URBAN FLOWS OBSERVATORY

Whole Life Material Efficiency Research -a summary update

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Vision: to quantify, across scales, opportunities for whole life material efficiency in the built environment

and in doing so, to

inform design of individual buildings & local and national planning policy

Buildings – Cities - Nations

Resource Efficient Cities & Nations

The University Of Sheffield.

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City Scale Urban Flows Observatory

urbanflows.ac.uk

@urbanflowsObs

What is Sheffield made of?

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- What materials & where?

- Using cutting edge techniques to understand the existing stock
  - MARVeL (Multispectral Advanced Research VEhicLe) to capture remote sensing data & applying machine learning

Also, need to know:

- New build rate, construction types & material demand

- Where are unused buildings?
  - How could these be repurposed?

- Demolish rate & construction types
  - Reuse potential

MARVel
Multispectral Advanced Research VehicLe

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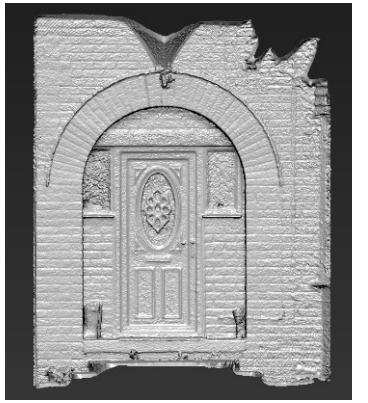
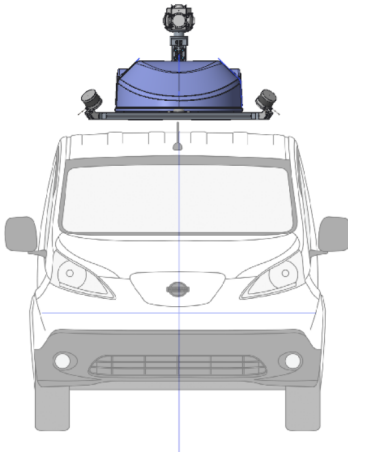
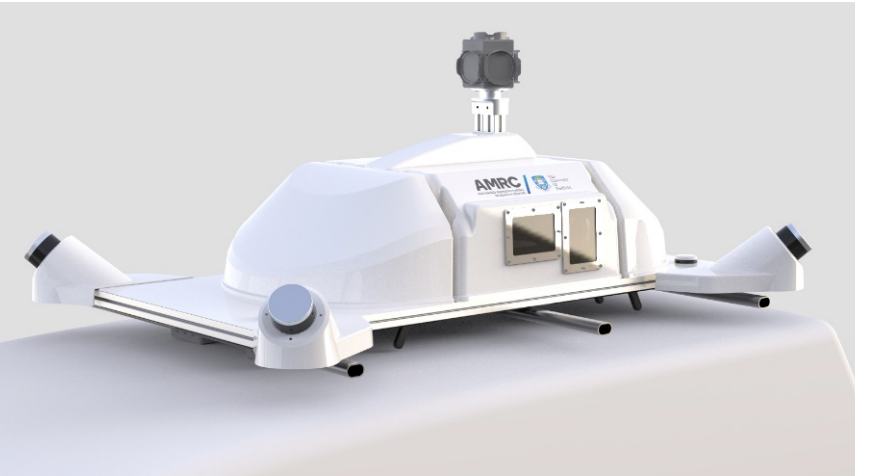




LiDAR Unit x 4

- 100m Range
- Up to 600,000 Points per Second

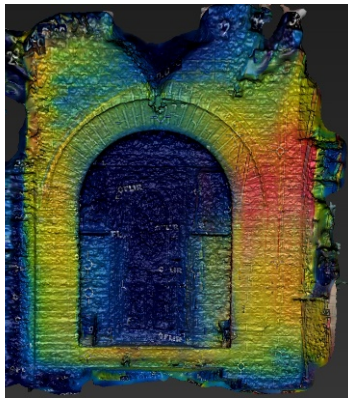


Visual Camera Unit

- A 360º spherical camera, 90% of full sphere.
- 30 MP (5 MP x 6 sensors)

