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Innovating Towards Net-Zero: Engineering Solutions for Climate Resilience;

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BACKGROUND

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- This statement is in response to a series of grand challenges facing a world of 7 billion people heading to 9 billion plus by 2050. Another response to these challenges can be seen in the United Nations Sustainable Development Goals (SDG's) for agenda 2030.

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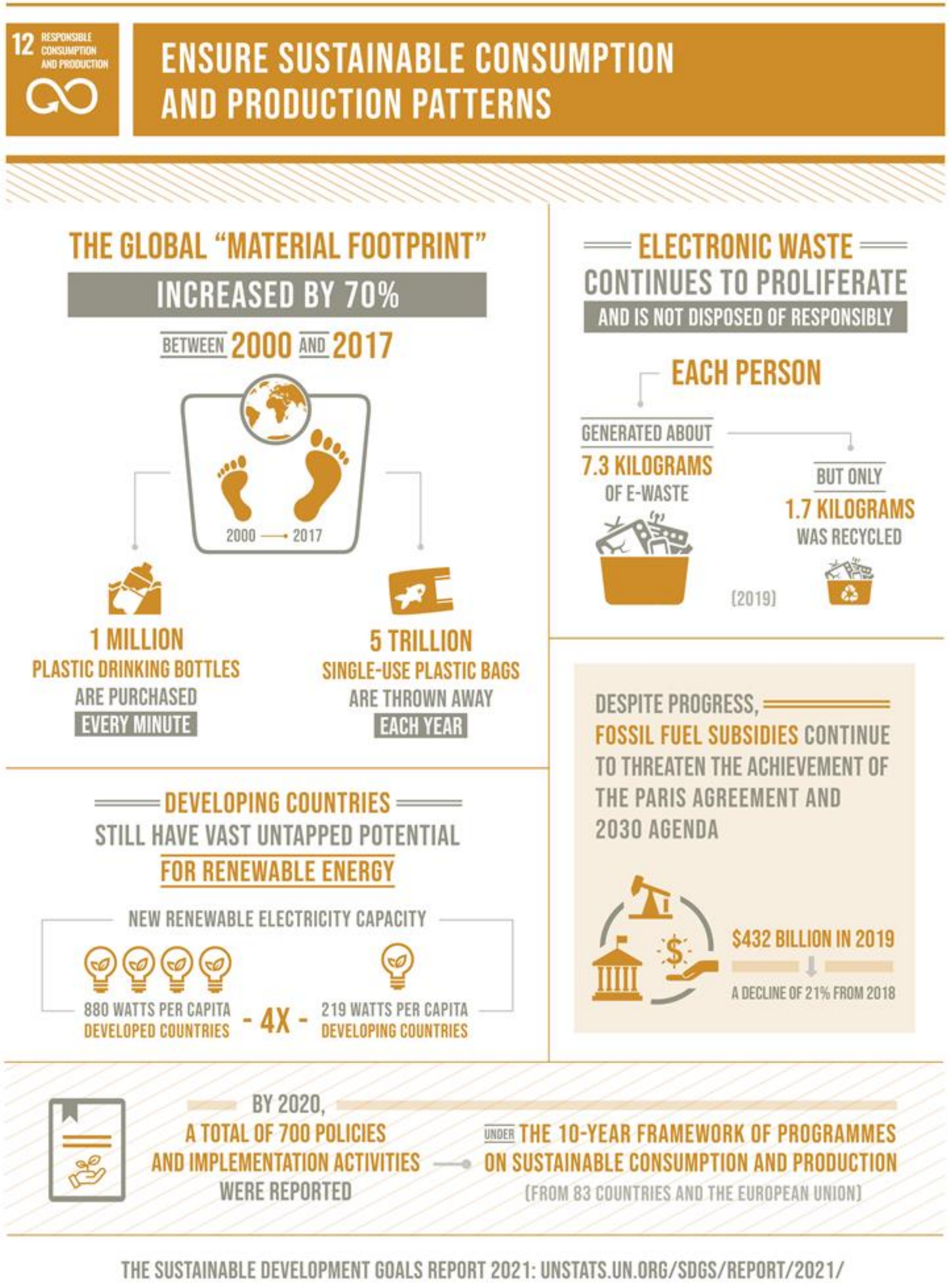
SDG12: Ensure Sustainable Consumption and Production;



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Resources

Population

1950 → 3 billion

2000 → 6 billion

2050 → 9 billion

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Floods in Pakistan/Bangladesh


Floods in Queensland
Australia

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Flooding in England January and February 2014

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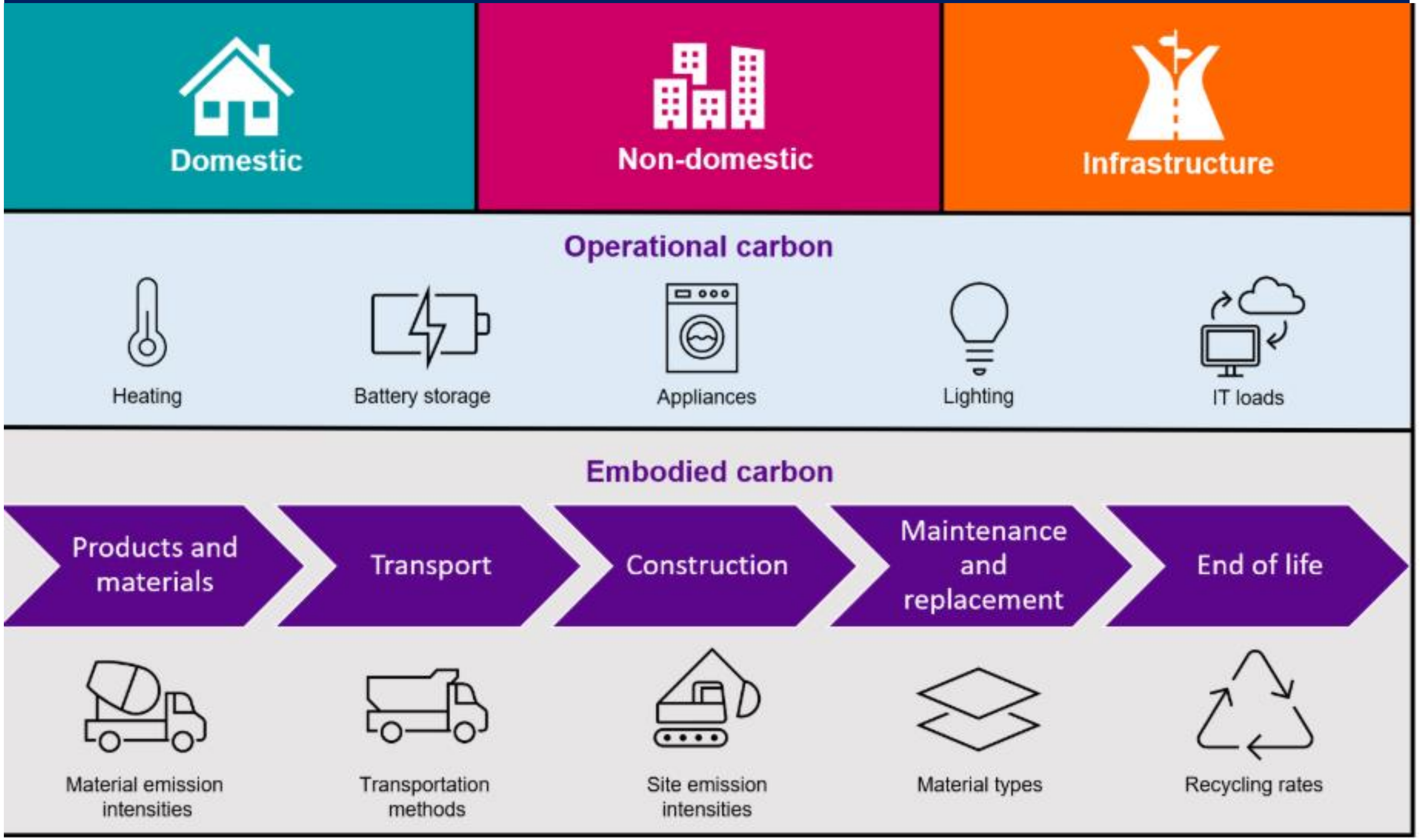
Net Zero Homes

Building Life Cycle



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Challenges /Opportunities of Low-Energy Retrofit

- **Challenges**
- Built environment accounts for large proportion of energy and carbon emission;
- Significant proportion of existing buildings were constructed when there was no strong energy efficiency component within the building regulations;
- These existing old buildings are reaching the end of their useful life;
- Significant cost and environmental impact to replace these buildings with new construction;
- Performance gap;
- Unintended consequences of building energy efficiency improvements;

LIVING/CATALYST LABS

Living Labs (LLs) are open innovation ecosystems in real-life environments using iterative feedback processes throughout a lifecycle approach of an innovation to create sustainable impact.

