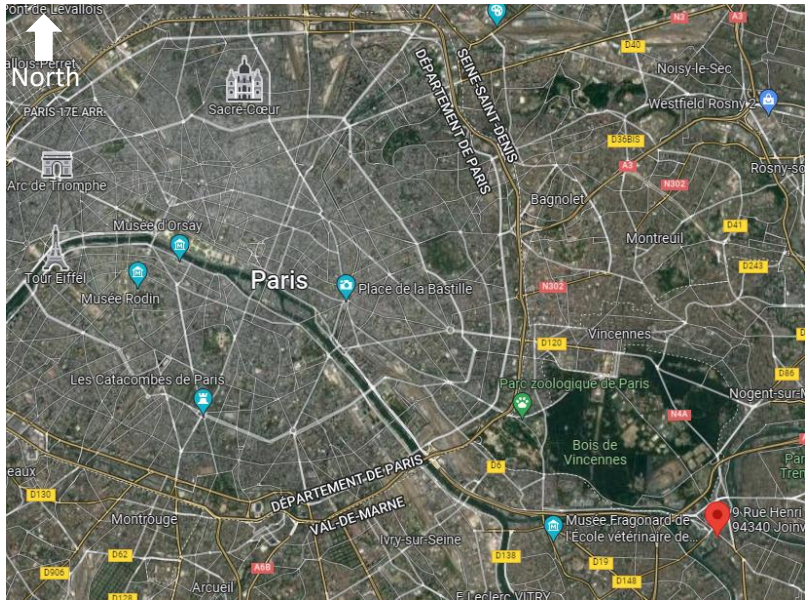
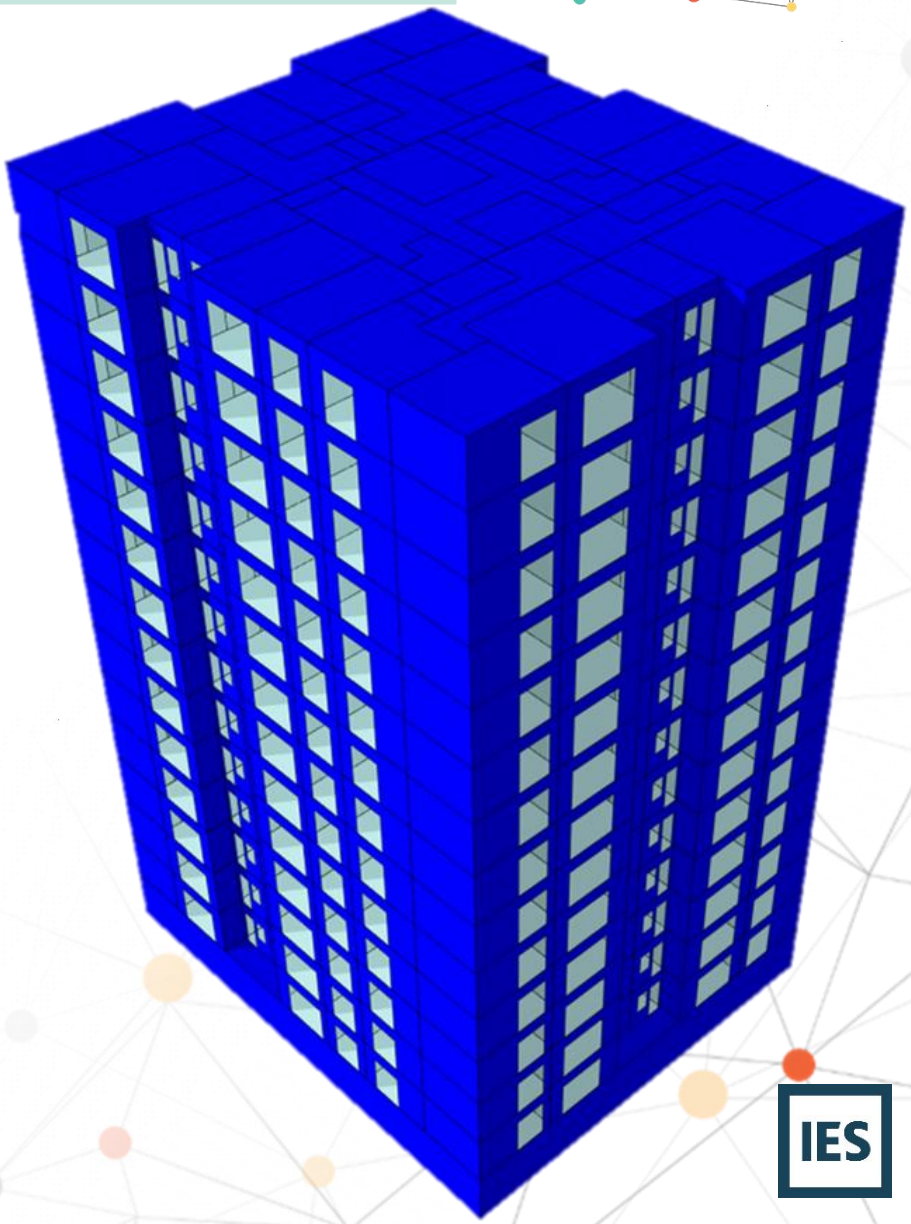
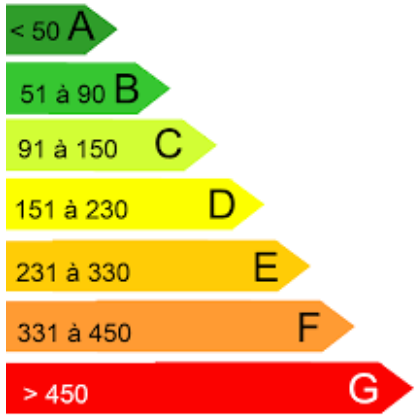
Renovation Scenario Optimisation

