University of Nottingham
Energy Institute

Net Zero Cities

Prof Lucelia Rodrigues

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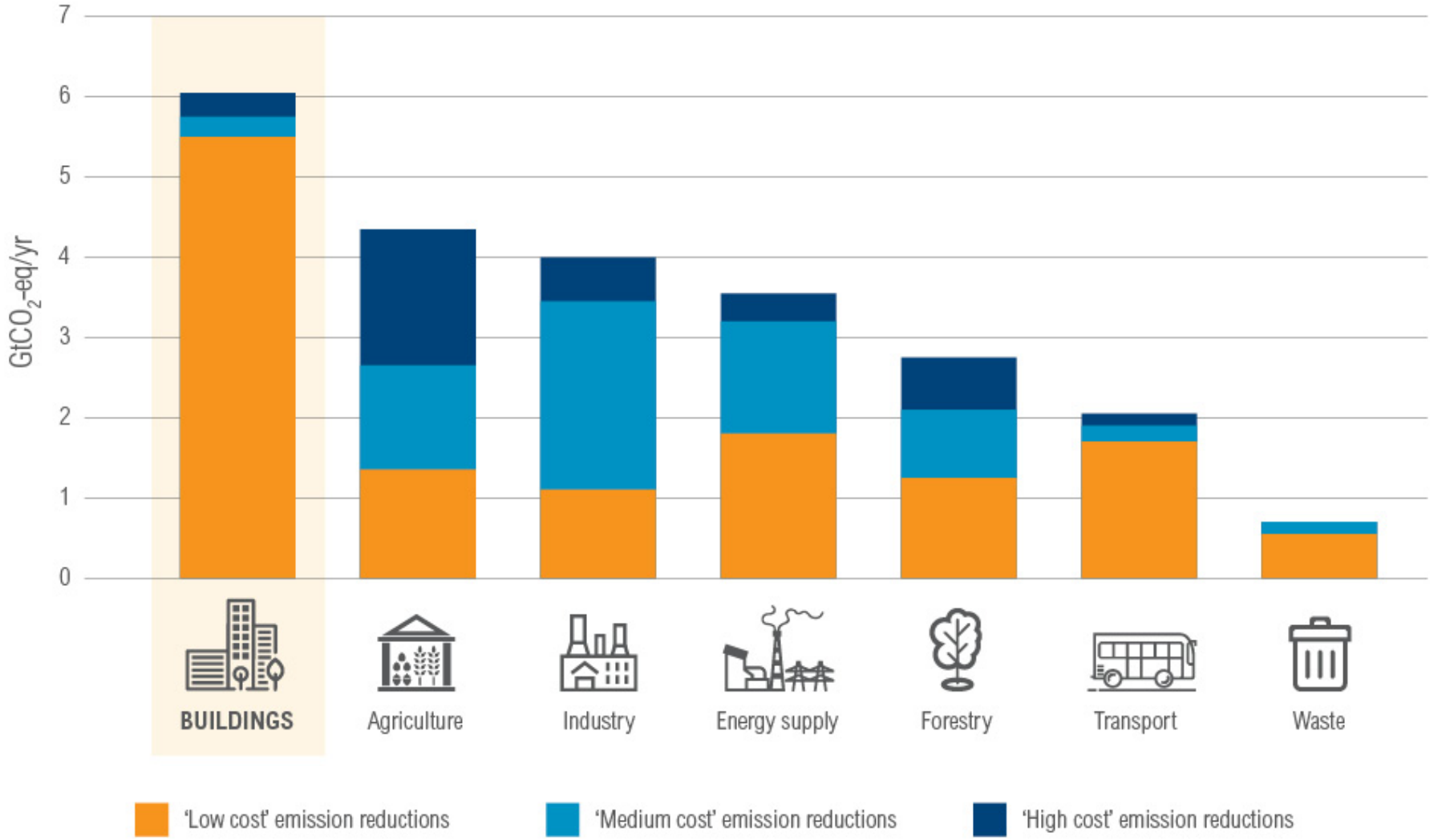
Head of Department of Architecture and Built Environment
Deputy Director of the Energy Institute

Association for Public Service Excellence - Energy Event 25.04.23

Free image by Callum Shaw – www.callumshaw.com

www.nottinghamcity.gov.uk/your-council/about-the-council/carbon-neutral-nottingham-2028/why-do-we-need-to-act/



wri.org/buildingefficiency

WORLD RESOURCES INSTITUTE

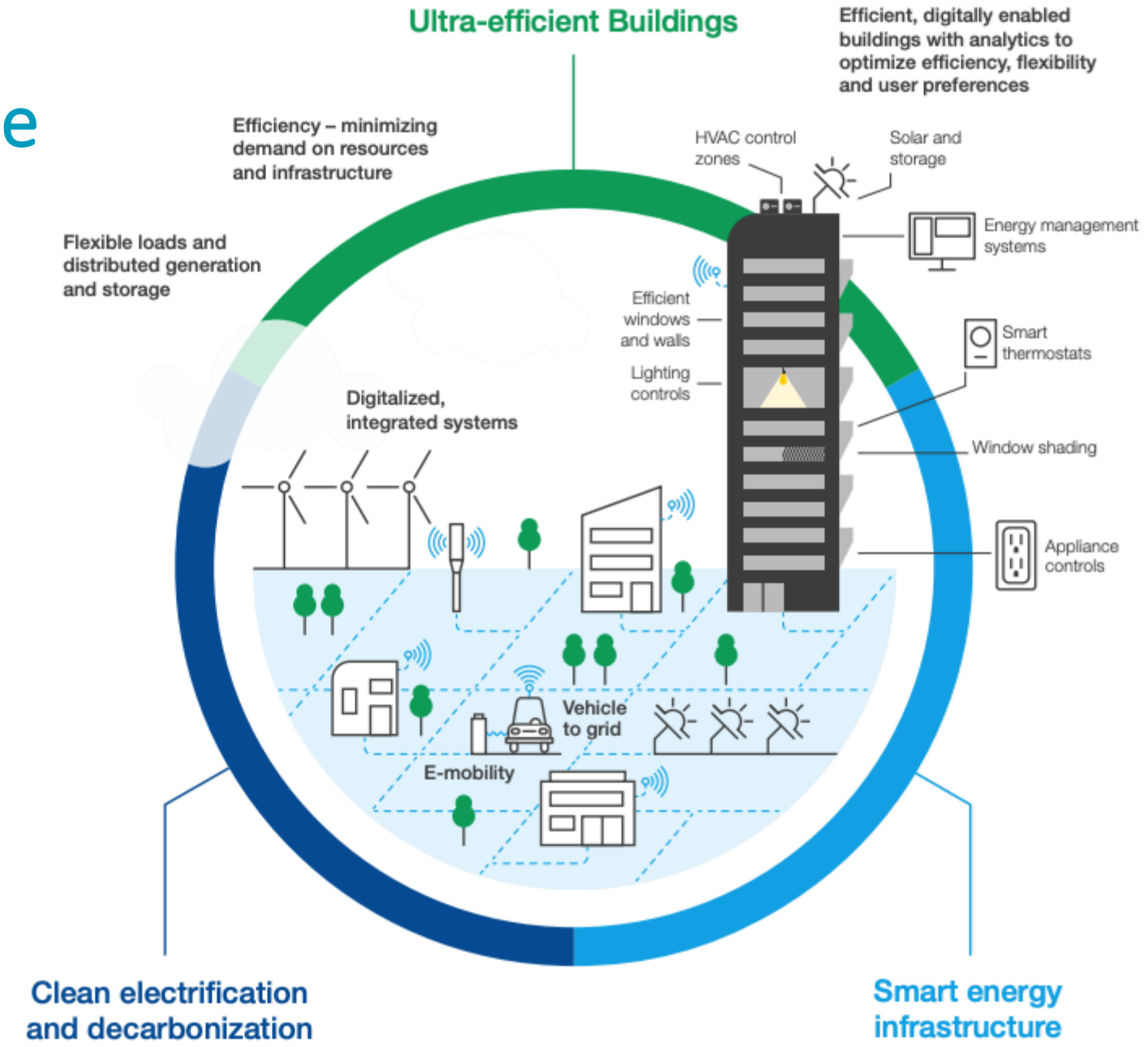
Economic Mitigation Potential by Sector, 2030

World Resources Institute, Accelerating building efficiency: Eight Actions for Urban Leaders. Available at https://publications.wri.org/buildingefficiency/

Rationalise

Smartify

Electrify



World Economic Forum

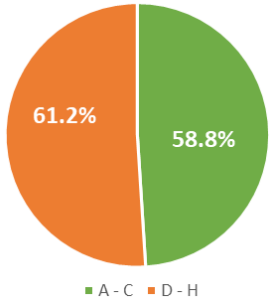
University of Nottingham
Energy Institute

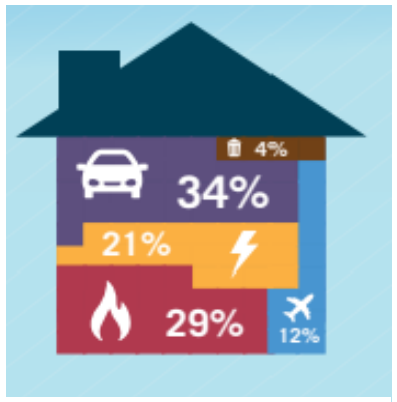
Rationalise

CN28

Carbon Neutral Nottingham 2028

164k

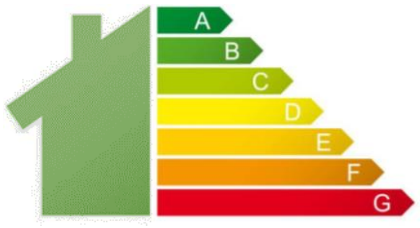


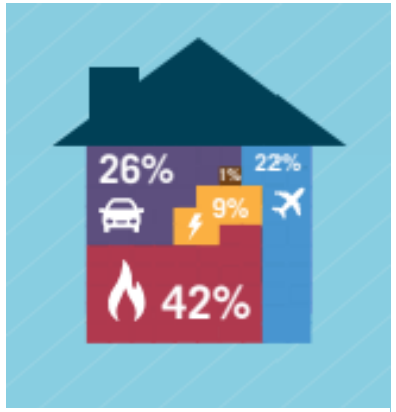


6 tonnes of CO_2

2030

164k





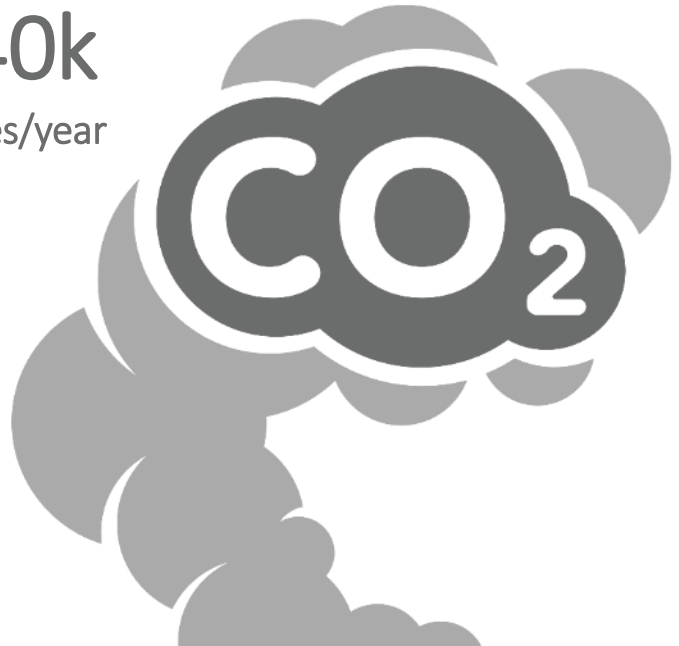
4.5 tonnes of CO_2

247k

tonnes/year

740k

tonnes/year




…74,000 hectares of trees…

Funded by:

UK Government

@UoN_Cities
@NottinghamCEDI
#NottinghamRetrofit

NOTTINGHAM RETROFIT ROADMAP

Partners:

Nottingham City Council

UK Government

University of Nottingham
UK | CHINA | MALAYSIA

nep nottingham energy partnership

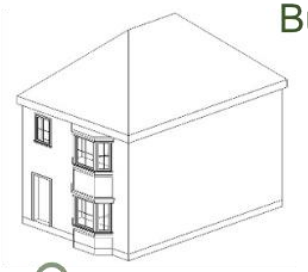
CN28 Carbon Neutral Nottingham 2028

European Union
European Regional Development Fund

ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

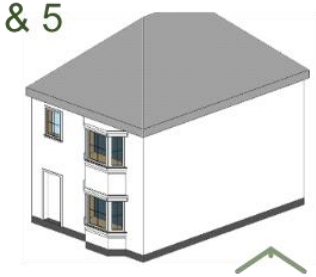
FOCUS
Create. Deliver. Assess.

DEEP AND TYPICAL RETROFIT MEASURES

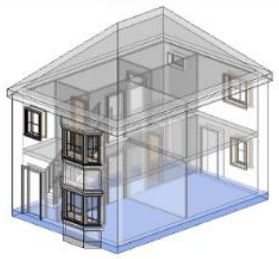


Building fabric optimisation key: ● Deep retrofit measures: 1, 2, 3, 4 & 5 ● Typical retrofit measures 1, 3, & 5

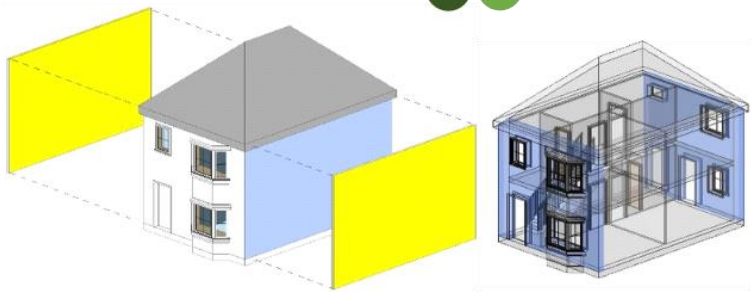
Whereas deep retrofit involves taking a wide range of measures to reduce a building's energy needs considerably, typical retrofit measures exclude more costly and disruptive measures. Measure can be broken into 3 stages including: **Retrofit Stage 1** - **building fabric optimiisation**; **Retrofit Stage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