Thermal Camera x 4

- Resolution of 640 × 512



Hyperspectral Camera
Spec TBC

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Machine Learning to automate material recognition

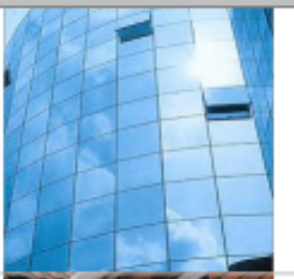
Tensorflow

Property	89%
Residential Area	80%
Mansion	57%
Screenshot	56%
Suburb	55%

Brick	98%
Brickwork	98%
Wall	83%
Material	63%

Color	97%
House	79%
Illustration	54%

File Name	Test Image	Justification/Description	Classificatior
			500 Iterations
timber_002.jpg		Side facing image of a timber connection.	Timber 0.72767437 Bricks 0.13041435 Concrete 0.10056331 Steel 0.023839109 Glazing 0.017508868 Evaluation time: 0.732s
timber_004.jpg		Front facing image of a timber shell building (including a concrete base/foundations).	Timber 0.7976539 Concrete 0.07596642 Bricks 0.056142557 Glazing 0.04952056 Steel 0.020716513 Evaluation time: 0.761s
timber_093.jpg		Front facing image of a timber horizontally clad building (with glazing and tiled roof).	Bricks 0.43397826 Glazing 0.30880725 Timber 0.21485986 Concrete 0.026323248 Steel 0.016031336 Evaluation time: 0.749s
timber_231.jpg		Side facing image of a vertically clad timber structure.	Timber 0.8917128 Glazing 0.09392864 Bricks 0.0063875476 Concrete 0.0047886833 Steel 0.0031823635 Evaluation time: 0.718s
timber_209.jpg		Side facing image of a timber roof structure.	Timber 0.47294402 Glazing 0.25415573 Steel 0.16148311 Bricks 0.073806666 Concrete 0.037610576 Evaluation time: 0.763s
Final test accuracy of simulation			88.1%

File Name	Test Image	Justification/Description	Classification
			500 Iterations
glazing_013.jpg		Side facing image of a fully glazed facade.	Glazing 0.72471374 Concrete 0.12537274 Steel 0.0979159 Timber 0.027446369 Bricks 0.024551224 Evaluation time: 0.729s
glazing_004.jpg		Side facing image of a typical residential window with brick wall.	Glazing 0.873808 Bricks 0.110593915 Timber 0.0084427465 Concrete 0.0038805883 Steel 0.0032747118 Evaluation time 0.742s
glazing_021.jpg		Side facing image of a glazed system.	Glazing 0.9481818 Timber 0.015983082 Concrete 0.015353925 Steel 0.012056595 Bricks 0.0084246695 Evaluation time: 0.767s
glazing_065.jpg		Front facing image of a typical residential window with brick wall.	Glazing 0.95424855 Bricks 0.039273195 Timber 0.002495824 Concrete 0.0023764893 Steel 0.0016060292 Evaluation time: 0.758s
glazing_278.jpg		Side facing image of a glazed facade.	Glazing 0.6881535 Timber 0.15066157 Steel 0.0992248 Concrete 0.034043185 Bricks 0.027916903 Evaluation time: 0.757s

CORONA Project Workflow

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An integrated mobile sensing platform that creates high resolution, mutli-spectral 3D urban surface maps, to classify materials and thermal performance, and prioritise retrofit investment."

PHASE 1: Capture Data

- Visual
- Thermal
- LiDAR
- GPS
- IMU

PHASE 2: Derive Features

- Classify Material
- Identify Façade Structure
- Identify Property Boundaries
- Calculate Building Mass

PHASE 3: Thermal Performance

- Detect Thermal Faults
- Identify Relative and Absolute Heat Loss
- Identify Heat Loss Remediation

PHASE 4: Optimization

- Cost of Retrofit vs Thermal Efficiency Gain
- Socioeconomic Identification

Optimise against other systemic influences (available power capacity in local power grid, climate variation (exposure) etc).

