Institution: University of West London

Unit of Assessment: UoA 12 - Engineering

Title of case study: A holistic assessment of energy and CO2 measures within existing buildings to enhance the heating and cooling performance, and to achieve near zero energy targets

Period when the underpinning research was undertaken: 2011 to 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g., job title):	Period employed by submitting HEI:
Ali Bahadori-Jahromi	Professor of Civil Engineering	2008 to date

Period when the claimed impact occurred: 2015 to 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

Improving the energy efficiency of existing buildings is a crucial factor in addressing climate change. When retrofitting a building, engineers must consider many factors in determining whether any new energy or sustainability investment will deliver the required outcomes in any specific situation. Research led by Professor Bahadori-Jahromi has produced a novel methodology and modelling to help engineers undertake these assessments holistically. This has been an industry-focused programme of work, in collaboration with the Chartered Institute of Building Services Engineers (CIBSE) and with Hilton, the global hospitality company. CIBSE has used the findings to inform professional development and practices. The hotel chain has been able to assess more specifically than before which retrofit investments are likely to achieve requirements within their estate.

2. Underpinning research (indicative maximum 500 words)

Research at the University of West London (UWL) in building performance and climate change has been led by Professor Ali Bahadori-Jahromi since 2011. The work programmes have been aimed at providing practical solutions for reducing the energy demand and CO2 emissions within the building sector, predicting future building performance, maintaining building resilience in the face of a changing climate, and offering cost effective approaches for adopting new sustainable technologies.

This has been achieved by developing a methodology to realistically predict and validate energy performance and CO2 emission of buildings using computational fluid dynamic simulation combined with weather data provided by CIBSE and surveying the relevant residential and commercial buildings. This methodology uniquely is validated against the actual energy consumption of commercial and residential buildings. The demonstrated difference between actual consumption and validation is less than 10% (bridging the gap between design forecast and actual performance data). [R1 and R2]

Professor Bahadori-Jahromi was responsible for the conception and design of this research programme, including all the outputs listed in section 3. The programme included contributions from several PhD candidates at UWL, and contributions from collaborators at CIBSE and Hilton on R3, R4, R5 and R6 who reviewed progress of this research and provided weather data, buildings data and access to their sites for surveying the buildings.

Research projects have deployed and tested the methodology in several instances, as described below.

Optimum size selection of CHP retrofitting in existing UK hotel buildings

Studies have highlighted that Combined Heat and Power (CHP) systems are a reliable technology to improve the efficiency of heat and electricity generation, with the capacity to reduce building emissions. Bahadori-Jahromi applied his methodology to evaluate the impact of CHP systems on the energy performance of an existing UK hotel and to contribute to the selection of optimum CHP size. Results of the investigation demonstrated that CHP systems in hotel buildings can provide considerable economic and environmental benefits with either maximally sized CHP systems founded on the building's base heat demand or with reduced CHP system size of more than 50% smaller than the estimated maximum size. Optimum size reduction is obtained through evaluation of the relationship between the main performance parameters and their variation with CHP system sizes. [R2 and R3]

Impact of Window Films on the Overall Energy Consumption of Existing UK Hotel Buildings

This research used the developed methodology to evaluate the impact of solar window films on the overall energy consumption of an existing commercial building via the use of a case study UK hotel and TAS (Thermal Analysis Simulation) software. The study demonstrated that the impact of window films on the overall energy consumption of a case study hotel was approximately 2%. However, an evaluation of various overall energy consumption components showed that the window films reduced the annual total cooling energy consumption by up to 35% along with a marginal 2% increase in the annual total heating energy consumption. They could also provide overall cost and CO2 emissions savings of up to 3%. This demonstrated that window film has no commercial benefit in term of energy saving (3% saving is too little). These values were presented in terms of percentage, as buildings come with different sizes but these percentage values stay the same. [R4]

Meeting the Near Zero Energy Building (nZEB) Standard in existing UK hotels

Research investigated the potential contribution of various energy-efficient measures to reducing energy consumption, primary energy consumption and CO2 emissions whilst taking into consideration the energy and cost savings of those measures. The analysis was carried out using TAS software. The model validation obtained a performance gap of less than 5%. The results show that it is possible to achieve the nZEB standard for older UK hotel buildings if several measures are implemented and the initial selection of these is carefully investigated. [R5]

The practical implication of Minimum Energy Efficiency Standard (MEES) for UK hotels

Since the start of the project in January 2019, three different areas have been investigated with findings as below.

