Funded by:

UK Government

NOTTINGHAM RETROFIT ROADMAP

Agencies:

Ministry of Housing, Communities & Local Government

Department for Levelling Up, Housing & Communities

UK Shared Prosperity Fund

Coordination:

Nottingham City Council

CN28 Carbon Neutral Nottingham 2028

Partners:

University of Nottingham UK | CHINA | MALAYSIA

nep nottingham energy partnership

ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

FOCUS Create. Deliver. Assess.

Welcome: Why Retrofit?

Funded by:

UK Government

WHY RETROFIT?

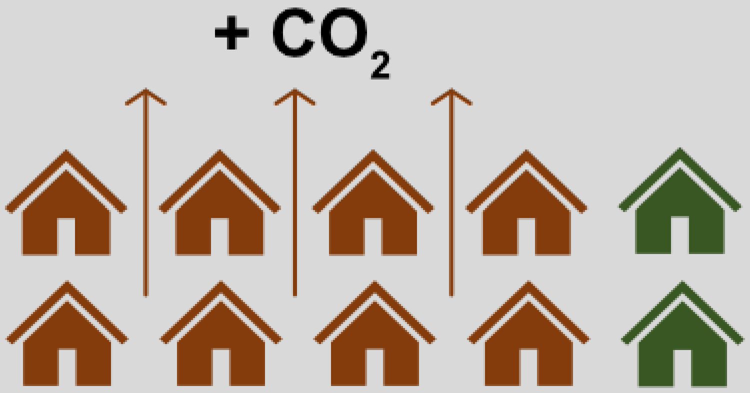
The UK has some of the oldest and least energy-efficient housing stock in Europe

22%

of total greenhouse gas emissions are produced by residential buildings in the UK (LETI, 2020, p. 14, 58)

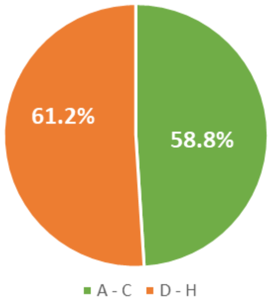
80%

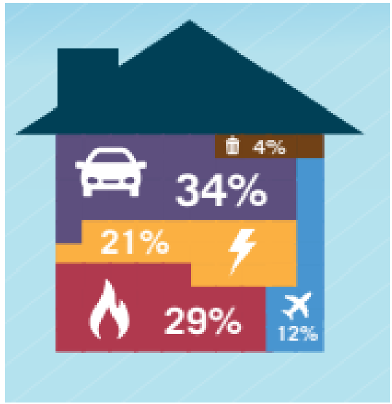
of the buildings that will form the UK 2050 housing stock were built before the introduction of energy performance standards and are far from meeting future energy needs (Passivhaus Trust, 2022, p. 6)



Why Retrofit?

164k

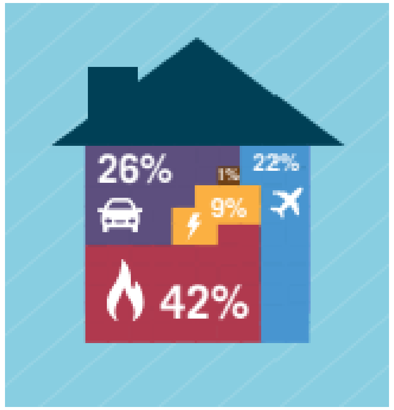




6 tonnes of CO_2

2030

164k



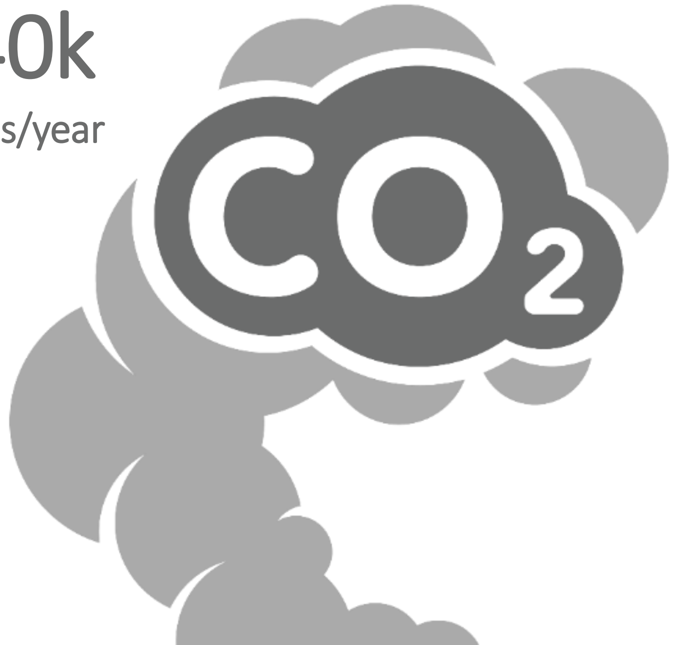
4.5 tonnes of CO_2

247k

tonnes/year

740k

tonnes/year



Nottingham's Existing Stock

Housing type

164,460
Housing units

62% Houses

30% flats

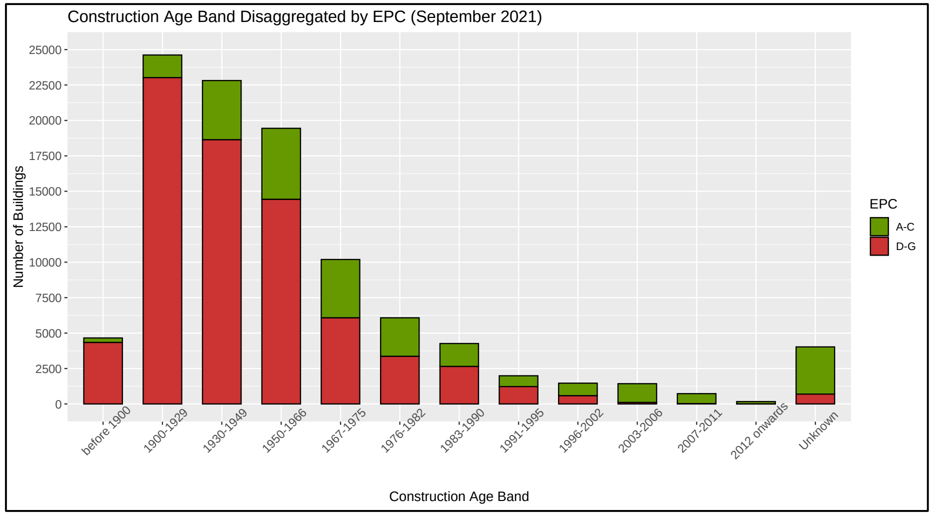
Property Types (Houses)

Detached	5.8%	9,588
Semi-Detached	20.3%	33,418
Mid-Terrace	22.4%	36,904
End-Terrace	13.4%	21,972

Performance

68%
78%
75%
79%

of the properties are **EPC D-G**



61.2% Energy Performance Certificate below C

UK GOVERNMENT 2021. Energy Performance of Buildings Data England and Wales.

NOTTINGHAM'S EXISTING STOCK

Housing tenure

	Owner-occupied	Social rented	Privately rented
All Properties	31.1% 51,229	35.9% 59,009	27.5% 45,241
Detached	71.1% 6,815	2.8% 265	18.2% 1,743
Semi- Detached	45.6% 15,253	29.4% 9,882	20.5% 6,855
Mid-Terrace	33.1% 12,215	35.7% 13,162	28.6% 10,552
End-Terrace	32.9% 7,238	41.3% 9,071	22.5% 4,930

Floor space

	England	Nottingham
Detached	152m²	107m²
Semi- Detached	93m²	83m²
Mid-Terrace	81m²	79m²
End-Terrace	86m²	79m²

Housing type

80%
of the all properties are gas-supplied

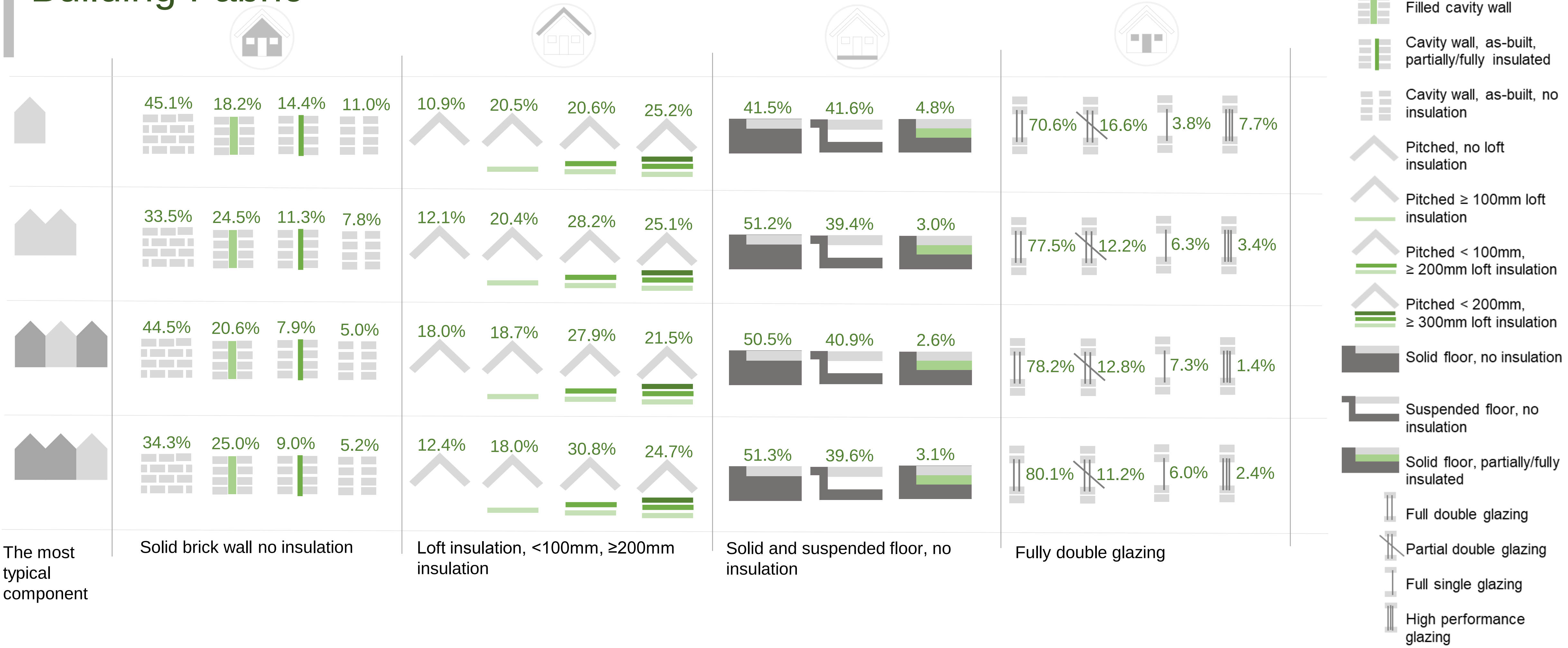
Percentage of properties supplied by gas boilers within **EPCD-G**

Detached	96%
Semi- Detached	94%
Mid-Terrace	92%
End-Terrace	93%

UK GOVERNMENT 2021. Energy Performance of Buildings Data England and Wales.
MINISTRY OF HOUSING; COMMUNITIES & LOCAL GOVERNMENT 2018. English Housing Survey Floor Space in English Homes – main report.

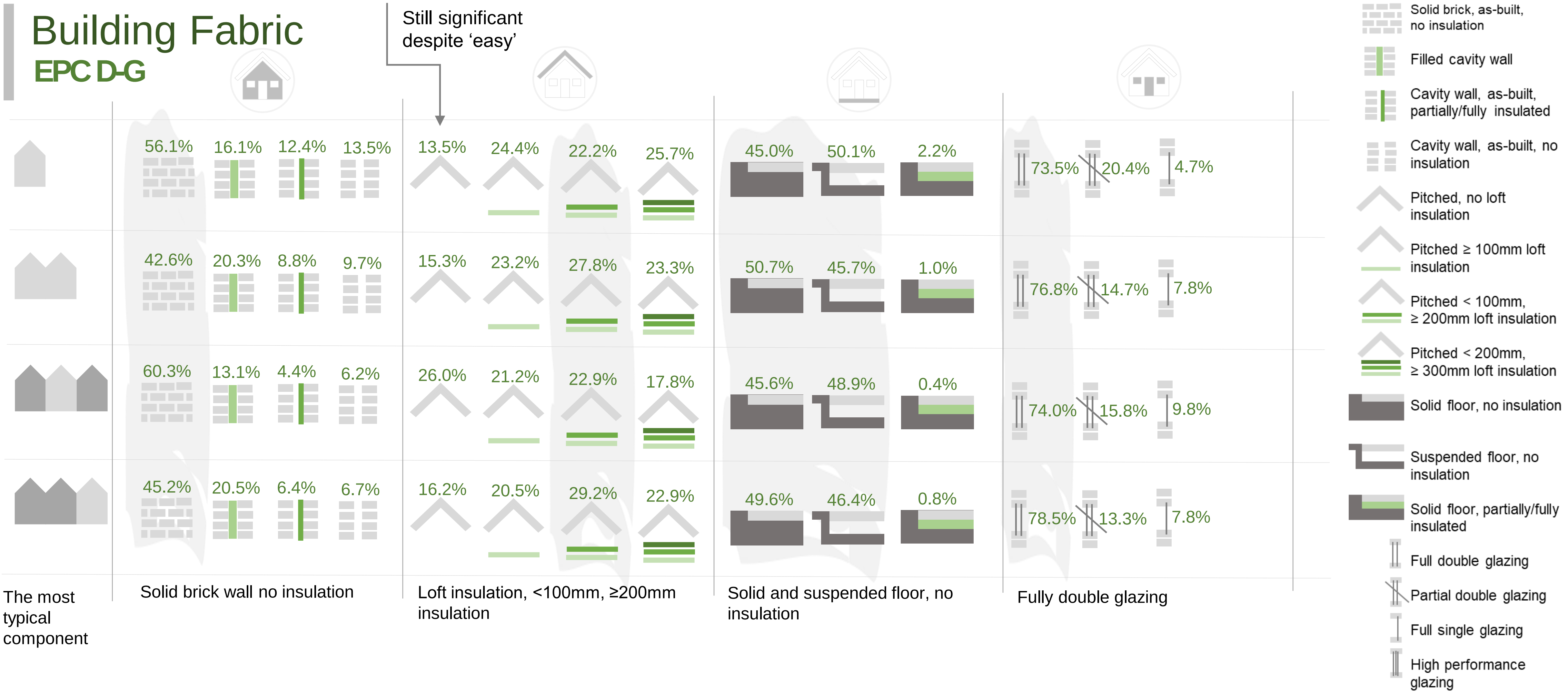
Nottingham's Existing Stock

Building Fabric



UK GOVERNMENT 2021. Energy Performance of Buildings Data England and Wales.

NOTTINGHAM'S EXISTING STOCK



UK GOVERNMENT 2021. Energy Performance of Buildings Data England and Wales.

Getting to Net Zero

1

Better understanding of what stock exists its current energy performance…

2

What energy infrastructure is the stock connected to…

3

What is the actual condition of the stock…

4

What is the evidence base to support measure selection and optimisation…

Fuel Poverty

Funded by:

UK Government

FUEL POVERTY IN NOTTINGHAM

~35,000

Households

- In 2020, 20.6% of households were considered to be in fuel poverty, just over 35,000 households
- This significantly higher than the national rate of 13.2% of households

(BEIS, 2022)

Nottingham ranked

6th

Among all English LAs

- Among all English local authorities, Nottingham has the 6th highest rate of fuel poverty

(BEIS 2022)

- Fuel poverty levels in Nottingham are currently higher than they have been at any time over the last 10 years

Deep and Typical Retrofit

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ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

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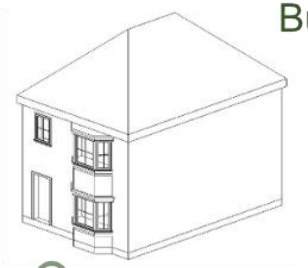
HOW DO WE RETROFIT?

The solution lies in an integrated whole-house retrofit approach to bring existing houses to near net zero energy demand*.

Stage 1 Building fabric optimisation	Stage 2 Low-carbon heating systems	Stage 3 Renewable energy generation & storage integration

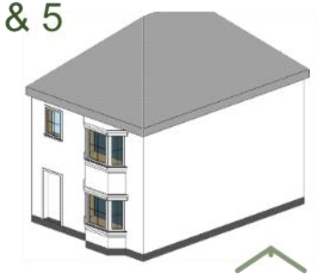
*Performance Target: Part L 2021 notional levels

Deep and Typical Retrofit Measures



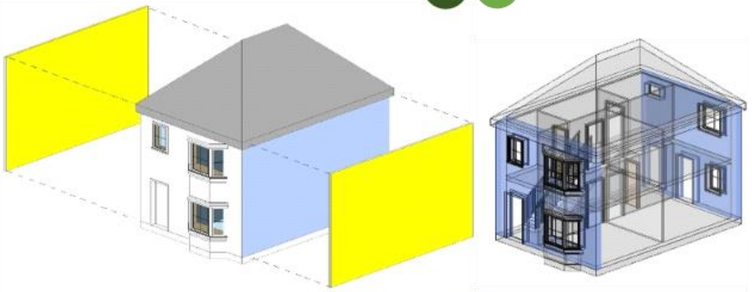
Building fabric optimisation key: Deep retrofit measures: 1, 2, 3, 4 & 5 Typical retrofit measures 1, 3, & 5

Whereas deep retrofit involves taking a wide range of measures to reduce a building's energy needs considerably, typical retrofit measures exclude more costly and disruptive measures. Measure can be broken into 3 stages including: **Retrofit Stage 1** - **building fabric optimiisation**; **Retrofit Stage 2** - low-carbon heating systems and **Retrofit Stage 3** - renewable energy generation and storage.