1. Add loft insulation

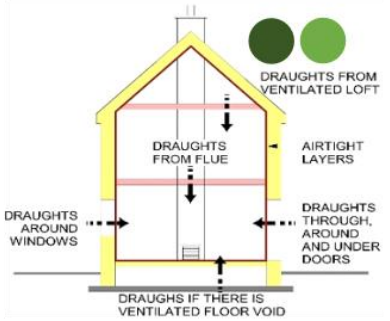


2. Add floor insulation



3. Add wall insulation

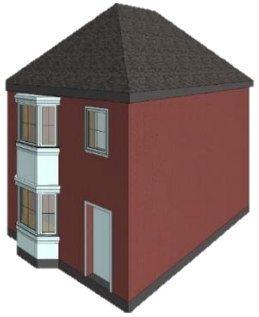
4. Add energy efficient glazing/doors



5. Draught proofing and airtight envelope

Generic Representative Models

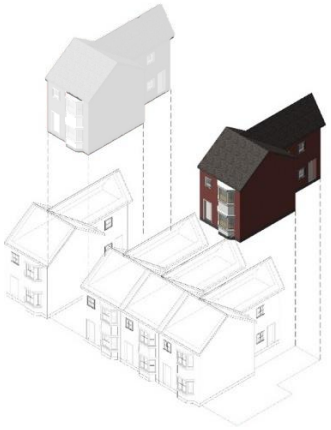
Detached

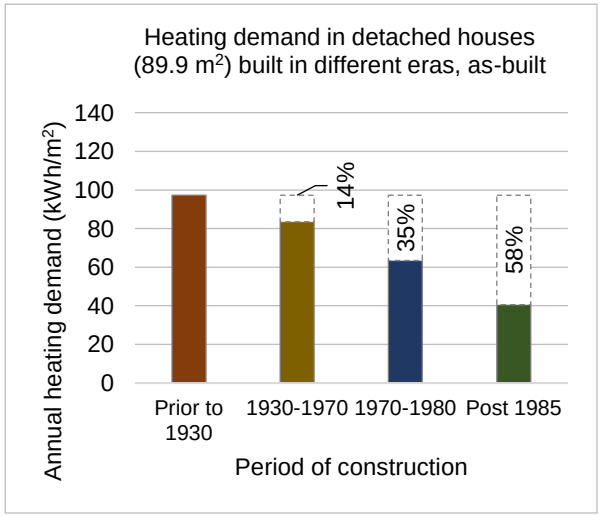


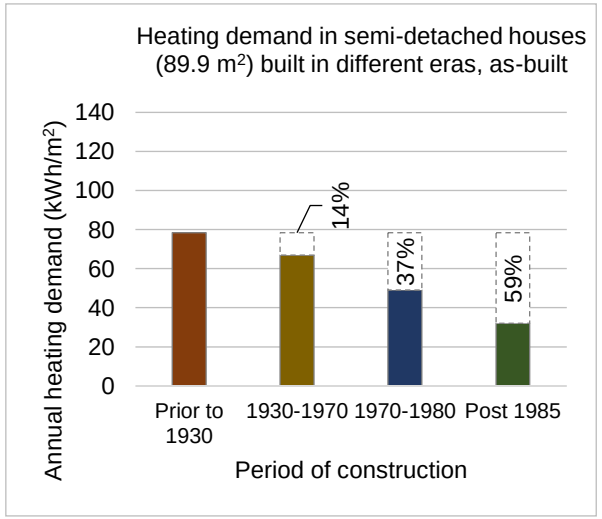
Semi-detached

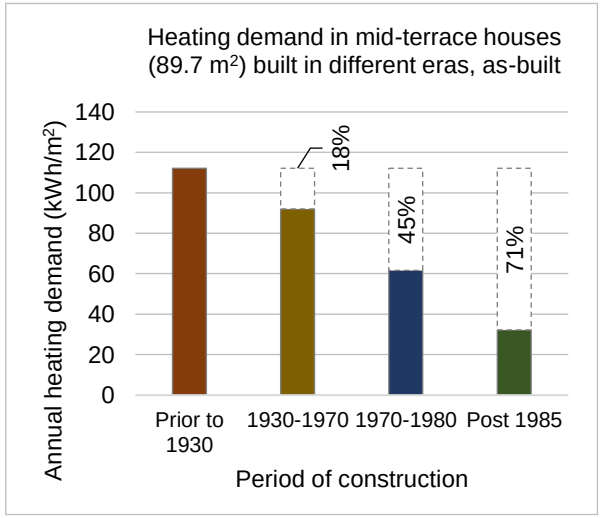
Mid-terrace

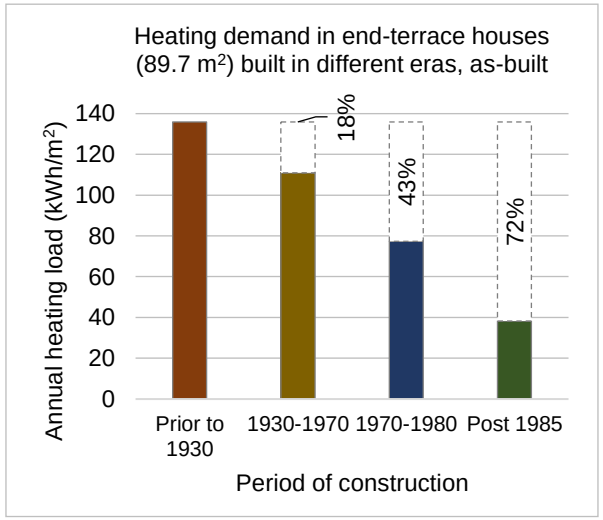
End-terrace











Case Study Mid-terrace Archetype in Sneinton

- 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-terraced House & End-terraced House

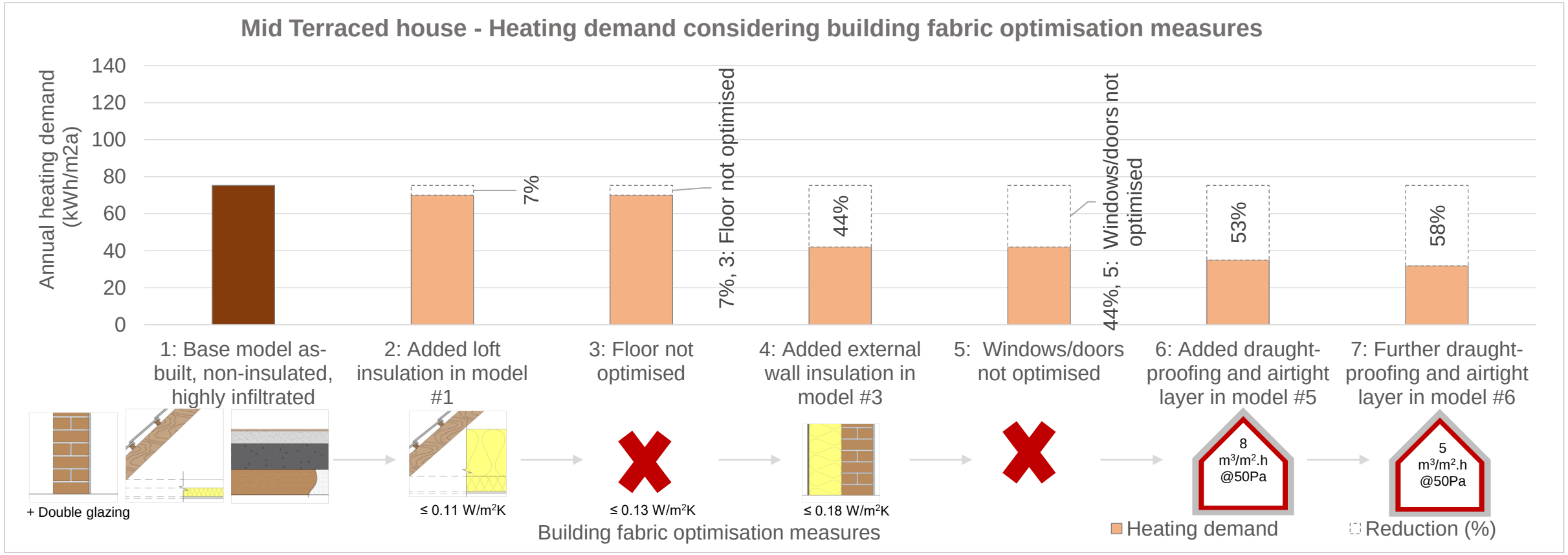
Mid-terraced Flat (First Floor) & End-terraced Flat (Ground Floor)

Site Plan. Based on Nottingham City Council (2022)

MID-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

Typical Air-Source Heat Pump vs Typical Boiler

Electricity

5kW

An Air-Source Heat Pump is around 250-300% efficient, so for every 1 kWh of electricity, an air source heat pump can produce 3kWh of heat

Ideal 35°C, maximum 50-55°C

Heat Pump

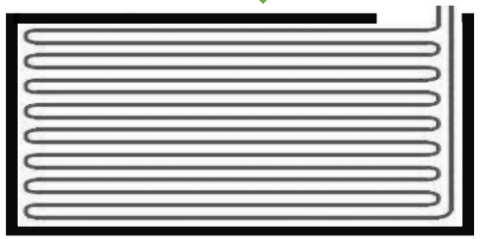
Gas

24-42kW

Boiler

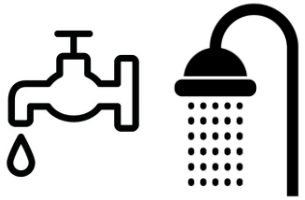
The most efficient gas boilers are only around 80-90% efficient, so for every 1kWh of gas you put in, you might get 0.9kWh of heat

Typical 70-82°C



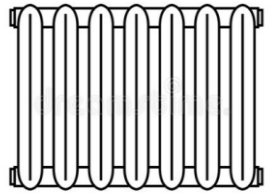
Typical 30-35°C

Underfloor Heating



Typical 50-60°C

Hot Water



Typical 60-70°C

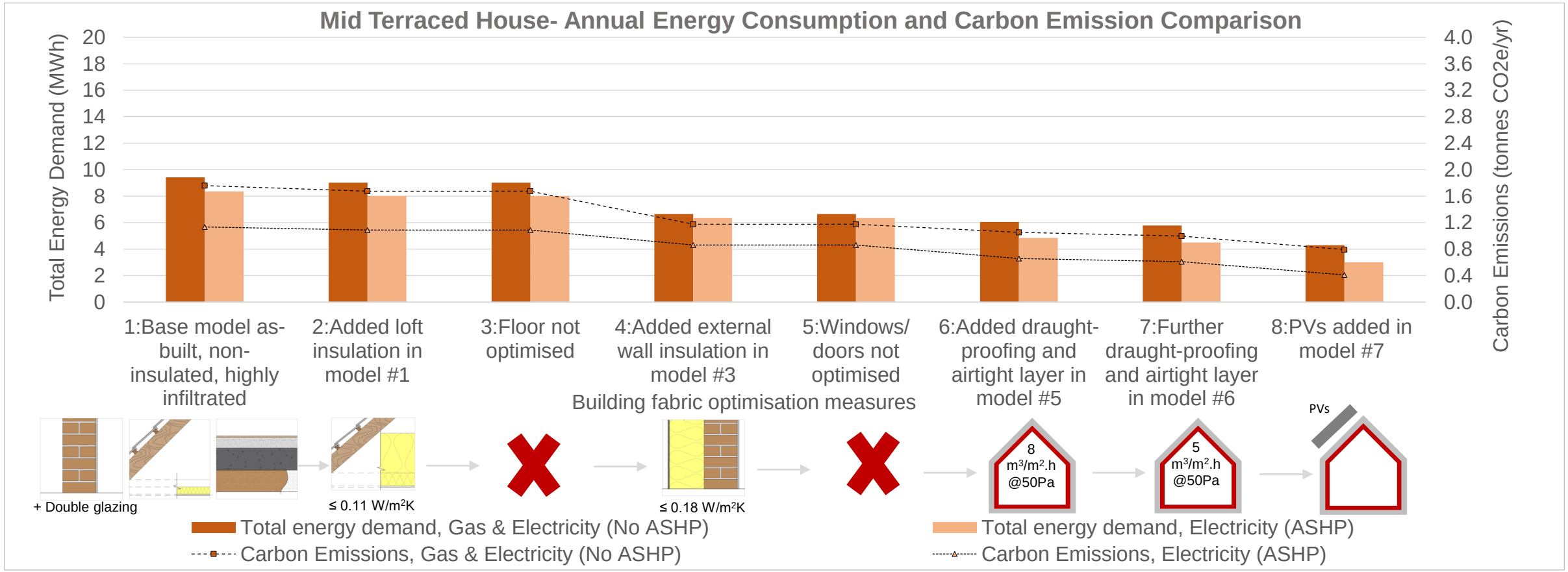
Radiator Heating

High temperature heat pumps can achieve operating temperatures of between 60-80°C but cannot produce the heat at the same rate as a boiler and require more electricity because the unit has to work harder

MID-TERRACE ARCHETYPE – TYPICAL RETROFIT

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

Prior to 1930



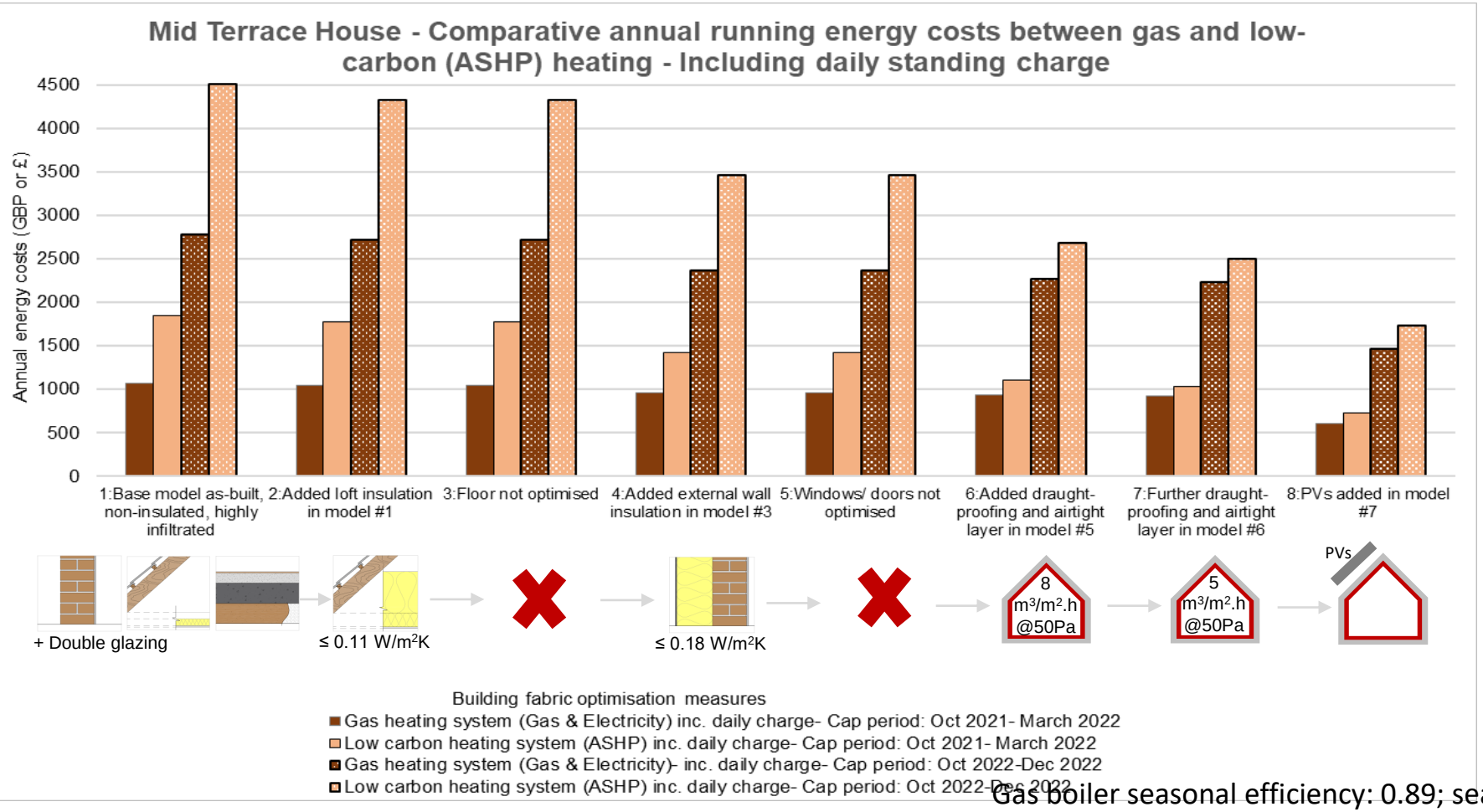
*A comparison of annual energy consumption and carbon emissions values after integration of low-carbon heating systems (with and without air source heat pumps [ASHP]).

