

Institution: Cardiff University		
Unit of Assessment: Architecture, Built Environment and Planning (13)		
Title of case study: Changing EU directives to improve the energy efficiency of non-residential buildings across Europe		
Period when the underpinning research was undertaken: 2000 – 2014		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Ian Knight Afroditi Konidari	Professor Research Associate	14/12/1987 – present 5/11/2011 – 30/06/2014
Period when the claimed impact occurred: 31/07/2014 – 31/12/2020		
Is this case study continued from a case study submitted in 2014? Yes		
1. Summary of the impact (indicative maximum 100 words) <p>Buildings are the single largest energy consumer in Europe, representing almost 40% of consumption and 36% of CO₂ emissions in 2016. Cardiff research into air conditioning components and systems determined that a new method of continuous monitoring of building services and systems is more effective at identifying sub-optimal energy performance than physical inspections. This research was instrumental to the 2018 revision of the EU Energy Performance of Buildings Directive, which defines current legal standards for building energy performance across all 28 EU member states. Cardiff's methodology for continuous monitoring was also incorporated into a £4.4B building programme for new schools by the UK Department for Education.</p>		
2. Underpinning research (indicative maximum 500 words) <p>The complex interplay of building components and systems has a pronounced effect upon the efficiency and operational performance of large buildings. The team at Cardiff University's Welsh School of Architecture (WSA), led by Knight, has been instrumental in several European Union research projects that have quantified the benefit of continuous monitoring of building services and systems, resulting in increased energy efficiency and reduced carbon emissions.</p> <p>Between 2000 and 2003, Cardiff's research, funded by the Building Research Establishment (BRE), Toshiba Carrier, Electricity Association and National Grid Transco [G1], investigated the monitoring of energy use of air conditioning (AC) systems in UK office buildings, including the various components of AC systems. This research provided insight into the ranges of energy consumption achieved by various types of AC systems in UK offices, revealing how energy consumptions achieved in practice could vary wildly between system types and design approaches, despite serving similar activities [3.1, 3.2].</p> <p>2.1 Continuous energy monitoring vs. individual physical inspections</p> <p>Following these unique findings, Knight was requested to participate in the €0.8M EU project AuditAC [G2], coordinated by École des Mines, Paris, between 2005-2006. In addition to contributing across the project, Knight was the lead on Work Package 6, exploring the efficiency of inspections when linked with existing performance data, including focussed performance data and pre-inspection data. The project demonstrated the difficulty in applying the European Committee for Standardisation (CEN) Standard for the mandatory Energy Performance of Buildings Directive (EPBD) Inspection of AC systems. Specifically, the project concluded that sufficient inspection would be difficult to achieve in Europe given the number of accredited inspectors required, limiting how cost-effective this approach could be [3.3].</p> <p>Building on these findings, Knight went on to lead the follow-on €1.8M EU project HARMONAC from 2007-2010 [G3], which measured the practical impact of inspecting air conditioning systems on energy efficiency. Results showed that individual AC inspections were limited to 37% of potential energy savings and were unlikely to incentivise energy-efficient measures</p>		

due to cost. The report concluded that the most viable long-term solution was to make it cheaper for building owners to run systems efficiently through continuous monitoring of building systems, and that this would require better understanding within the market of the effect of AC system choice on efficiency [3.4, 3.5].

2.2 Leading the iSERVcmb project

From 2011-2014, the Cardiff team proposed and coordinated the €3.3m pan-European iSERVcmb project to demonstrate an energy-efficiency framework compatible with all EU member states [G4]. The iSERVcmb approach uses existing data explored in the AuditAC Work Package 6, including metering and sensors and information on buildings assets and activities, to produce benchmarks for individual building configurations and uses. The iSERVcmb process was then tested on over 2,800 AC systems within 330 buildings across 15 EU member states [3.6].

Published in 2014, the project results showed that buildings that underwent the iSERV process reduced total electrical energy use by up to 33%, with an average saving of 9% [3.6]. A comparison between iSERV and physical inspections found that continuous monitoring could not only detect more energy conservation opportunities than physical inspections but was also significantly cheaper to undertake. Through field testing of continuous monitoring, building owners and operators also stated that immediate operational feedback of energy use had a greater effect in addressing energy saving issues than time-delayed physical inspection reports. Ultimately, the project predicted that, should all EU member states conform to iSERV processes, annual cost savings could range between €1.4 billion to €7.1 billion.