- Residential Building
- Built in 1974
- 5645 m^2
- 13 floors
- 83 flats







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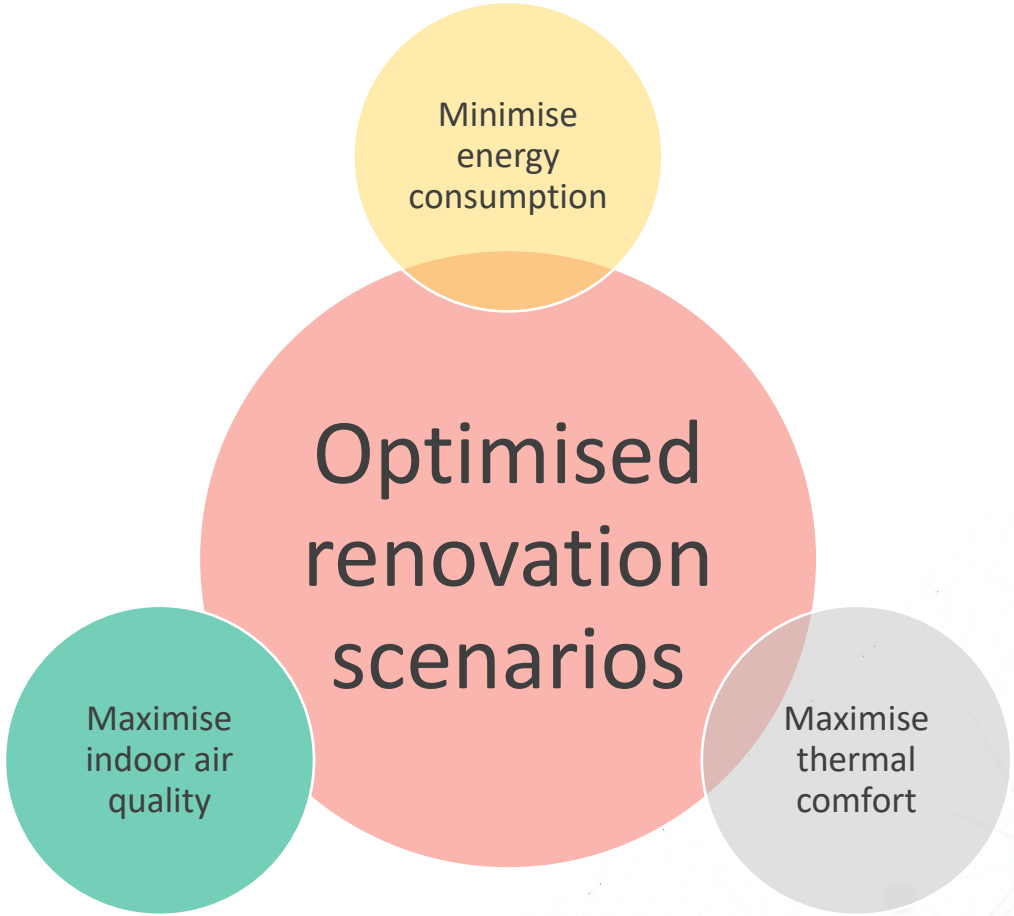
Baseline and proposed interventions