Phase 1: Capture Data

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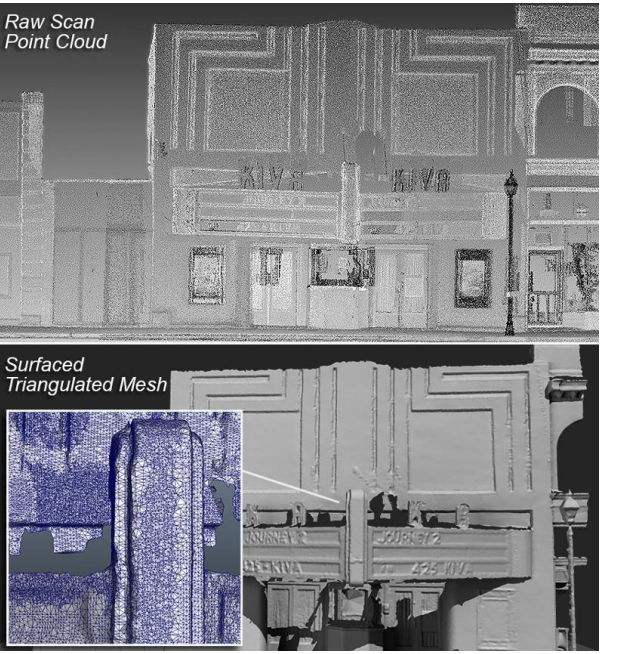
Develop an integrated mobile sensing platform to collect visual, thermal and 3D image capture (i.e. laser scanning) data.

Visual

Thermal



LiDAR

Phase 2: Derive Features

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Develop a workflow for automatic detection of buildings with heterogeneous appearance, classification of building materials and identification of building façade structures.

Phase 3: Thermal characteristics

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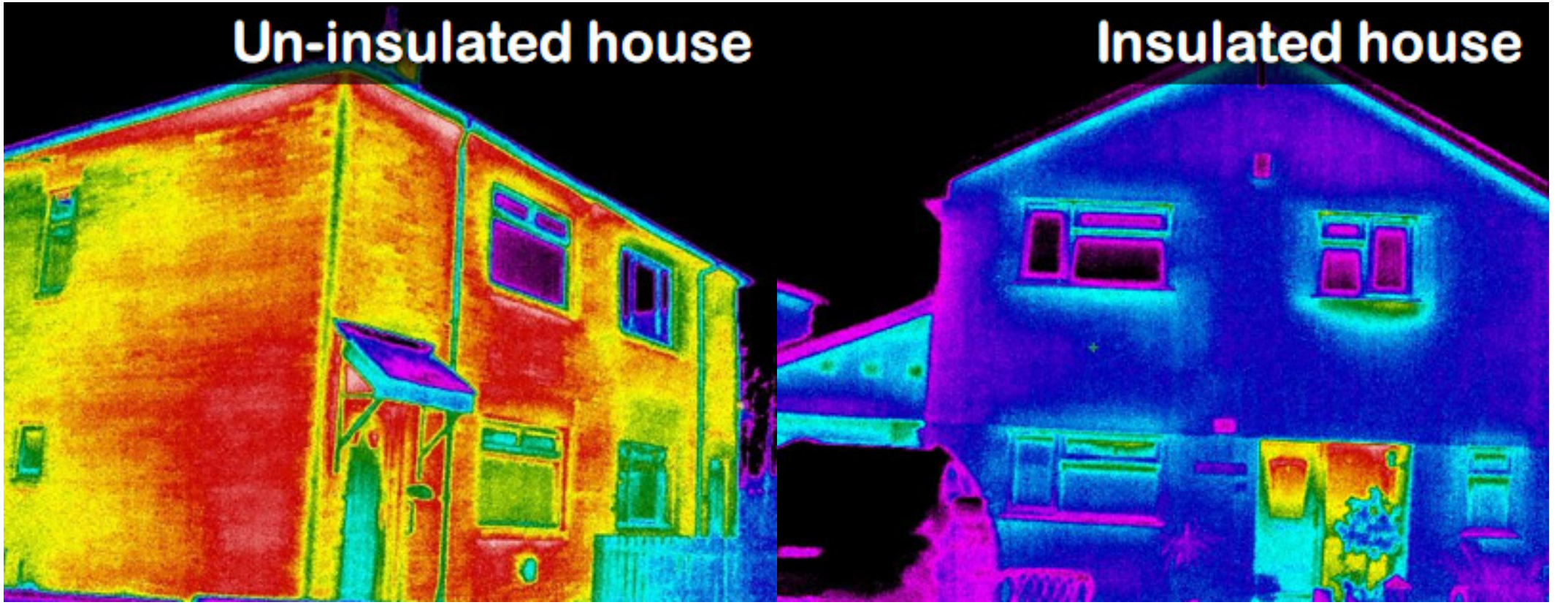
Develop a workflow for automatic classification of the thermal characteristics of the built environment.