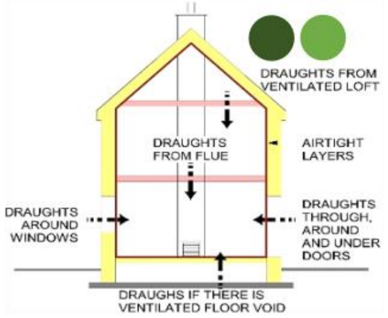
1. Add loft insulation

2. Add floor insulation



3. Add wall insulation

4. Add energy efficient glazing/doors

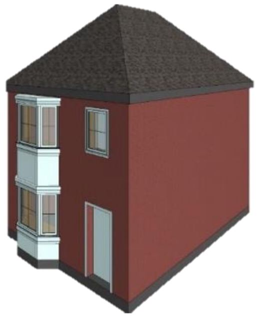


5. Draught proofing and airtight envelope

SIMULATION MODELS (ARCHETYPES)

- Four models representing the most typical house types
- Each house considered to be two-storey with similar floor area

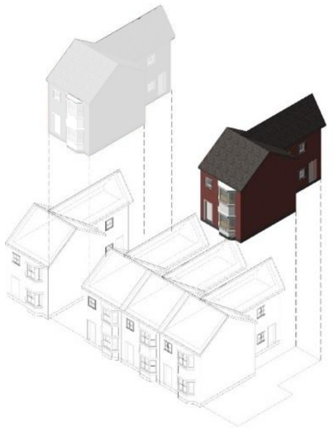
Detached



Semi-Detached

Mid-Terrace

End-Terrace



DEEP RETROFIT MEASURES

To reduce the number of permutations, this has been done by mapping the cumulative benefits gained from a range of improvements based on the likelihood and construction practicality

1. Base model (as-built): highly permeable and not insulated building envelope

2. Added loft insulation

3. Added floor insulation

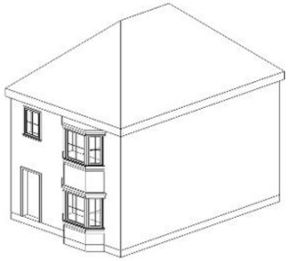
4. Added walls insulation

5. Added energy-efficient glazing/ doors

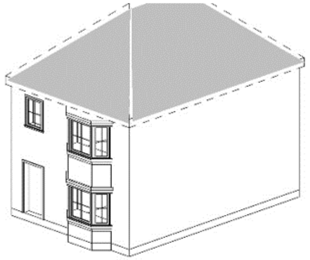
6. Added draught proofing

7. Added extra draught proofing

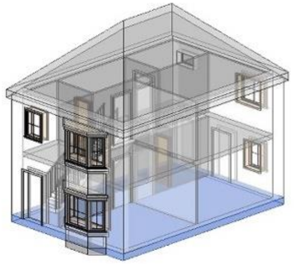
- Target: Part L 2021 notional levels.
- Heating on from Oct-Mar using occupant profiles
- No cooling systems
- No active design improvements



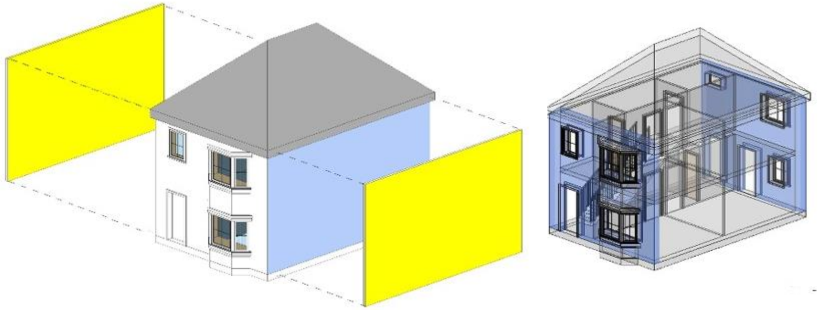
1. Base model (as-built)



2. Loft insulation

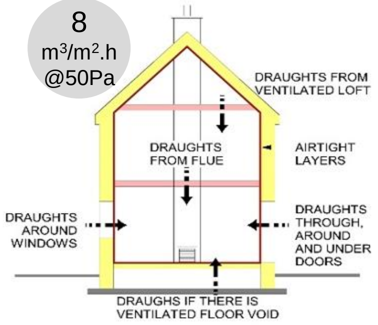


3. Floor insulation

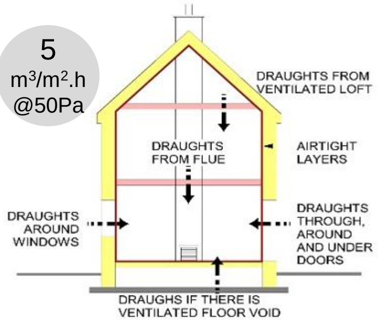


4. Wall insulation

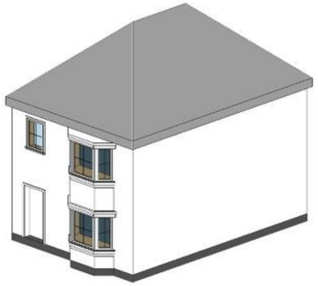
5. Energy-efficient glazing/ doors



6. Draught proofing and airtight envelope



7. Draught proofing and airtight envelope



Optimised model

Typical Retrofit Measures

Typical retrofit excluded more costly and disruptive measures and was based on typical retrofit projects developed in Nottingham:

1. Base model (as-built): highly permeable and not insulated building envelope

2. Added loft insulation

3. Added floor insulation

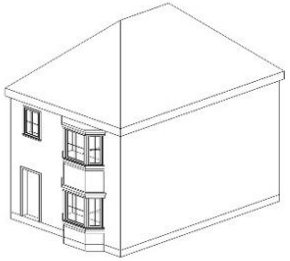
4. Added walls insulation

5. Added energy-efficient glazing/ doors

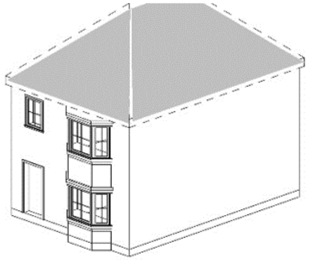
6. Added draught proofing

7. Added extra draught proofing

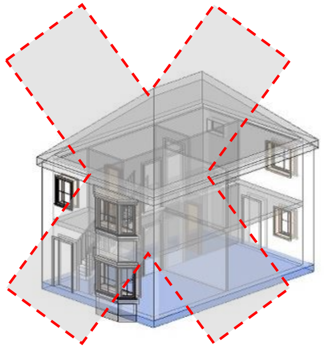
- Target: Part L 2021 notional levels.
- Heating on from Oct-Mar using occupant profiles
- No cooling systems
- No active design improvements



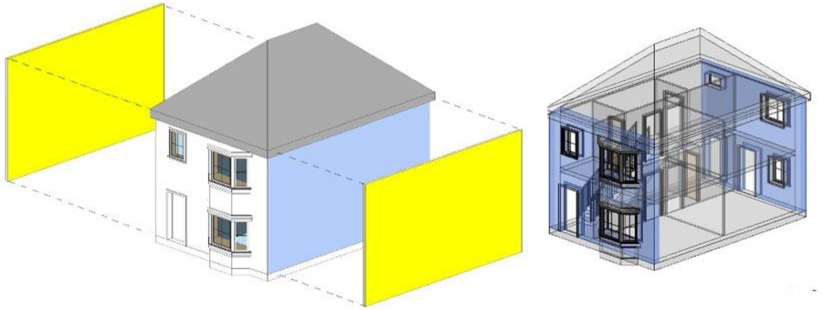
1. Base model (as-built)



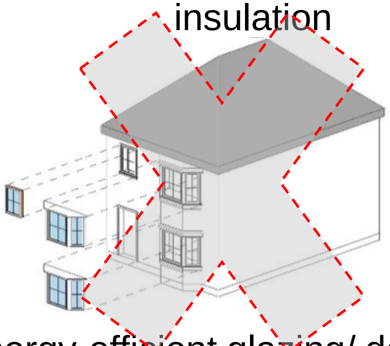
2. Loft insulation



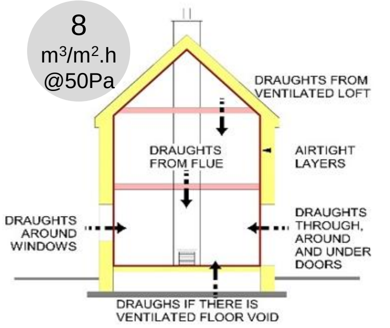
3. Floor insulation



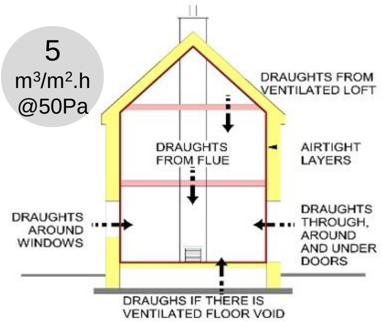
4. Wall insulation



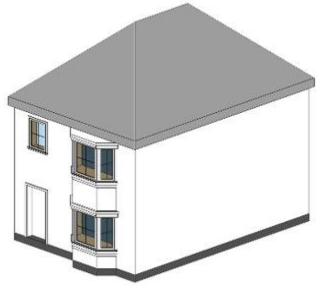
5. Energy-efficient glazing/ doors



6. Draught proofing and airtight envelope



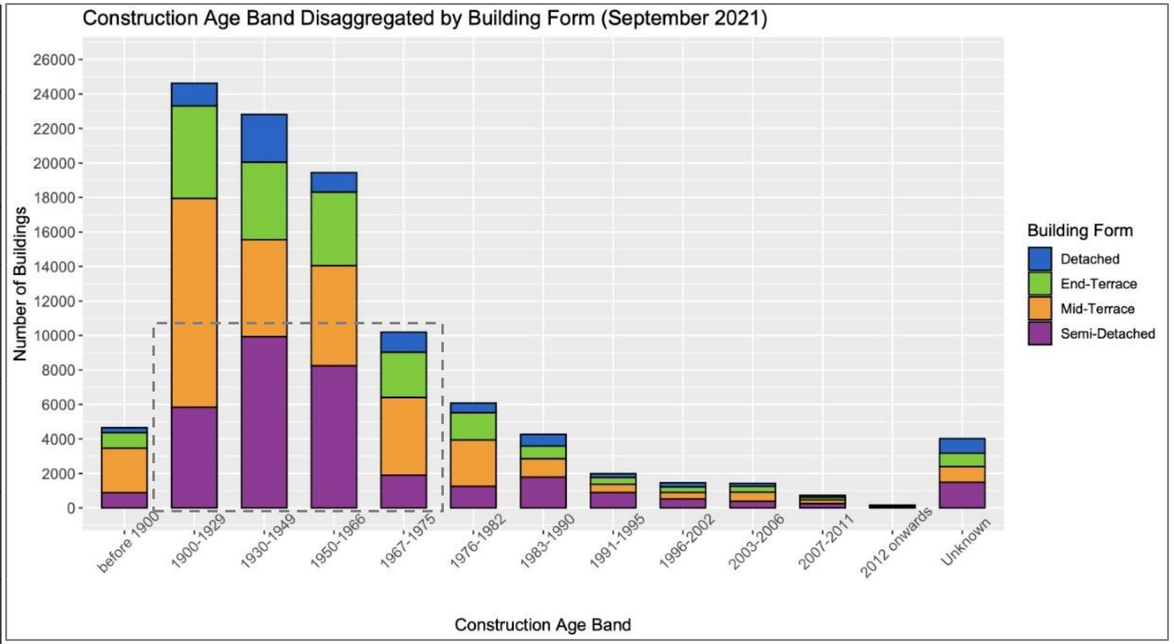
7. Draught proofing and airtight envelope



Optimised model

U-VALUE & AIRTIGHTNESS LIMITS

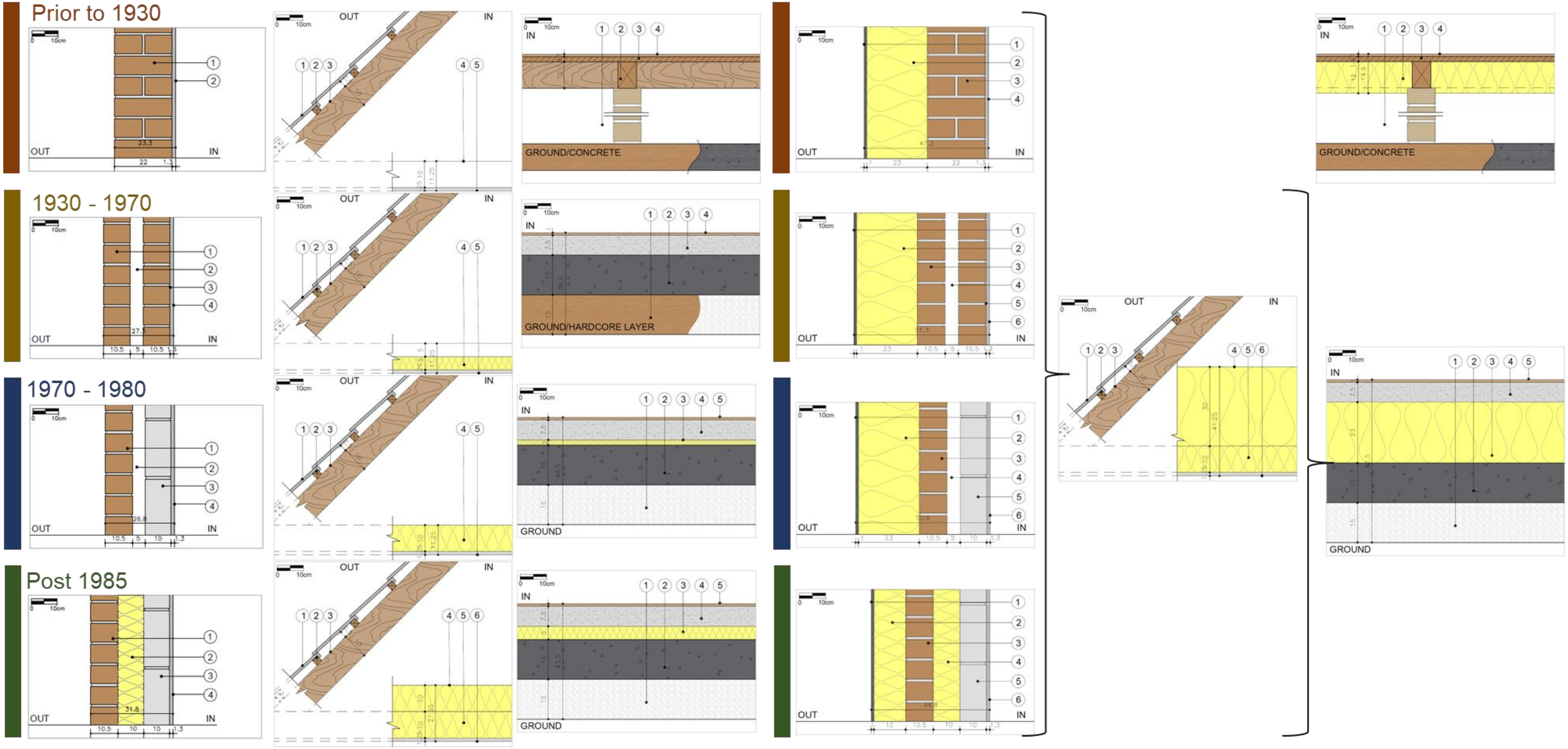
Building Energy Regulation	U-values (W/m²K)					Air permeability (m³/m²h) @ 50 Pa
	Roof	Walls	Floor	Windows	Party wall	
1965 Building Regulation [6] (UK Government, 1965, p. 52, 166)	1.42	1.70	1.42	5.7, 12% wall max.	-	
1976 Building Regulation (UK Government, 1976, p. 4307)	0.60	1.00	1.00	5.7, 12% wall max.	-	
1985 Building Regulation (UK Government, 1985, p. 3414)	0.35	0.60	0.60	5.7, 12% wall max.	-	
The **1991** Building Energy Regulations (Department of the Environment and the Welsh Office, 1992, p. 5)	0.25	0.45	0.45	5.7, 15% floor	-	
The 1991 Building Energy Regulations. Part L1A **1995** edition (Department of the Environment and the Welsh Office, 1995, p. 8)	0.20/ 0.25[7]	0.45	0.35/ 0.45	3.0/ 3.33	-	
The Building Regulations 2000 Part L1A **2002** (Office of the Deputy Prime Minister, 2002, p. 12)	0.25[8]	0.35	0.25	2.20	-	10.0
The Building Regulations 2000 Part L1A **2006** (Office of the Deputy Prime Minister, 2006, p. 18)	0.25	0.35	0.25	2.20	-	10.0
The Building Regulations 2000 Part L1A **2010**. (HM Government, 2010, p. 15)	0.20	0.30	0.25	2.00	0.20	10.0
The Building Regulations 2010. Part L1A 2013 edition/ **2016 amendments** (HM Government, 2016, p. 15)	0.20	0.30	0.25	2.00	0.20	10.0
The Building Regulations 2010. Part L **2021** (HM Government, 2021b, p. 21)	0.16	0.26	0.18	1.60 1.60 doors	0.20	8.0 or 1.57m³/m²h @4Pa
Part L **2021 notional building** (Ministry of Housing; Communities and Local Government, 2021, p. 113)	0.11	0.18	0.13	1.20 1.00 doors	-	5.0
Passive House Standard	0.15	0.15	0.15	0.80 0.85 installed	-	0.6 ach at 50 Pa MVHR