Area of intervention	Area of interest	Baseline	Retrofit	Range	Name	Notes
Envelope	Exterior wall	Concrete 15 cm + 5 cm insulation **U = 0.66 W.m²/K**	Mineral wool (rock) 14 cm (λ=0.032 W/m.K) or equivalent R = 4.4 m²K/W	-	STD_WAL4	U=0.26
			Mineral wool (rock) 20 cm (λ=0.032 W/m.K) or equivalent R = 4.4 m²K/W	-	STD_WAL5	U=0.19
			Mineral wool (rock) 25 cm (λ=0.032 W/m.K) or equivalent R = 4.4 m²K/W	-	STD_WAL6	U=0.15
	Upper floor basement	Concrete 20 cm + 5 cm insulated woodwool panel **U = 3.22 W.m²/K**	Spray applied insulation 12 cm or equivalent R ≥ 3 m².K/W	-	STD_FLO3	U=0.19
			Spray applied insulation 16 cm or equivalent R ≥ 3 m².K/W	-	STD_FLO4	U=0.14
			Spray applied insulation 20 cm or equivalent R ≥ 3 m².K/W	-	STD_FLO5	U=0.12
	Roof	Concrete 20 cm + 4 cm polyurethane **U = 0.63 W.m²/K**	Polyurethane 12 cm (λ=0.023 W/m.K) or equivalent R ≥=5.2 m².K/W	-	STD_ROO1	U=0.23
			Polyurethane 16 cm (λ=0.023 W/m.K) or equivalent R ≥=5.2 m².K/W	-	STD_ROO2	U=0.17
			Polyurethane 20 cm (λ=0.023 W/m.K) or equivalent R ≥=5.2 m².K/W	-	STD_ROO3	U=0.1448
Glazing and doors	Windows	Double glazed **Uw= 2.8 W.m²/K**	Low-E Double Glazing SC=0.6	-	LWDB0045	U=2.06
			Low-E Triple Glazing SC=0.65	-	LWTR0005	U=1.35
	Landing door	Non-insulated door **Ud = 3.5 W.m²/K**	Wooden door insulated Ud < 2.19 W/m²/K	-	WDND0000	U=2.19
			Wooden Door 60 mm Ud < 1.6 W/m²/K	-	WDND0002	U=1.6
Air tightness	Air tightness	**0.25 ach**	Infiltration rate [ach]	[0.26 - 0.1]	-	-
Ventilation	Vent. rates	**1.9 ach**	Auxiliary ventilation [ach]	[1.5 - 2.5]	-	-
Lighting	Lighting	**11 W/m²**	Efficient lighting [W/m2]	[3-15]	-	-
Heating set point	Set-points	**20 °C**	Heating set point change [°C]	[18-22]	-	-
DHW	Fixtures	**26 l/h**	Reduction of DHW consumption. Improvement of fixtures [l/h]	[15-26]	-	-
System	Efficiency, Heat recovery, DHW supply T	S_{EFF} = 0.9 HR=0% DHW_ST =60 °C	Seasonal efficiency 0.90, Heat recovery effectiveness 0.3, DHW Hot water supply temperature 58 °C	-	SYST0003	
			Seasonal efficiency 0.92, Heat recovery effectiveness 0.45, DHW Hot water supply temperature 55 °C		SYST0005	
			Seasonal efficiency 0.94, Heat recovery effectiveness 0.55, DHW Hot water supply temperature 53 °C		SYST0006	