Phase 4: Optimisation

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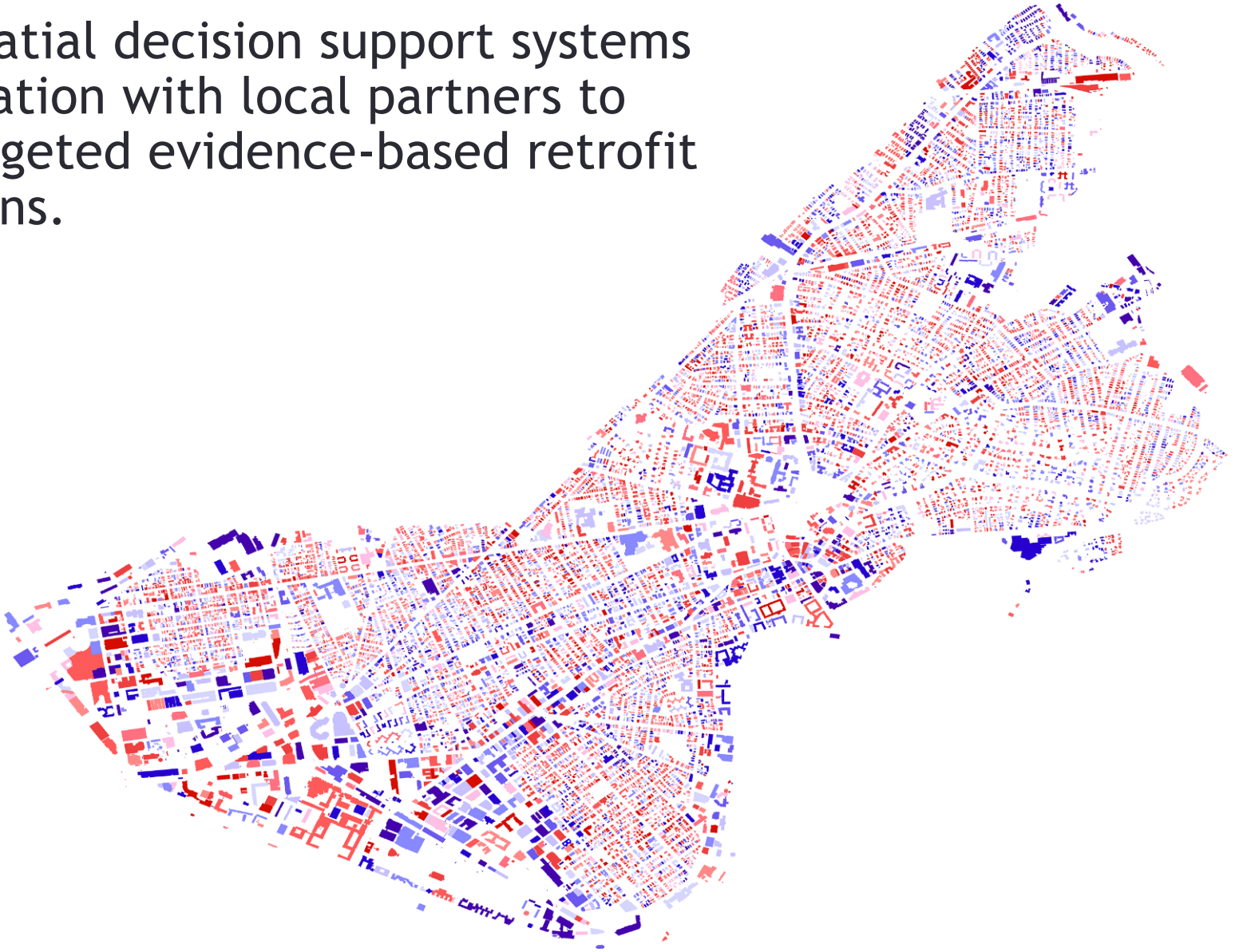
Develop spatial decision support systems in collaboration with local partners to support targeted evidence-based retrofit interventions.