The simulations used models deemed more representative of the housing stock:

- Victorian solid brick house
- Typical post-war (1950) cavity wall house

BUILDING FABRIC OPTIMISATION



END-TERRACE ARCHETYPE

Funded by:

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ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

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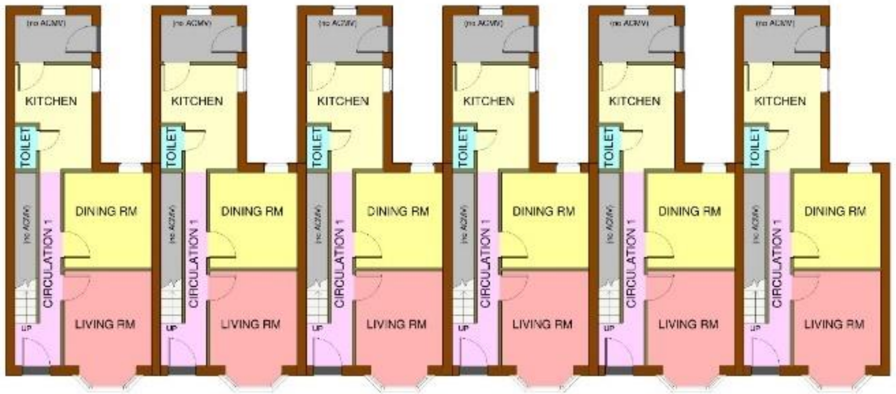
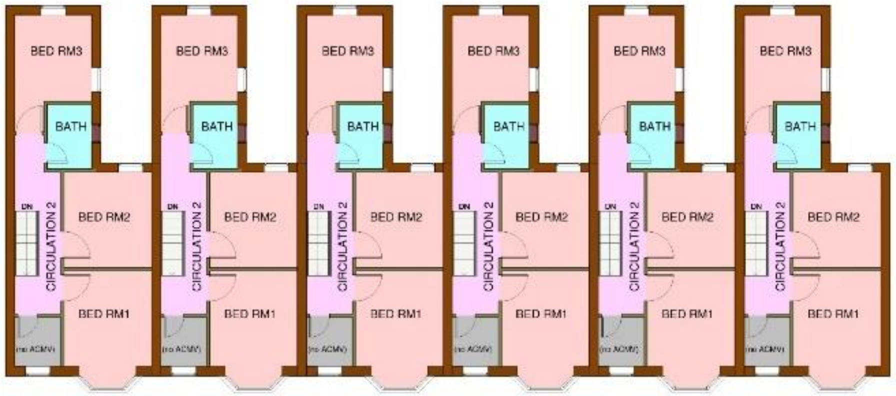
End-Terrace Archetype – Typical Characteristics

This housing typology represents 20.2% of Nottingham's total housing stock.

The typical EPC rating of this housing typology ranges from D-G (75.4%).



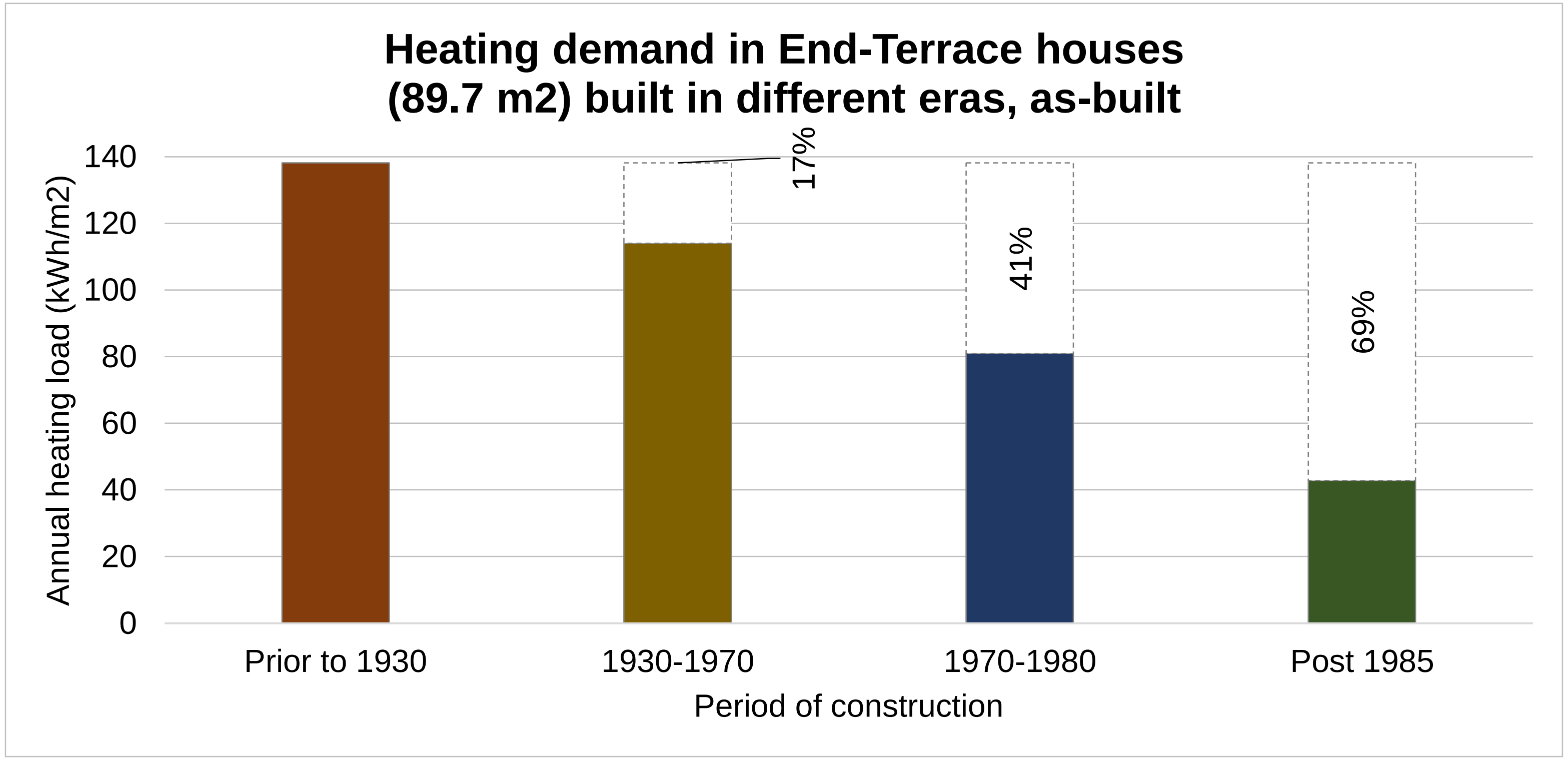
Ground Floor



First Floor

End-Terrace Archetype – Heating Demand

The performance of a typical End-Terrace Nottingham housing archetype was considered as was built over four time periods (**prior to 1930**, **1930-1970**, **1970-1980**, **and post-1985**), to determine incremental retrofit performance improvements.



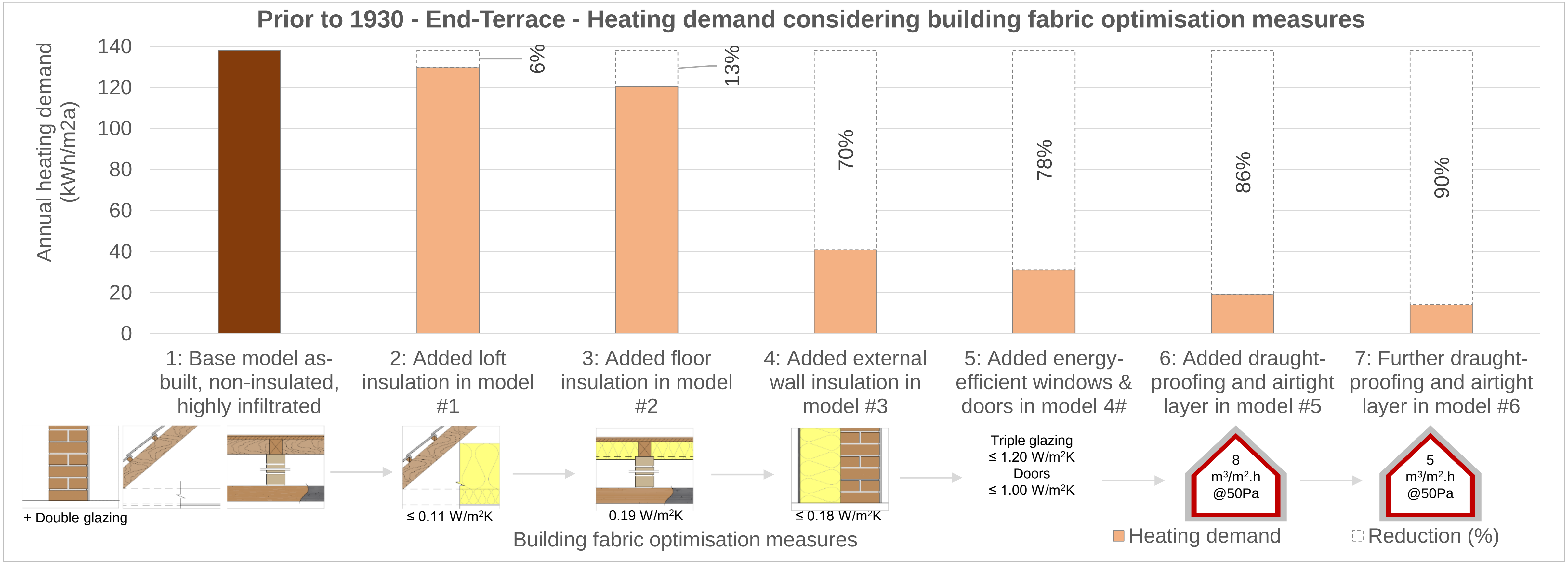
- Heating on from Oct-Mar using occupant profiles
- No cooling systems
- No active design improvements

Retrofit Stage 1: Building Fabric Optimisation

End-Terrace Archetype – Deep Retrofit

Retrofit Stage 1 – building fabric optimisation

Prior to 1930



Target: Part L 2021 notional levels

Heating on from Oct-Mar using occupant profiles

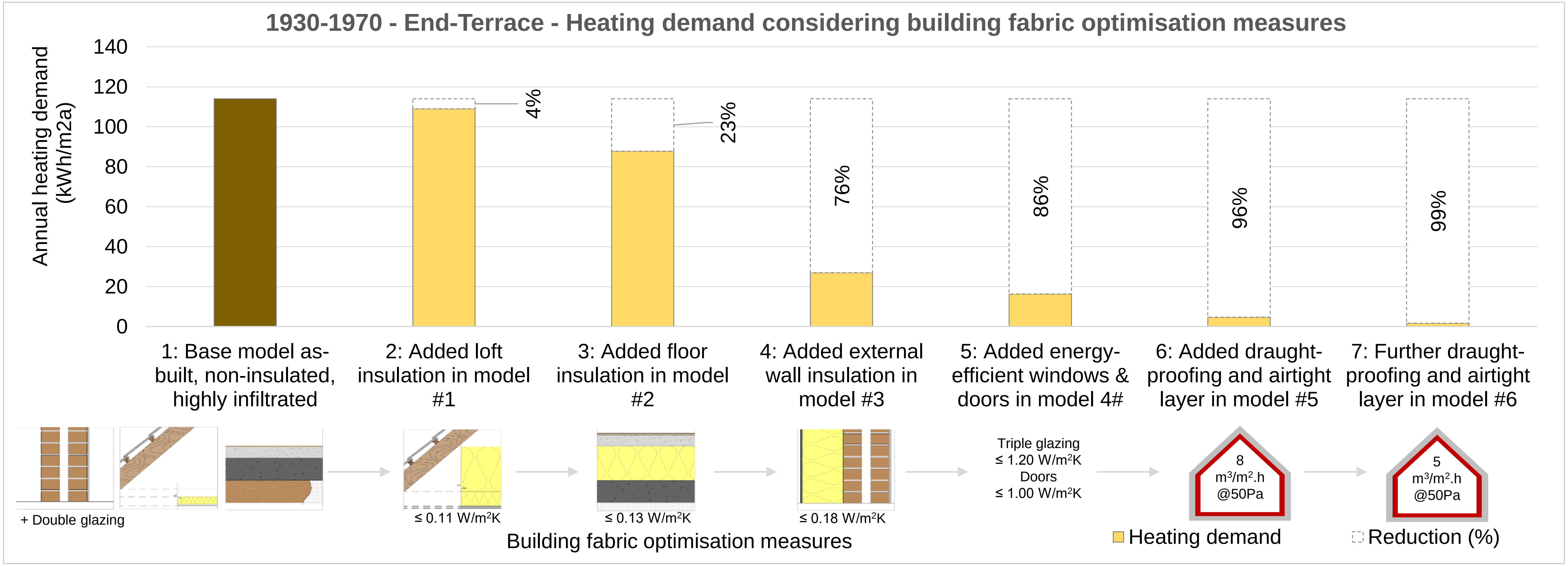
No cooling systems

No active design improvements

End-Terrace Archetype – Deep Retrofit

Retrofit Stage 1 – building fabric optimisation

1930-1970

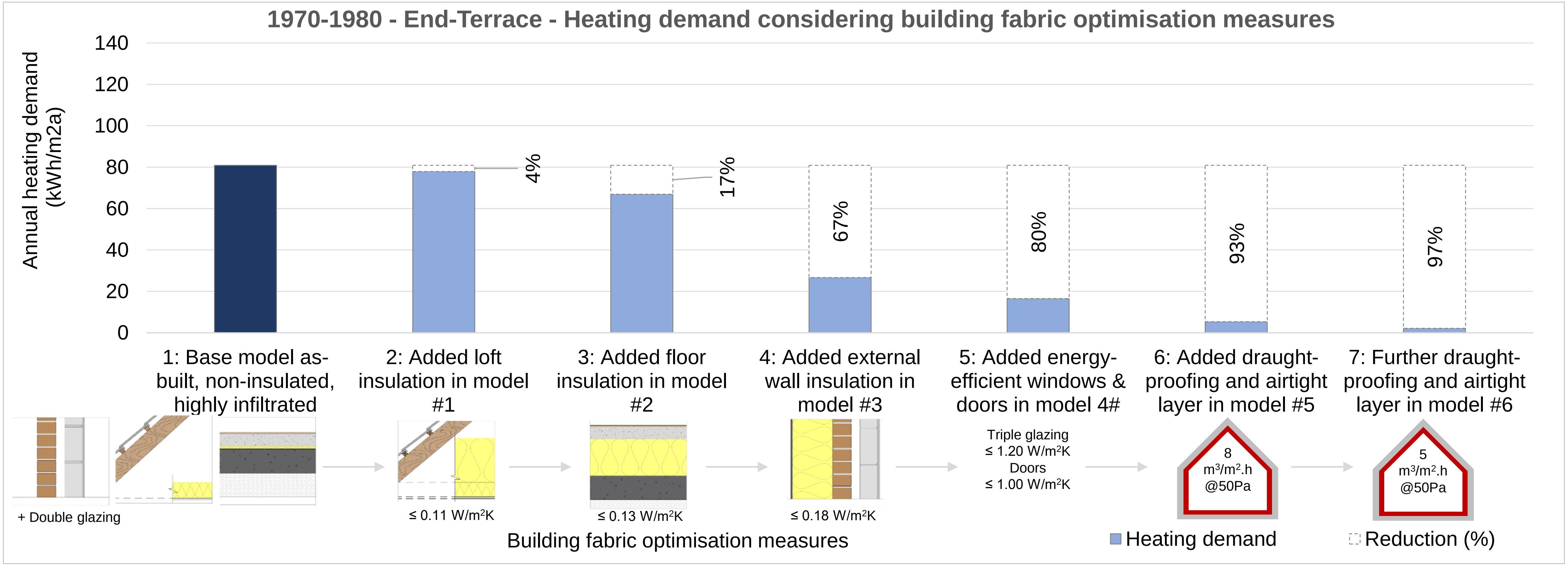


Target: Part L 2021 notional levels
Heating on from Oct-Mar using occupant profiles
No cooling systems
No active design improvements