In this context, living labs operate as intermediaries/orchestrators among citizens, research organisations, companies and government agencies/levels. Within a wide variety of living labs, they all have common characteristics, **user and co-creation environment.**

Technology Readiness Levels

Opportunities – New materials and technologies

Envelope Elements

- Aerogel mortar
- VIP
- Ventilated Facade
- BIPV System
- EC Glazing
- High Efficiency Glazing

Building Services/passive and active thermal storage

- HVAC system optimization
- PCM cooling and storage
- Seasonal thermal storage

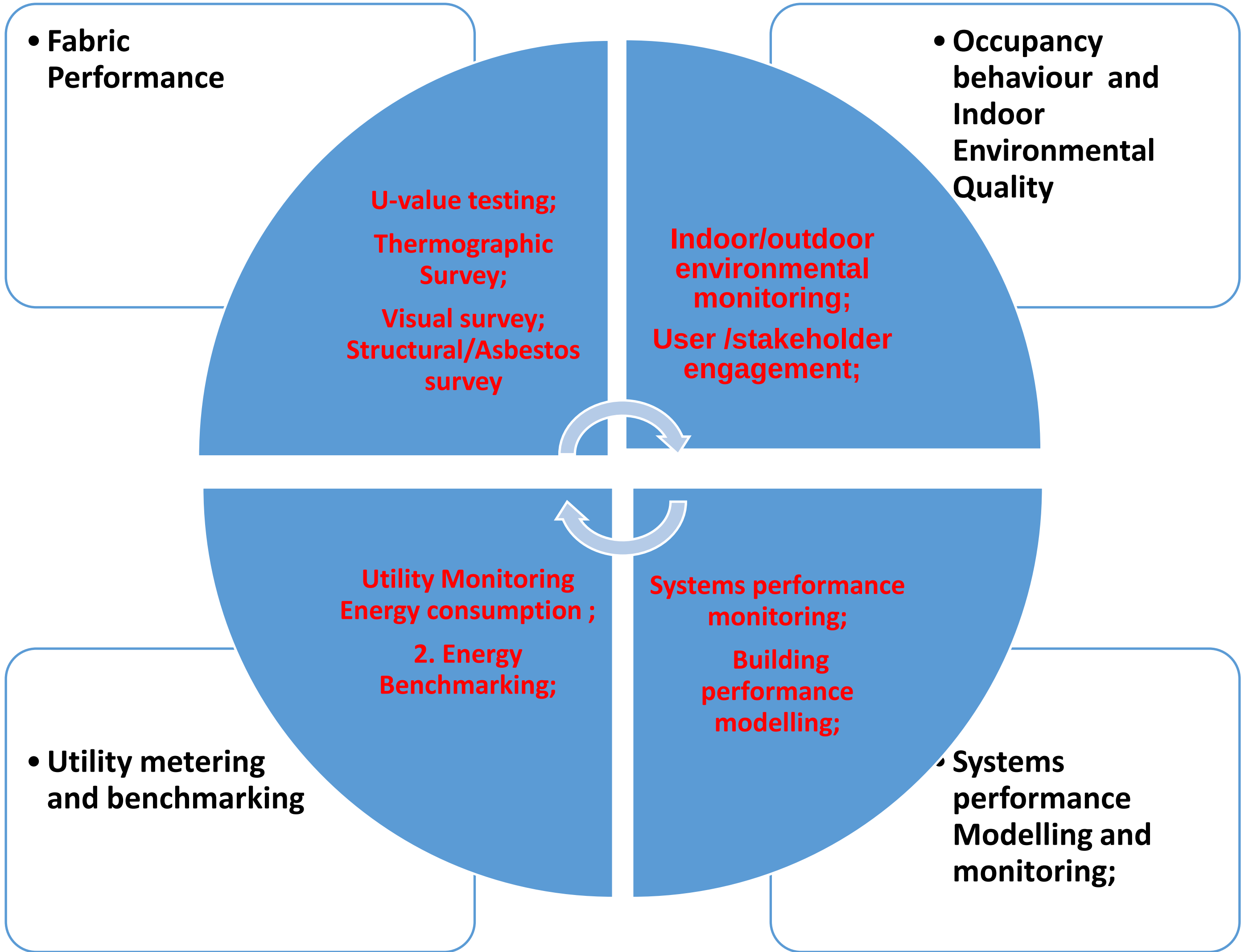
Lighting

- LED lighting

Renewables

- Solar thermal collectors
- Solar PV panels

BUILDING PERFORMANCE DIAGNOSTIC METHODOLOGY



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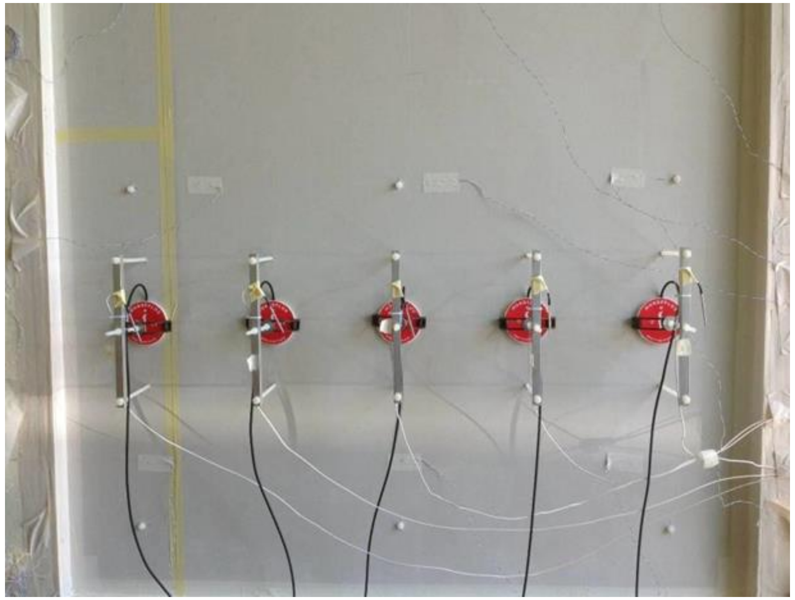
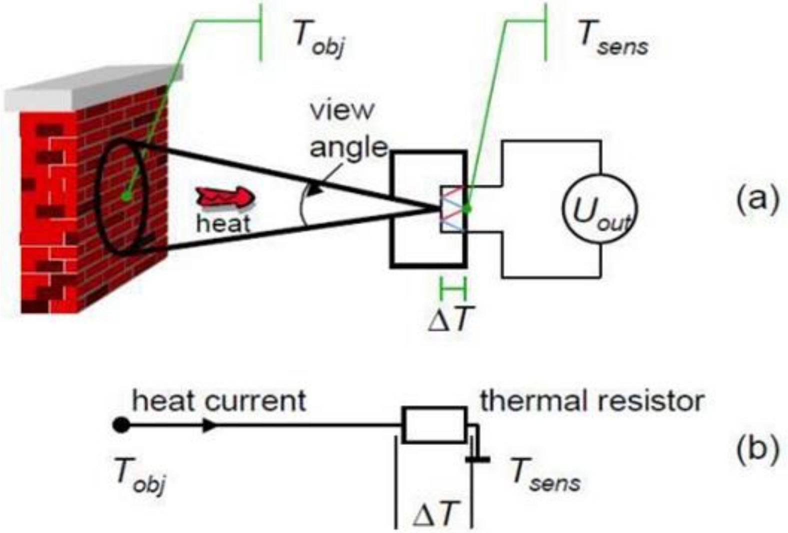
U-VALUE MEASUREMENT APPROACH

Surface Heat Flux measurement



$$Q = U\,[T_{in} - T_{out}] \quad (1)$$

Non contact method



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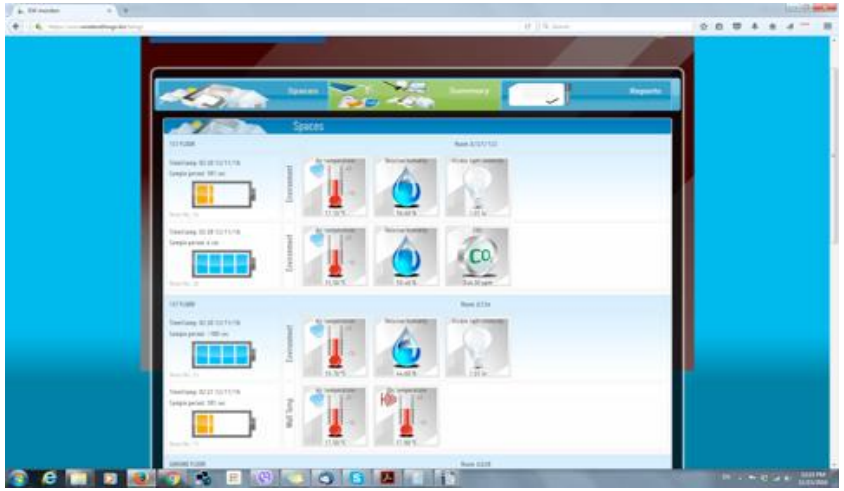
Data Dashboard



Weather Station

Temperature/humidity sensors

IoT Desktop Station with Wlan and Ethernet;

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TECHNOLOGY INTEGRATION

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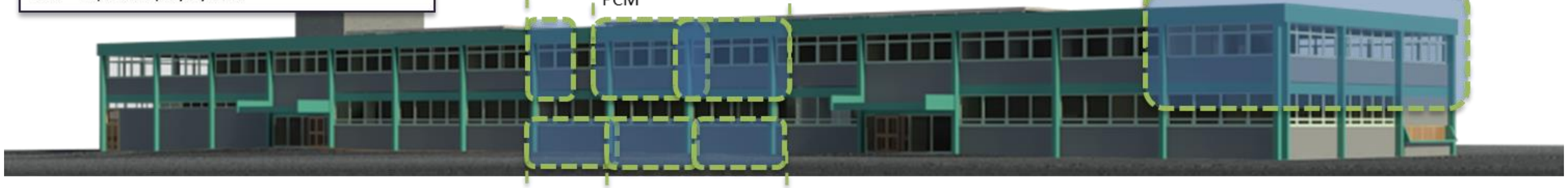
PCM – Phase Change Materials
PV – Photovoltaics
VIP - Vacuum Insulated Panels
DGU – Double Glazed Unit
ETICS – External Thermal Insulation Composite System
EPS - Expanded polystyrene