Gas boiler seasonal efficiency: 0.89; seasonal coefficient of performance (SCoP): 0.8
ASHP SCoP for Space heating – 1.8 for non-retrofit and increased to 2.8 at later stages
ASHP SCoP for Domestic hot water - 1.5 for non-retrofit and increased to 2 at later stages

MID-TERRACE ARCHETYPE – HEATING SYSTEMS

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

prior to 1930

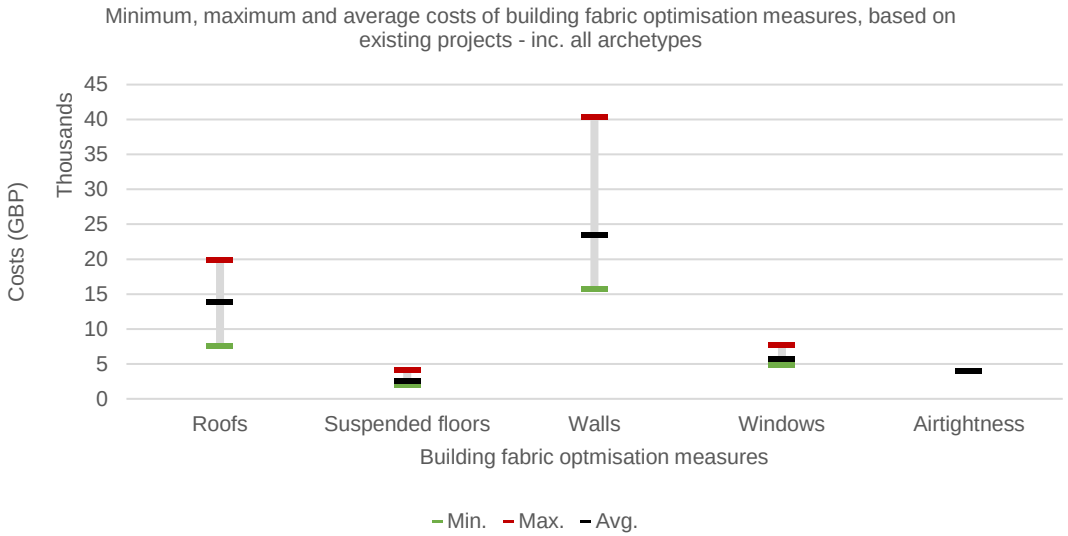


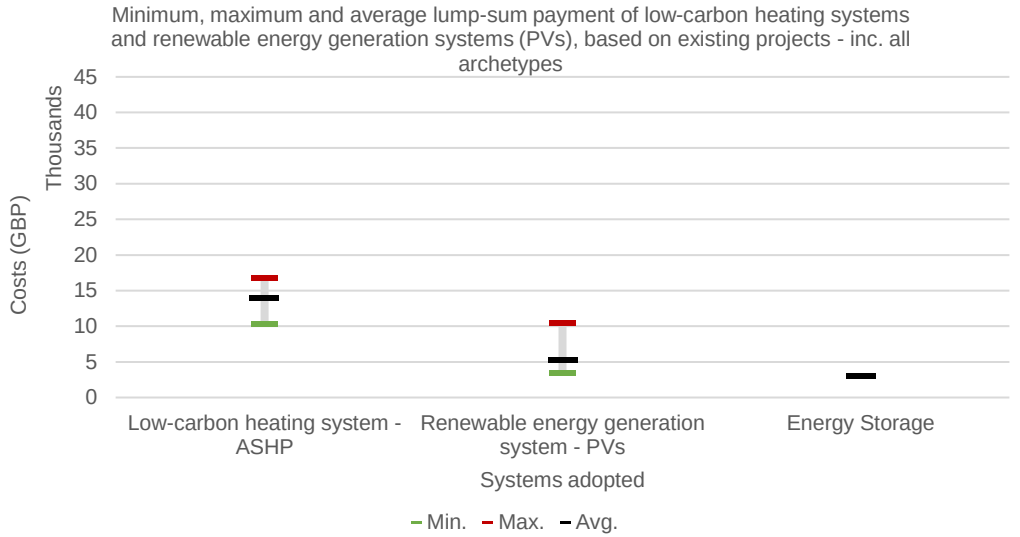
Gas price cap (Oct 2021- March 2022) (Ofgem, 2022b)	0.04 GBP per kWh
Gas daily standing charge (Oct 2021- March 2022) (Ofgem, 2022b)	0.26 GBP
Gas price cap (Oct 2022- Dec 2022) (Ofgem, 2022b)	0.15 GBP per kWh
Gas daily standing charge(Oct 2022- Dec 2022) (Ofgem, 2022b)	0.28 GBP
Natural Gas Carbon Emission Factor - SAP 10.2 (BRE, 2022, p. 189)	0.210 $kgCO_2e$/ kWh
Electricity price cap (Oct 2021- March 2022) (Ofgem, 2022b)	0.21 GBP per kWh
Electricity daily standing charge(Oct 2021- March 2022) (Ofgem, 2022b)	0.25 GBP
Electricity price cap (Oct 2022- Dec 2022) (Ofgem, 2022b)	0.52 GBP per kWh
Electricity daily standing charge(Oct 2022- Dec 2022) (Ofgem, 2022b)	0.46 GBP
Electricity Grid Carbon Emission Factor - SAP 10.2 (BRE, 2022, p. 189)	0.136 $kgCO_2e$/ kWh

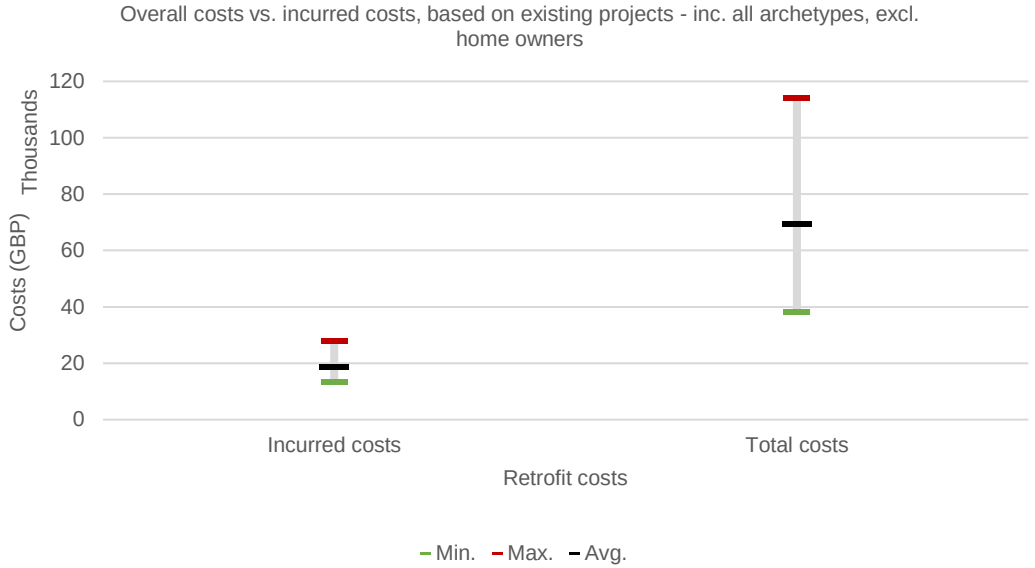
*Data considered is as per price cap details released in September 2022. For more information, please refer to the Nottingham Carbon Neutral Housing Report.

Gas boiler seasonal efficiency: 0.89; seasonal coefficient of performance (SCoP): 0.8
ASHP SCoP for Space heating – 1.8 for non-retrofit and increased to 2.8 at later stages
ASHP SCoP for Domestic hot water - 1.5 for non-retrofit and increased to 2 at later stages

COSTS PER RETROFIT INITIATIVE - 224 PROPERTIES







Incurred costs might include fees, surveys, preliminary costs, contingency, overhead, profit and others

Cost examples of Nottingham retrofit programmes

Archetype	Description	M2 (gross internal floor area)	Cost
0	Semi/End/Mid Terraced house, 2/3 bed Trad House Pre 1945	94	£74,069

Element	Cost per M2	Overall cost for element
EWI Works - Mauer External Wall Insulation System - Including enabling works, lintels and wall ties -0.2 U-Value	£188	£17,633
Window Replacement -UPVC, White A rated 1.2 U-Value	£62	£5,800
Renewable Energy Generation System & Storage	£37	£3,473
Roof Works- Removal and reinstatement of roof coverings, including insulation of the roof -Removal and renewal of clay tile roof covering; (Northstone Donard Old English Red) -400mm thick (min U Value of 0.8 W/m2K) mineral wool quilt insulation to the whole footprint of the roof void -Tyvec Supro (or equal and approved) breather membrane to the whole of the pitched roof area	£152	£14,318
Ground floor insulation- Q Bot insulation to ground floor area -Utilising Q-Bot technology apply insulation materials to the underside of the existing suspended timber floors; average depth to be 150mm thick and achieving a nominal U-Value of 0.15 W/m2K	£23	£2,195
Heating and ventilation -Boiler & Flue Adaption, and replacement of extract fans with heat recovery -Air Source Heat pump and installation costs	£127	£11,922
Materials Storage & Transportation Costs	£3	£255
Site Accommodation/Preliminary Costs	£12	£1,083
General Building/ enabling Works	£27	£2,577
Contingency Allowance - 10%	n/a	£5,926
Over head - 10%	n/a	£5,926
Profit - 5%	n/a	£2,963
Total Per Property:		**£74,069**

Element	M2 Cost	Cost for Element
Fees -Crane License Fee	£9	£454
Substructure works -Site Preparation -Alterations to gullys - Hand dig Excavation below ground level to expose existing gully / Break into existing drain / Fit new gully / Supply of new gully / Make good existing area after new gully is fitted / Slabbed area -Foundations to the front and rear elevations	£150	£7,213
EWI System -Factory production of insulated timber panels including external weatherboarding, prefitted windows, flashings - Panel Installation -Craneage for offloading and erection of panels -Undercroft ceiling works -includes building fabric sundries	£511	£24,550
Scaffolding Cost - per property	£30	£1,417
Renewable Energy Generation System	£184	£8,848
Renewable Energy Generation System - Battery	£62	£2,953
Roof Works -Factory production of roof cassette -Strip & clear existing roof covering including tiles, felt & batten -Install Roof Cassette -Supply and Install new plastic fascia board -Supply and Install new plastic rwps and gutters	£356	£17,090
Heating & Ventilation - Internal Heating system alterations, including decommission, flushing & removal of gas boiler, pipework & flue, radiator stats, room stats - Including Electrical Disconnection Works and mechanical alteration works to existing services. - Supply & Install of air source heating system- Vaillant/Pochin (including enabling works and commissioning) -Removal of existing ventilation system -Supply and installation of loft hatch -Aereco - supply and installation of demand controlled ventilation system, including fans, grills, trickle vents. - Supply and installation of Ductwork (verplas) -Builders work and making good included	£216	£10,377
Electrical Works - Controls and sensors installation (carnego) (£4,109) -Other associated works, including further sundry electrical works and builders work etc	£168	£8,043
Surveys -Asbestos, Non notifiable asbestos, bat surveys	£20	£971
Preliminaries (Figure based on total prelims cost for the programme/14 properties - scaffolding)	£203	£9,751
Risk & Contingency - Provisional allowance for compliance Works over and above that included in the Employers Works Information	n/a	£1,437
Overhead - 10%	n/a	£9,310
Profit - 5%	n/a	£4,655
Total Per Property		**£107,070**

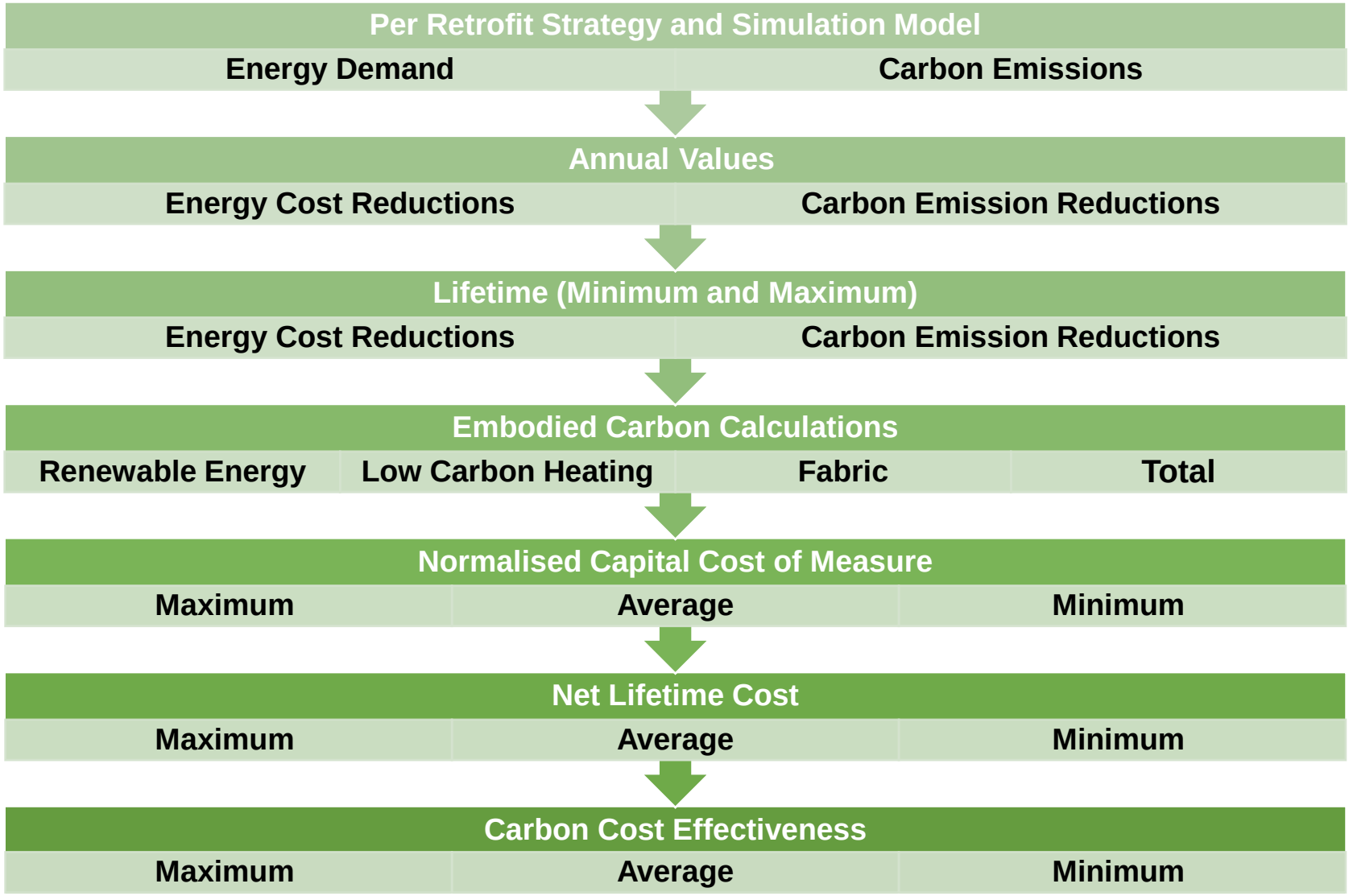
Archetype	Description	M2 (Gross internal floor area)	Cost
1	Terraced House	96	£114,075
2	Bungalow	48	£107,070

Costs (£ thousand) including all case studies and archetypes

Min.	Max.	Avg.
38k	114k	69k

Costs vary significant depending on the retrofit initiatives

METHOD

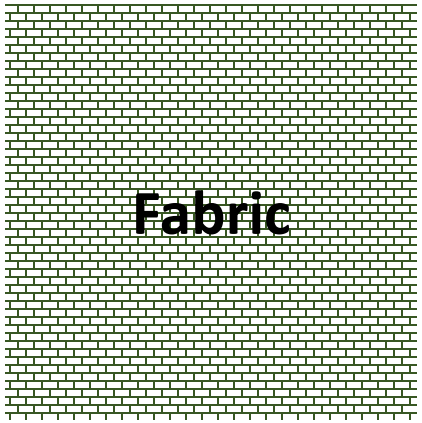


Simulation outputs always assume a fabric-first retrofit process
Costs are exclusive of VAT
Lifespan assumptions made (see following slide)
Degradation of PV performance not factored over lifetime of the installation
Carbon factors and energy tariffs assumed (see following slide)
Capital cost assumptions made in accordance with the full report and detailed calculation spreadsheet (available as an Appendix).
Embodied carbon calculation spreadsheet available as an Appendix. Assumptions made according to the main report (generally WLC Stages A1-A3)
Net Lifetime Cost is provided as a total value specific to the particular property. Costs and other assumptions are linked to property GIA.
Carbon Cost Effectiveness is provided as a total value specific to the particular property. Costs and other assumptions are linked to property GIA.