End-Terrace Archetype – Deep Retrofit

Retrofit Stage 1 – building fabric optimisation

1970-1980



Target: Part L 2021 notional levels

Heating on from Oct-Mar using occupant profiles

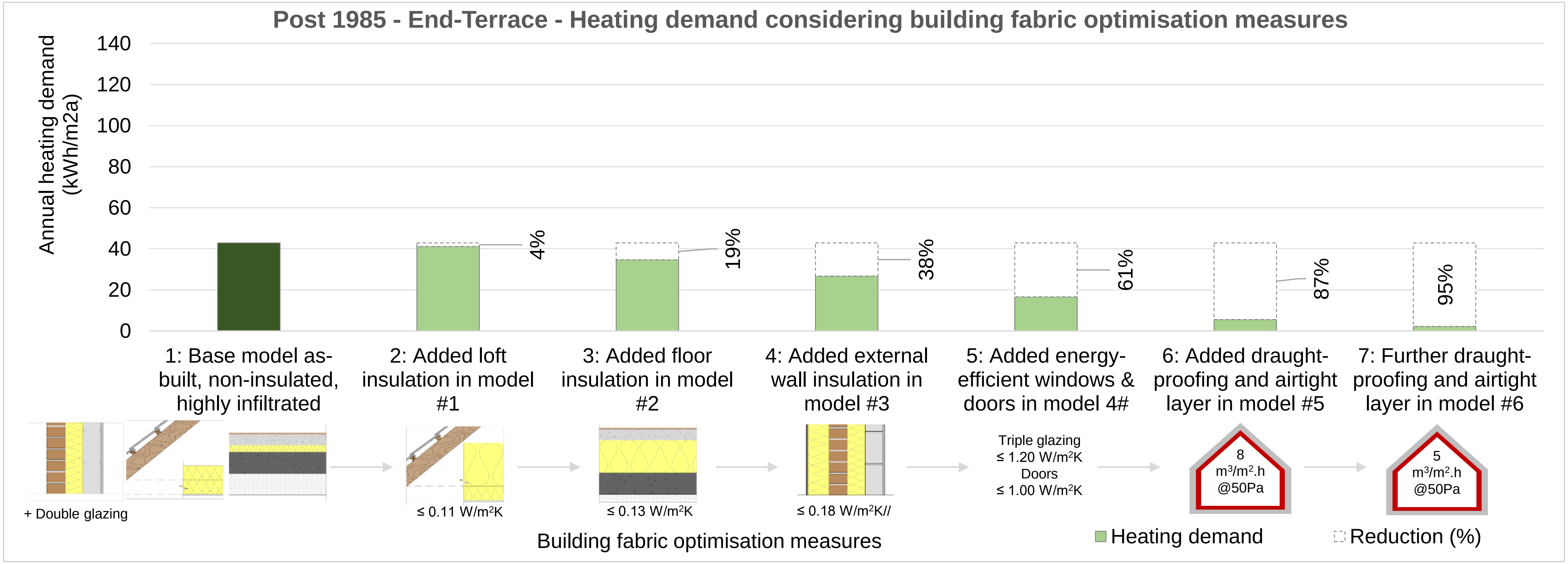
No cooling systems

No active design improvements

End-Terrace Archetype – Deep Retrofit

Retrofit Stage 1 – building fabric optimisation

Post 1985

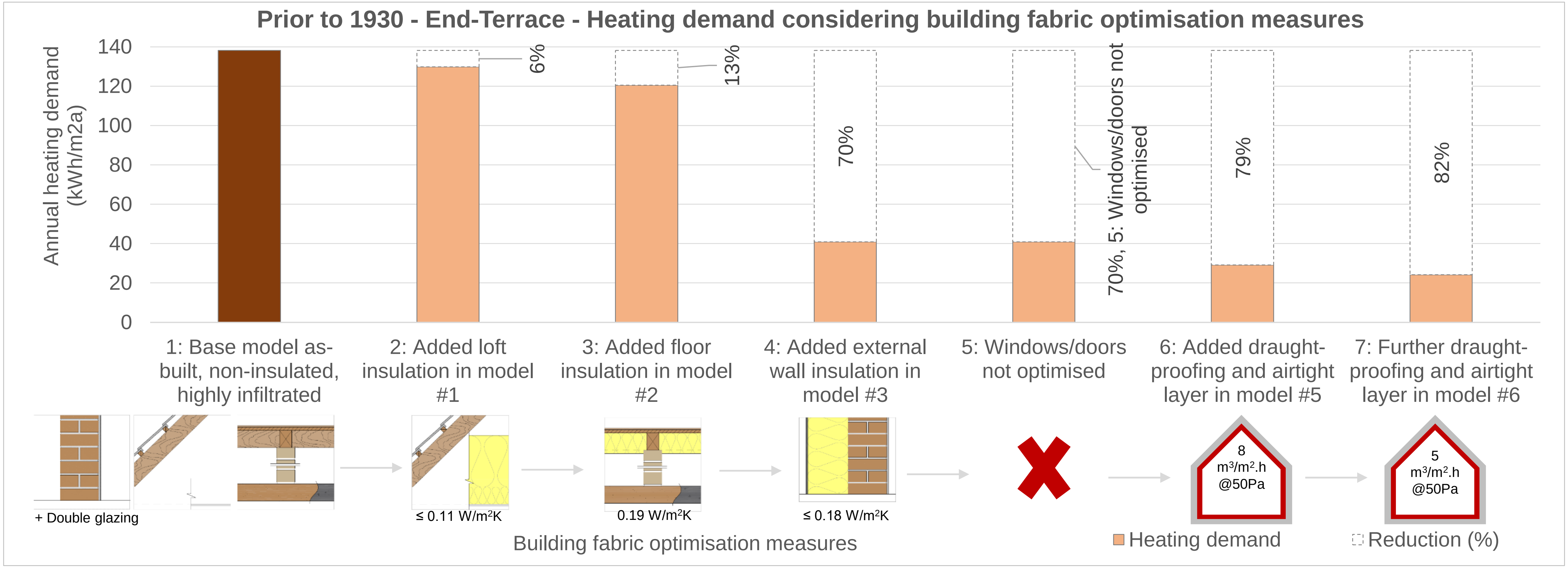


Target: Part L 2021 notional levels
Heating on from Oct-Mar using occupant profiles
No cooling systems
No active design improvements

End-Terrace Archetype – Typical Retrofit Only

Retrofit Stage 1 – building fabric optimisation

Prior to 1930

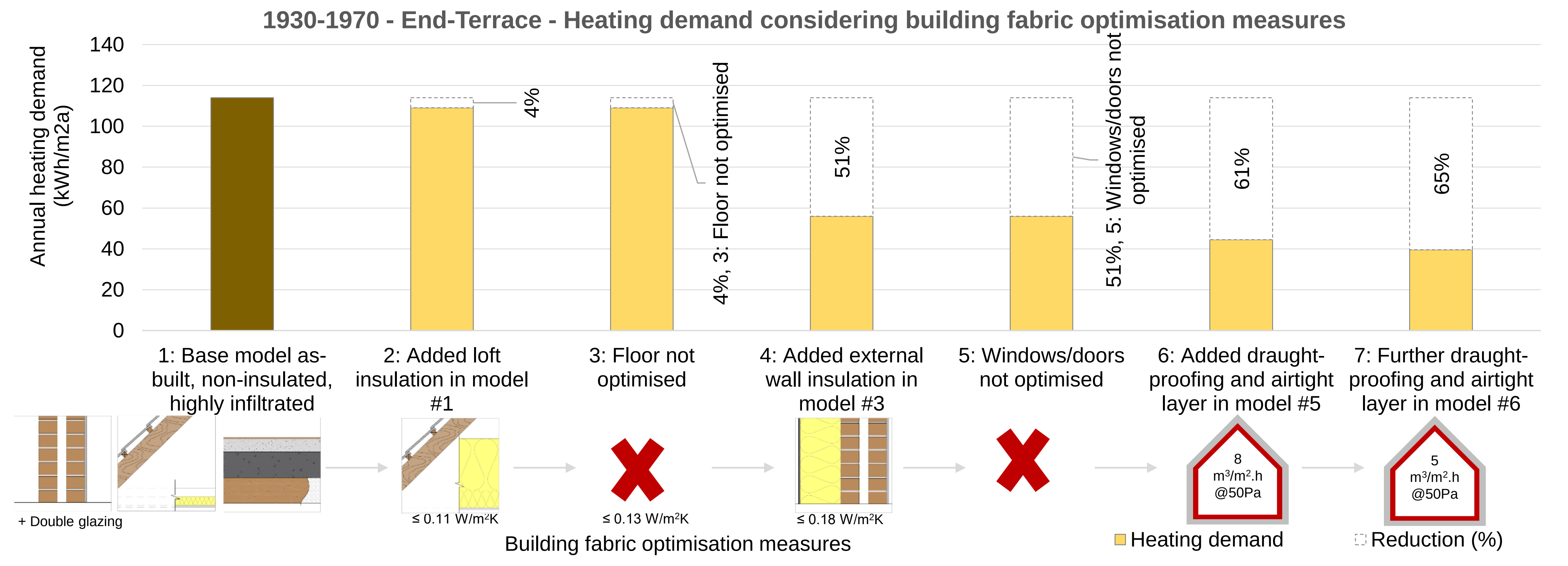


Target: Part L 2021 notional levels
Heating on from Oct-Mar using occupant profiles
No cooling systems
No active design improvements

END-TERRACE ARCHETYPE – TYPICAL RETROFIT ONLY

Retrofit Stage 1 – building fabric optimisation

1930-1970



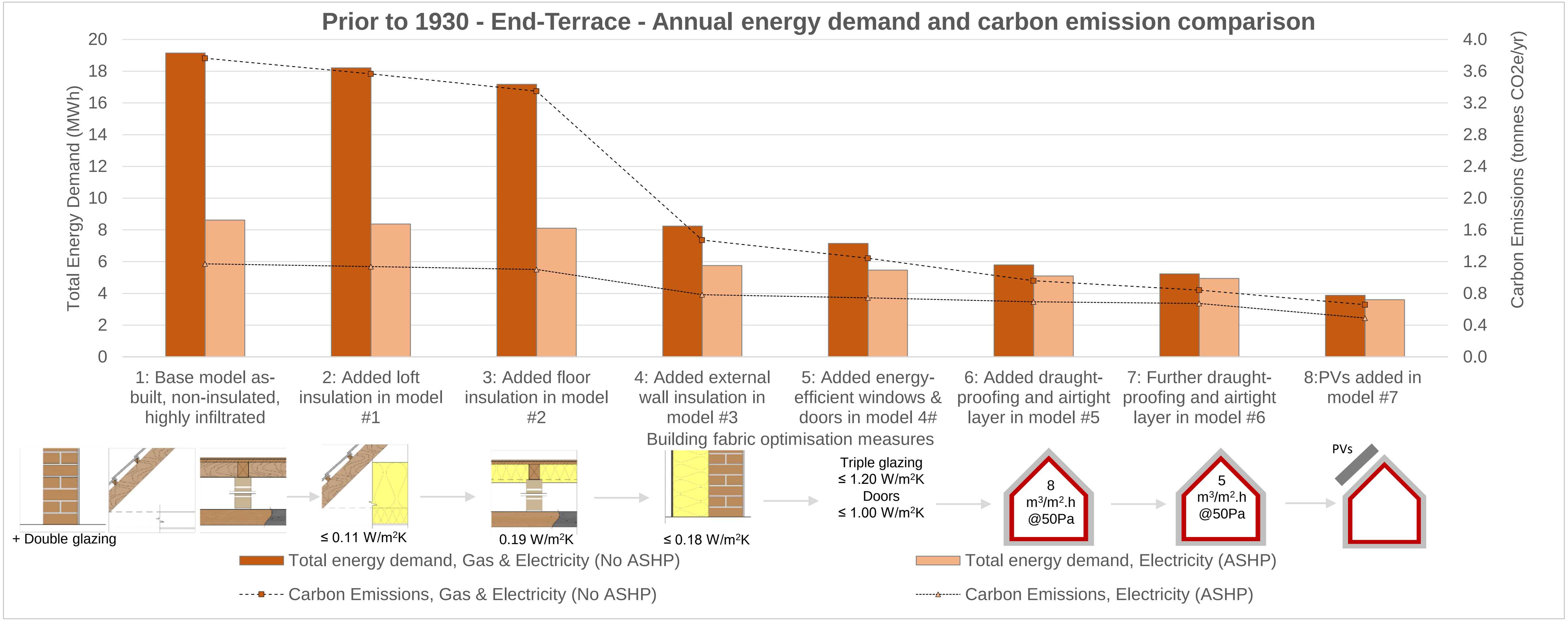
Target: Part L 2021 notional levels
Heating on from Oct-Mar using occupant profiles
No cooling systems
No active design improvements

Retrofit Stage 2: Low-Carbon Heating Systems
&
Retrofit Stage 3: Renewable Energy Generation

END-TERRACE ARCHETYPE – DEEP RETROFIT

Retrofit Stage 2 – integration of low-carbon heating systems*

Prior to 1930



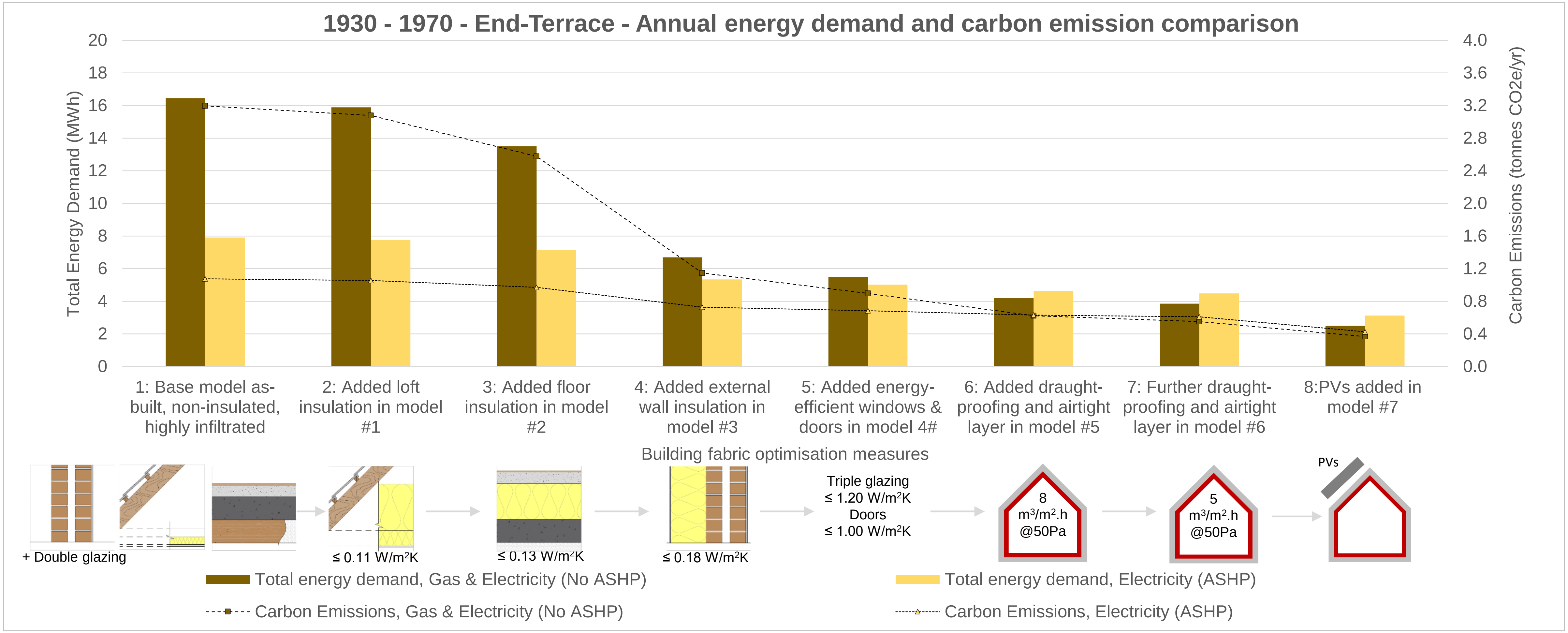
*A comparison of annual energy consumption and carbon emissions values after integration of low-carbon heating systems (with and without air source heat pumps [ASHP]).