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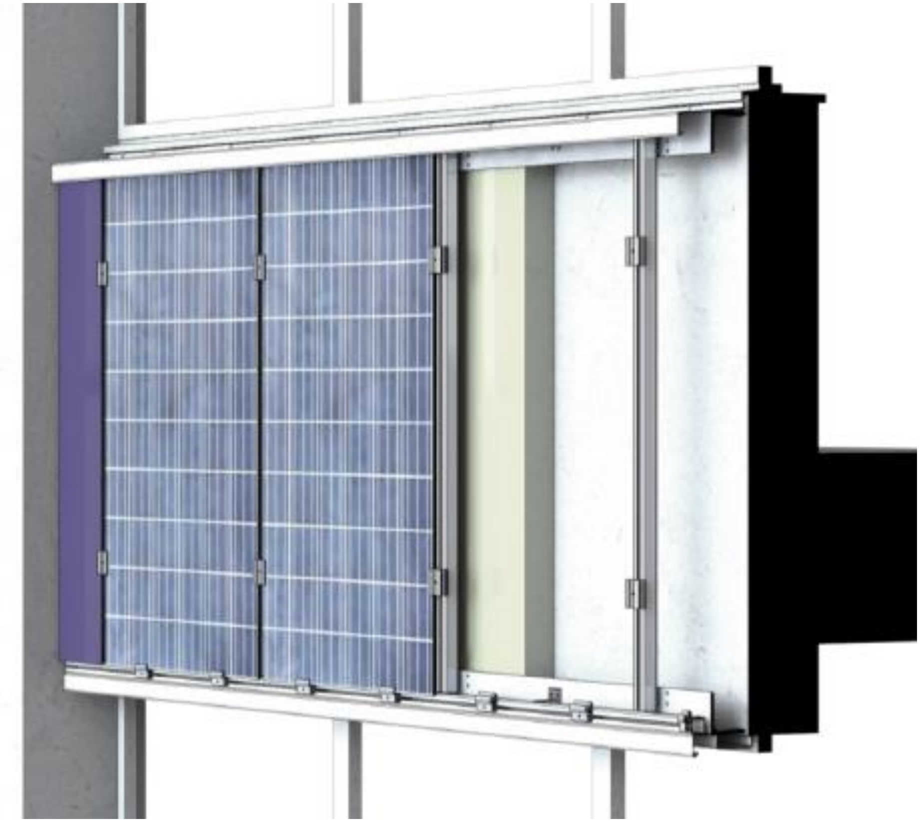
PV Ventilated Façade

- Avoids thermal bridges
- Improvement of thermal and acoustic performance of the envelope
- Electric power generation
- Change in the aesthetics of the building



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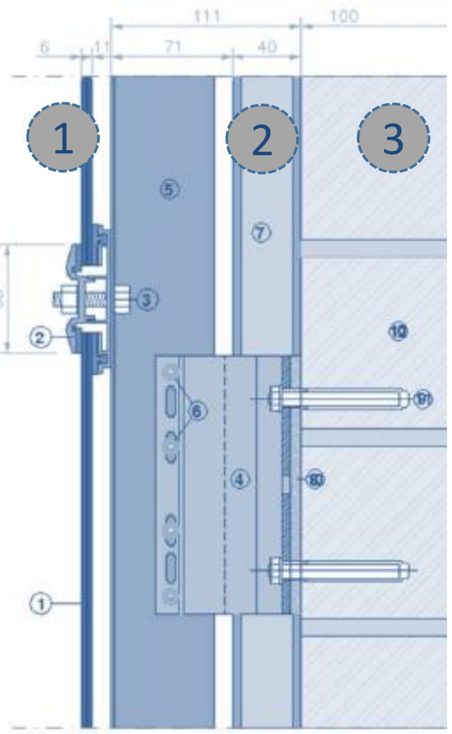
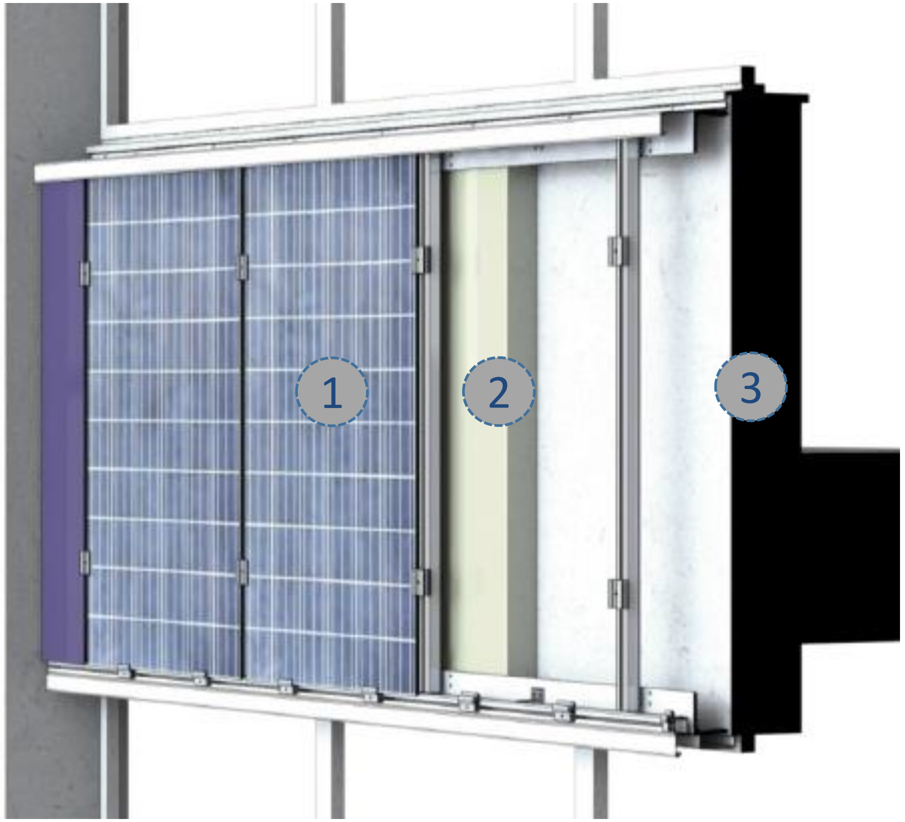
PV Ventilated Façade

1. Photovoltaic panel
2. Vacuum insulated panel
3. Existing wall





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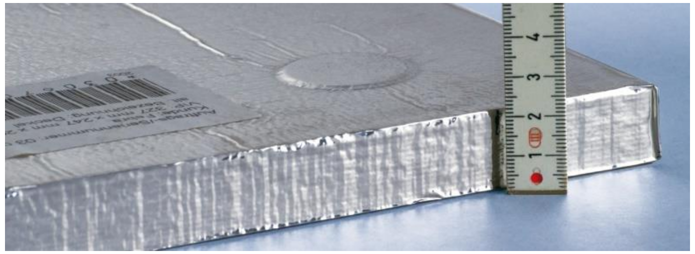
Vacuum Insulated Panels



Core material + foil envelope
The core of the plate is evacuated.
Foil envelope keeps the vacuum inside.

High-efficiency insulation with reduced thickness

Low value of thermal conductivity (λ= 0,003-0,004 W/mK)

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EC/PV WINDOWS

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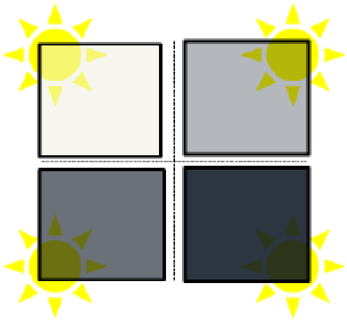
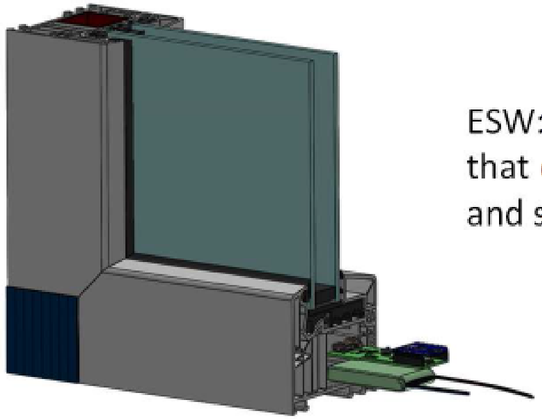
EC/PV windows





ESW: variable tinting that control glare and solar heat gain.

Can change the light transmission properties in a controlled and reversible manner when a small electric current flows through the device

Reduces energy expenses by 19% and 48% in cooling and lighting demand

Considered SMART WINDOWS

Aerogel Based Super-insulating Mortar

Combines aerogel with cement to provide a super-insulating mortar.

Low thermal conductivity at <0.020W/mK.

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Aerogel Based Super-insulating Mortar

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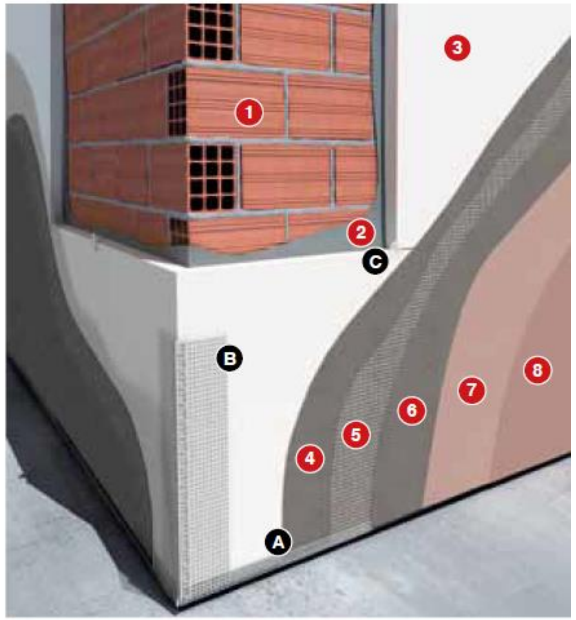
Aerogel Based Super-insulating Mortar



Aerogel mortar in external wall insulation

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PCM

PCMs: store and release thermal energy during the process of melting & freezing.

When they freeze, they release large amounts of energy. When they melt, energy is absorbed from the environment as it changes from solid to liquid.