Optimisation Objectives



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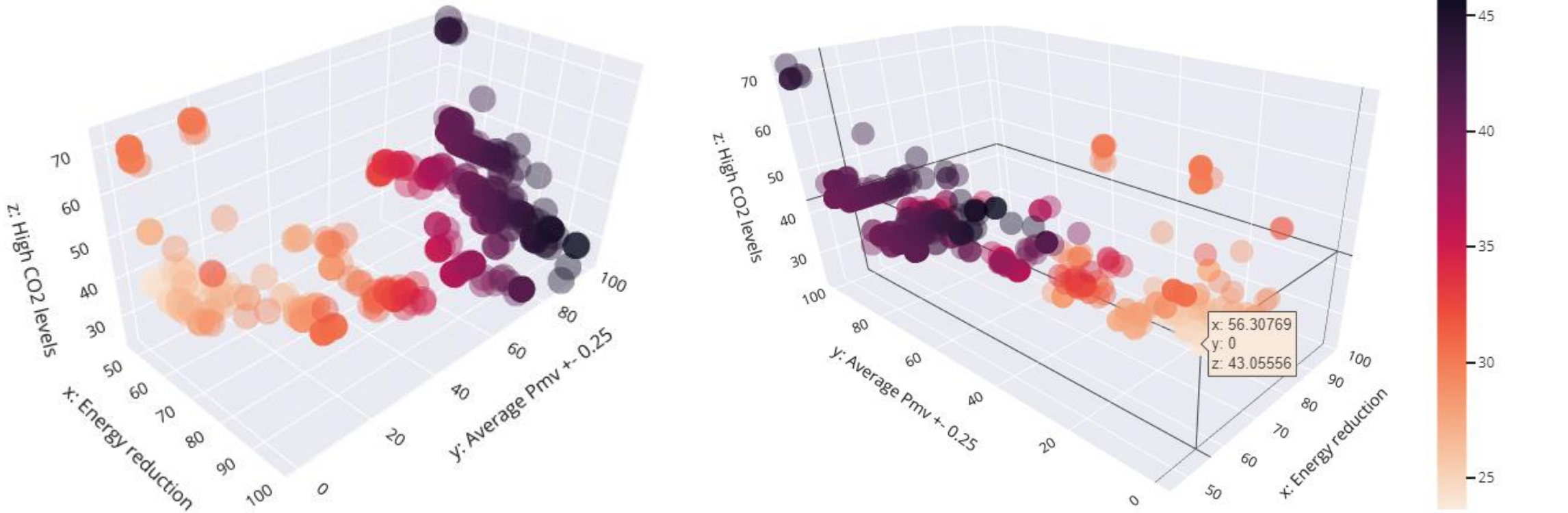
Optimisation results



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Set of best solutions

Ext Wall	Roof	Ground Floor	Ext Window	Int Door	Apache System	Infiltration	Auxiliary Vent	Lighting	Heating set-point	DHW Consumption	Energy reduction from baseline	PMV percentage of time discomfort	CO2 air quality improvement
-	-	-	-	-	-	[ach]	[ach]	[W/m2]	[C]	[l/h]	%	%	%
STD_WAL5	STD_ROO3	STD_FLO5	LWTR0005	WDND0002	SYST0005	0.10	2.18	4.2	21.4	15.29	43.8	0	57
STD_WAL5	STD_ROO3	STD_FLO5	LWTR0005	WDND0002	SYST0006	0.11	2.17	4.2	21.4	15.29	43.8	0	57
STD_WAL5	STD_ROO3	STD_FLO5	LWTR0005	WDND0002	SYST0006	0.11	2.17	4.2	21.4	15.29	43.8	0	57

Ext walls: Mineral wool (rock) 20 cm (λ = 0.032 W/m.K) or equivalent R = 4.4 m²K/W
Roof: Polyurethane 20 cm (λ = 0.023 W/m.K) or equivalent R ≥ 5.2 m².K/W
Ground Floor: Spray applied insulation 20 cm or equivalent R ≥ 3 m².K/W
Ext windows: Low-E Triple Glazing SC = 0.65
Doors: Wooden Door 60 mm Ud < 1.6 W/m²/K
System: Seasonal efficiency 0.92, heat recovery effectiveness 0.45, DHW hot water supply temperature 55° C
Air tightness: Infiltration rate 0.1 ach
Auxiliary ventilation: 2.18 ach
Lighting: Efficient lighting e.g led 4.2 W/m2
Heating set-point: 21° C
DHW consumption: Efficient fixtures 15.29 l/h