Gas boiler seasonal efficiency: 0.89; seasonal coefficient of performance (SCOP): 0.8
ASHP seasonal efficiency: 3.35; SCOP: 3.0

End-Terrace Archetype – Deep Retrofit

Retrofit Stage 2 – integration of low-carbon heating systems*

1930-1970



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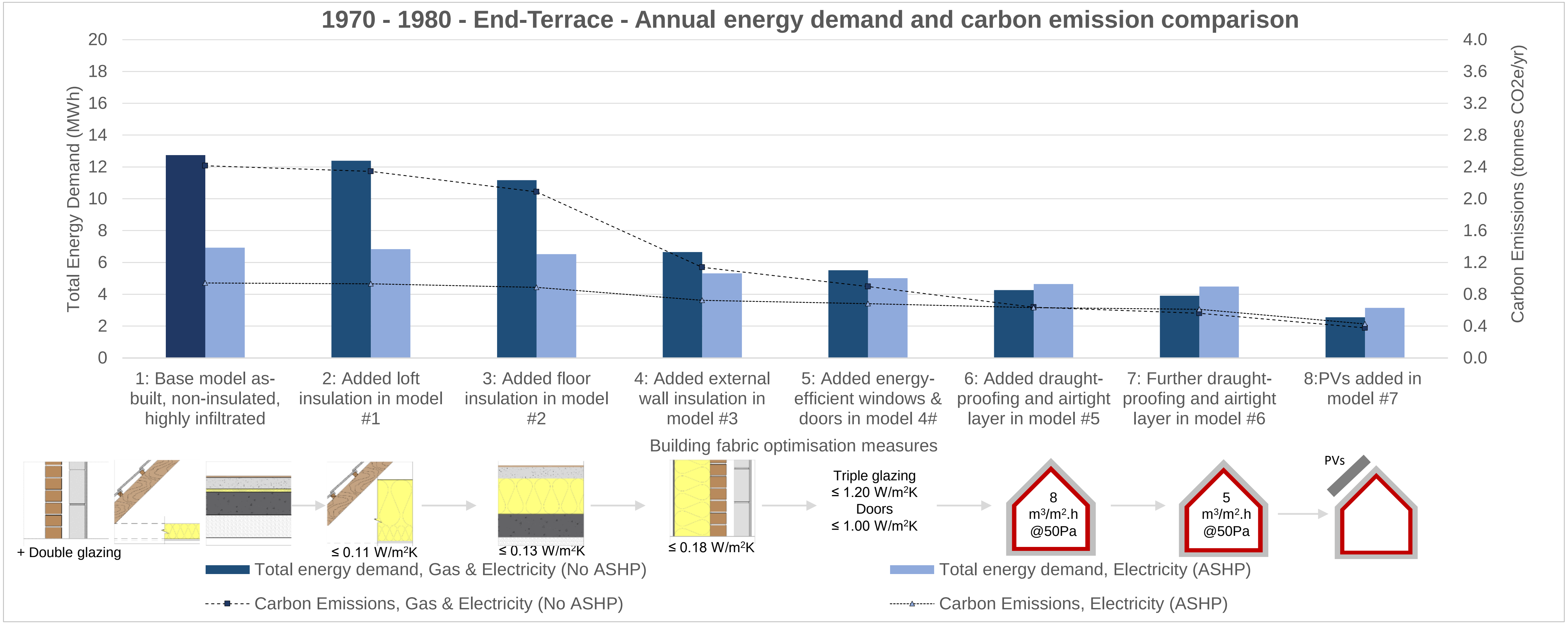
END-TERRACE ARCHETYPE – DEEP RETROFIT

Retrofit Stage 2 – integration of low-carbon heating systems*

1970-1980



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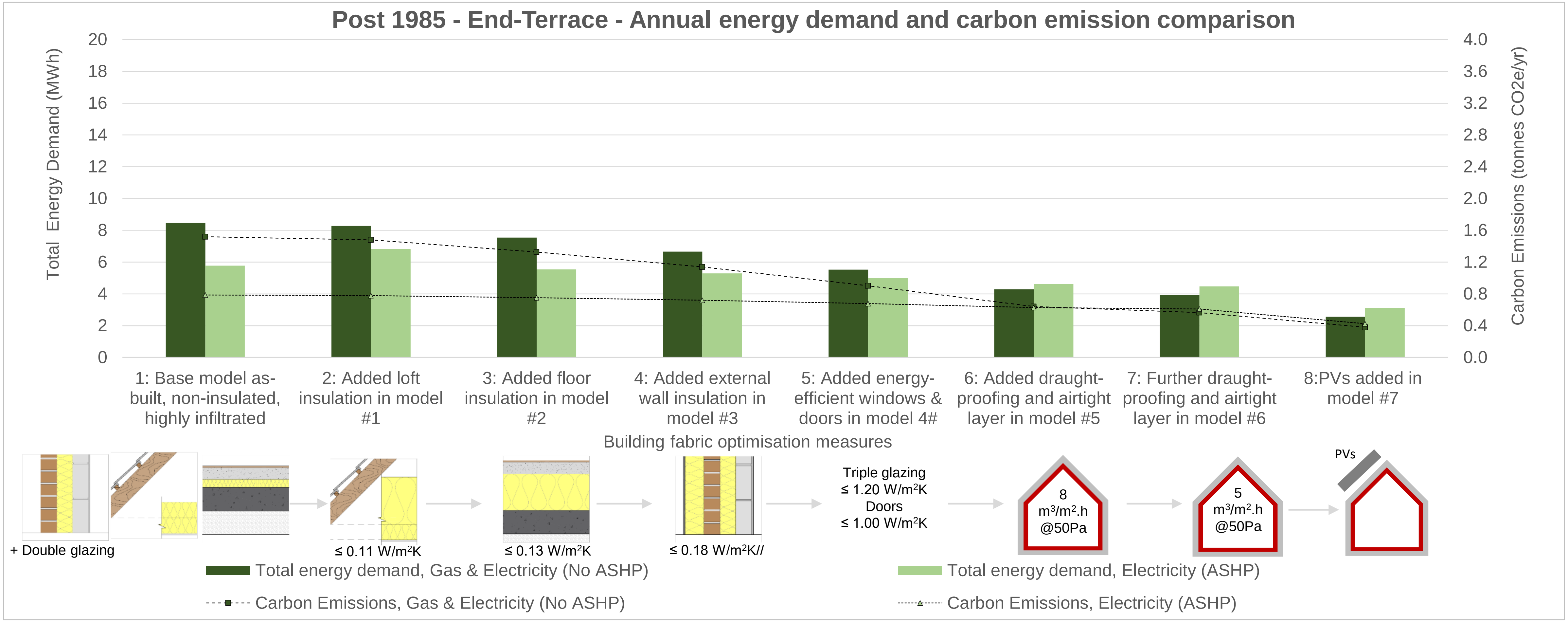
End-Terrace Archetype – Deep Retrofit

Retrofit Stage 2 – integration of low-carbon heating systems*

Post 1985



*A comparison of annual energy consumption and carbon emissions values after integration of low-carbon heating systems (with and without air source heat pumps [ASHP]).

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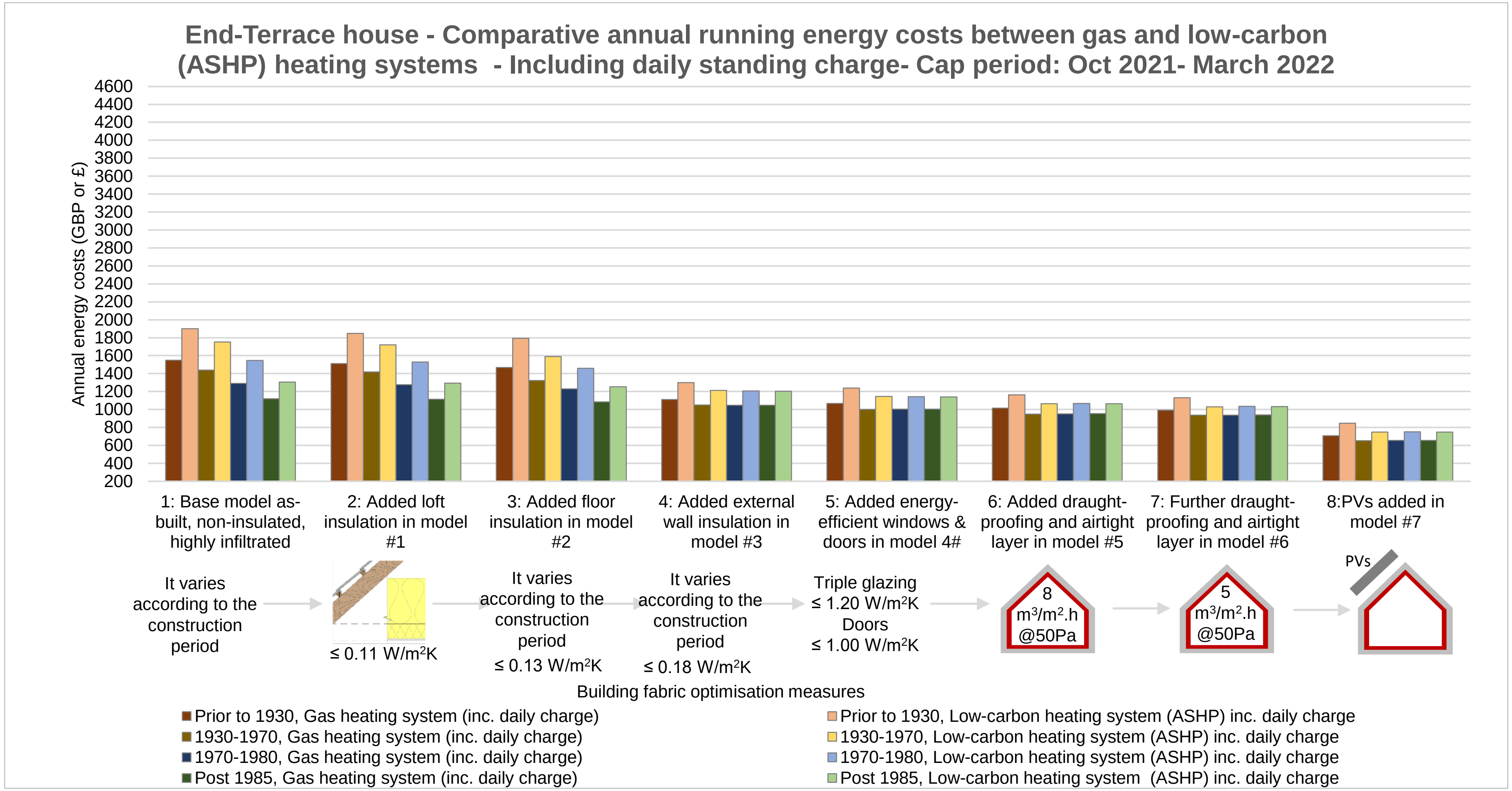
ASHP seasonal efficiency: 3.35; SCOP: 3.0

End-Terrace Archetype – Heating Systems

Retrofit Stage 2 – annual running cost comparison- winter 2021*

prior to 1930, 1930-1970, 1970-1980 and post-1985



Gas price cap (Oct 2021- March 2022) (Ofgem, 2022b)	**0.04 GBP per kWh**
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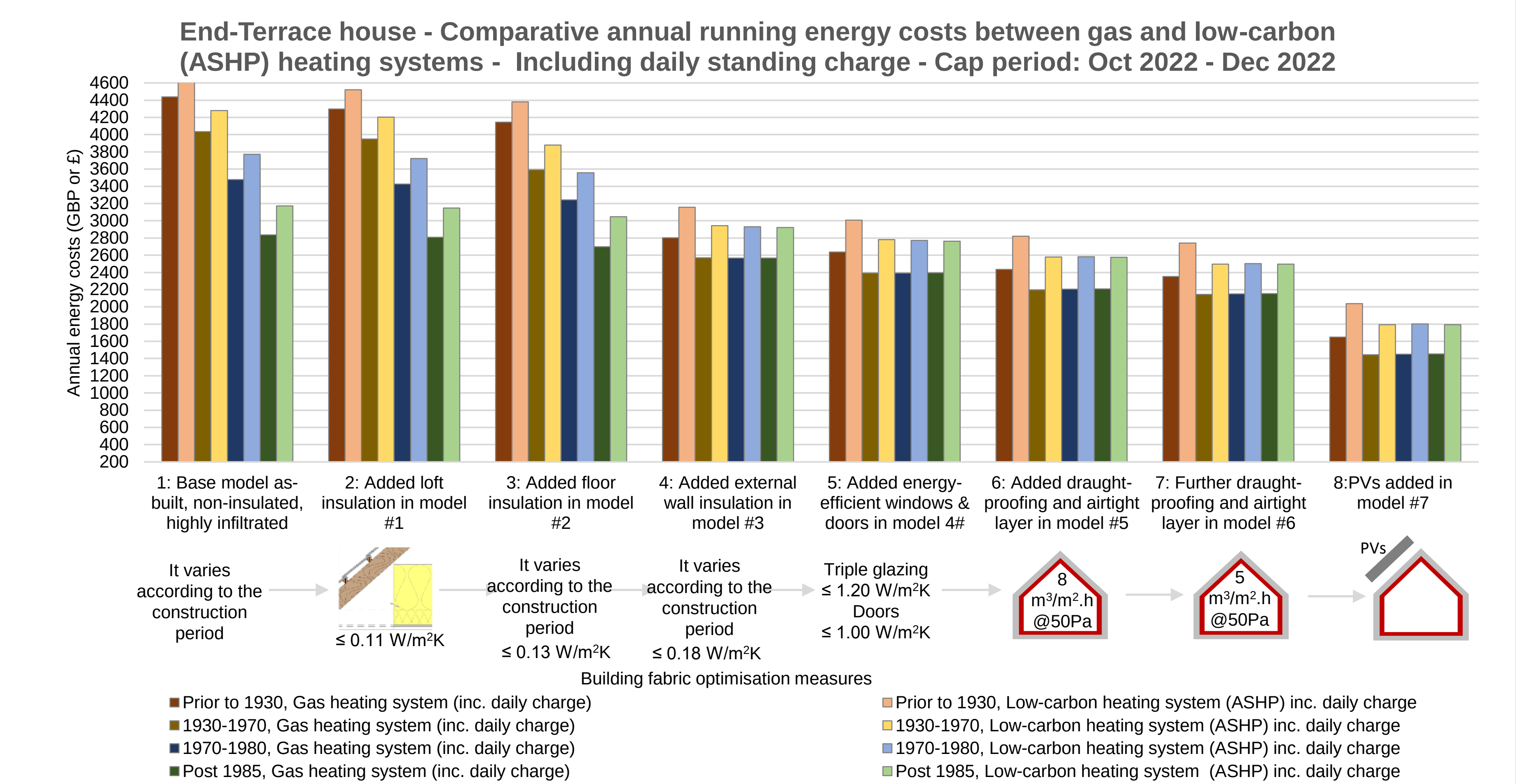
End-Terrace Archetype – Heating Systems

Retrofit Stage 2 – annual running cost comparison- winter 2022*

prior to 1930, 1930-1970, 1970-1980 and post-1985



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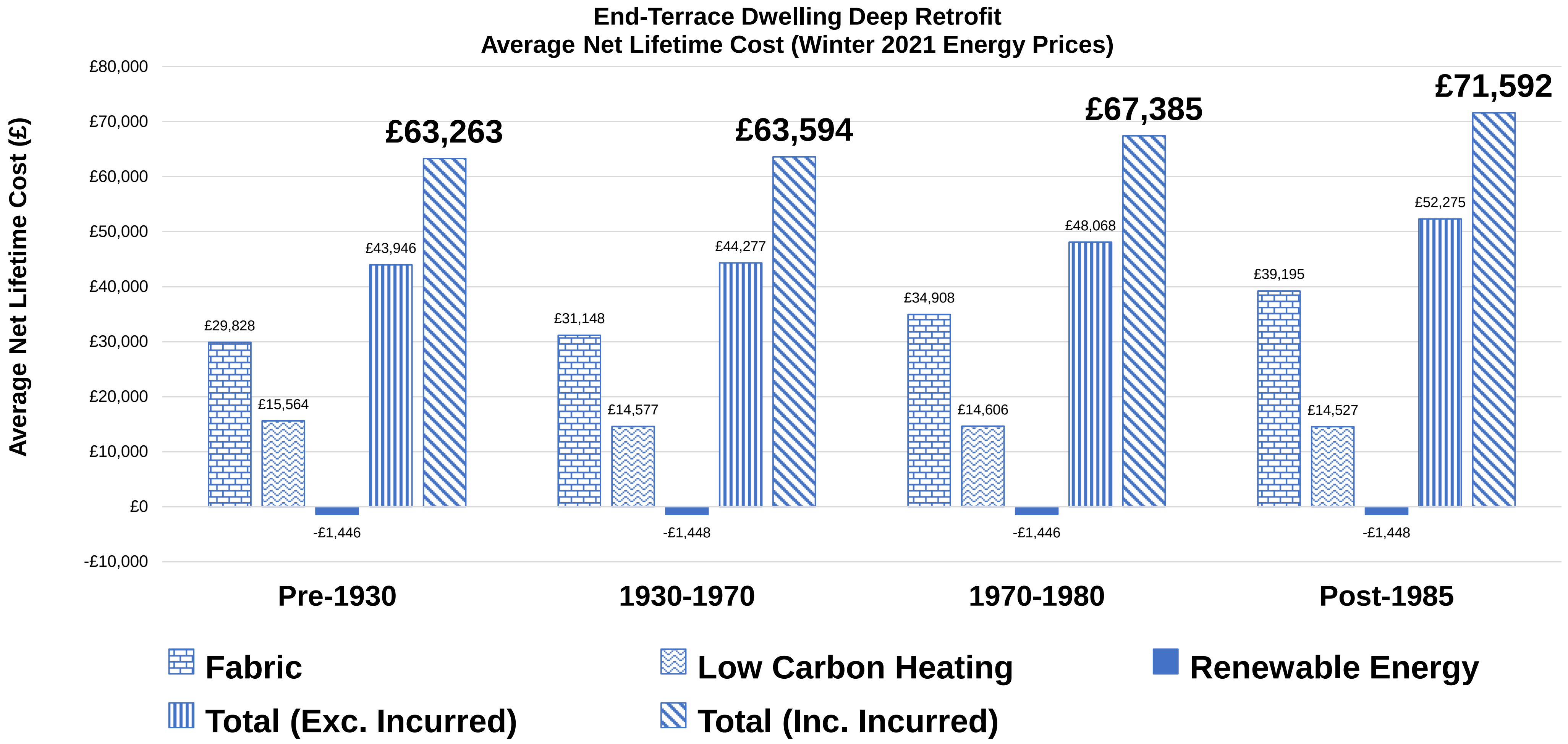
End-Terrace Archetype – Deep Retrofit
Net Lifetime Cost – All Ages (Pre-1930 to Post-1985)