First, the impact of adding CHP systems to the EPC rating of UK hotels improves the numerical value of EPC rating within the same energy efficiency band. Second, that by following the current procedure for generating an EPC for commercial buildings (as required by the NCM), adding cooling systems will not adversely affect the EPC. Therefore, compliance with the MEES will not be impacted but in reality, depending on the occupant behaviour, adding cooling systems increases the energy consumption and CO2 emissions of a building to a considerable degree. Third, that there were uncertainties in the process for generating an EPC and in the assumptions involved.

The recurring discrepancies between EPCs generated by two different software packages (both accredited by the UK government as fit for the purpose) and further investigation into the causes of this, directed the researchers to reassess some of the assumptions that need to be accepted and followed in the process of generating a non-domestic EPC in the UK. It was found that the current assumptions from NCM for hotel domestic hot water consumption may be very unrealistic

(i.e., overestimation) which can result in an overestimation of the EPCs. This finding can become significant for the whole sector. [R6]

3. References to the research (indicative maximum of six references)

R1. Amoako-Attah, J. and Bahadori-Jahromi, A. (2015) Method comparison analysis of dwellings' temperatures in the UK. Proceedings of the Institution of Civil Engineers - Engineering Sustainability, 168 (1). pp. 16-27. DOI: 10.1680/ensu.14.00022

R2. Rotimi, A., Bahadori-Jahromi, A., Mylona, A., Godfrey, P. and Cook, D. (2017) Estimation and Validation of Energy Consumption in UK Existing Hotel Building Using Dynamic Simulation Software. Sustainability, 9(8):1391. DOI: 10.3390/su9081391

R3. Salem R, Bahadori-Jahromi A, Mylona A, Godfrey P, Cook D. (2018) Comparison and Evaluation of the Potential Energy, Carbon Emissions, and Financial Impacts from the Incorporation of CHP and CCHP Systems in Existing UK Hotel Buildings. Energies. 11(5):1219. DOI: 10.3390/en11051219

R4. Bahadori-Jahromi A, Rotimi A, Mylona A, Godfrey P, Cook D. (2017) Impact of Window Films on the Overall Energy Consumption of Existing UK Hotel Buildings. Sustainability. 9(5):731. DOI: 10.3390/su9050731

R5. Salem, R., Bahadori-Jahromi, A., Mylona, A. et al. (2019) Investigating the potential impact of energy-efficient measures for retrofitting existing UK hotels to reach the nearly zero energy building (nZEB) standard. Energy Efficiency 12, 1577–1594. DOI: 10.1007/s12053-019-09801-2

R6. Amirkhani S, Bahadori-Jahromi A, Mylona A, Godfrey P, Cook D. (2020) Impact of Adding Comfort Cooling Systems on the Energy Consumption and EPC Rating of an Existing UK Hotel. Sustainability, 12(7):2950. DOI: 10.3390/su12072950

Quality statement: All listed outputs have been published in peer-reviewed journals. R1 has received 7 citations; R2, 14 citations; R4, 21 citations; R5, 11 citations. [source: Google Scholar]

Grants: PI Bahadori-Jahromi in all instances.

1. Project title Resilience of buildings to extreme weather events. Sponsor: CIBSE. Grant period: 2015-2019. Grant value: £51,000.
2. Project title: Impact of the Uses of Various Technologies on the Thermal Performance and Efficiency of UK Hotel Buildings. Sponsor: Hilton Worldwide. Grant period: 2015-2018. Grant value: £33,000
3. Project title: Design and evaluation of Nearly Zero Buildings and their viability under current and future UK climate conditions. Sponsor: CIBSE. Grant period: 2016-2021. Grant value: £48,000.
4. Project title: Minimum Energy Efficiency Standards (MEES) for hotel buildings. Sponsor: Hilton Worldwide. Grant period: 2019-2022. Grant value: £24,000.

4. Details of the impact (indicative maximum 750 words)

Professor Bahadori-Jahromi's methodology and modelling has enabled building service engineers, particularly in the hospitality industry, to identify the holistic impact of energy efficiency measures. This has enabled comprehensive assessments of the benefits of introducing specific energy efficiency measures into existing buildings and improved approaches to meeting new regulatory standards.

The pathway to this impact has been through an industry-based collaboration initiated by Bahadori-Jahromi in 2015 with the CIBSE and with Hilton.