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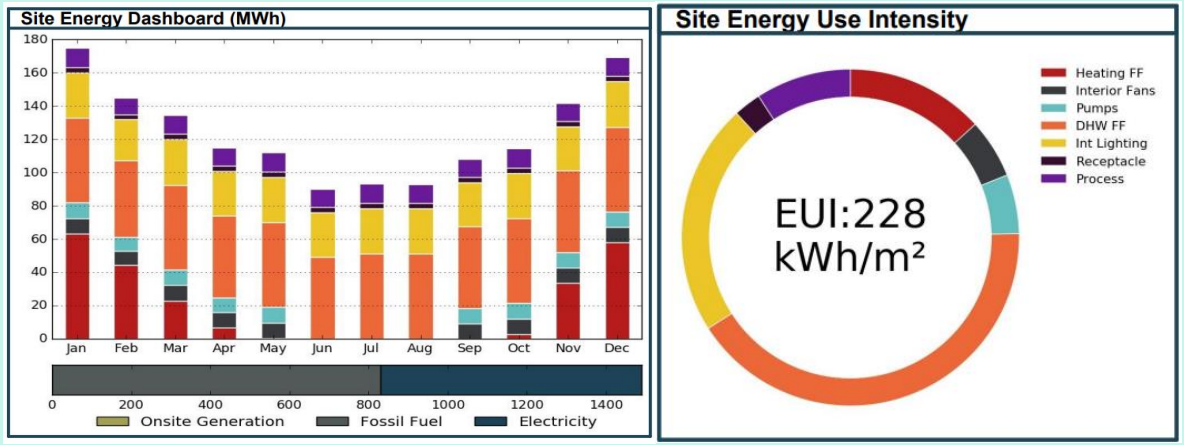
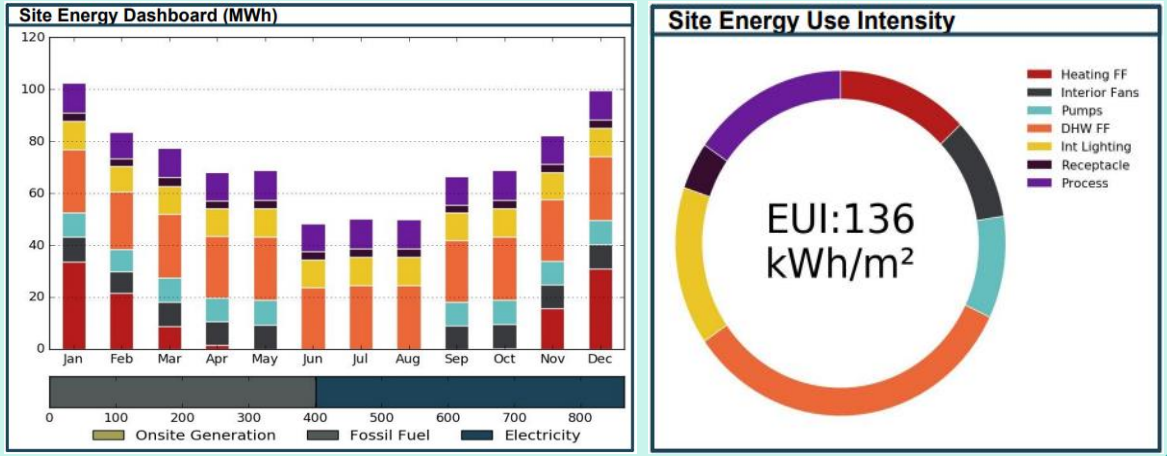
Optimal renovation scenario

Baseline



Optimal renovation scenario



43.8% energy reduction

No thermal discomfort

57% improvement air quality

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Life Cycle Assessment + Costing

B-BEST –BIM4REN
Building Environmental Sustainability Tracker

ekodenge

BIM Data

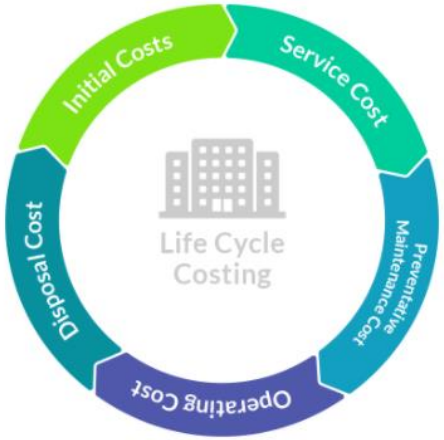
B-BEST

Life Cycle Assessment

Environmental assessment of renovation

- Embodied material & energy footprint
- Embodied Carbon

Costing database + user inputs on costs and benefits



B-BEST

Life Cycle Costing

Economic assessment of renovation (investment vs energy savings)