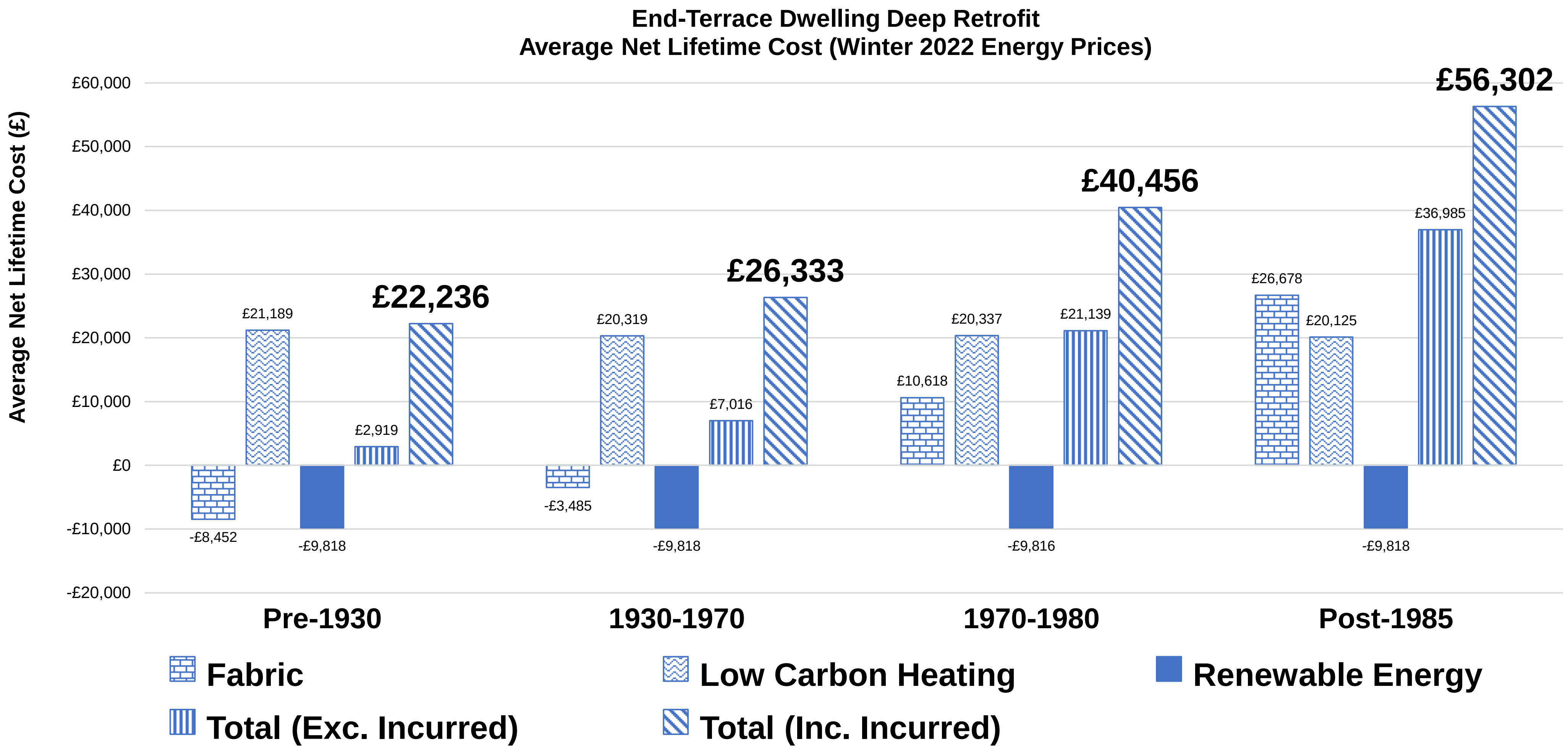
(GIA = 89.7m²)



Winter 2021 Energy Prices

End-Terrace Archetype – Deep Retrofit
Net Lifetime Cost – All Ages (Pre-1930 to Post-1985)

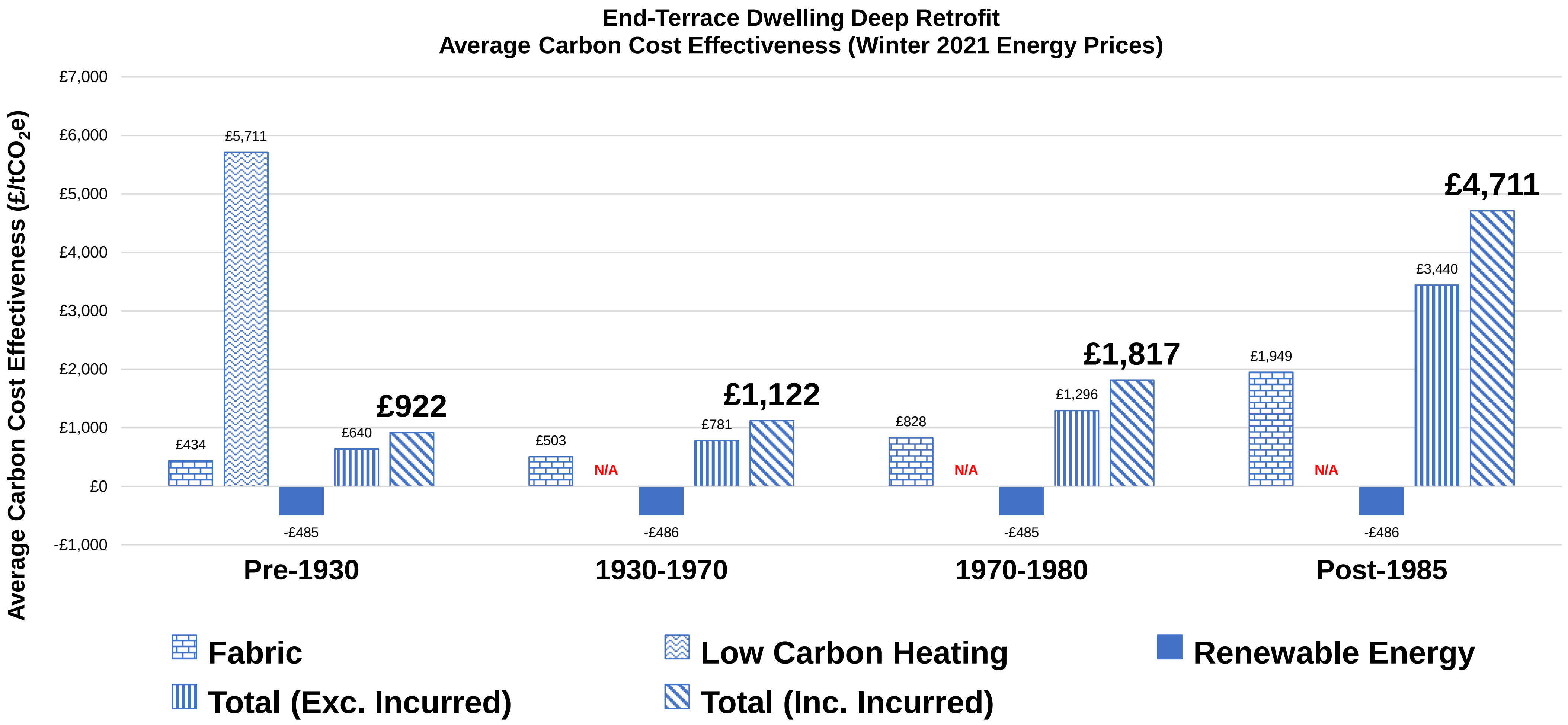
(GIA = 89.7m^2)



Winter 2022 Energy Prices

End-Terrace Archetype – Deep Retrofit
Carbon Cost Effectiveness – All Ages (Pre-1930 to Post-1985)

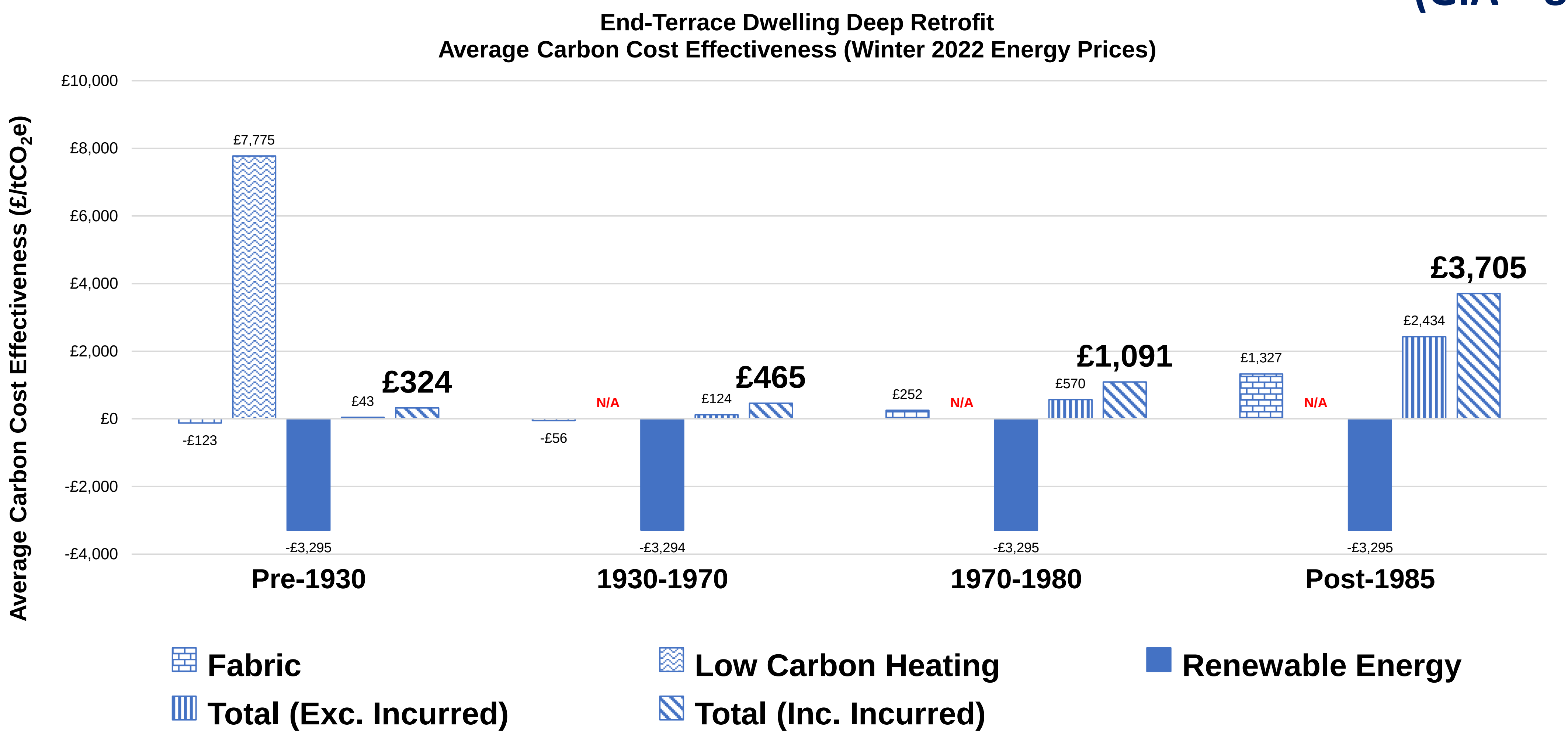
(GIA = 89.7m²)



Winter 2021 Energy Prices

END-TERRACE ARCHETYPE – DEEP RETROFIT
CARBON COST EFFECTIVENESS – ALL AGES (PRE-1930 TO POST-1985)

(GIA = 89.7m²)



Winter 2022 Energy Prices

NOTTINGHAM RETROFIT CASE STUDIES PERFORMANCE ASSESSMENT

Funded by:

UK Government

University of Nottingham UK | CHINA | MALAYSIA

nep nottingham energy partnership

ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

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Simulation Models (Archetypes)

- The case studies are part of the DZ2 Project and include different archetypes: End-Terrace, Mid-Terrace, and flats. End and Mid-Terrace houses are oriented both east-west and west-east while flats are oriented north-south only.

- The End-Terrace, Mid-Terrace archetypes are 3-storey, 3-bedroom houses.

- The flats (First floor; Mid-Terrace flat & Ground floor; end terrace flat) are 1- bedroom properties.

Mid-Terrace House &
End-Terrace House

Mid-Terrace Flat (First Floor) & End-terraced Flat (Ground Floor)

Site Plan. Based on Nottingham City Council (2022)

Typical Retrofit Measures

Typical retrofit excluded more costly and disruptive measures and was based on typical retrofit projects developed in Nottingham:

1. Base model (as-built): highly permeable and not insulated building envelope

2. Added loft insulation

3. Added floor insulation

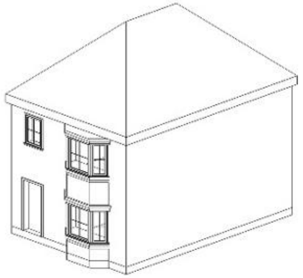
4. Added walls insulation

5. Added energy-efficient glazing/ doors

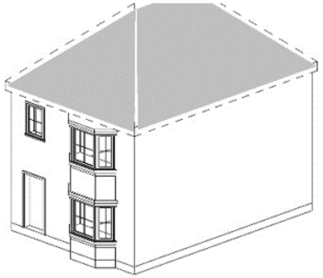
6. Added draught proofing

7. Added extra draught proofing

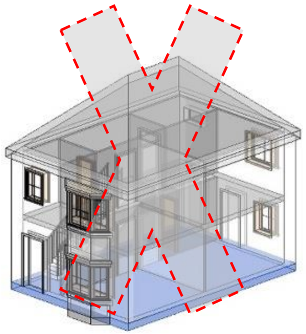
- Target: Part L 2021 notional levels.
- Heating on from Oct-Mar using occupant profiles
- No cooling systems
- No active design improvements



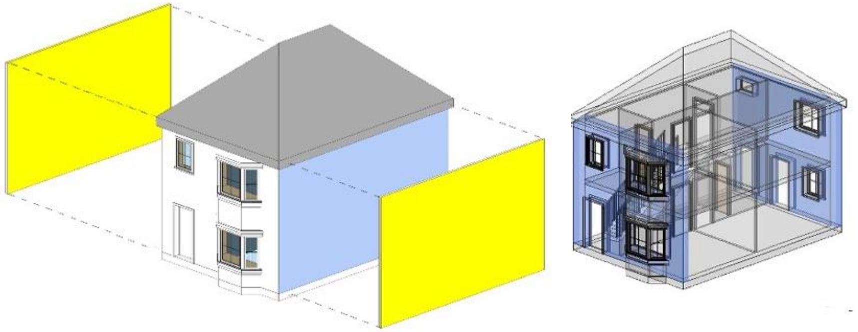
1. Base model (as-built)