Cataloguing City Assets

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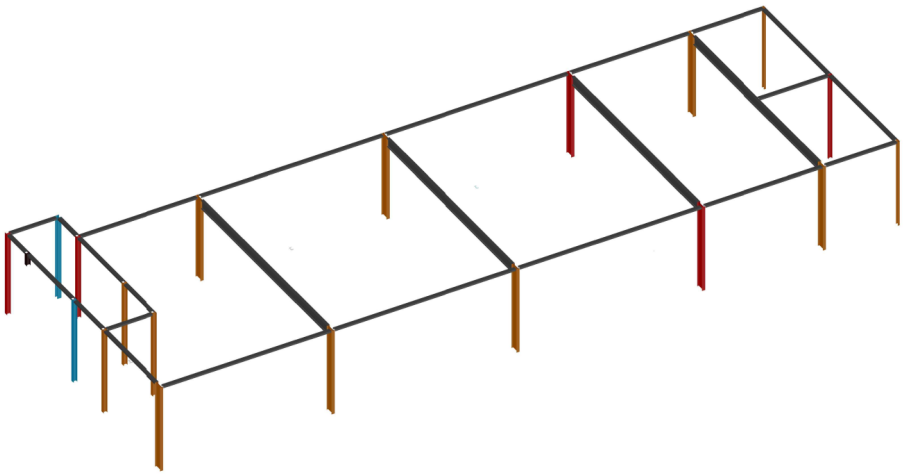
- 475,000 bricks in a street
- 75% of area pre-1925 construction, 3% 1925-1955, 22% Post 1955
- Can estimate that 364,800 bricks could be salvaged in the future
- Price of a new face brick approx. 75p
- Asset value: £273,600
- Embodied Carbon stock: 200,640 $kgCO_2$

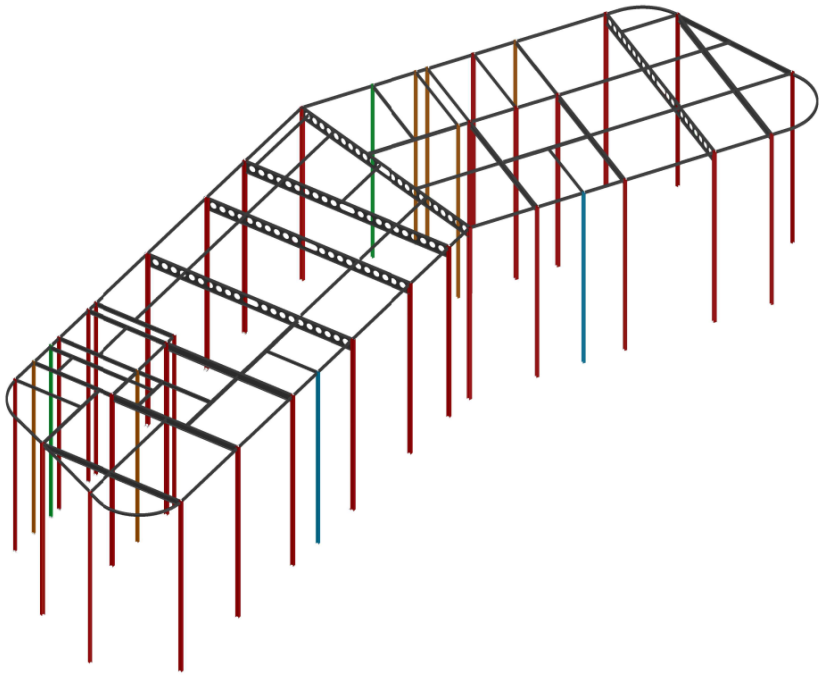
Age	Mortar types in Europe	Assumed reusability
Pre-1925	Likely to be lime mortar	100%
1925-1955	Could be lime, cement, or a mixture	60%
Post-1955	Likely to be cement	0%