- Net Present Value
- Payback time

Renovation project assessment

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B-BEST – LCA module

LCA Module

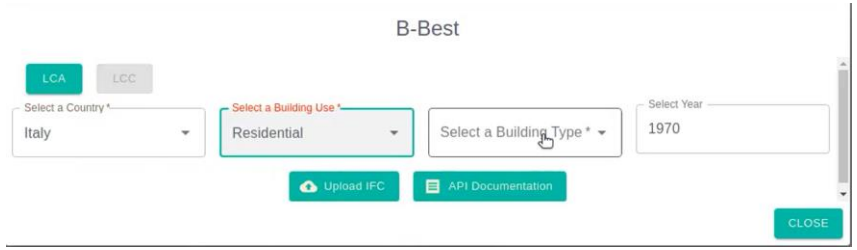
BIM / IFC

buildingSMART GERMAN SPEAKING CHAPTER

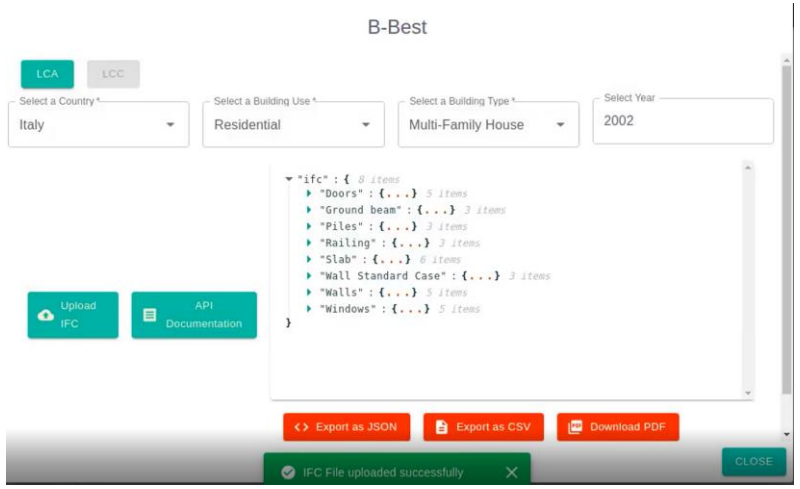
B-BEST - Life Cycle Assessment

Environmental assessment of renovation (energy & material footprint, CO2 emissions)

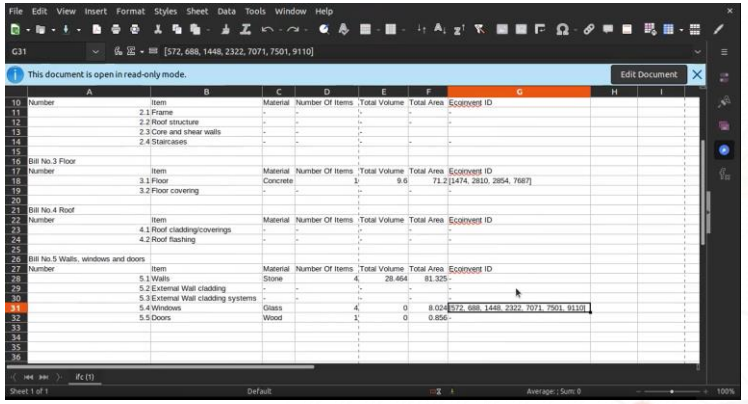
1. Enter renovation details location, building, year



2. Upload IFC file and check component info



3. Download and check auto-generated Bill of Materials

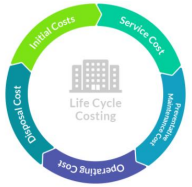


4. Obtain building energy & material footprint info

(to be finalised)