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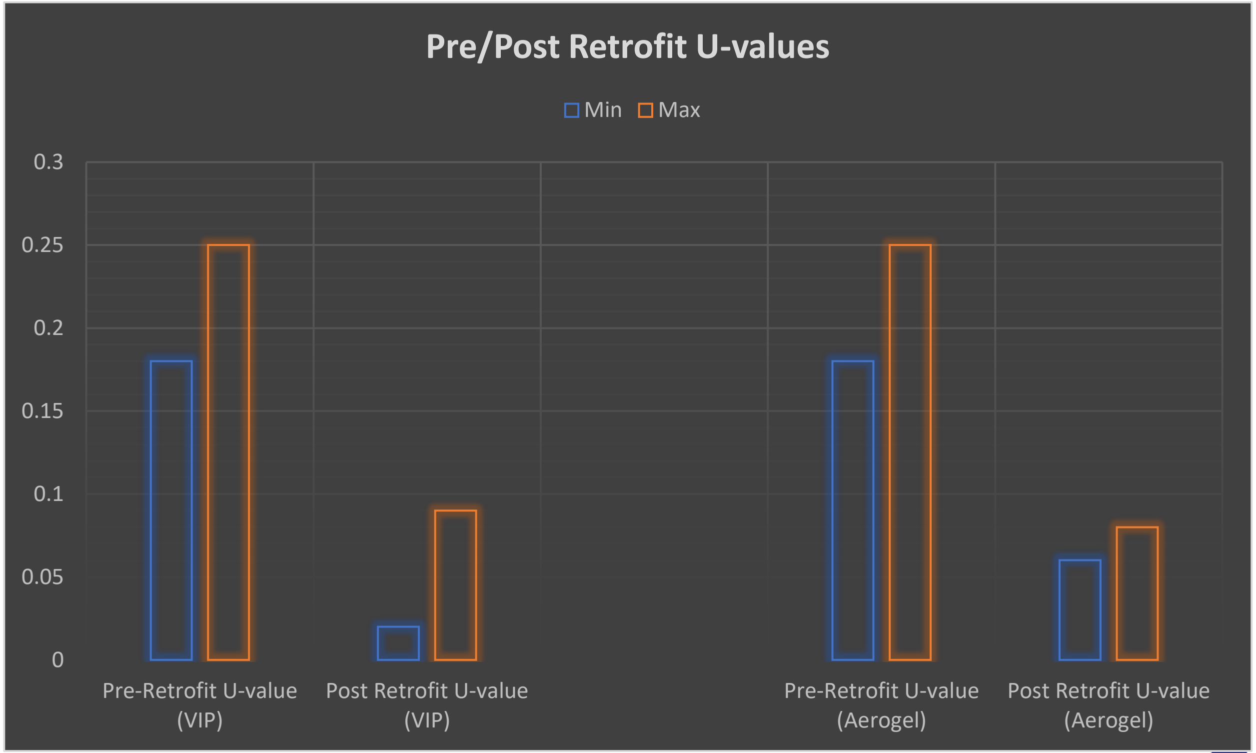
U-Values Measurement Result



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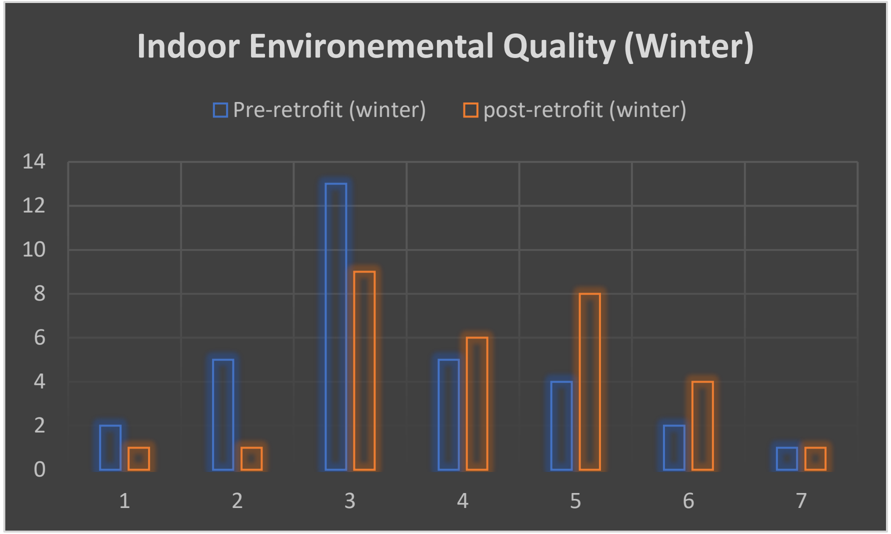
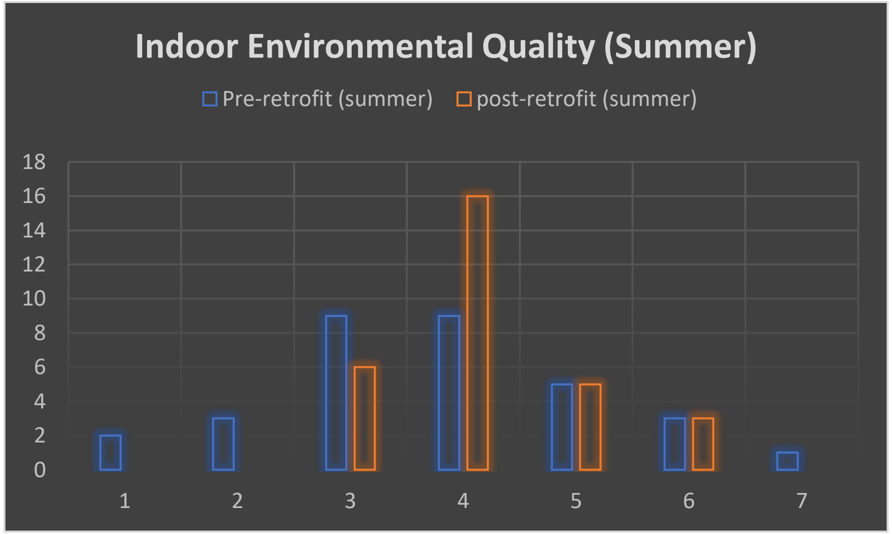
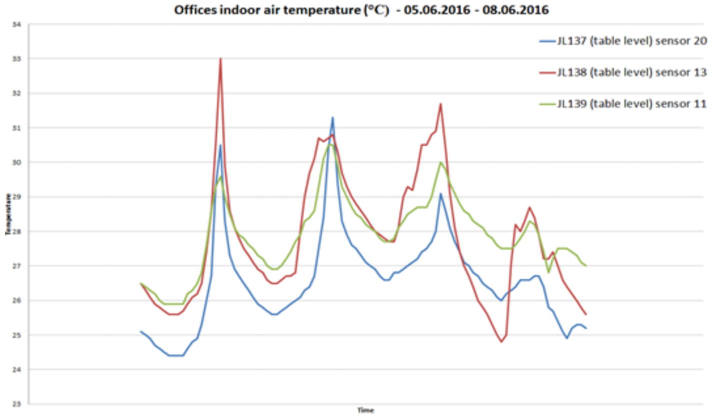
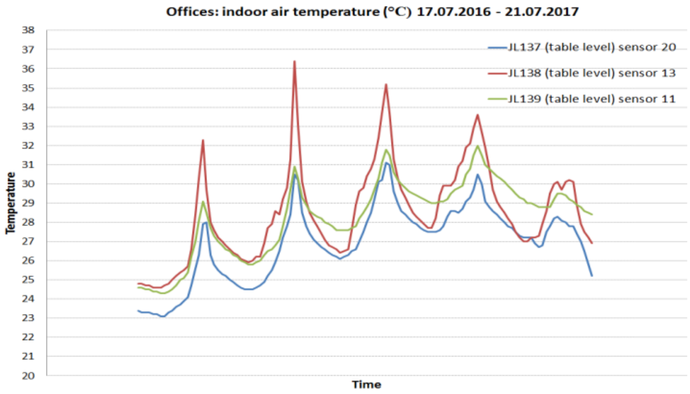
PCM IEQ - User Acceptance









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Energy Performance Result

	Richard Crossman Building				John Laing Building			
	Pre	Post Full	Change	Pre	Post	Post Full	Change	
Boilers energy (MWh)	2593.34	749.83	0.71	418.76	399.30	371.25	0.11	
Total system energy (MWh)	3180.57	1097.08	0.66	448.84	428.90	401.35	0.11	
Total lights energy (MWh)	0.00	0.00		0.00	0.00	0.00		
Total equip energy (MWh)	0.00	0.00		0.00	0.00	0.00		
Total nat. gas (MWh)	2593.34	749.83	0.71	418.76	399.30	371.25	0.11	
Total electricity (MWh)	1103.26	1168.41	-0.06	30.08	30.10	30.10	0.00	
Total Carbon Emissions (Kgco2)	1132751.00	632847.00	0.44	106064.00	101614.00	95810.00	0.10	
Total energy (MWh)	3696.60	1885.39	0.49	448.84	428.90	401.35	0.11	
Total energy (MWh/m2)	0.39	0.20	0.49	0.12	0.12	0.11	0.11	
Total energy (KWh/m2)	393.46	200.68	0.49	122.63	117.19	109.66	0.11	
Total grid disp. Elec (Mwh)	0.00	-32.84						