Adapted from Nordby et al. (2009)

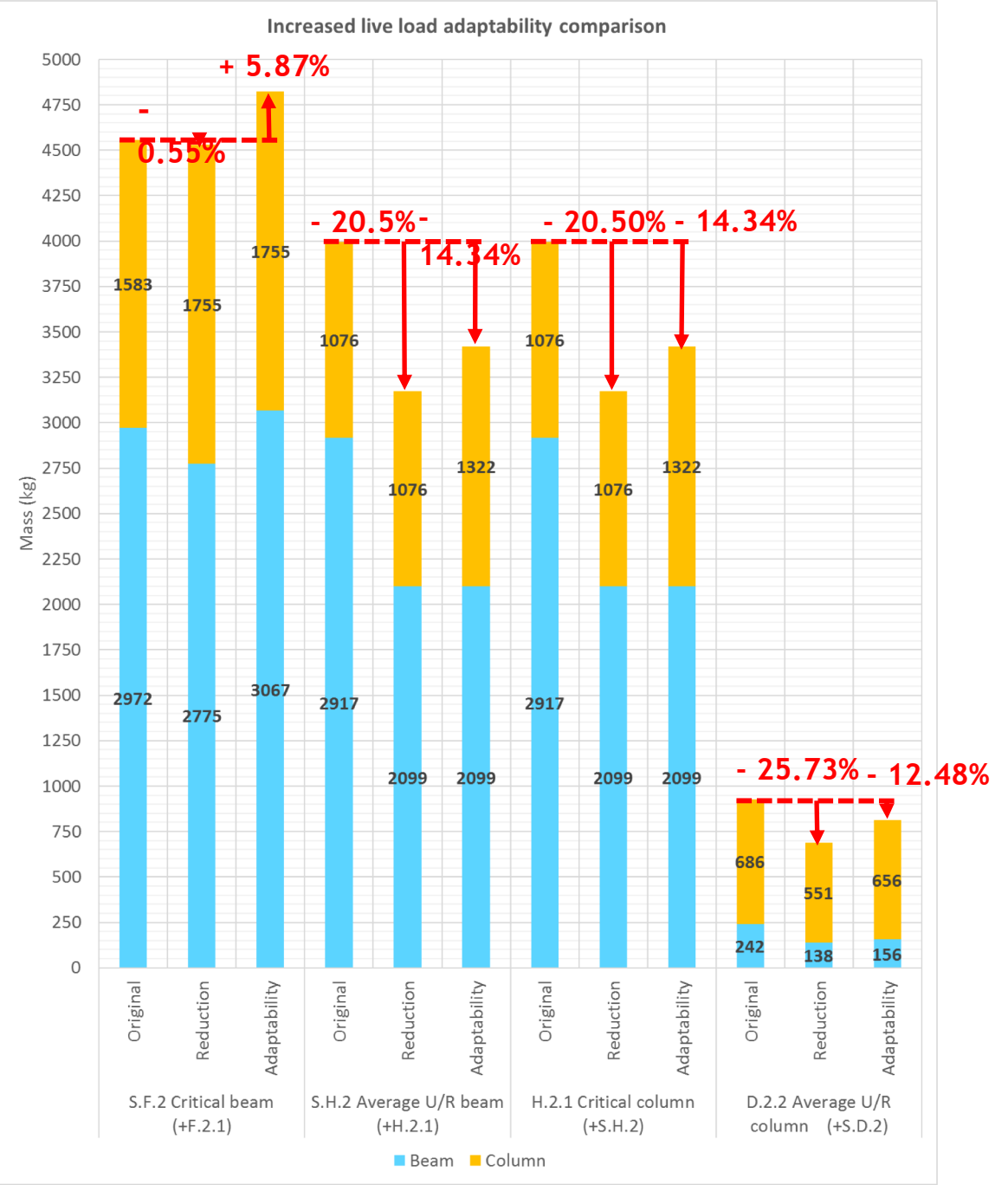
Building Scale: Adaptable Buildings

Material Demand of Adaptability: Case Study Assessment & Re-Design

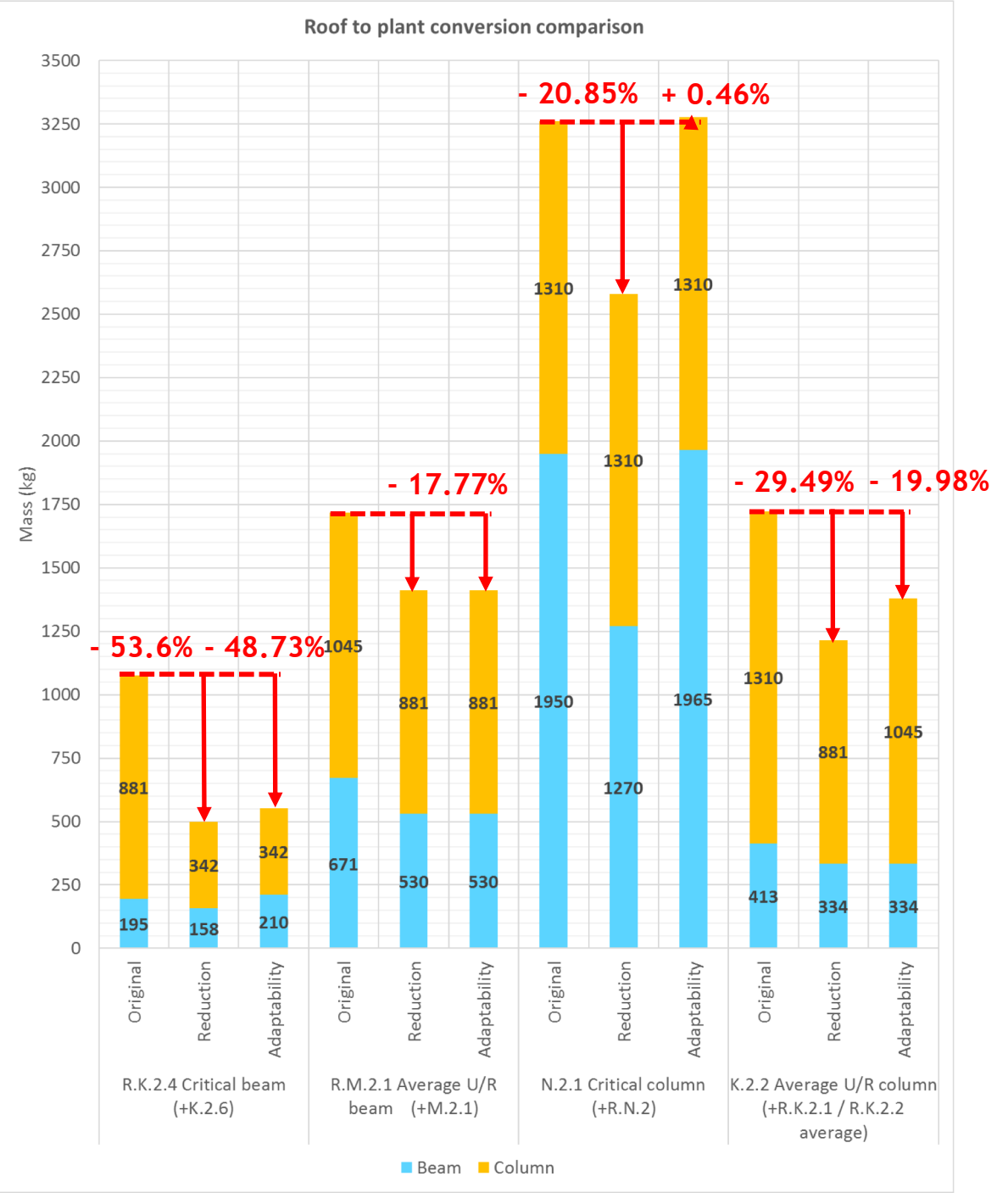




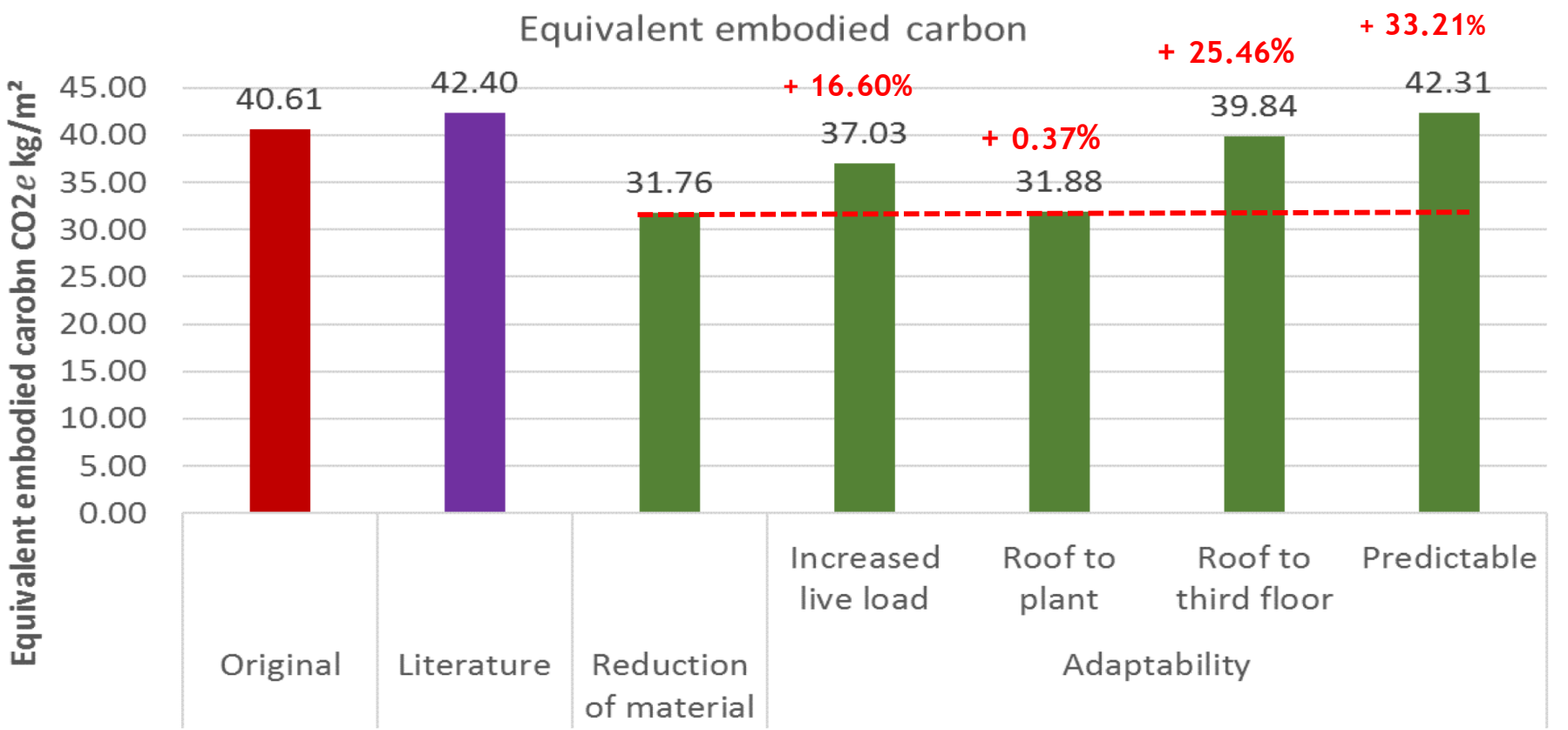
Live load increase: 3.5KN/m² to 5KN/m²



Converting roof to plant room



Embodied carbon variation across design options



Adaptability Next Steps & Future Work

- Building up case study set –investigating if other case studies show the same patterns
- Aiming to assess 20 steel frame buildings
- Expand adaptability criteria investigated – include potential for vertical expansion – same construction method & lighter materials, e.g. CLT
- Investigate concrete & timber construction – do the same patterns hold?

Upcoming Work

- PhD Project: Understanding the relationship between resource consumption & development levels

- PhD Project: The potential of vertical extension in providing residential accommodation in the UK.