Net Lifetime Cost

Net Lifetime Cost (£) = **Total Lifetime Capital Cost (£)** − **Total Lifetime Savings (£)**

Simulation outputs always assume the following retrofit sequence:

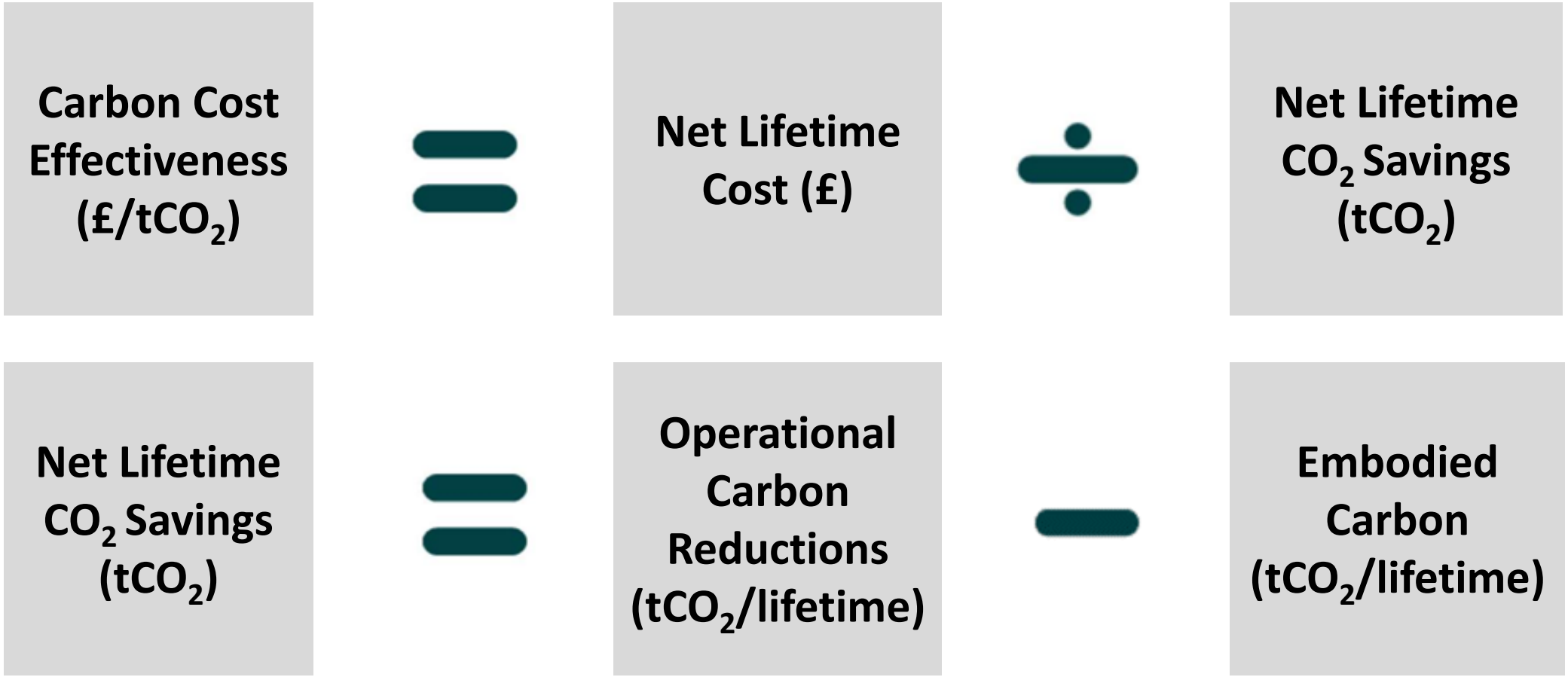


→ **Low Carbon Heating** →

Renewable Energy

Based on 'case study retrofit' simulation model
All costs are exclusive of VAT
Areas are updated according to the revised Case Study model (52.87m² GIA)
Incurred Costs include: preliminary costs, enabling works, contingency allowances, overheads, profits, and retrofit preconstruction costs including assessment, design and coordination
Lifetime Capital Costs do not make allowances for lifetime repairs, upgrades and maintenance
Fabric Measures. Total Capital Costs include: External Wall Insulation (EWI) and removal and reinstatement of roof covering including insulation
Low Carbon Heating Measures. Total Capital Costs include: 5kW Vaillant aroTHERM Air Source Heat Pump (ASHP), demand controlled ventilation
Renewable Energy Measures. Total Capital Costs include: 5x 400Wp Monocrystaline Jinko solar panels, battery storage installations

Carbon Cost Effectiveness



Lifetime assumptions are made on a minimum and maximum basis: fabric 20-30 years, low carbon heating 20-25 years, renewable energy 15-25 years
All Net Lifetime Cost assumptions, limitations and exclusions apply
Based on 'case study' simulation model
All costs are exclusive of VAT
Incurred Costs include: preliminary costs, enabling works, contingency allowances, overheads, profits, and retrofit preconstruction costs including assessment, design and coordination
Embodied Carbon calculations are based on a series of assumptions highlighted within the report
In general, Whole Life Cycle stages A1-A3 are considered within Embodied Carbon calculations

Capital Cost and Carbon Emissions Reduction

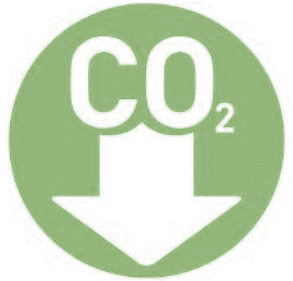
	Capital Cost (£ billion)	Net Carbon Reduction (Tonnes of CO2e thousand)
Detached	£0.68bn	553k
Semi-detached	£2.6bn	301k
Mid-Terraced	£2.1bn	1,073k
End-Terraced	£1.4bn	1,273k
Total (Exc. VAT)	£6.7bn	3,200k

6,700,000,000

capital investment in retrofit of houses

3,200,000

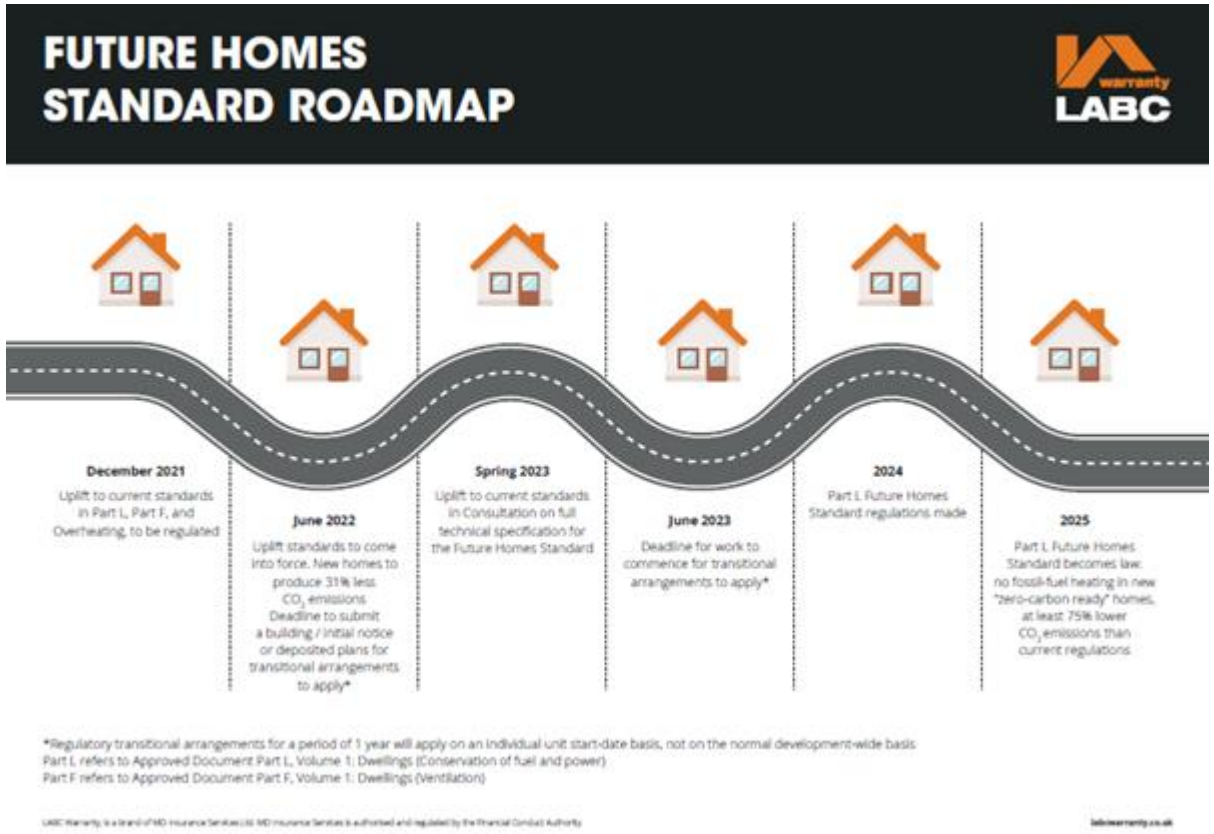
tonnes over lifetime of intervention



Future Homes Standard

The cost of retrofitting new homes built to current standards today has been estimated at **5 times** the cost of building to the **Future Homes Standard now**

(Holmes et al., 2019)



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Govt warns transport services face 'significant disruption'
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Professor Lucelia Rodrigues
University of Nottingham
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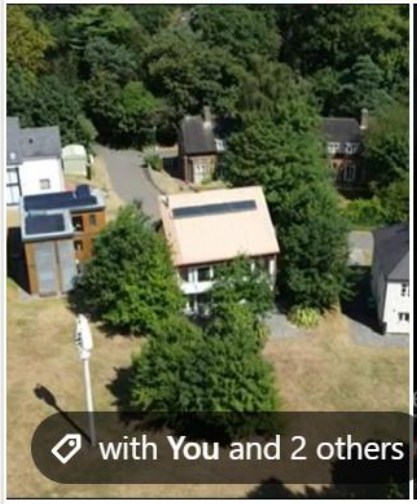
31C recorded in Northolt, London - making it hottest day of year so far
14:50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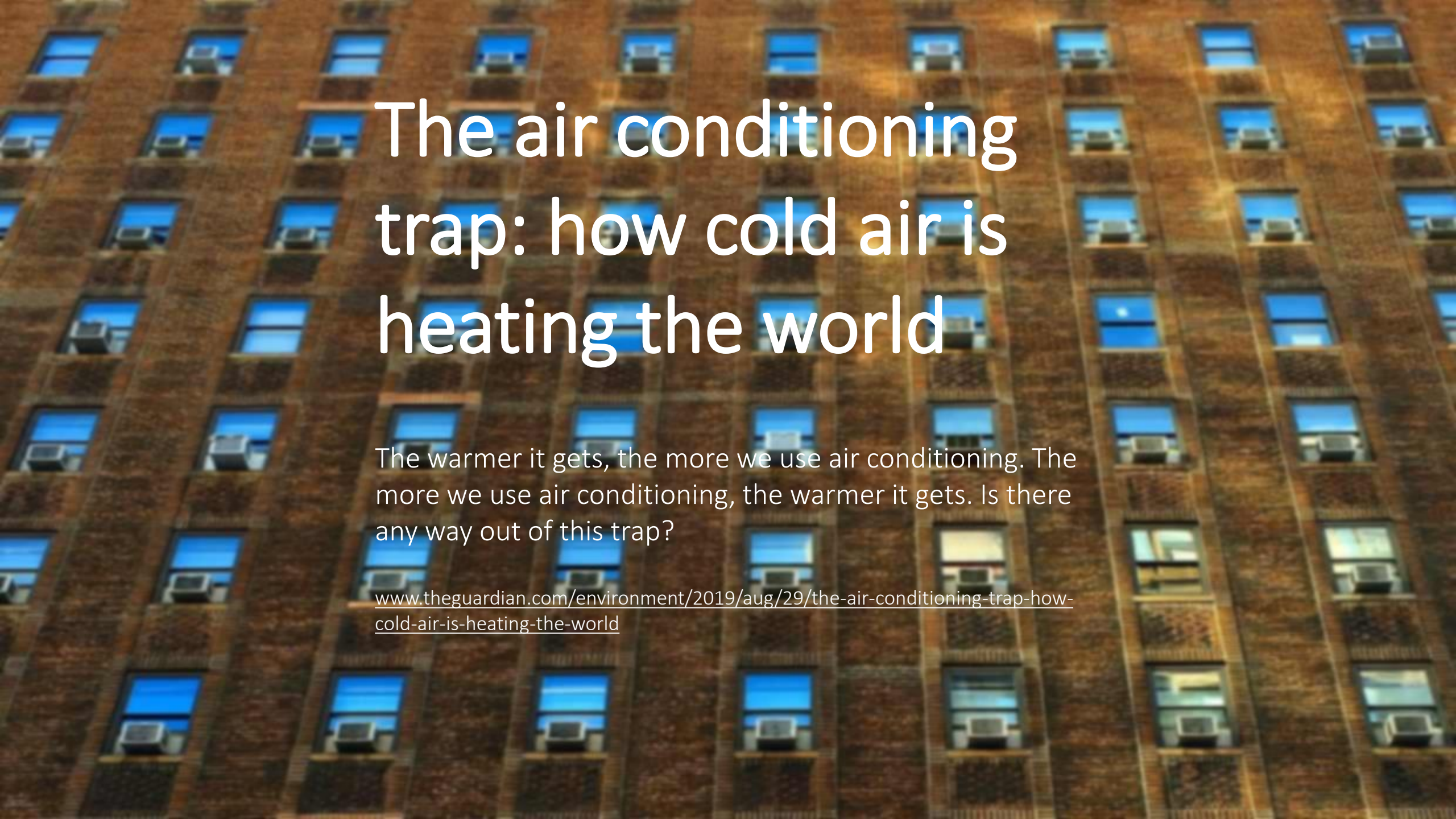
MIDLANDS TODAY


notts tv ON DEMAND
Notts Today, Thursday 11th August



The air conditioning trap: how cold air is heating the world

The warmer it gets, the more we use air conditioning. The more we use air conditioning, the warmer it gets. Is there any way out of this trap?