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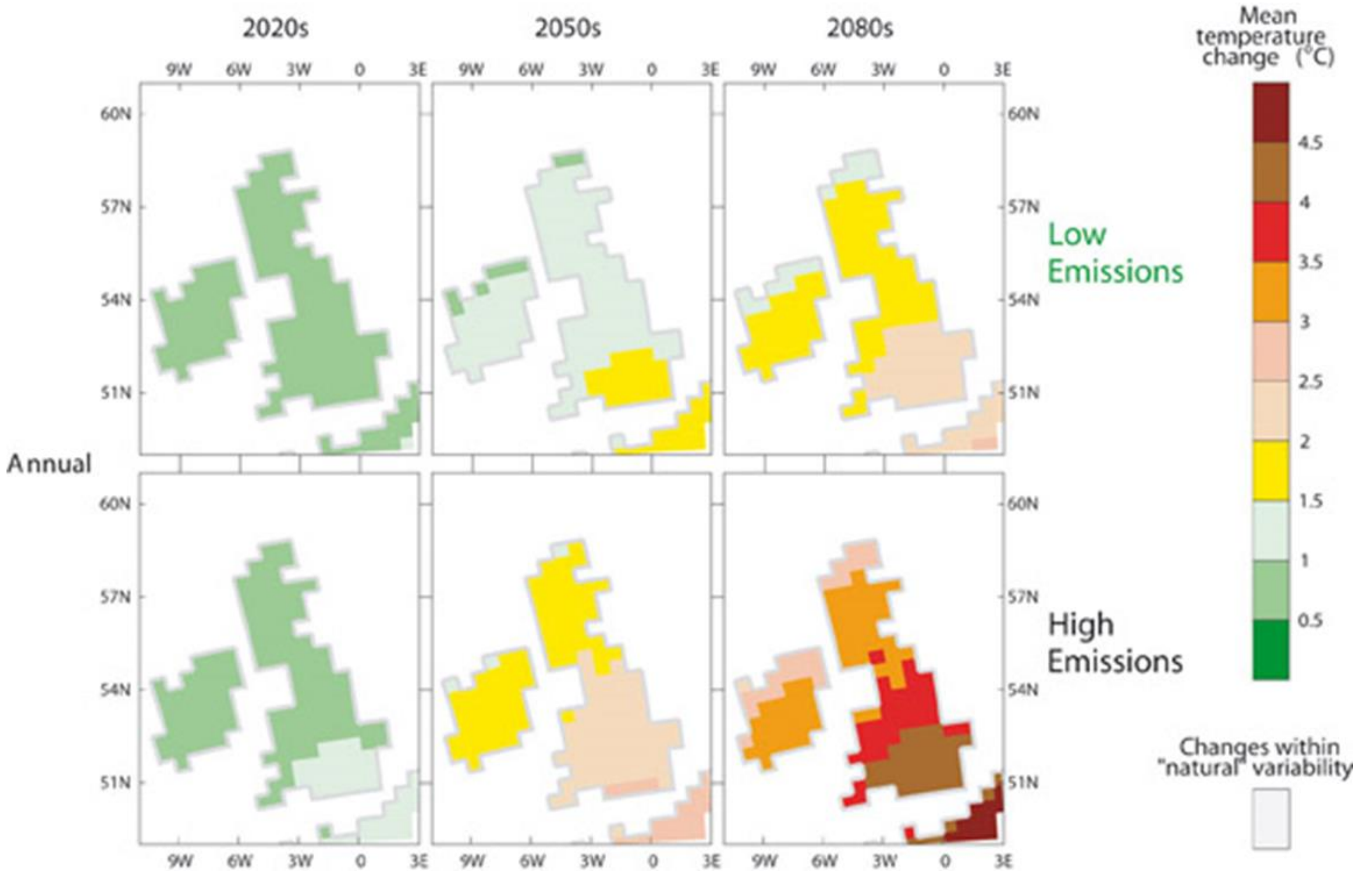
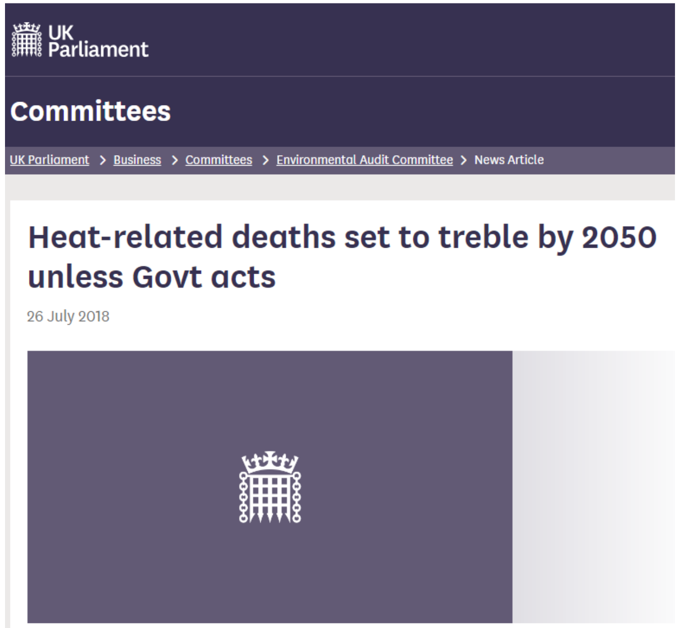
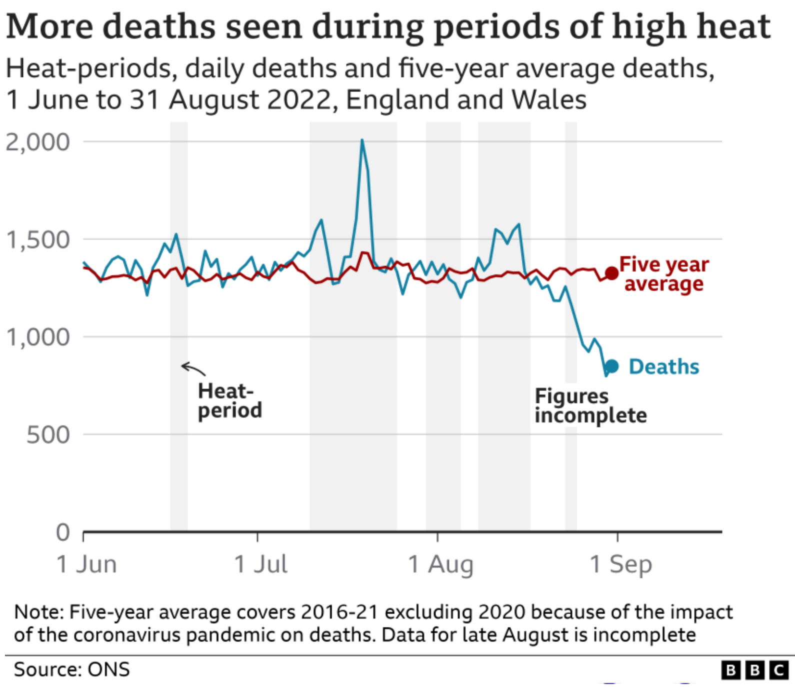
CLIMATE CHANGE IMPACT







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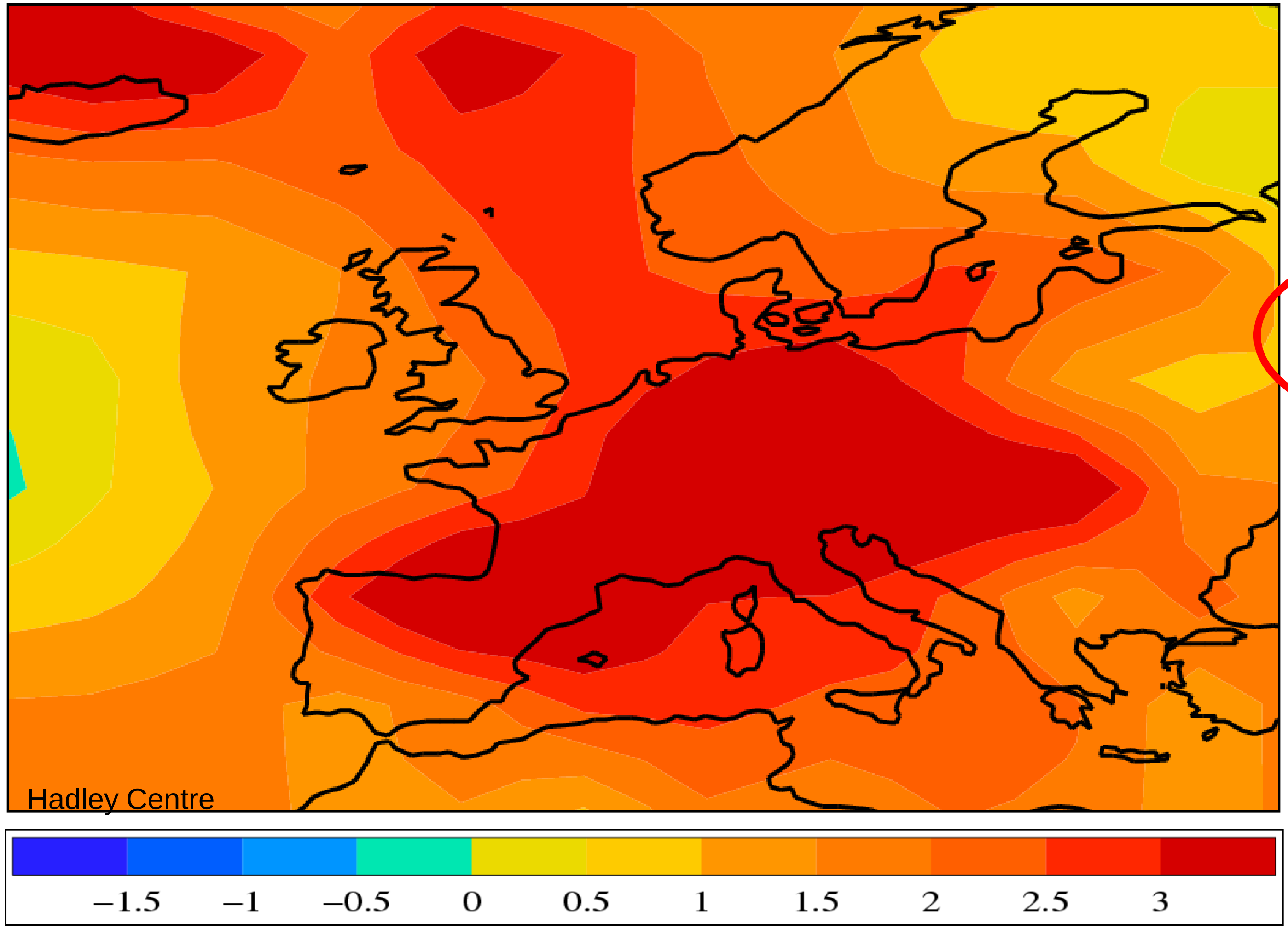
Introduction: Overheating risk

- The risk of overheating in buildings is increasing and projected to increase under different future climatic conditions.

- Therefore adaptation of existing buildings is required to mitigate this risk and ensure sustainability and resilience of the buildings stock.