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

[3.1] Knight IP and Dunn GN – “Measured Energy Consumption and Carbon Emissions of Air-Conditioning in UK Office Buildings”. Building Services Engineering Research & Technology Journal, pp.89–98, 26-2 CIBSE (2005) London. DOI: 10.1191/0143624405bt111oa

[3.2] Knight IP, Dunn GN and Hitchin ER – “Measuring System Efficiencies of Liquid Chiller and Direct Expansion”, ASHRAE Journal, 47(2) pp.26–32, February 2005. ISSN: 0001-2491. Available from HEI on request.

[3.3] Adnot J, Knight IP, et al – “AUDITAC - Field benchmarking and Market development for Audit methods in Air Conditioning. Final Report to European Commission”. January 2005 to December, 2006. Grant Agreement EIE/04/104/S07.38632. pp.104 February 2007. http://eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=1439

[3.4] Knight IP et al – “HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector. Energy Consumption in European Air Conditioning Systems and the Air Conditioning System Inspection Process. Final Report to European Commission.” September 2007 to August 2010. Grant agreement no. EIE/07/132/SI2.466705. pp. 240 (Appendices pp. 2000+) December 2010. Accessed 09/02/2018. <https://ec.europa.eu/energy/intelligent/projects/en/projects/harmonac>

[3.5] Knight IP et al – “Benchmarking HVAC System Energy Use Using Sub-hourly Data”, CLIMA 2013 Conference, pp. 12, Prague, June 2013 published in proceedings. Available from HEI.

[3.6] Knight I et al – “Final Report: The inspection of building services through continuous monitoring and benchmarking –the iSERVcmb project”, Overall final project report from iSERVcmb (Inspection of HVAC Systems through continuous monitoring and benchmarking), Intelligent Energy Europe Project Number: IEE-10-272. July 2014. <https://ec.europa.eu/energy/intelligent/projects/en/projects/iserv>

Selected grants:

[G3.1] Building Research Establishment (BRE), Toshiba Carrier, Electricity Association and National Grid Transco. Total value £148,704.

[G3.2] Field benchmarking and Market development for Audit methods in Air Conditioning (AUDITAC). EU Project EISAV/EIE/04/104/2004, January 2005 to December 2006, total value €838,141.

[G3.3]: Harmonizing air-conditioning inspection and audit procedures in the tertiary building sector (HARMONAC). EU Project EISAV/EIE/07/132/2007, September 2007 to August 2013, total value €1,818,418.

[G3.4]: Inspection of HVAC systems through continuous monitoring and benchmarking (ISERV). EU Project IEE/10/272, May 2011 to May 2014, total value €3,293,562.

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

In 2016, buildings across the EU represented almost 40% of the final energy consumption and 36% of CO₂ emissions, and were the single largest energy consumer. Cardiff's research demonstrated the advantages of continuous energy monitoring over physical inspections to identify effective energy conservation opportunities in air conditioning (AC) systems. This research led to the adoption of automatic and continuous energy monitoring systems within the European Commission Energy Performance of Buildings Directive (EPBD). The EPBD directive affects the design of new and revitalised buildings across Europe, and the directive's principles are now adopted into law for all EU member states. The energy monitoring process enabled by Cardiff's research is also now the required method within the UK Department for Education £4.4 billion investment in building and refurbishing new schools across England.

4.1 Adoption of continuous monitoring in EU Directives and national policies

The EPBD is the EU's main legal instrument to promote optimal energy performance of buildings. Cardiff's research has been fundamental to revisions on legislation and policy, having been presented twice to the European Commission's Concerted Action 3 (CA3) project during international workshops and technical committees. CA3 was aimed at aiding EU member states' legislators implement changes to the EPBD in their own states' laws.

In 2016, the Commission's Impact Assessment **[5.1]** was published, which details evidence for potential changes to the EPBD. On measures aimed at "modernisation using smart technologies and simplification of outdated provisions", the Impact Assessment confirmed that "the EPBD will be amended to repeal the provisions related to regular inspections" and introduce "active energy management systems". In support of these amendments, the Commission's Impact Assessment explicitly cites the findings of the iSERV project, noting that electronic monitoring of technical building services "has proven to be an effective substitution to the regular inspection with physical visits of inspectors" **[5.1]**.