B-BEST – LCA module

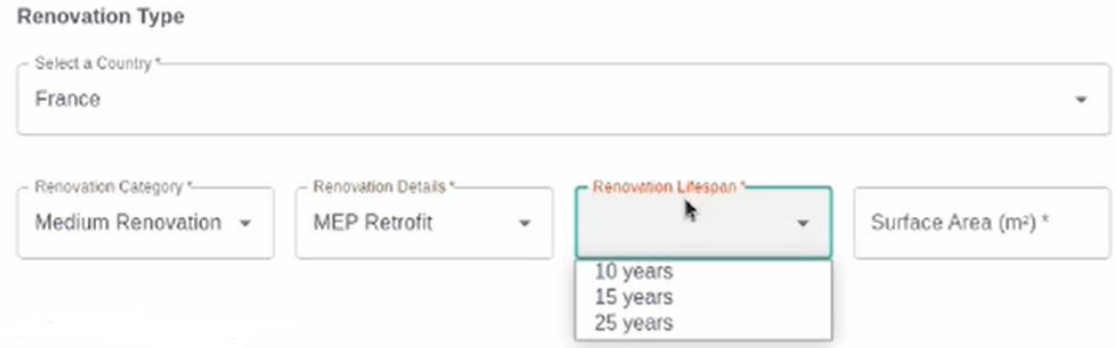
LCC Module



B-BEST - Life Cycle Costing

Economic assessment of renovation (investment vs energy savings)

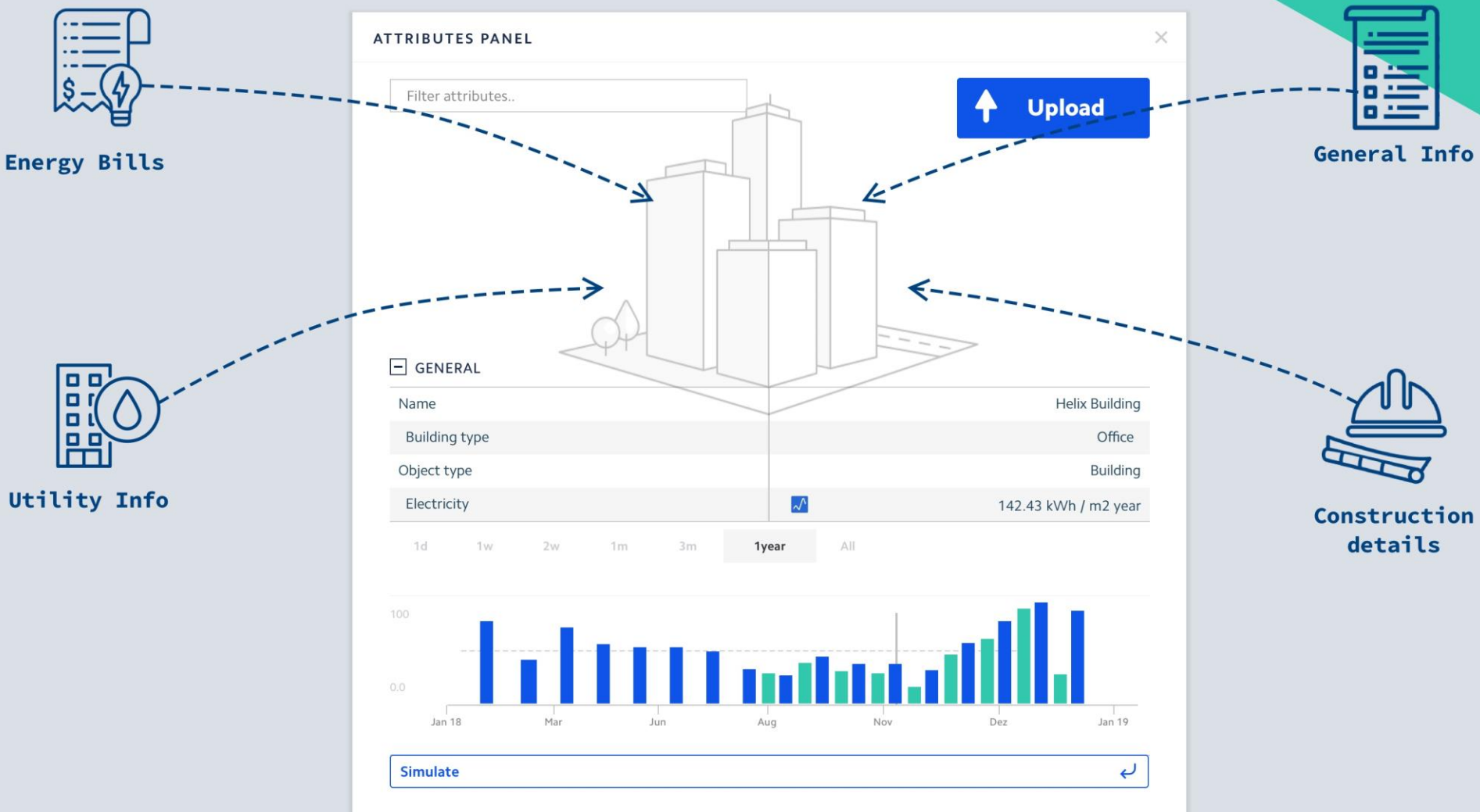
1. Enter renovation details - location, category, type, lifespan and surface area