Practitioner impact: professional development and guidance to the building services industry

CIBSE is the professional body that supports building services engineering and has 20,000 members across 98 countries. Its members are engineers who design, install, operate, maintain and refurbish the energy using systems installed in buildings, including homes, and are specifically trained in the assessment of heat loss from building fabric and the design of energy using systems for the provision of heating and hot water, lighting, ventilation and cooling, and small power distribution in homes.

Bahadori-Jahromi has been collaborating with CIBSE since 2015 on a series of industry-focused research-led projects which address some of the key issues for their members, particularly in relation to building retrofit and refurbishment. CIBSE has used these research findings to inform professional development and guidance for building service engineers.

CIBSE have reported that the findings from the collaboration on the thermal performance and efficiency of UK hotel buildings, completed in 2019, were valuable for the hospitality sector as it provided an intelligent methodology for choosing the most cost-effective adaptations.

They have also indicated that the pioneering research led by Bahadori-Jahromi on the feasibility of Nearly Zero Energy Buildings for UK residential and commercial buildings provides ".a valuable insight for the UK building industry before adapting their buildings". [S1]

As a result, CIBSE asked Bahadori-Jahromi and his team to produce an industry practical guidance document using the initial findings from the research programme on the application of the nearly-zero energy buildings for existing residential and commercial buildings. This was published in CIBSE's Research Insight series in July 2020 as *Nearly-zero energy buildings: retrofitting to meet the standard.* CIBSE have reported there were 338 downloads of the publication by the end of December 2020. [S2]

Due to the industry interest in the topic, CIBSE requested that the research team deliver an online webinar on Achieving the Nearly-zero energy Building Standard in July 2020. CIBSE confirmed that this was one of their best attended webinars attracting more than 950 practitioners and academics internationally, including from Australia, Hong Kong, India and the UAE, as well as from the UK. [S1]

The publication and linked webinar demonstrated the potential benefits but also identified the risks associated with achieving such high energy-efficiency standards within the built environment, including overheating issues and cost implications.

The project findings were also highlighted to building engineers in the CIBSE Journal in January 2020 [S3].

The findings from these collaborative projects are widely distributed by CIBSE to its membership through its website, conferences and CIBSE knowledge portal, thereby adding to professional knowledge and development in the industry.

Hilton hotel retrofit impact

Hilton, a global hospitality company with more than 5,800 properties across 114 countries, has benefited from the series of four climate-change related collaborative projects with Bahadori-Jahromi to provide them with a stronger evidence base for decision-making related to sustainability and energy efficiency in their building stock.

Hilton frequently retrofit their buildings to reduce CO2 emissions and energy consumption, while enhancing guest comfort. Consequently, they have found that manufacturers frequently approach them with various energy efficiency or sustainability products and presented favourable data in support of these.

In 2014, Hilton identified that Bahadori-Jahromi's methodology could provide them with a unique and innovative method to consider the holistic effect of each product or technology and assess its impact on energy performance and CO2 emissions. They therefore began to work jointly with Bahadori-Jahromi on these issues, generating the following benefits:

Hilton have said they will use the learning and methodology from the window film project at Hilton Reading to examine the benefits of similar projects within their portfolio and believe this will allow them to make improved investment decisions.

The combined heat and power project at Hilton London Gatwick produced practical guidelines for Hilton that will be applied in future CHP opportunities.

The nZEB project at Hilton Edinburgh Grosvenor outlined the methodology for meeting this standard and the feasibility of this approach in a listed building. This has provided results which the company can apply to other buildings that need to meet this standard.

The study at Hilton Watford allowed the company to establish that improving guest comfort through the addition of air-conditioning would not worsen the hotel's EPC rating, and it could therefore continue to meet the Minimum Energy Efficiency Standard (MEES) despite an increase in energy consumption and CO2 emissions. Hilton also became aware that the National Calculation Methodology (NCM), used to generate non-domestic EPC ratings, may overestimate energy consumption in hotels. Any future correction to the NCM to reflect this could reduce the requirements for retrofitting hotels if they were marginally below required standards. [S4]

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1. Letter dated 10th August 2020 from Head of Research, CIBSE.

S2. Research Insight 03*: Nearly-zero energy buildings: retrofitting to meet the standard.* Published by CIBSE, July 2020. ISBN 978-1-912034-72-7 and email from Head of Research, CIBSE, dated 24/2/21.

S3. *Net gains – retrofitting scenarios for net zero carbon,* CIBSE Journal, January 2020 https://www.cibsejournal.com/technical/net-gains-retrofitting-for-net-zero-carbon/

S4. Letter dated 1st June 2020 from Director Energy & Environment EMEA, Hilton.