INTRODUCTION: EXTREME EVENT



Europe:

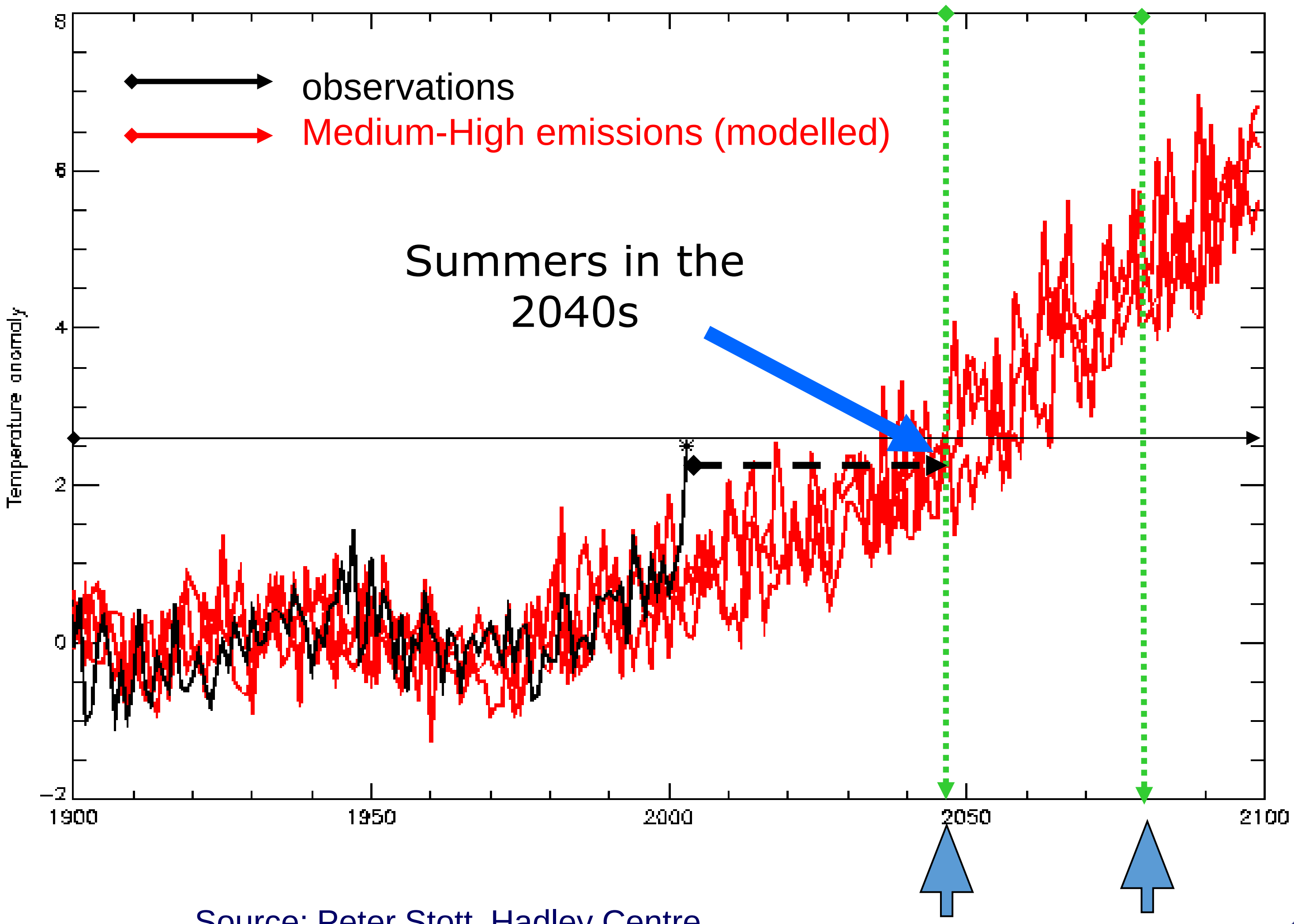
30,000 deaths attributed to the heat wave

Forest fires and crop damage seriously impacted economy

Economic losses in excess of £7.5bn

2003 TYPE OF SUMMER COULD BE NORMAL BY 2040S & COOL BY 2080S

European summer temperatures



Source: Peter Stott, Hadley Centre

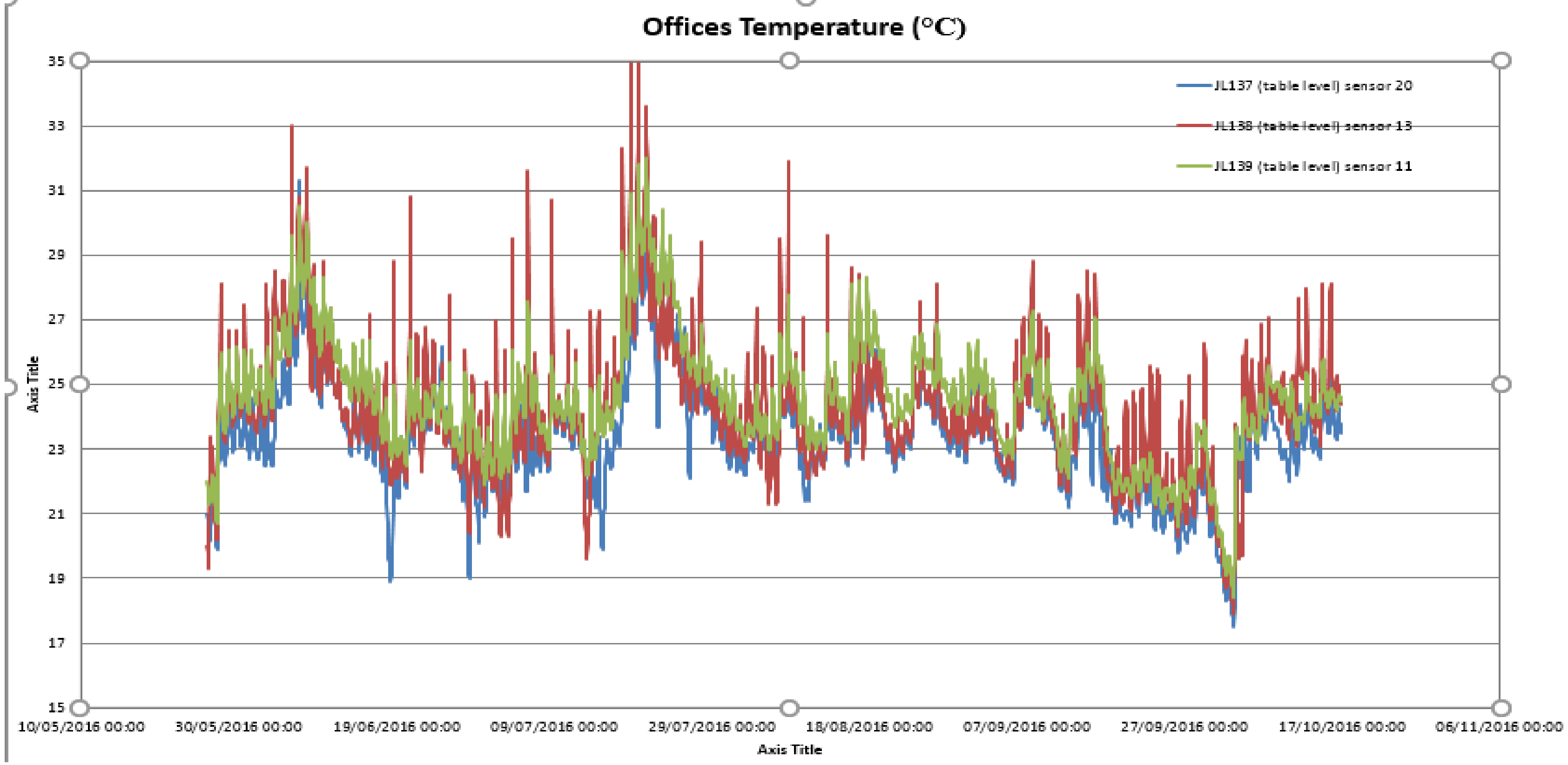
Ref : UK CIP

PCM INTEGRATION

PCM

- PCM was selected for use in the architectural studio space to counteract overheating.
- High Internal gains: Density of occupancy and heat emitting equipment gain;
- The space is naturally ventilated providing the ideal environment for testing a passive solution.
- To investigate different space use and control mechanisms: (control room)
- The selected offices – location and risk of overheating;

RESULTS: OFFICE TEMPERATURE



- Maximum value of indoor temperature over the summer period of 32°C and 31°C compared to 36.4°C in the control room;
- Temperature difference of up to 5K.

Indoor temperature

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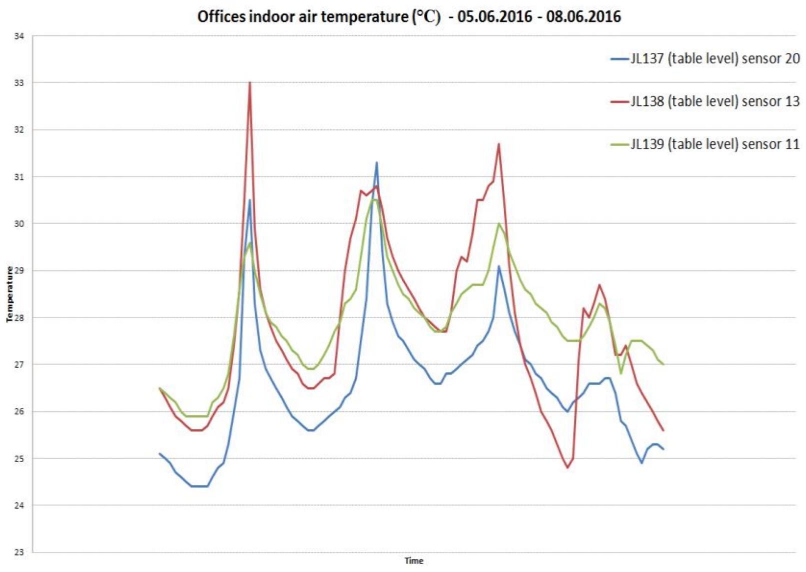