www.theguardian.com/environment/2019/aug/29/the-air-conditioning-trap-how-cold-air-is-heating-the-world

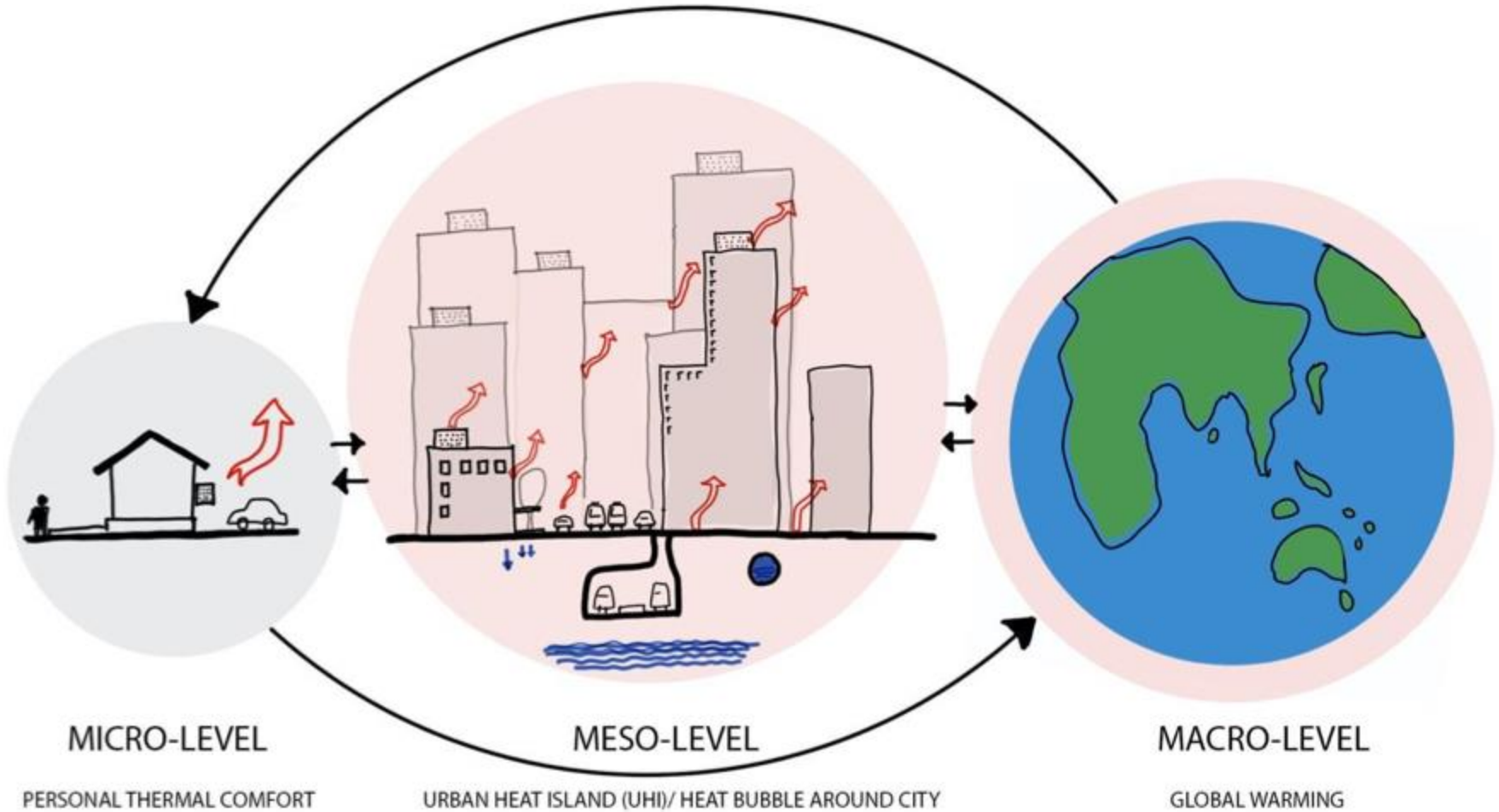


Illustration showing three scales at which climate change occurs, with cities contributing to climate change via the urban heat island (UHI) effect (Source: Vahanvati 2019)
https://www.thefifthestate.com.au/articles/how-design-of-our-cities-is-amplifying-urban-heat-and-what-to-do-with-it/

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Climate Resilience in UK Housing

The Green Street

Super-high levels of insulation, whole-house heat recovery, industry leading levels of air tightness and maximum use of natural light, with homes meeting the AECB Silver Standard.

www.blueprintregeneration.com

Trent Basin

Sustainable neighbourhood, super-high levels of insulation, industry leading levels of air tightness, maximum use of natural light, on site energy generation and storage within a community energy scheme.

www.trentbasin.co.uk

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Trent Basin: Collaborative Planning

By applying Blueprint's Footprint Policy urban design principles and low-energy principles to the building fabric, Blueprint and a team of industry and University of Nottingham academic experts came up with a vision for this new neighbourhood back in 2013

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Smartify

University of Nottingham
Energy Institute

Project SCENe

Innovate UK

ENERGY RESEARCH ACCELERATOR

Funded by Innovate UK and the Energy Research Accelerator

SCENe

Sustainable Community Energy Networks

TRENT BASIN
WATERSIDE

SCENe looks to accelerate the adoption of community energy schemes, which can help promote the infrastructural, social and cultural changes we need to reduce the impact of climate change and increase energy security

University of Nottingham
UK | CHINA | MALAYSIA

ATKearney

SMARTKLUB
Empowering Cities Together

SOLAR READY

Loughborough University

blueprint

SIEMENS

Stickyworld

urbed

Slam Jam

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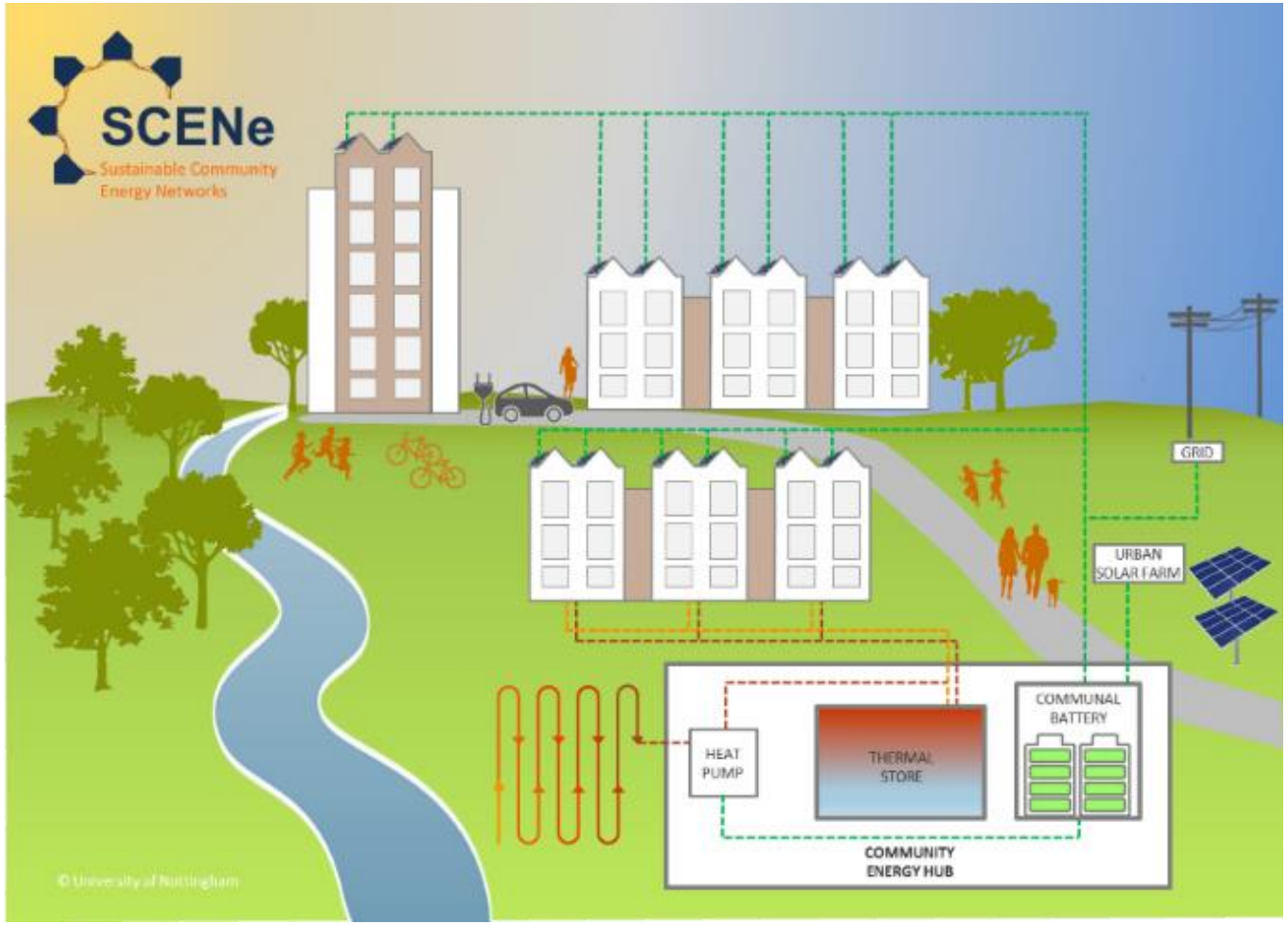
SCENe at the Trent Basin

- It includes:
  - an urban solar farm (200 KWp),
  - rooftop solar panels,
  - Europe's largest community energy battery (Tesla 2.1MWh),
  - and local thermal energy production, distribution and storage.
- The aim is to generate renewable energy and deliver grid services to the National grid, increasing efficiencies, reducing costs and decreasing the overall carbon emissions from the energy system



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The Realisation

3D Energy Interactive Model: http://uk.ies-icl.com/UoNTrentBasin

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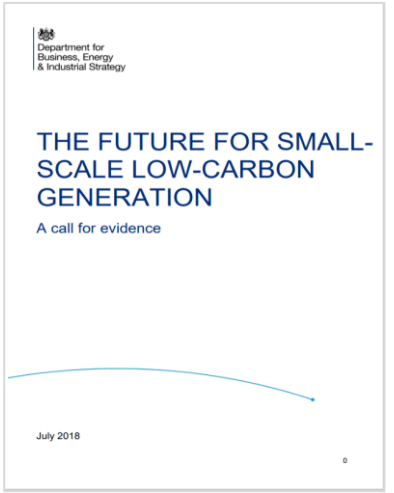
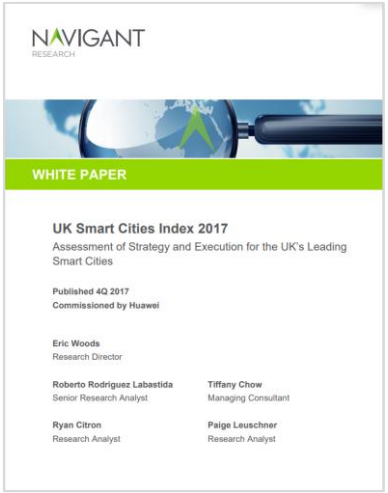
Project SCENe: Impact

- The project appeared in 43 recorded press releases and media publications
- It produced 18 academic publications to date
- Received several important visits such as Sir David King, Foreign Secretary's Special Representative for Climate Change, Foreign & Commonwealth Office, and Climate Change Minister Claire Perry
- The UK100 has featured the project in its latest report "Financing the Transition: Harnessing UK Cities' Ambition for Clean Energy (2017)"
- The UK Government's Department BEIS featured the project as a case study in "The Future for Small-Scale Low-Carbon Generation – A call for evidence" (July, 2018)
- The UK Smart Cities Index (2017) recognised Project SCENe as one of the key projects contributing to Nottingham ranked 8th place between the UK 20 leading smart cities and the top smart city for energy.
- Featured in the Innovate UK Energy Heroes campaign: Clean Growth – How Nottingham Trent Basin is Generating Electricity
- Session at the Nottingham in Parliament Day: Future of Energy, the Community Energy Revolution
- Green Gown Award 2018 Highly Commended - Benefitting Society Category
- Business Link Magazine's East Midlands Bricks Awards 2018 winner - Sustainable Development of the Year
- The Decentralised Energy Awards 2018 winner - Innovation Award
- Collaborate to Innovate 2019 winner - energy and environment category
- British Renewable Energy Awards 2022 winner - community category





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Active Building Centre

The Active Building Centre's vision is to transform the UK construction and energy sectors through the deployment of Active Buildings contributing to more efficient energy use and decarbonisation.

INDUSTRIAL STRATEGY

UK Research and Innovation

ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

CONSTRUCTION INNOVATION HUB

TRANSFORMING CONSTRUCTION NETWORK PLUS

University partners:

- Swansea University
- Cardiff University
- Imperial College London
- University of Sheffield
- Newcastle University
- Loughborough University
- University College London
- University of Birmingham
- University of Nottingham

Commercial collaborators:

- Tata Steel UK
- Pilkington Group Ltd
- Hale
- BIPVCo
- Wernick
- City and County of Swansea
- United Welsh
- AkzoNobel UK
- Cisco Systems UK
- PA Consulting Group
- Sero Energy
- Arup (Ove Arup and Partners Ltd) (UK)
- Powell Dobson
- Neath Port Talbot County
- Coastal Housing Group
- GridDuck
- HTA Design LLP
- Siemens PLC
- Sheffield City Council
- Welsh Government
- Greater London Authority (GLA)
- Bere Architects