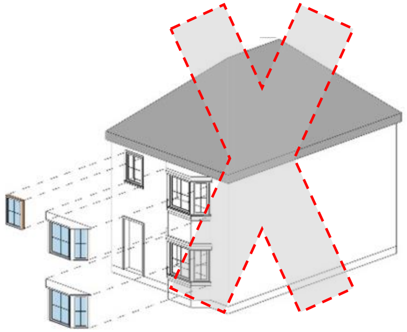
2. Loft insulation



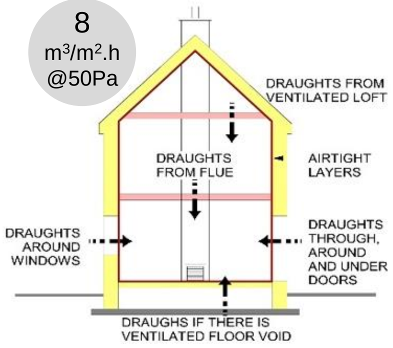
3. Floor insulation



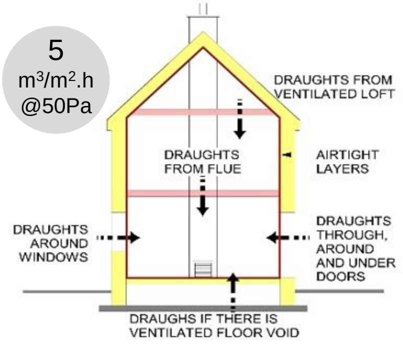
4. Wall insulation



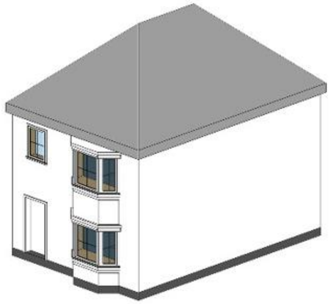
5. Energy-efficient glazing/ doors



6. Draught proofing and airtight envelope



7. Draught proofing and airtight envelope



Optimised model

Building Construction Components

As-built (prior to 1930)

	Archetype 1 End-Terrace	Archetype 2 Mid-Terrace	Flats (First floor; Mid-Terrace flat) (Ground floor; End-Terrace flat)
Characteristics	3-storey 3-bedroom		1-bedroom flats
Ext. Wall	1. 13mm plaster 2. 215mm existing solid brick 3. 13mm plaster		1. 13mm plaster 2. 215mm existing solid brick 3. 13mm plaster
Roof	1. Existing insulation: 90mm insulation in the sloped roof (warm) and 130 mm in the ceiling (cold); 100mm gable walls (as per architectural drawings). 2. Existing plasterboard ceiling		1. 100m existing insulation Flat ceiling (cold roof) 2. Existing plasterboard ceiling
Part walls	Existing walls: 1. 13mm Lime Paster 2. 215mm existing solid brick 3. 13mm Lime Plaster		Existing walls: 1. 13mm Lime Paster 2. 215mm existing solid brick 3. 13mm Lime Plaster
Internal partitions	Ground floor: 140mm lath and plaster/ stud walls First floor: 100mm plaster internal studs		Ground floor flat: 140mm and 100mm plaster internal studs / 350mm solid wall First-floor flats: Varying wall thickness (assumed 140mm for analysis purposes) 100mm plaster internal studs
Ground floor	Typical solid ground floor		Typical solid ground floor
Intermediate floors	Assumed timber construction 1. 19mm timber flooring on 100 mm joists 2. 12.5mm plasterboard ceiling		Assumed timber construction 1. 19mm timber flooring on 100 mm joists 2. 12.5mm plasterboard ceiling

BUILDING CONSTRUCTION COMPONENTS

Optimised

	Archetype 1 End-Terrace	Archetype 2 Mid-Terrace	Flats (First floor; Mid-Terrace flat) (Ground floor; End-Terrace flat)
Characteristics	3-storey 3-bedroom		1-bedroom flats
Ext. Wall (≤ 0.18W/m²K target)	Proposed external walls 1. 13mm plaster 2. 215mm existing solid brick 3. 13mm plaster 4. 200mm rock wool insulation (160mm EWI with Soltherm brick slips when thicker wall 280mm brick wall); 50mm EWI by the access only on Archetype 1) 5. Base Coat + mesh+ colour primer + finishing coat (10mm)		Proposed external walls 1. 13mm plaster 2. 215mm existing solid brick 3. 13mm plaster 4. 200mm rock wool insulation (160mm EWI with Soltherm brick slips when thicker wall 280mm brick wall); 5. Base Coat + mesh+ colour primer + finishing coat (10mm)
Roof **Warm roof, sloped Insulation (≤ 0.12 W/m²K target)** **Cold roof, flat insulation (≤ 0.10W/m²K target)**	Proposed roof: Flat ceiling 'a' (cold roof): 1a. Replace existing insulation by 450mm rock wool insulation 2a. Plasterboard ceiling Sloped roof 'b' (warm roof): 1b. 40mm Xtratherm Safe-R SR/PR between rafters (90mm – 50mm ventilation to avoid condensation) 2b Plasterboard ceiling Sloped roof 'c' (cold roof): 3c. 40mm Xtratherm Safe-R SR/PR between 90mm rafters (50mm left for ventilation to avoid condensation) 3c. 112.5mm Xtratherm Safe-R SR/PR below rafters 3c. Plasterboard ceiling		Flat ceiling (cold roof): 1a. Replace existing insulation by 450mm rock wool insulation (U-value target 0.11 W/m²K) 2a. Plasterboard ceiling

END-TERRACE ARCHETYPE

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End-Terrace Archetype – Typical Characteristics

- The End-Terrace archetypes are 3-storey, 3-bedroom houses.
- They are oriented both East-West and West-East

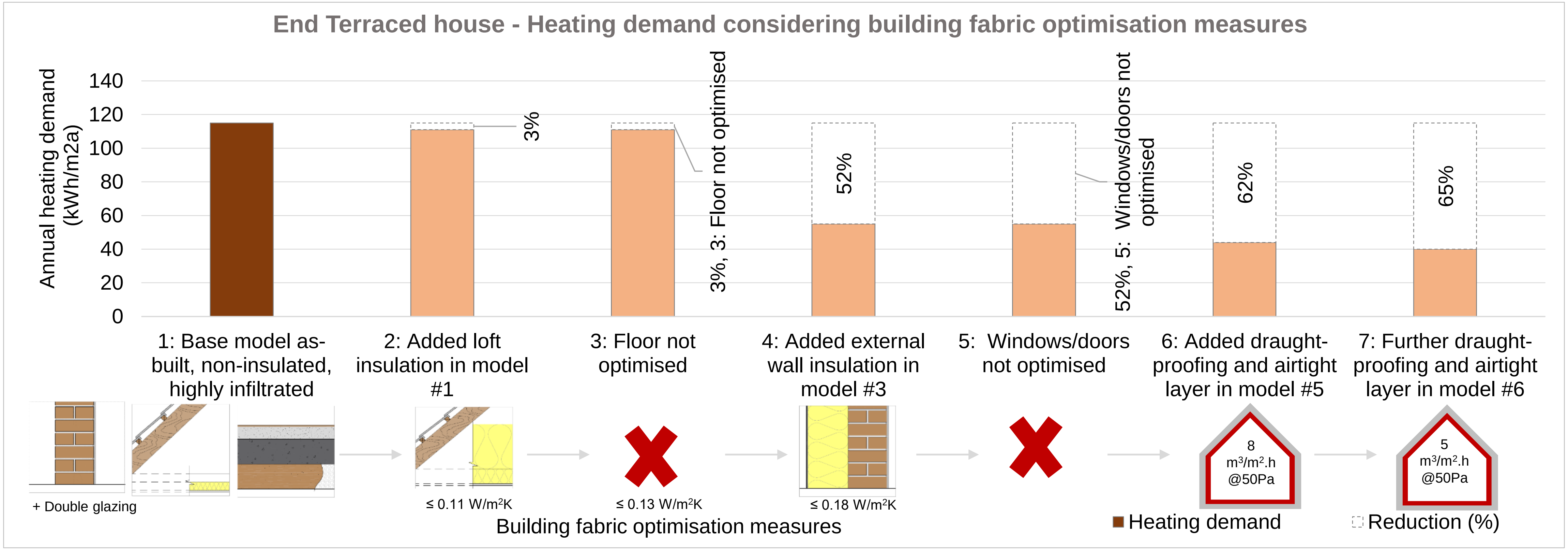
End-Terrace House

Retrofit Stage 1: Building Fabric Optimisation

End-Terrace Archetype – Typical Retrofit

Retrofit Stage 1 – building fabric optimisation

Prior to 1930



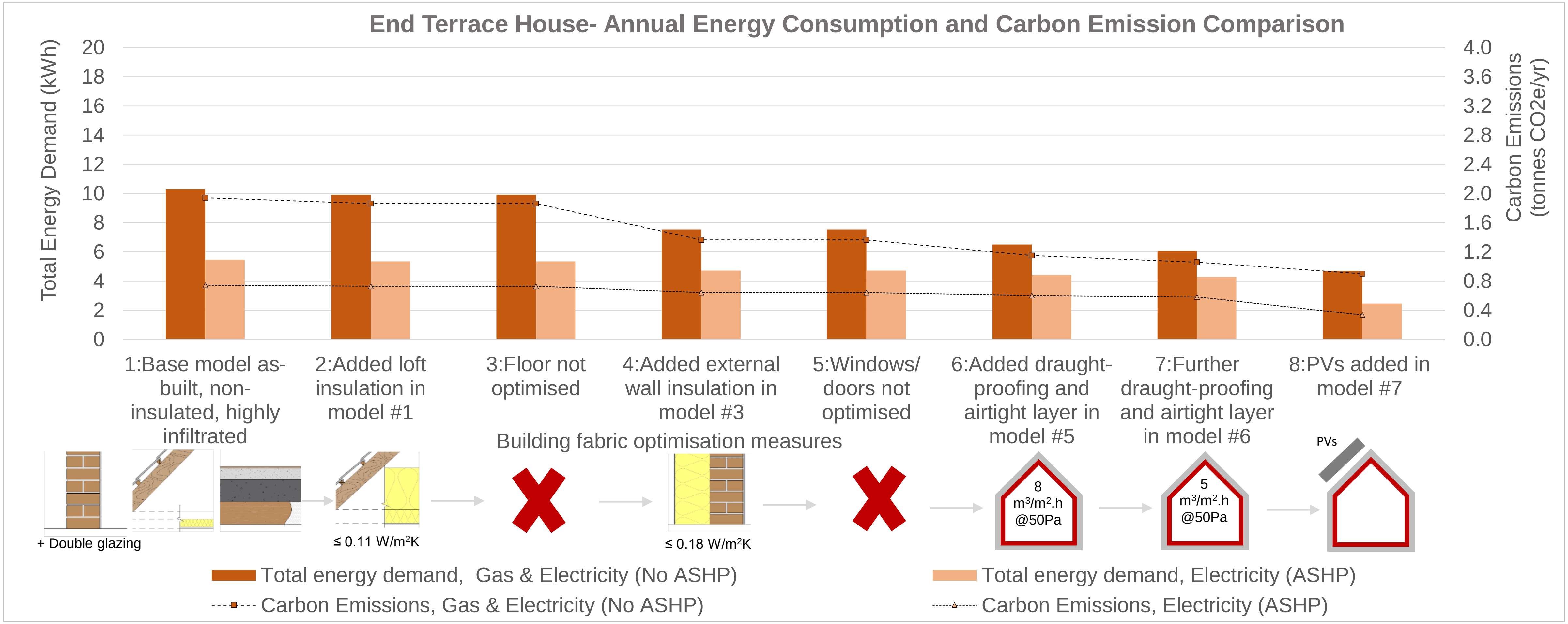
Target: Part L 2021 notional levels
Heating on from Oct-Mar using occupant profiles
No cooling systems
No active design improvements

Retrofit Stage 2: Low-Carbon Heating Systems
&
Retrofit Stage 3: Renewable Energy Generation

End-Terrace Archetype – Typical Retrofit

Retrofit Stage 2 – integration of low-carbon heating systems*

Prior to 1930



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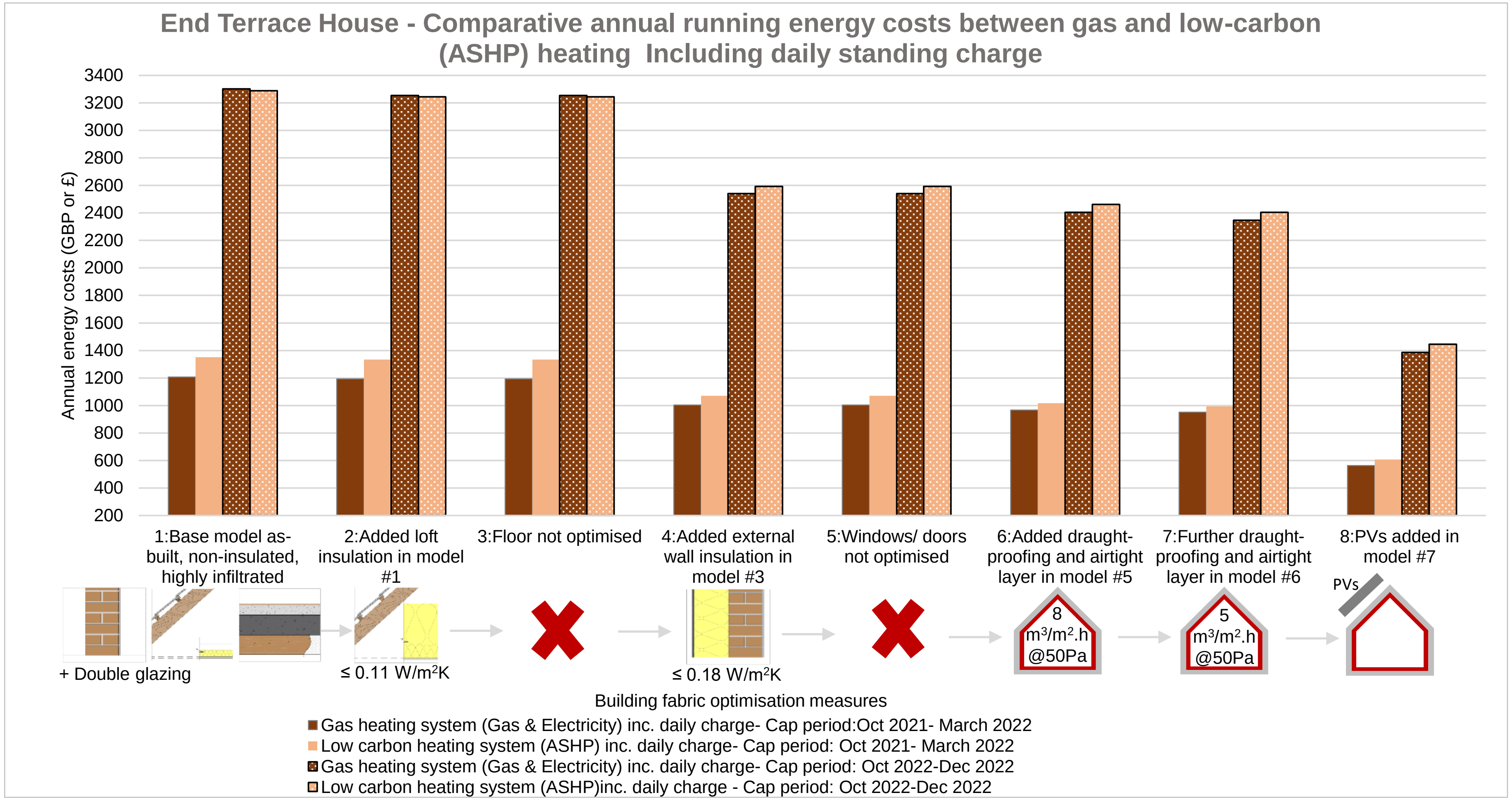
End-Terrace Archetype – Heating Systems

Retrofit Stage 2 – annual running cost comparison- winter 2021 & winter 2022*

prior to 1930



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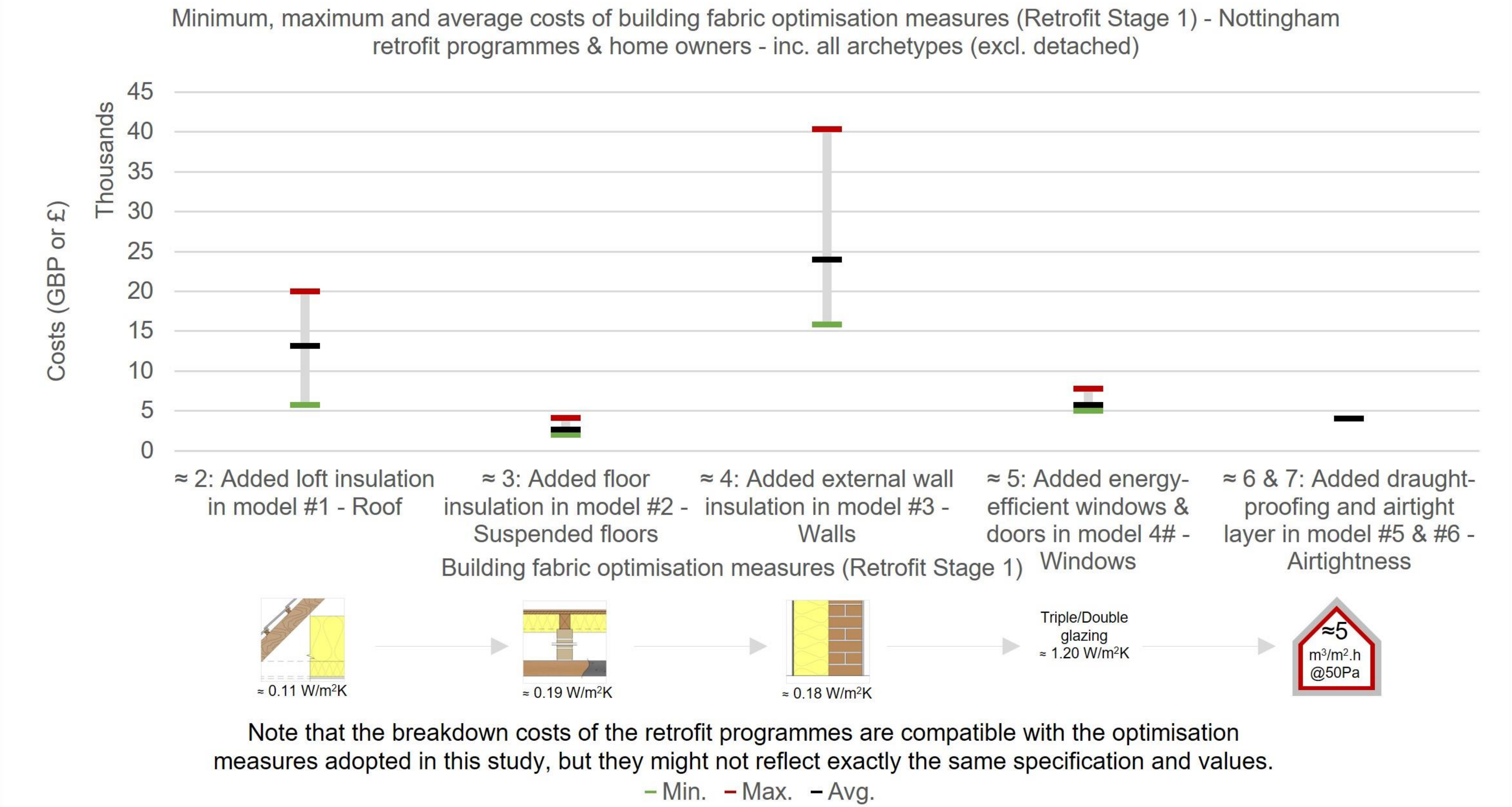
All Archetypes (excl. Detached) – Estimated Costs