2. Enter renovation cost information
3. Enter renovation energy savings (if applicable)
4. Enter expected building value increase

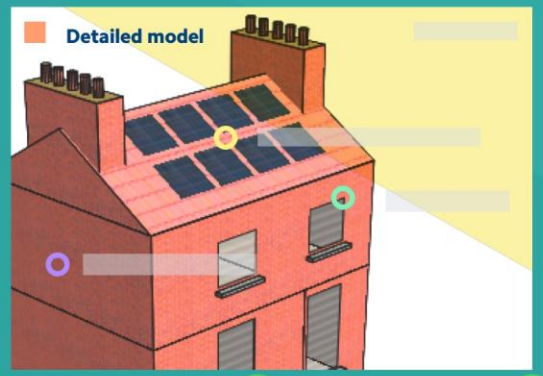
5. Obtain results of costs vs benefits

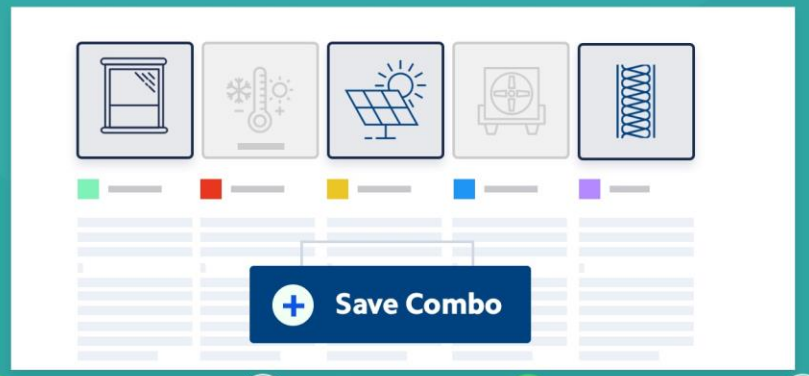
Populate your project with data

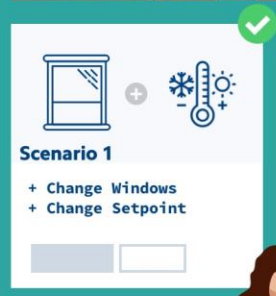


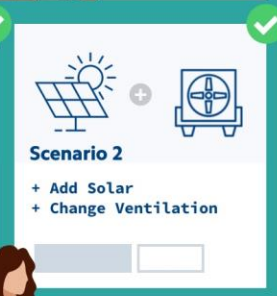
Model is updated with new datapoints

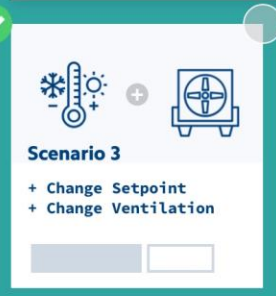
Renovation Scenarios

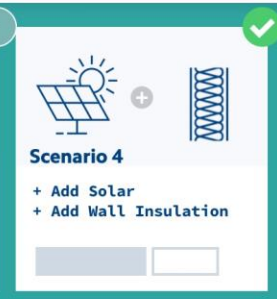












Compare

Make Decisions

Best for Comfort

+ Change Windows
+ Change Setpoint

Best for Overall

+ Add Solar
+ Change Ventilation

Higher Savings

+ Change Setpoint
+ Change Ventilation

BIM4Ren

TRAINING

Thank you for your attention

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http://bim4ren.eu/

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