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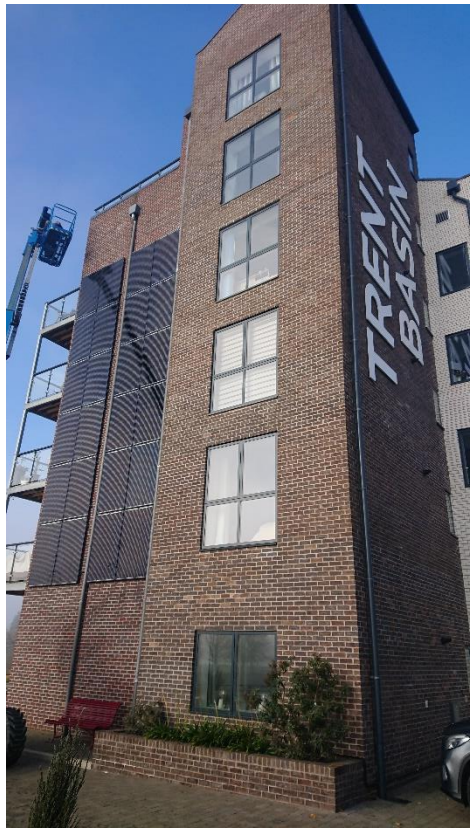
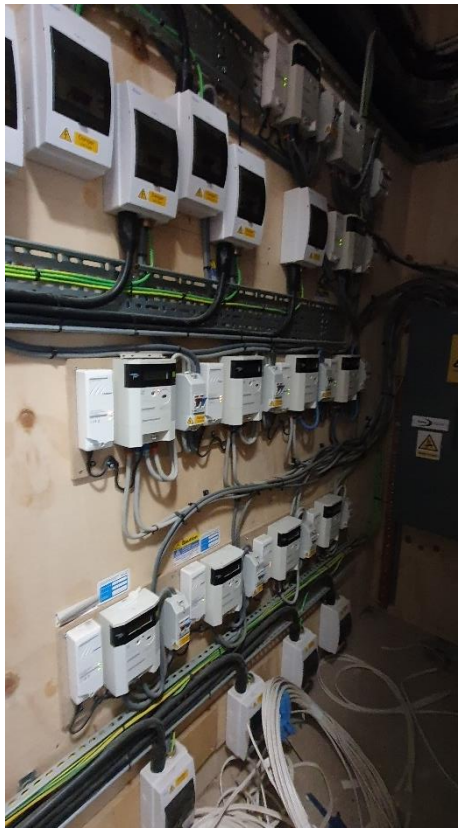
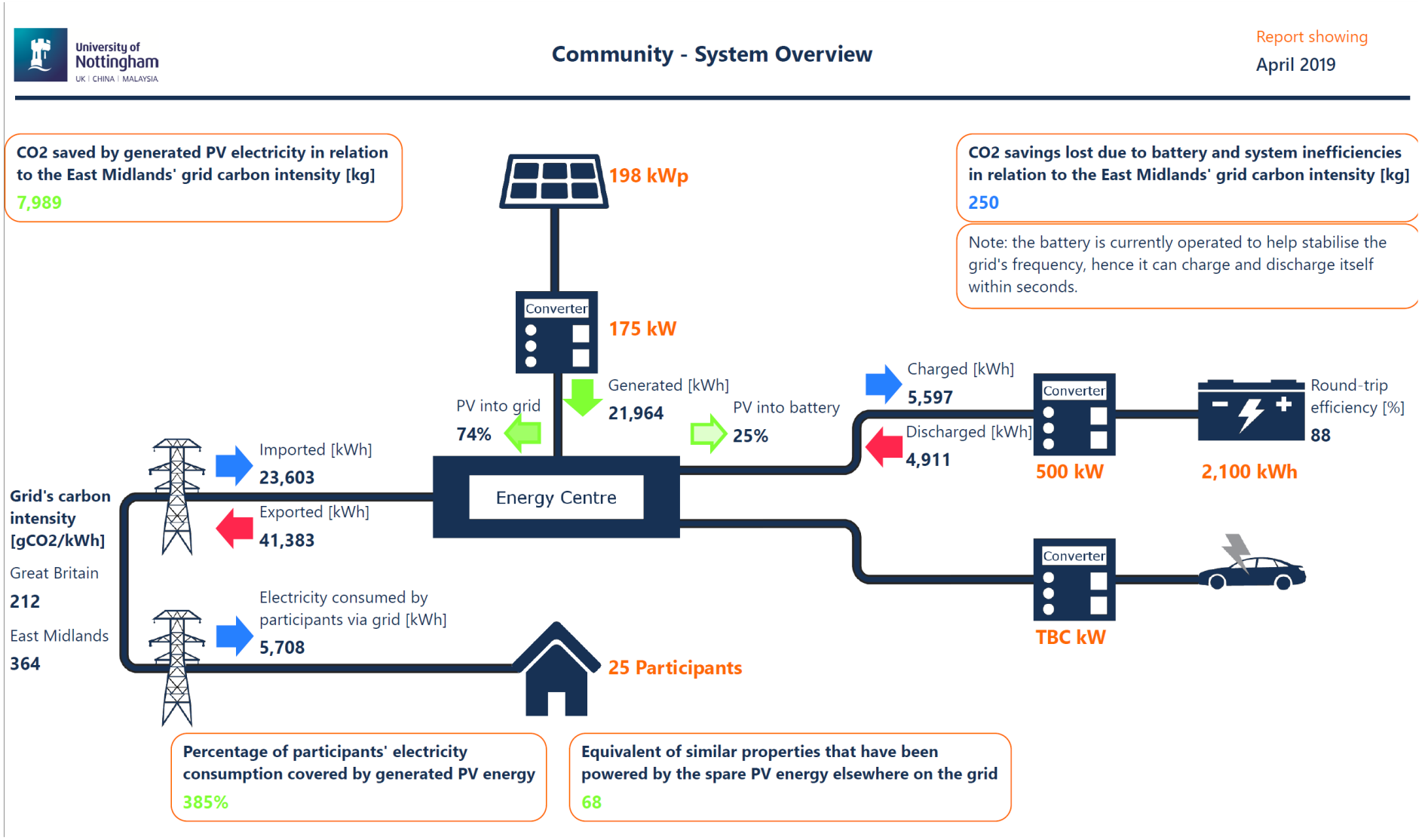
The Active Building Centre at the Trent Basin

- Behind the Meter Billing: optimise the mix of locally-generated and utility provided energy for residents





Smart Energy Systems



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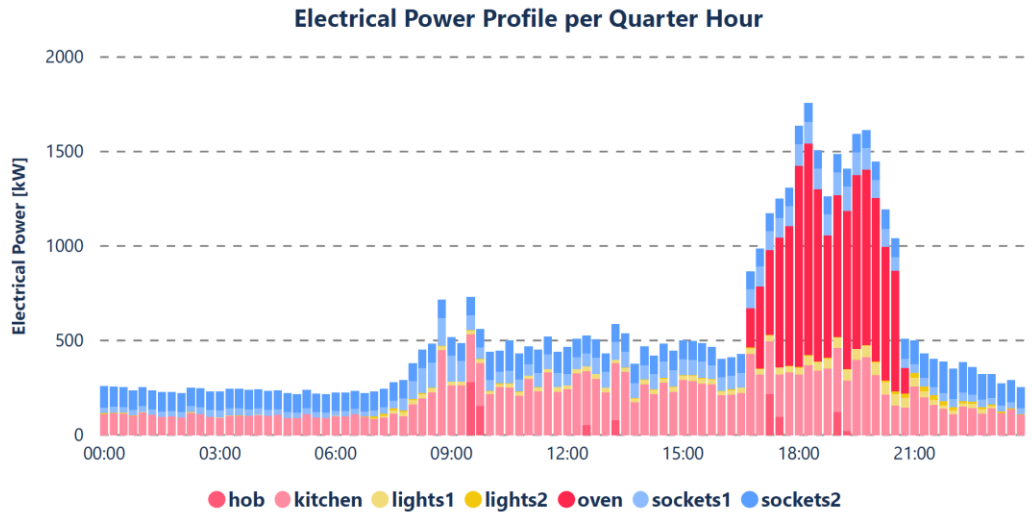
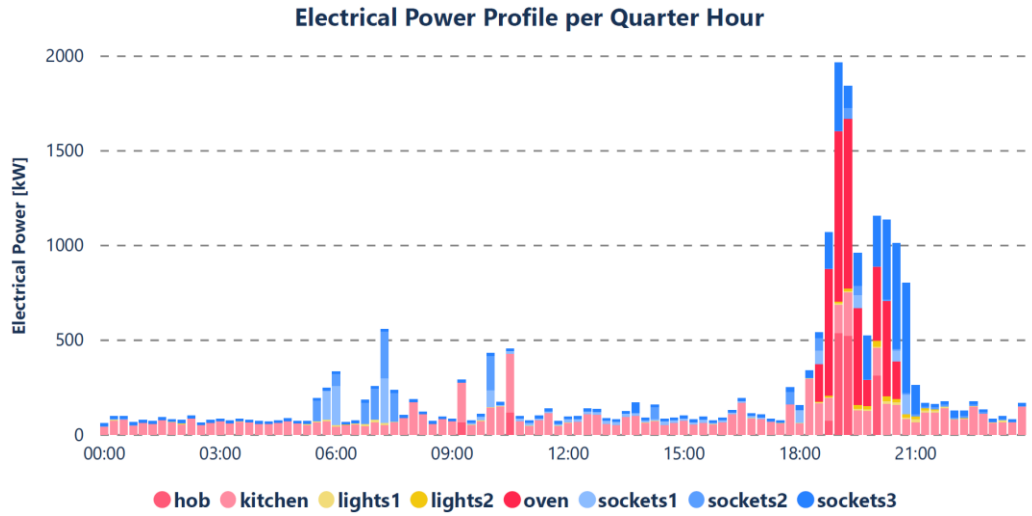
Smart Energy Systems