Accompanying the Commission's Impact Assessment was the Commission's Staff Working Document '*Good practice in energy efficiency*', which also confirmed the importance of Cardiff research. The *Good practice* report cited the HARMONAC project, reporting that: "average energy savings potential for individual AC systems was 40% of their measured consumption and indicated that monitoring was more likely to be cost-effective than universal inspection" **[5.2]**. Specifically referring to iSERV, the proposal recognised that "automatic monitoring revealed many installations had much greater potential for savings than the inspections had suggested" and to find measures that "an inspection alone would not be able to identify" **[5.2]**.

As a result, on 30 May 2018, the EPBD was amended by the European Parliament and Council in line with the above recommendations (EU Directive 2018/844) and now specifies clauses on continuous monitoring and feedback in buildings as an alternative route to compliance with the directives **[5.4, Articles 14 and 15]**. Member states are responsible for ensuring all non-residential buildings, with heating, air conditioning, and ventilation systems with an effective rate of over 290kW, "are equipped with building automation and control systems by 2025" **[5.3, p.12]**. With the adoption of the Directive, all EU member states were required to transpose the changes to the EPBD into national law by March 2020 **[5.3, p.15]**.

4.2 Defining the energy-monitoring for a £4.4 billion school development programme

The Cardiff-led iSERV project has been adopted as the energy evaluation measure for a £4.4 billion investment by the Department of Education (DfE) to support the rebuilding and

refurbishment of 537 schools across England from 2015 to 2022. The DfE Priority Schools Building and Free Schools Building Programme (PSBP) [5.4], now mandates the use of the iSERV methodology to monitor and benchmark operational energy performance in all new schools and major refurbishments in England in order to meet required energy use targets.

Hershil Patel, Head of Energy, DfE Design Team, stated that iSERV was chosen for PSBP as “it enables us to obtain this information [on energy performance] in a technology and design neutral manner”, and “demonstrated an ability to reduce operational energy use in practice that will enable us to optimise the operational performance of the new school buildings” [5.5]. Adoption of iSERV allowed the creation of a consistent Schools Operational Performance Database, to which all PSBP-funded schools will upload data every 15 minutes. In turn, this will be used to collect operational energy and indoor environment performance data. The DfE stated this data will inform meeting design potential and achieve greater understanding of building design and occupancy. Additionally, measured air temperature, CO₂ data and domestic hot water consumption data will determine impacts on design decisions and amend benchmarks for consumption [5.5].

Patel stated that without the use of iSERV, these project specifications “would otherwise not have occurred”. A sample of the first 260 schools built under the programme have been assessed by the iSERV methodology, with the results feeding back to refine the schools currently being designed and built across the country. Patel indicated that early data collected by the iSERV method have already been used to amend the PSBP guidance documents used to define the design and construction of new schools under the programme [5.5].

4.3 Summary of Impact

Cardiff research demonstrated the efficacy of continuous monitoring of building energy usage to identify new energy conservation opportunities, leading to:

- Adoption of continuous energy monitoring within the EU’s Energy Performance of Buildings Directive (EPBD), incorporated into national law of all EU member states in March 2020, and requiring all large non-residential buildings to adopt building automation and control systems by 2025.
- Defined the method to monitor energy performance within the UK government’s £4.4 billion Priority Schools Building and Free Schools Building Programme, evaluating the energy use of retrofitted and newly constructed schools across England.

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

[5.1] COMMISSION STAFF WORKING DOCUMENT, Impact Assessment. Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings, SWD(2016) 414 final, Brussels, 30.11.2016. Accessed 09/02/2018.

[5.2] COMMISSION STAFF WORKING DOCUMENT, Part 1 version 4. Good Practice in Energy Efficiency, SWD(2016) 404 final, Brussels, 30.11.2016. Accessed 09/02/2018.

[5.3] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance) Accessed 23/07/2019.

[5.4] Output Specification 2017: ESFA Employer’s Requirements part B Annex 2H and 2I reference iSERV. Accessed 23/07/2019.

[5.5] Testimonial from Hershil Patel, Head of Energy, DfE Design Team on utility of iSERV for the Priority Schools Building and Free Schools Building Programme (PSBP).