Retrofit Stage 1 only*

Case study performance assessment data findings



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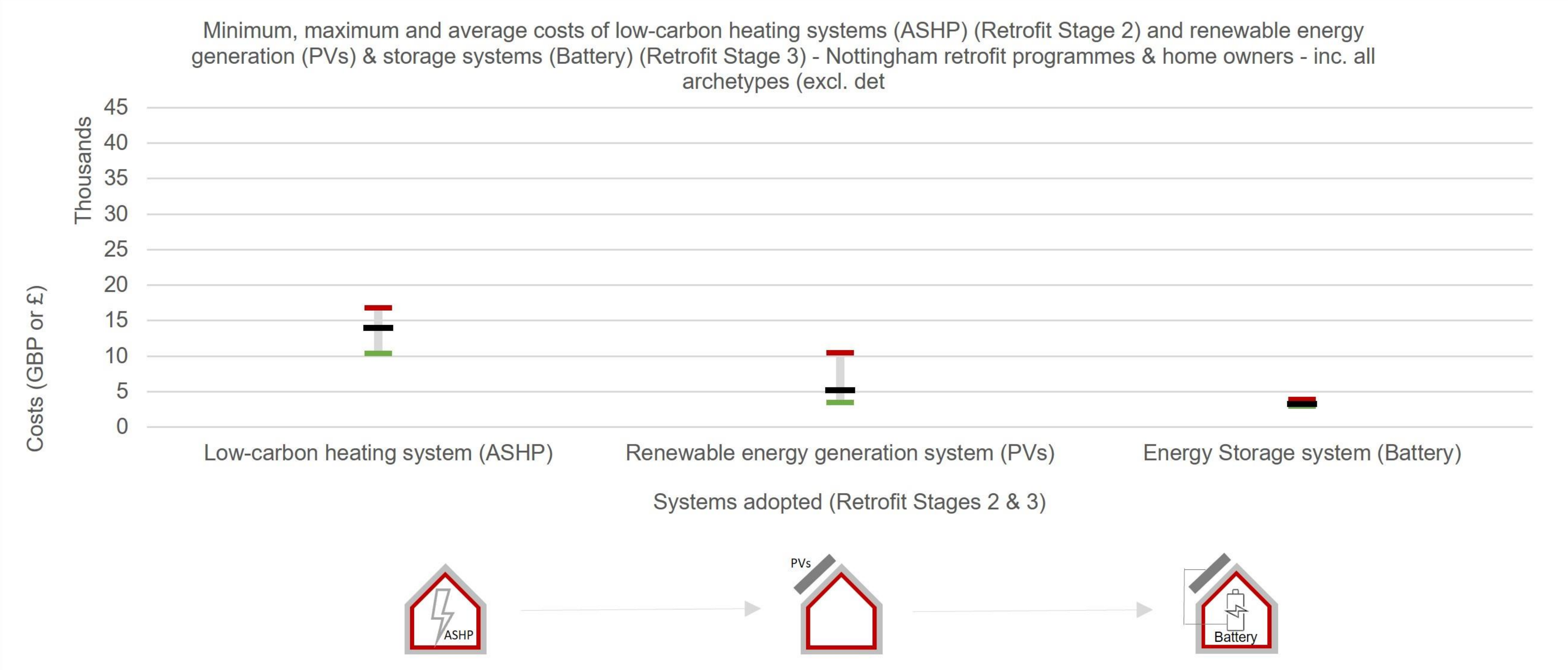
ALL ARCHETYPES (EXCL. DETACHED) – ESTIMATED COSTS

Retrofit Stage 2 and 3 only*

Case study performance assessment data findings



Note that the breakdown costs of the retrofit programmes are compatible with the optimisation measures adopted in this study, but they might not reflect exactly the same specification and values.

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END-TERRACE ARCHETYPES – ESTIMATED COSTS

Retrofit Stage 1 only*

Case study performance assessment data findings

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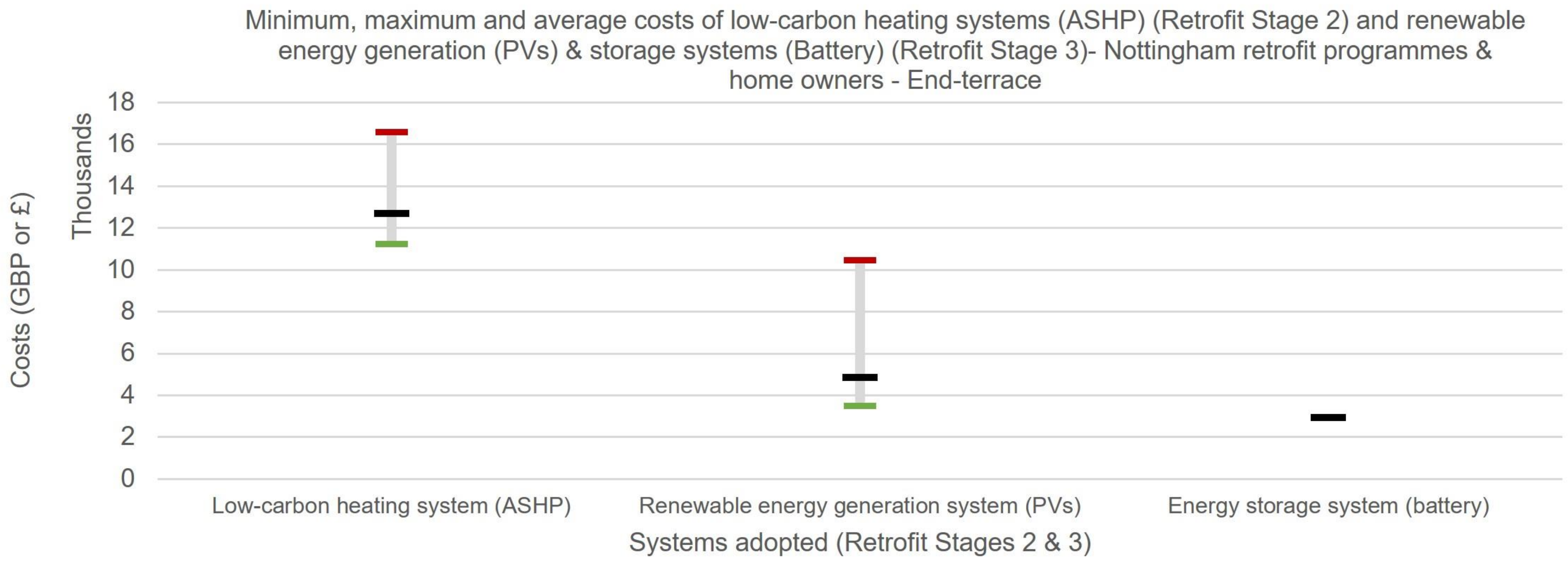
END-TERRACE ARCHETYPES – ESTIMATED COSTS

Retrofit Stage 2 and 3 only*

Case study performance assessment data findings



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– Min. – Max. – Avg.

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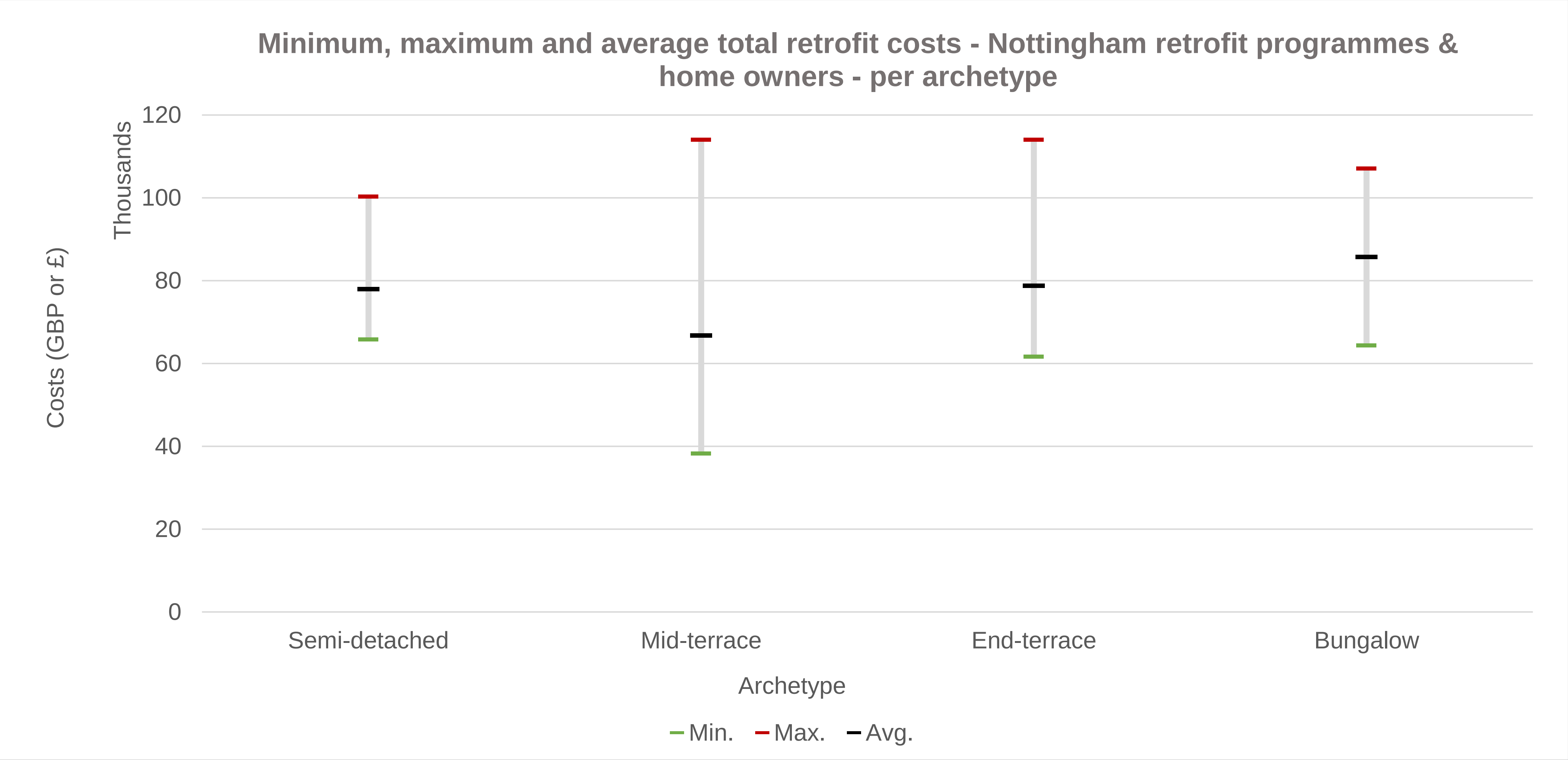
Per Archetype – Estimated Costs

Cost variation- Retrofit per archetype*

Case study performance assessment data findings



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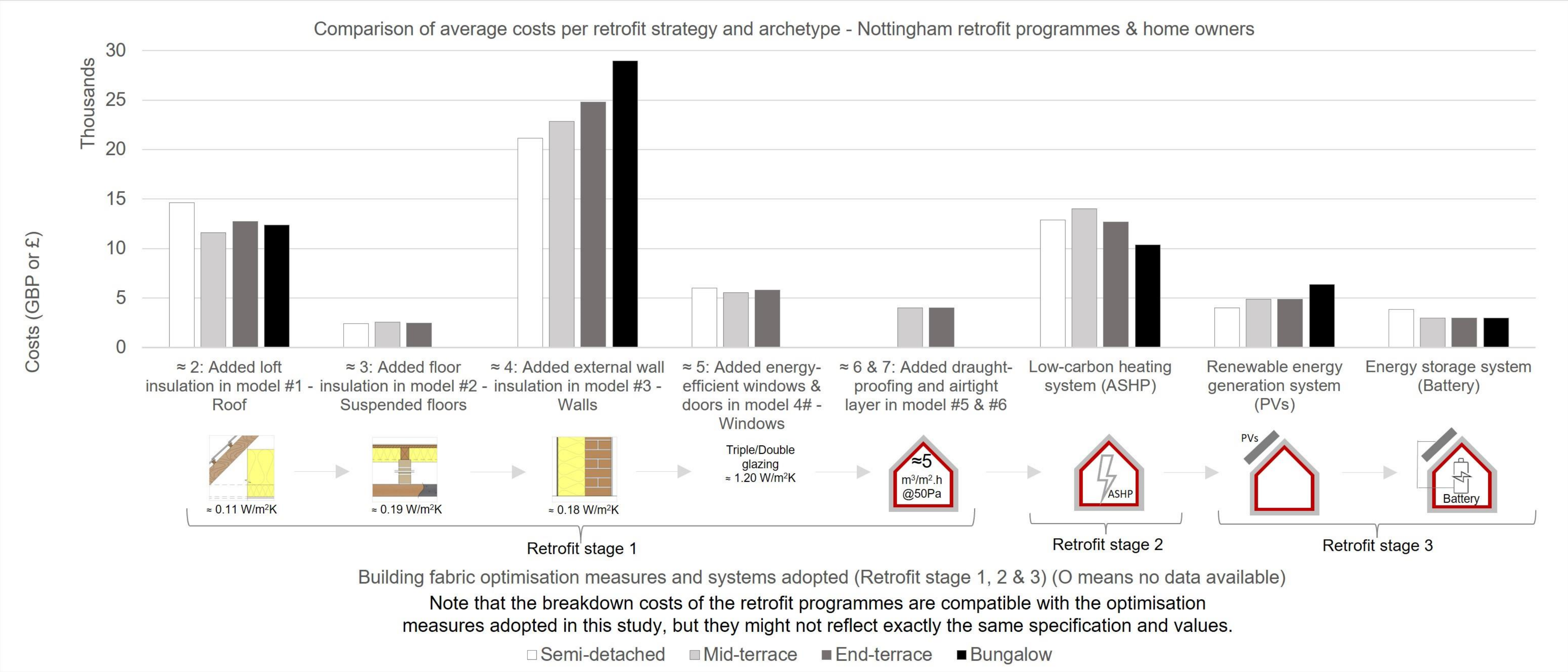
All Archetypes – Estimated costs comparison

Retrofit Stage1, 2 and 3*

Case study performance assessment data findings



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More Information

- Version number: v1.0_26.10.22
- Detailed information: See the Nottingham Carbon Neutral Housing Report, available here: https://www.nottinghamcedi.org/downloads/
- Disclaimer: This information has been generated and compiled as part of an ongoing research project. Any information herewithin must be considered within the scope of current legislative requirements.
- Acknowledgements: This project is funded by the UK Government through the UK Community Renewal Fund. The UK Community Renewal Fund is a UK Government programme for 2021/22. This aims to support people and communities most in need across the UK to pilot programmes and new approaches to prepare for the UK Shared Prosperity Fund. It invests in skills, community and place, local business, and supporting people into employment. For more information, visit: https://www.gov.uk/government/publications/uk-community-renewal-fund-prospectus

Project partners: University of Nottingham UK | CHINA | MALAYSIA; FOCUS Create. Deliver. Assess.; Active Building Centre Research Programme; nep nottingham energy partnership

Funded by: UK Government

Coordinated by: Nottingham City Council