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Sustainable Design and Construction: An Analysis of the West Cambridge Engineering Campus

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Abstract

This paper explores the sustainable design and construction approaches employed in developing the new engineering campus at the University of Cambridge. With sustainability as a core driver, the design aimed to minimize whole-life energy consumption and carbon footprint while providing an environment conducive to occupant well-being and promoting future flexibility. Using the innovative Energy Cost Metric (ECM) developed in collaboration with Sir David MacKay, this project exemplifies how whole-life energy assessments can guide sustainable decision-making in construction. Key sustainability strategies include energy-efficient building design, natural ventilation, renewable energy use, and integrating advanced building materials like self-healing concrete. The paper discusses the building's contribution to reducing embodied carbon, enhancing biodiversity, and promoting long-term adaptability, highlighting its alignment with the UN Sustainable Development Goals (SDGs).

Keywords: Sustainable design, energy efficiency, embodied carbon, renewable energy, building performance, flexibility, biodiversity, self-healing concrete

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1. Introduction

Sustainability in building design and construction has become critical in mitigating climate change and minimizing the environmental impact of urban development. The University of Cambridge's new West Cambridge Engineering Campus represents an ambitious effort to integrate sustainability throughout the building's lifecycle—from initial design to post-occupancy evaluation. This research examines the strategies deployed to reduce whole-life energy consumption and carbon emissions, promote user comfort, and enhance biodiversity on the site.

2. Design Objectives and Methodology

The brief for the engineering campus focused on creating a building that minimized whole-life energy and carbon emissions while maintaining a comfortable, flexible environment for occupants. The core design principles revolved around:

- Reducing whole-life energy and carbon emissions
- Promoting natural ventilation and minimizing mechanical systems where possible
- Ensuring long-term flexibility in building layout and services
- Avoiding unsustainable "green bling" technologies
- Meeting performance targets outlined during the design phase

Local planning requirements and the needs of the University shaped the building's form, massing, and layout. The project team aimed to balance sustainability goals with technical and operational requirements, ensuring that the building would perform as intended over its lifecycle.

3. Low Energy/Carbon Strategies

The project integrated several low-energy strategies to reduce the building's environmental impact:

- **Thermal Mass**: Exposed concrete slabs were used to stabilize indoor temperatures, storing heat in summer and releasing it during winter. This design feature reduced the need for mechanical heating and cooling, contributing to passive climate control.
- **Natural Ventilation and Cooling**: High-level actuated louvres and manual windows were incorporated into the design, providing natural ventilation and securing nighttime cooling. The building's layout was also optimized to allow cross ventilation, particularly in the office spaces.
- **Energy Use Intensity (EUI)**: The predicted energy use intensity (EUI) ranged from 105 to 148 kWh/m^2/yr, with a reported in-use EUI of 85 kWh/m^2/yr in 2021. The building is powered entirely by electricity, partly sourced from a 10.8 kW photovoltaic (PV) array, which generates approximately 5,242 kWh/yr.

4. Embodied Carbon and Construction Materials

The building's embodied carbon was addressed through innovative design and material selection. Although the total embodied carbon for the building has not yet been fully measured, the University plans to measure it retrospectively using as-built drawings and supply-chain documentation as part of its carbon-offsetting strategy.

One key innovation was **self-healing concrete** in collaboration with the Department of Engineering. This concrete employs a graphene additive that responds to cracks by releasing a binder, maintaining the concrete's structural integrity over time. This advancement reduces the need for repairs, extending the building's lifecycle and lowering its embodied carbon footprint.

5. Renewable Energy Integration

The building's energy systems were designed to reduce reliance on non-renewable resources:

- **Ground Source Heat Pump (GSHP)**: A GSHP system stores excess heat from the laboratories, providing heating and cooling for the building throughout the year. The system is connected to fan coil units and underfloor heating systems, optimizing energy efficiency while maintaining occupant comfort.
- **Photovoltaic Array**: A rooftop PV array generates electricity to power the building, reducing the demand for grid energy and contributing to the University's sustainability targets.

6. Biodiversity and Water Management

The project incorporated several strategies to enhance biodiversity on-site and manage water sustainably:

- **Green Roof and Woodland Management**: The entire roof was planted with sedum, creating habitats for local wildlife and contributing to a net gain in soft landscaping on the site.

Additionally, a woodland management plan was commissioned to restore and maintain the woodland belt to the east, which had been cut back and replanted.

- **Sustainable Drainage Systems (SuDS)**: A blue/green roof and on-site swales were installed to manage water runoff, ensuring the site's drainage needs were sustainably met.

7. Flexibility and Future Adaptation

The building was designed to accommodate future changes in use, ensuring a long service life. A **modular approach** to the planning grid and service distribution was adopted, maximizing the building's adaptability. Service cores were located at the perimeter, allowing for easy expansion or reconfiguration without significant disruptions. The project followed a **circular design approach**, with 80% of the structural steel and facade components designed to be recoverable.

8. Post-Occupancy and Performance Analysis

Following the UK Government's **soft-landings framework**, a two-year post-occupancy monitoring period was instituted to assess whether the building meets its predicted performance targets. Sensors integrated throughout the building provide real-time data on energy consumption and other environmental factors, allowing for ongoing performance optimization.

The innovative **Energy Cost Metric (ECM)**, developed by the late Sir David MacKay, was employed to evaluate whole-life energy savings and associated costs. The ECM influenced vital design decisions, including choosing a GSHP over traditional gas boilers. This metric is now part of the University's standard guidelines for new buildings.

9. Conclusion

The University of Cambridge's new engineering campus is a model of sustainable building design. The project demonstrates how academic institutions can lead the way in sustainable construction by minimizing whole-life energy and carbon, enhancing occupant comfort, and ensuring future adaptability. Integrating innovations like self-healing concrete, dynamic solar shading, and data-driven performance monitoring ensures that the building will meet its sustainability goals for years. This project also serves as a valuable case study for the construction industry, providing lessons that can be applied to future sustainable building designs.

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