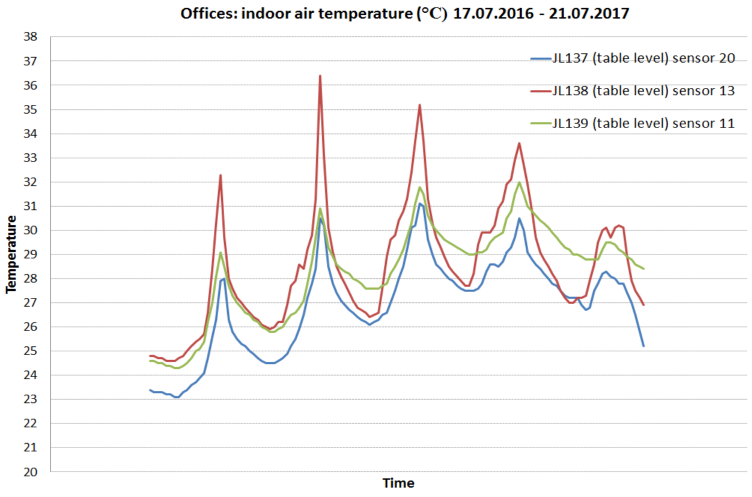

Diurnal temperature swing 6.8°C and 7.20 °C in rooms with PCM compared to 10.9°C in the control room;

The daily starting temperature is quite high

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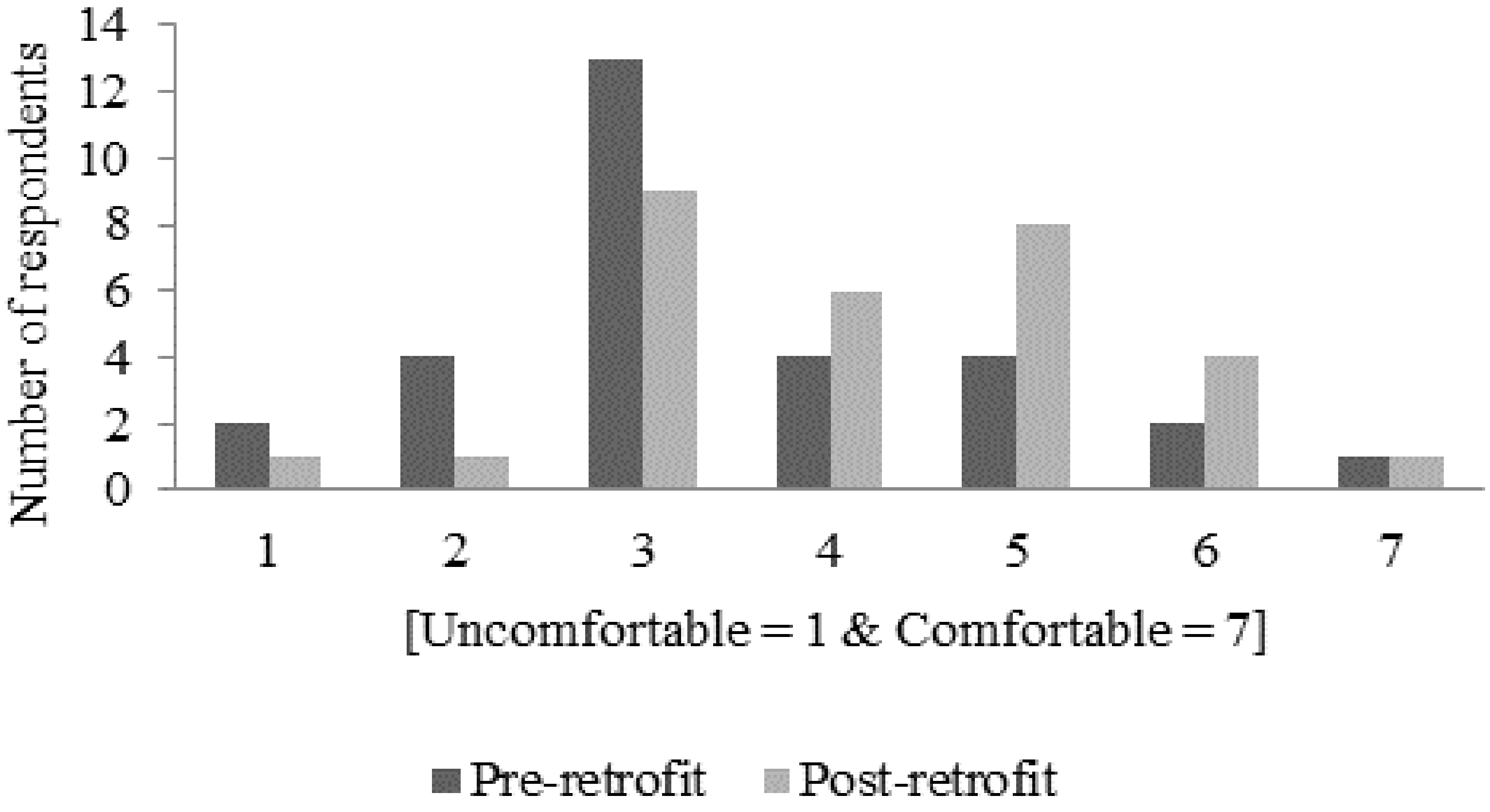
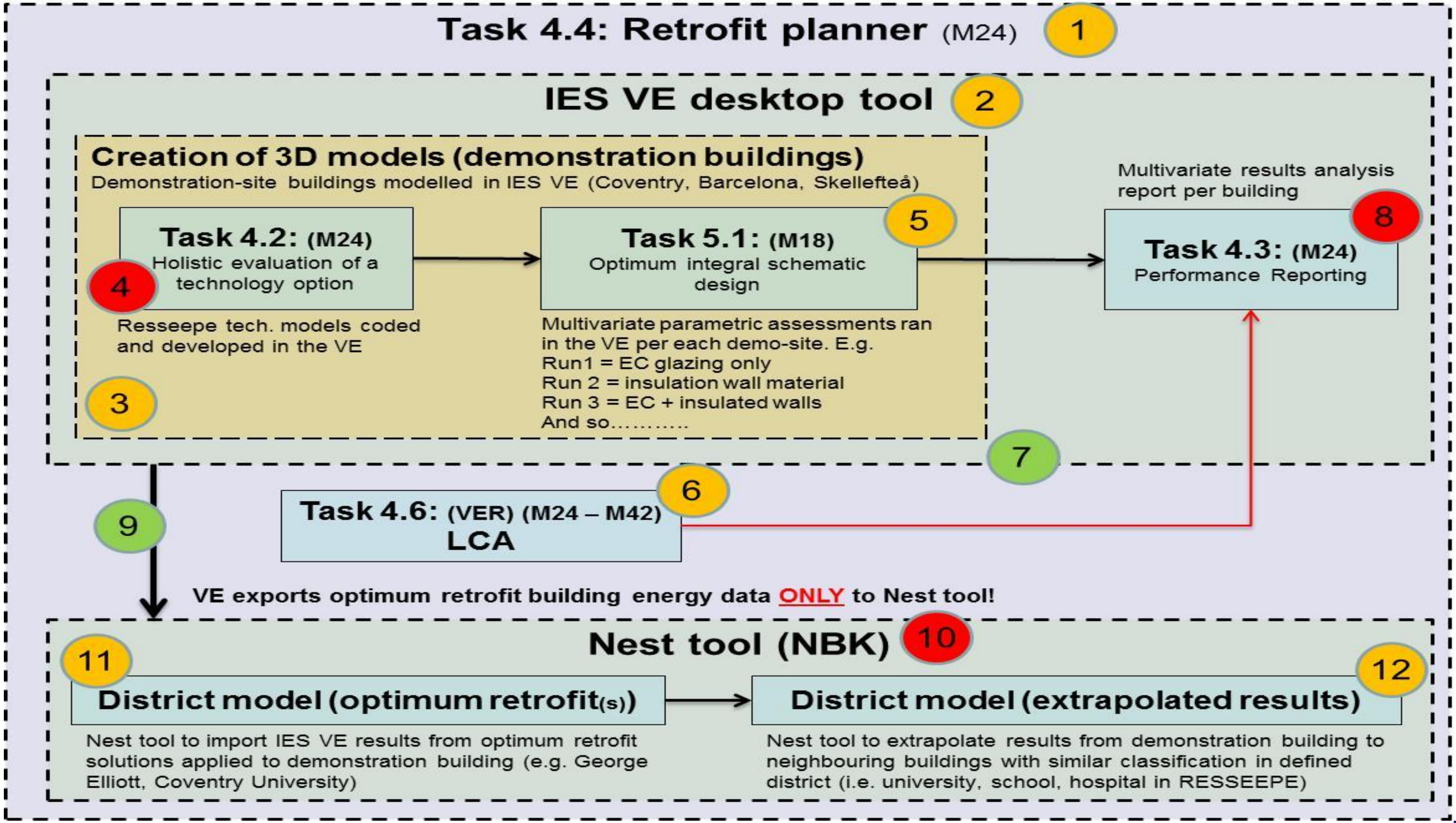
USER COMFORT EVALUATION



BUILDING PERFORMANCE MODELLING



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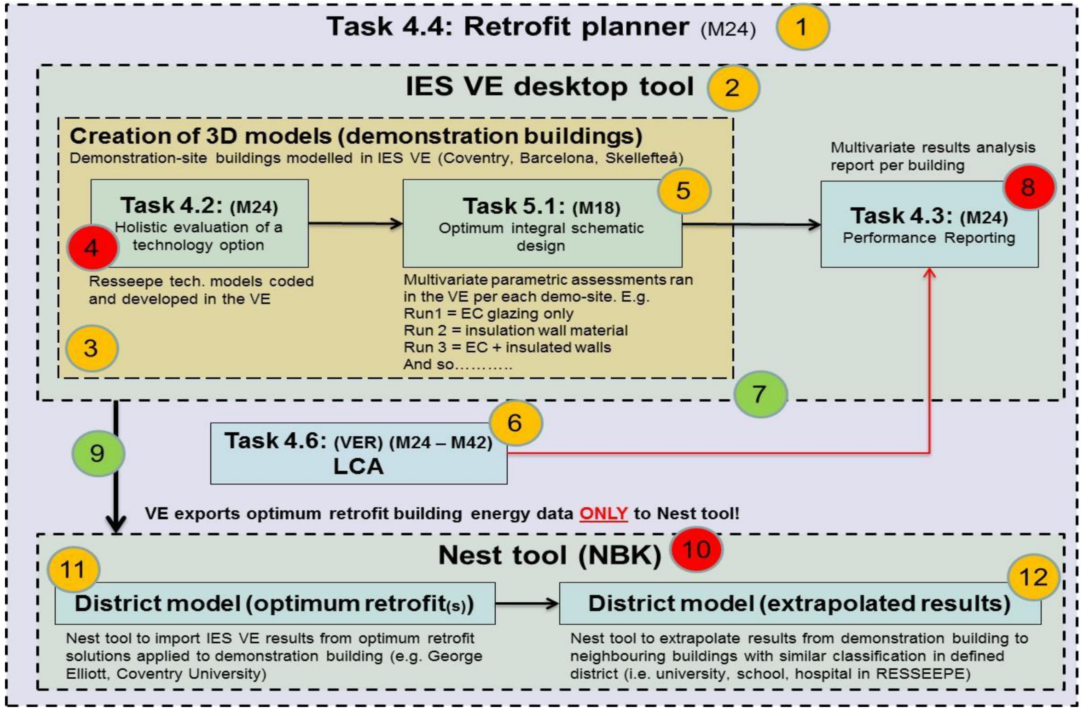
BUILDING PERFORMANCE MODELLING

Process of building performance modelling using IES virtual environment which includes the following key steps:

- Estimate the energy needs/consumptions before retrofitting
- Evaluate the impact of the solutions on the energy demand/consumption
- Justify the expected performance of the systems based on energy, cost, environment, comfort.
- Retrofit some areas of a building, and extrapolate the results to the whole building to evaluate the overall potential savings in the building after its refurbishment.