Prior to COVID-19 crisis, April 2019

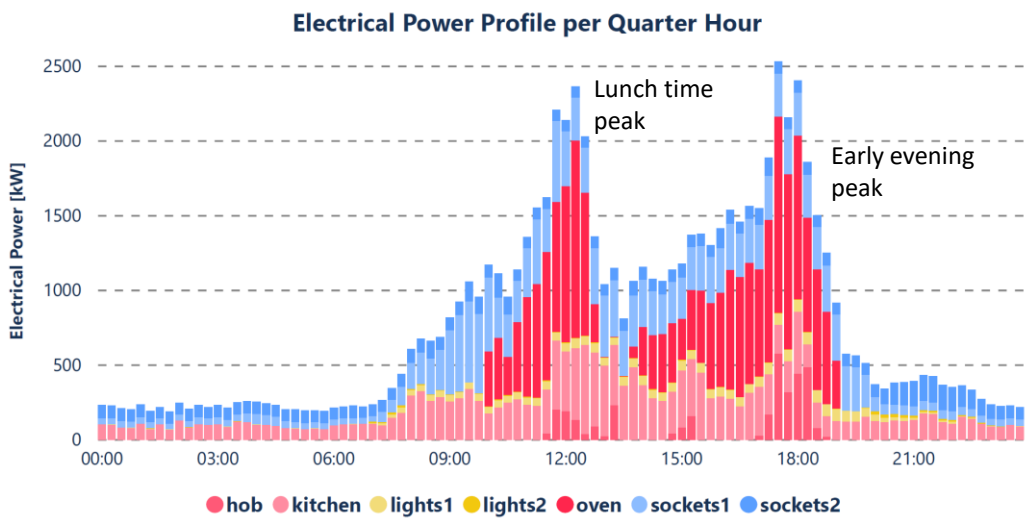
House x

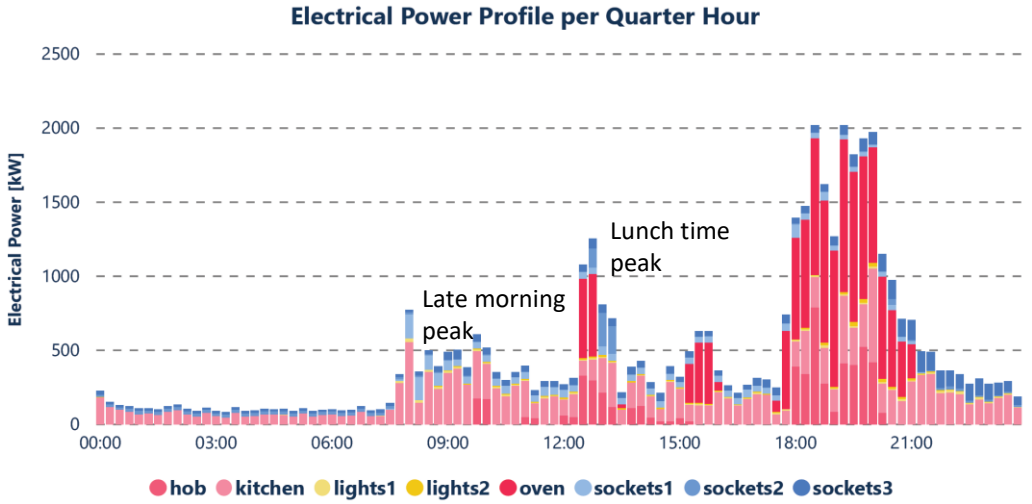


House y

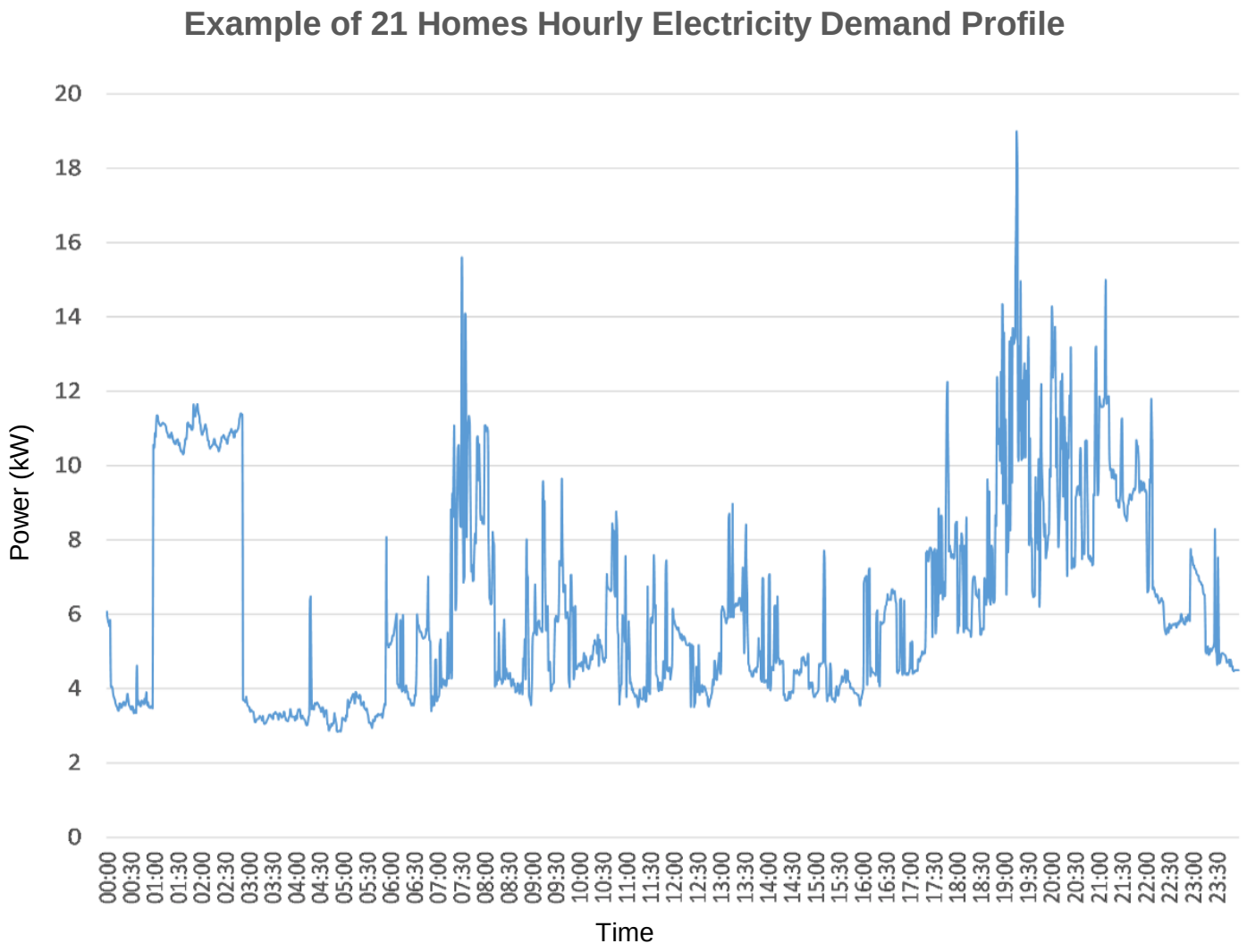


During COVID-19 crisis, in lockdown, April 2020

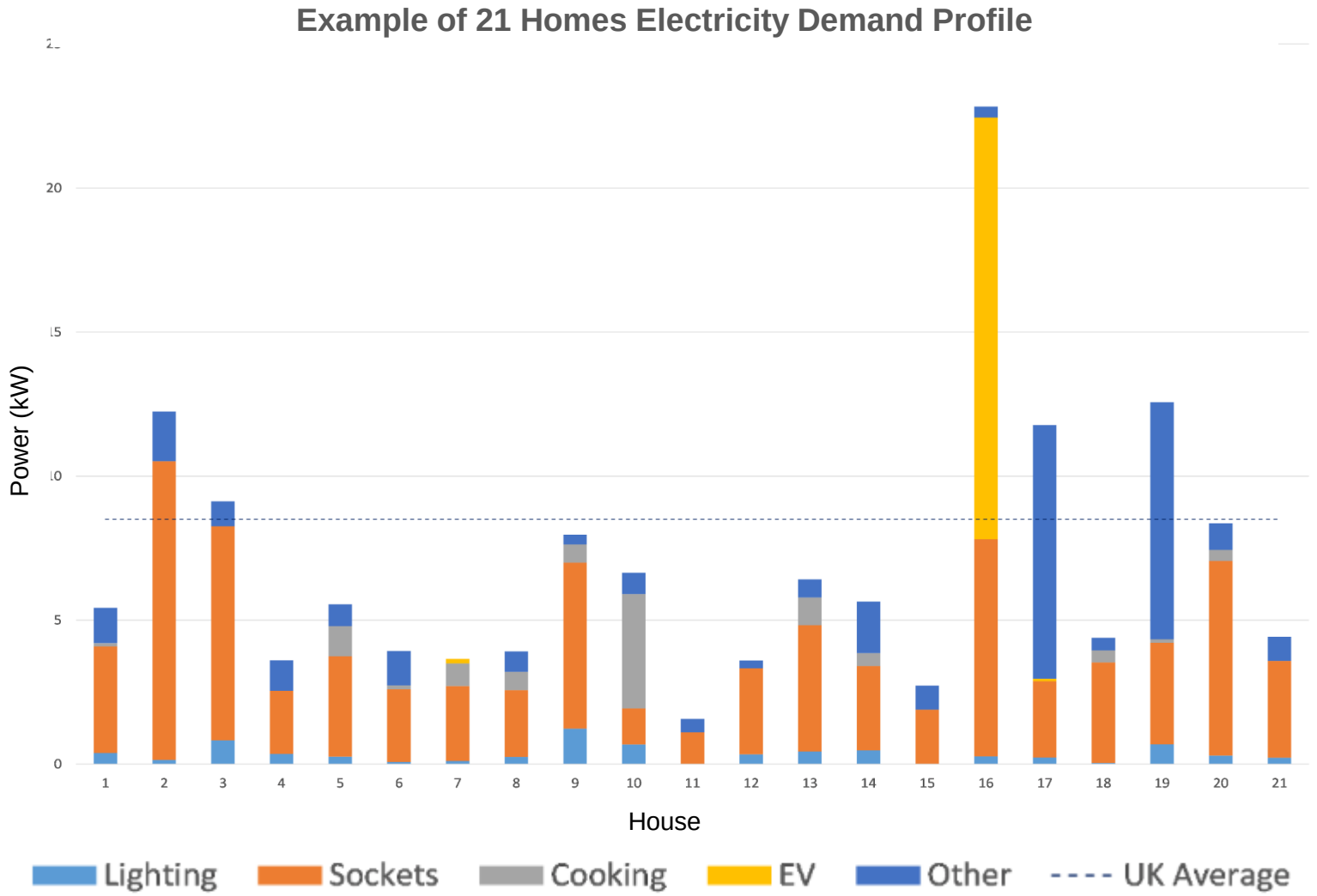




Home Monitoring: Community Profile



Home Monitoring: Disaggregated Data



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Electrify

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EV-elocity project

EV-elocity is a research and development project looking at increasing the uptake of electric vehicles through helping consumers to monetise their investment using vehicle-to-grid (V2G) innovation.

Funded by:

Department for Business, Energy & Industrial Strategy

Office for Low Emission Vehicles

Innovate UK

Partners:

cenex

CrowdCharge

Leeds City Council

Nottingham City Council

University of Nottingham UK | CHINA | MALAYSIA

WMG THE UNIVERSITY OF WARWICK

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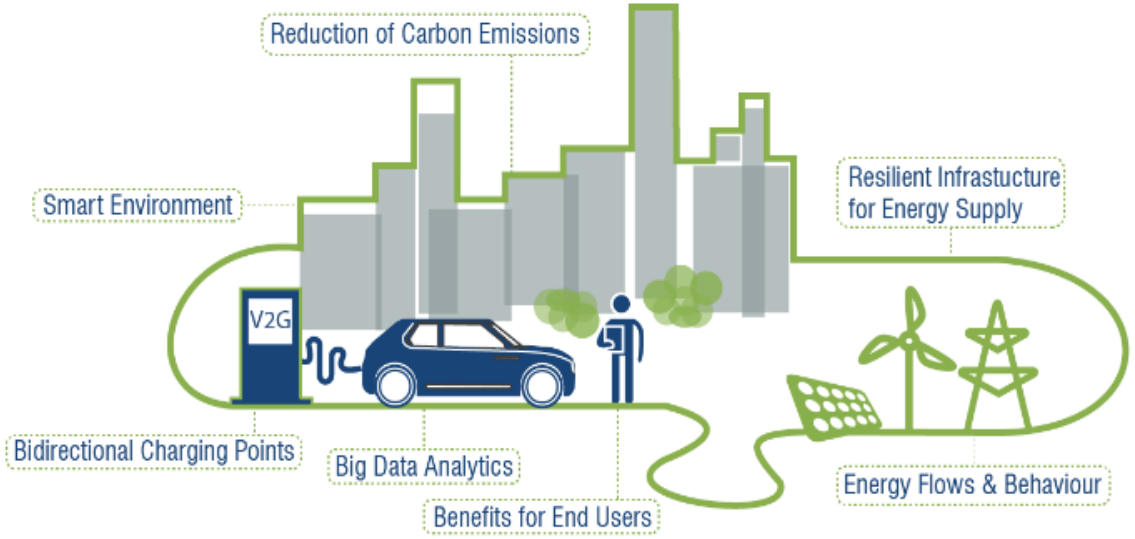
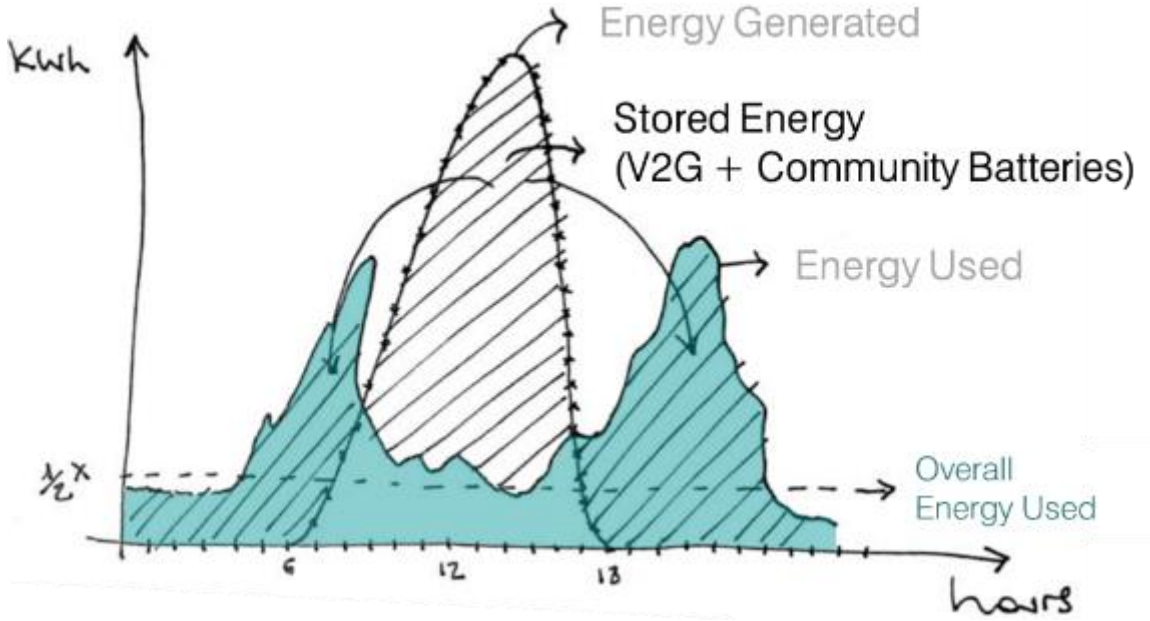
Vehicle-to-Grid (V2G)





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WALDRON, J., RODRIGUES, L., GILLOTT, M., NAYLOR, S., SHIPMAN, R., 2020. "Decarbonising Our Transport System: Vehicle Use Behaviour Analysis to Assess the Potential of Transitioning to Electric Mobility". *In*: 35th Passive and Low Energy Architecture Conference (PLEA): Planning post Carbon Cities, 1-3 September 2020, Coruna, Spain.

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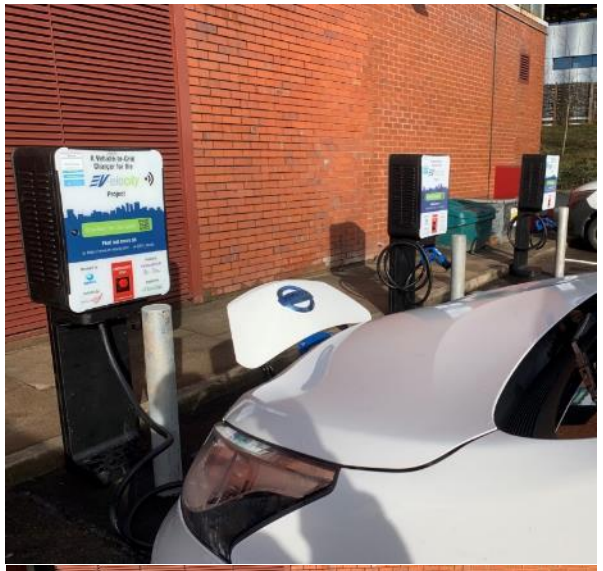
EV-elocity Case Studies



Leeds City Council

University of Nottingham

West Midlands Police
Worcestershire County Council

University of Warwick

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University of Nottingham V2G demonstrators

Location: Hallward Library
Use: University fleet

Location: Creative Energy Homes
Use: Integrating V2G & renewable energy generation

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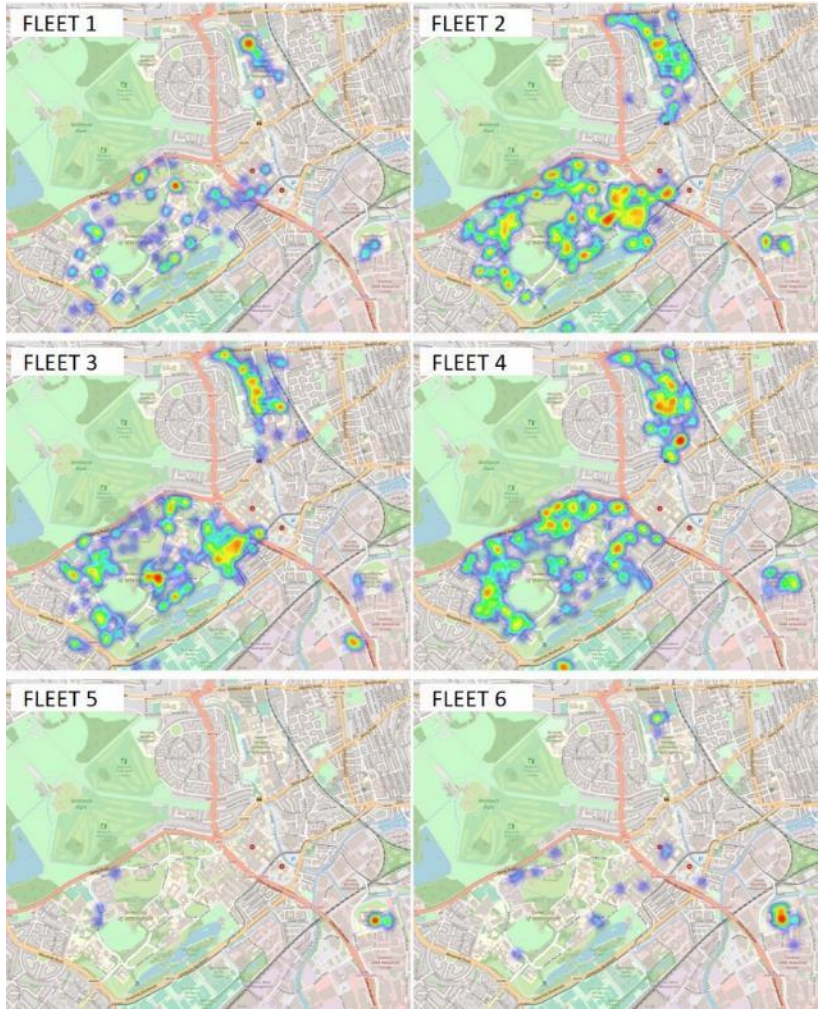
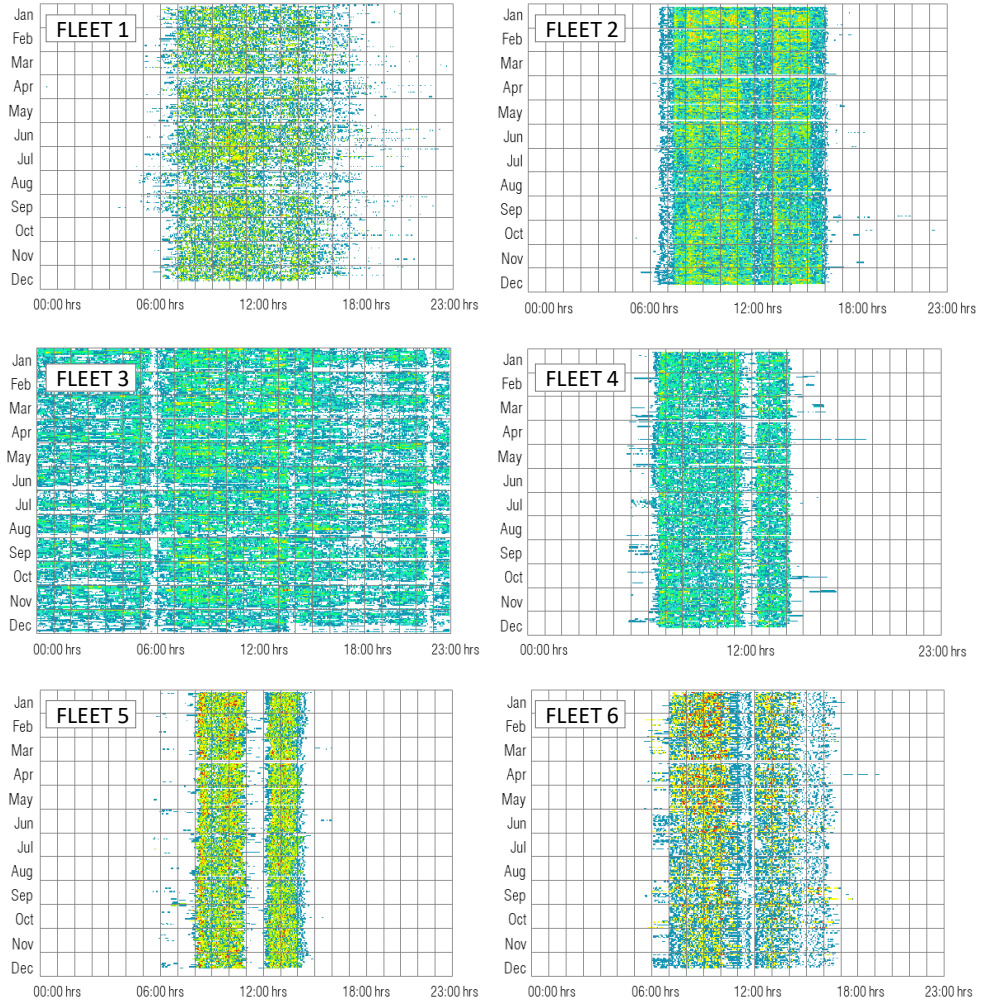
Behaviour data analysis