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Decision making and Technology Selection Process

Decision making criteria used to evaluate suitability of technologies for specific location, building energy and environmental performance as well as building use condition.

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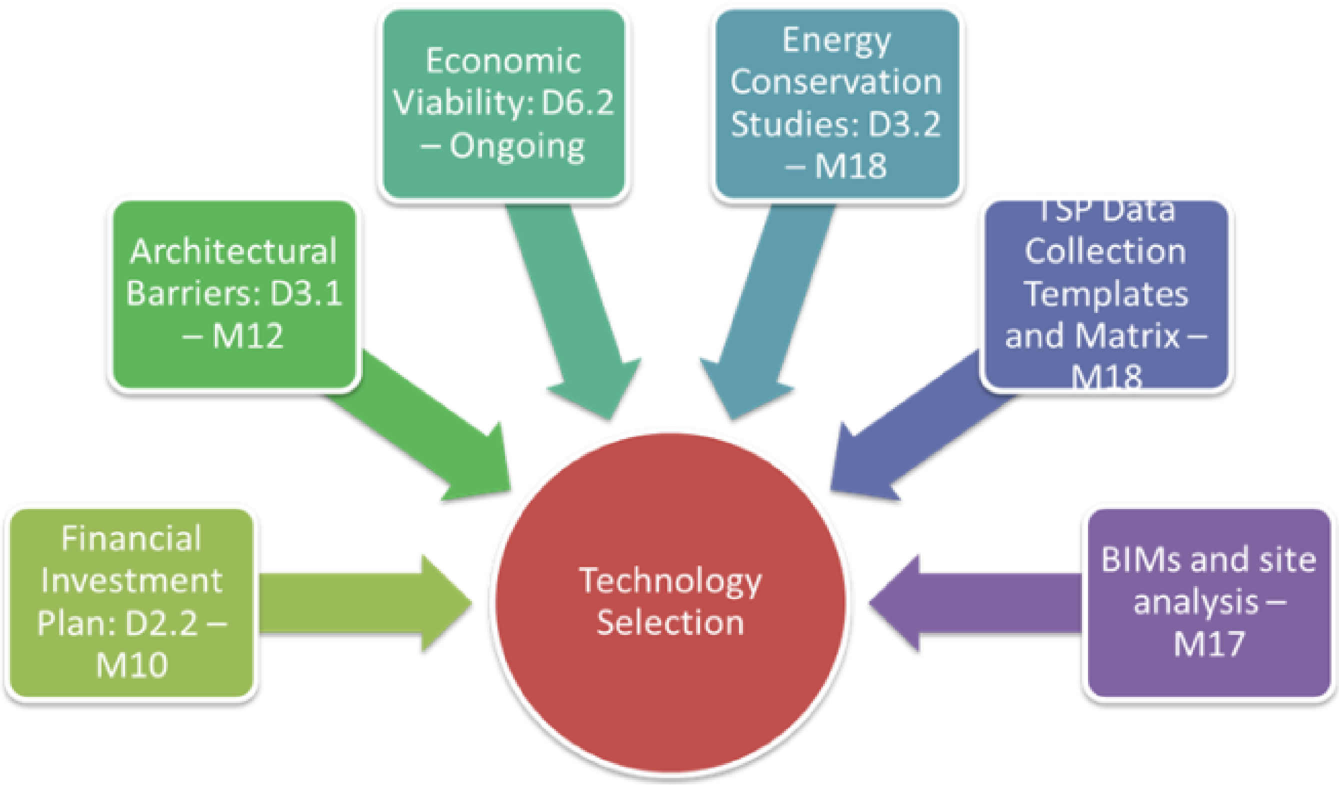
Decision making and Technology Selection Process



Evaluation procedures carried out for all demo-sites to ensure that the technologies selected will meet the objectives of the project both in terms of achieving 50% energy reduction within a specified budget.

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USER/STAKEHOLDER ENGAGEMENT PROCESS

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1
User perception before retrofitting

User satisfaction survey

User characteristics

User experience: Thermal, aural, and lighting comfort; IAQ, level of control, general maintenance

Performance data analysis

2
User acceptance of the selection process

Selection of building typology

Technology selection

Performance assessment

Cost evaluation

3
User acceptance of the installation process

User satisfaction survey

User characteristics

User experience: Level of disruption, Information and communication, Engagement and participation, Satisfaction / User acceptance

4
User perception after retrofitting

User satisfaction survey

Performance data analysis

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STAKEHOLDER ENGAGEMENT

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Lessons learnt from the stakeholder engagement:

- Stakeholder Engagement must be early, deliberate and for specific purpose;
- Stakeholder/user engagement must be planned through different stages of the project lifecycle;
- Engage wider stakeholders in the technology selection process;
- The engagement of users in the entire process will help long term performance of the Technologies;
- Understand the constraint and the potential impact on key users and stakeholders;

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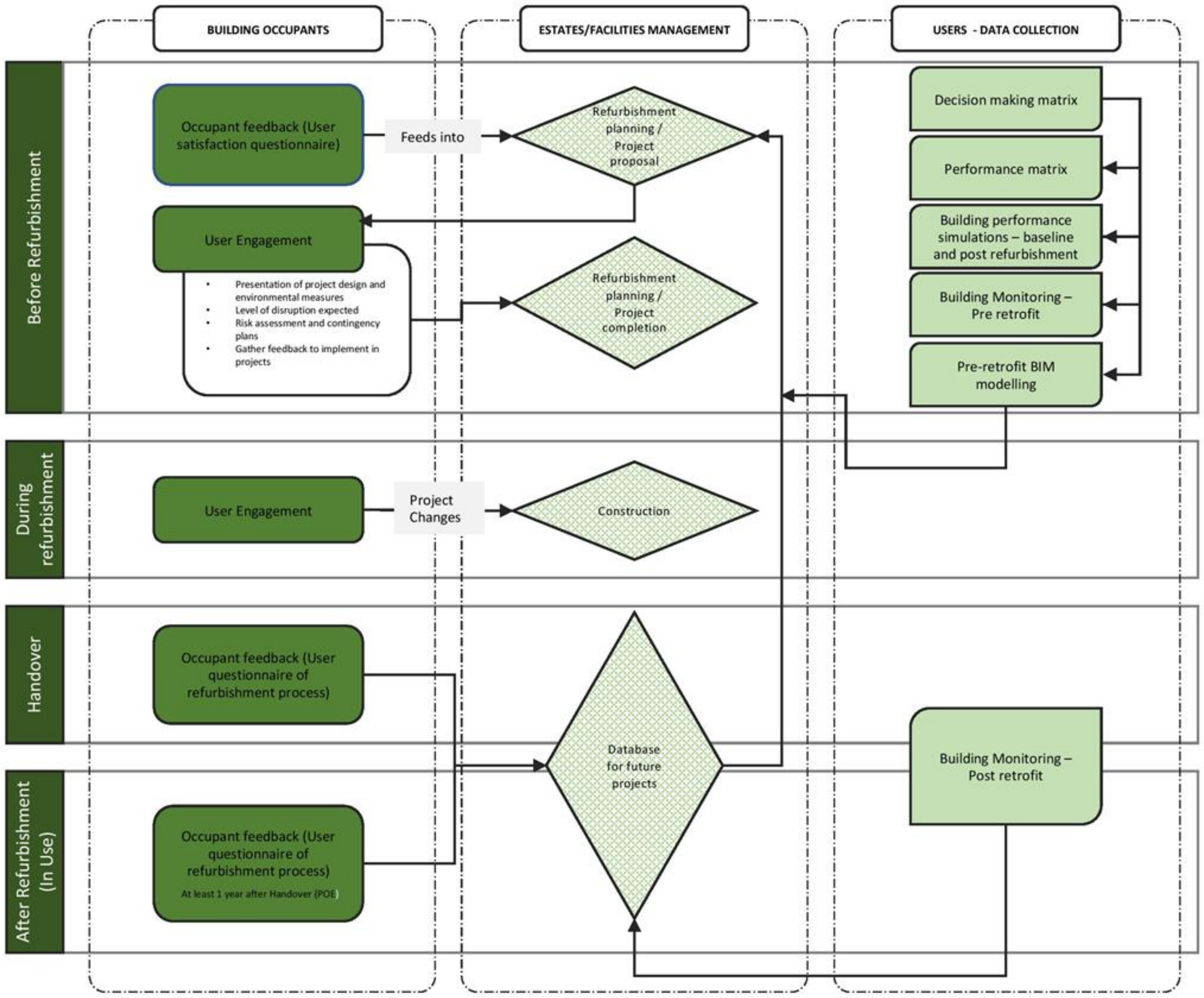
Framework for Performance Diagnostic/Evaluation



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Conclusion

- Integration performance evaluation;
- Human factors – Stakeholder engagement;
- Regulatory context;
- Business and operational environment;
- Local Technical Skills/upskilling needs;

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