Long dwell location analysis
(stops over 1 hr)

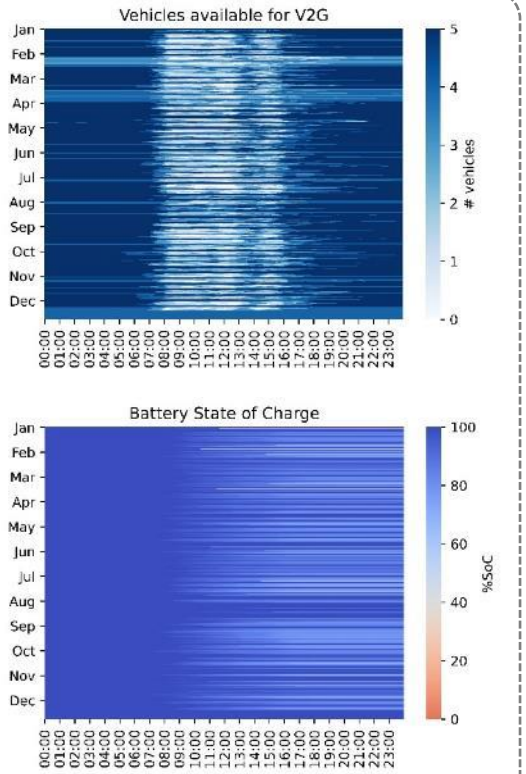


Fleet use patterns
(simultaneous use of vehicles)



Active Vehicles:
0% 100%

Vehicles Availability



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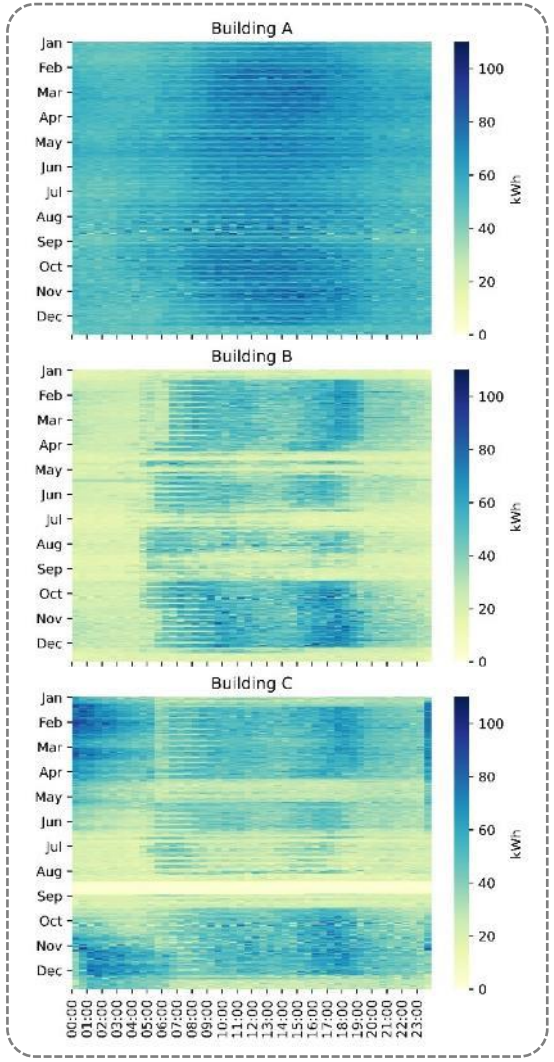
Building Energy Consumption



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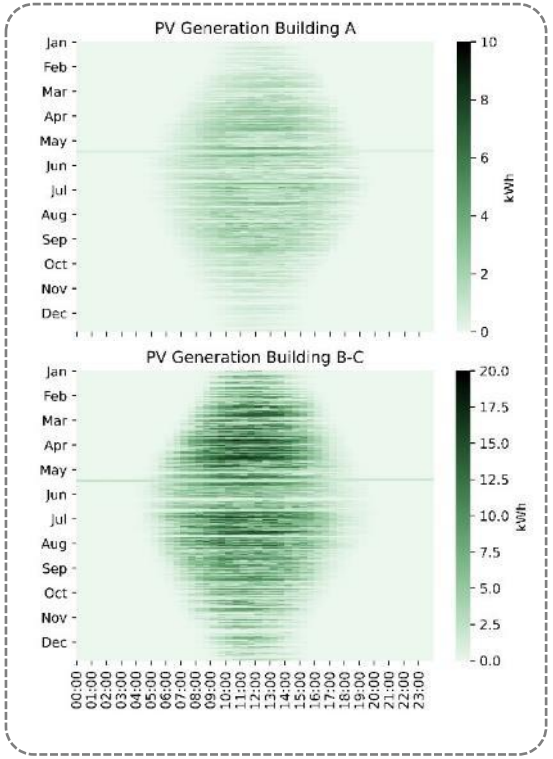
Renewable Energy Generation



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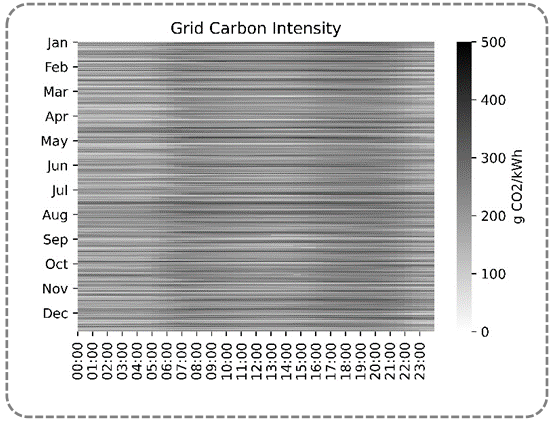
CO_2 Emissions



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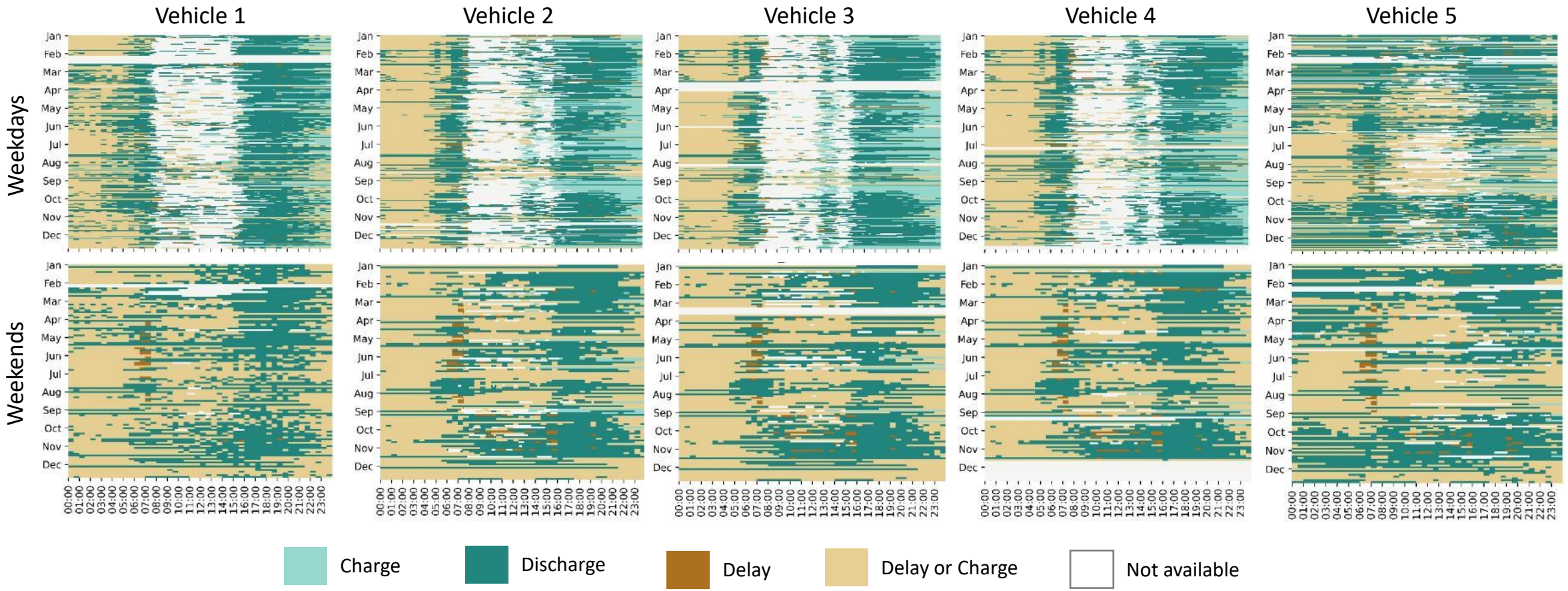
Charging/discharging to optimise environmental benefits



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EV-ShAIR

- Vehicle-to-everything (V2X) bi-directional charging
- £300k Innovate UK funded 12-month project
- Develop business models that will enable the creation of value from V2X technologies for the benefit of the electricity operations at airports by using the collective battery capacity of parked EVs
- Optimise renewable use, generate financial benefits, reduce operational carbon emissions, double the use of embodied carbon emissions in batteries
- Funded by the Department for Energy Security and Net Zero, delivered by Innovate-UK, part of the £65m Flexibility Innovation Programme

Department for Energy Security & Net Zero

UKRI Innovate UK

University of Nottingham UK | CHINA | MALAYSIA

SMARTKLUB Empowering Communities

GUPTA Smart Energy

EM ENERGY SOLUTIONS

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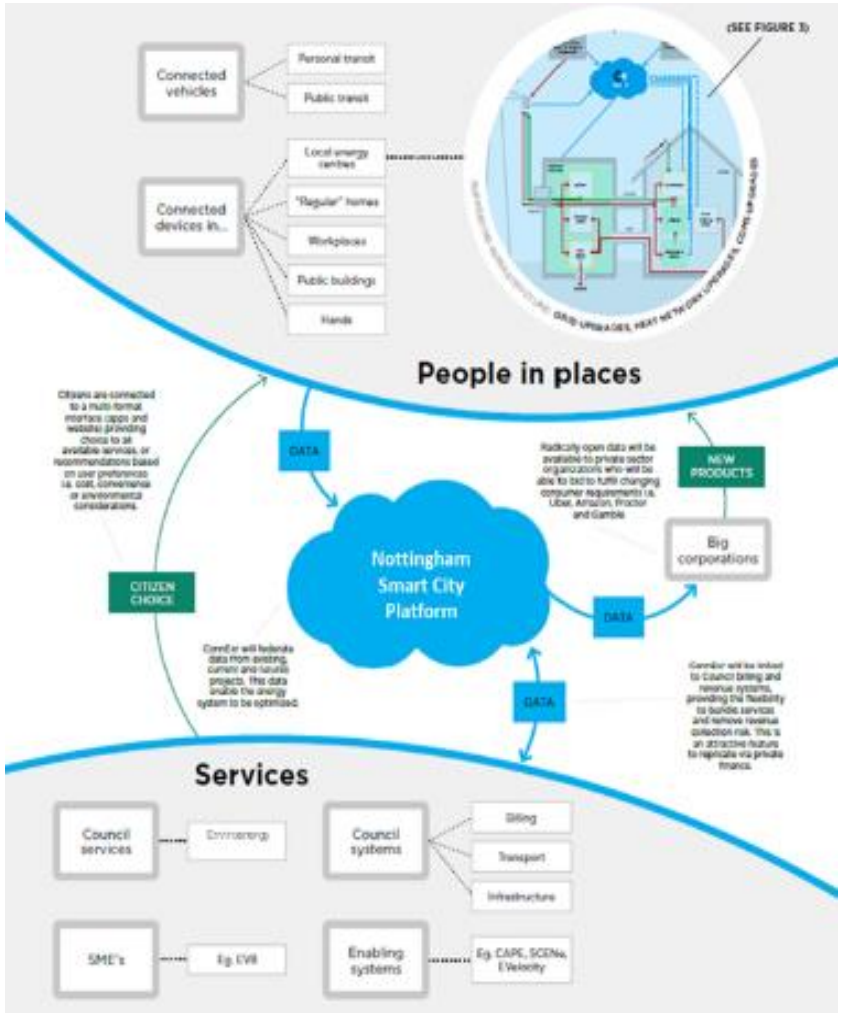
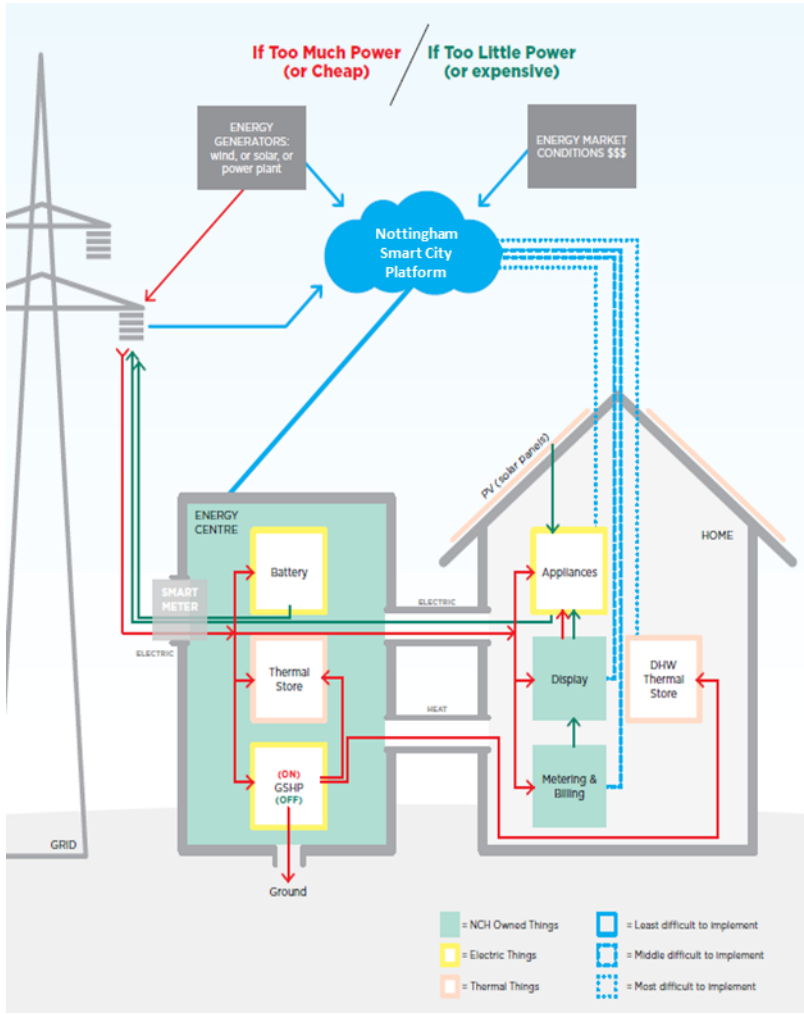
What next?





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Thank you!

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