Closing the energy gap in renovations of offices and hotels

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ALDREN [1], an EC-funded Horizon 2020 project, aims to establish the business case for deep renovation and accelerate the movement towards a nearly zero energy non-residential building stock by 2050. This paper describes a process developed to close the gap between calculated and measured energy performance in renovated offices and hotels.

Keywords: verified energy performance; deep renovation; retrofit; offices; hotels

Background

Two thirds of existing buildings in the EU are expected to be still in use in 2050, 30 years from today [2]. Many commentators assess that the EU's contribution towards the goals of the Paris Agreement can only be achieved if the energy demand from most of these buildings is drastically reduced by deep retrofits. Recital 16 of the Energy Efficiency Directive [33] defines 'deep renovations' in a broad way, as "*renovations which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high [efficient] energy performance*". One estimate is that only 1% of current renovations achieve this [4]. The Renovate Europe campaign proposes an energy demand reduction target of 80% by 2050 from 2005 levels [5]

The aim of ALDREN is to establish the business case for deep renovation in non-residential buildings with a focus on offices and hotels. The 3-year programme which started in November 2017 intends to encourage investment and accelerate the movement towards a nearly zero energy non-residential building stock across the EU, by 2050 to meet Paris Agreement commitments.

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A key attribute of the approach to be adopted by ALDREN is the idea of energy performance verification. This means that the energy performance predicted at the design stage of a deep renovation will be verified by measurements during the first year of full occupancy. The thesis of ALDREN continues that if we are going to start measuring the actual energy efficiency of buildings, then investors, developers and owners will want confidence that their renovated buildings will perform well. ALDREN is therefore a process which aims to underwrite the operational performance of building retrofits. It learns from Australia's success in improving the energy efficiency of commercial office buildings through Commitment Agreements [6] and previous EC-funded research on hotels [7].

This paper describes a methodology which supports both the achievement and verification of target energy performance outcomes. The energy scope is whole building HVAC, hot water and lighting which corresponds to the requirements of the amended EPBD Annex 1 [8].

Performance Verification protocol

The process proposed for ensuring the target energy performance of a deep retrofit is achieved and verified using measured data is illustrated in **Figure 1** and has these key steps:

1. Calculate energy performance for existing building under standard conditions
2. Calculate energy performance for existing building under actual conditions
3. Measure existing building energy use, compare with predicted energy use and calibrate model to match measurements
4. Use calibrated model to agree list of building improvements for fabric, plant, controls, etc.
5. Calculate energy performance under actual conditions
6. During first year of operation, compare measured vs calculated energy under actual conditions at monthly and sub-meter resolution
7. Calculate "verified" energy performance under standard conditions for upgraded building

Within steps 3 and 6, it is essential that comparisons of modelled and measured energy use are made on a like-for-like basis:

1. Each is subject to the same boundary conditions. Typically, this means ensuring that actual occupant numbers and hours of use, energy-using equipment density (W/m²) and weather over the year of measurement are applied (as far as possible [9]) in a re-run of the model.
2. Care is taken to compare results for the same energy uses. This requires a good understanding of what

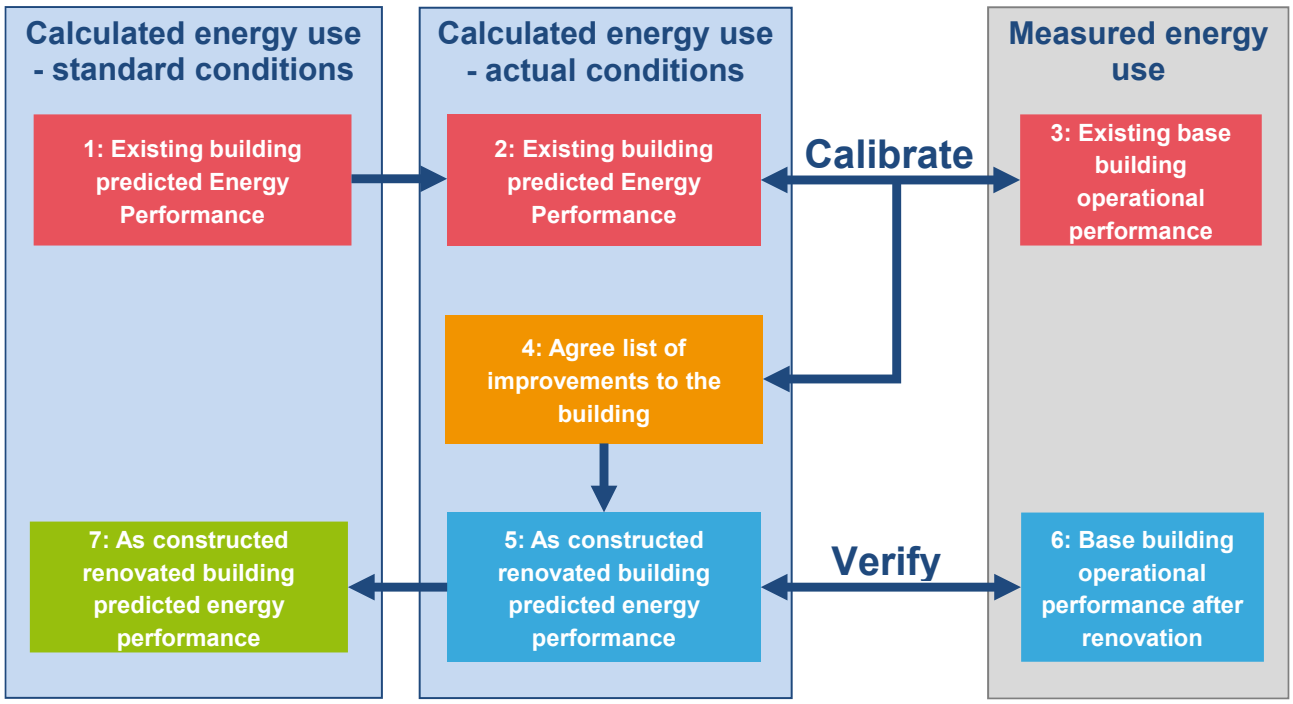

Figure 1. Planned energy performance verification process for deep retrofits.

is being measured by each sub-meter and mapping this to energy metering points in the model.

The ambition for verification of energy performance suggests an expectation that metered values will be close to the simulated targets, but there are three challenges:

1. **Inadequacies of models**. Commonly used models required for regulatory compliance and EPCs are unlikely to predict energy use by sub-meter accurately.

2. **Inefficient building operation**. Many (if not most) air-conditioned office buildings suffer from multiple imperfections in the way they are operated and controlled. Control systems are not designed and specified in sufficient detail, do not enable HVAC and lighting service levels to be tailored to demand, and rarely set out to limit services to unoccupied parts of a building (voids and when out of hours use varies across tenancies). Building managers and their facilities management teams often lack the skills needed to operate a building efficiently and are not incentivised to improve performance.

3. **Indoor environmental quality**. Control settings in a real building may not match the specifications assumed in the model.

The ALDREN energy performance verification protocol proposes three ingredients to overcome these challenges:

A. Dynamic thermal simulation of building design and HVAC system

During the design stages, simulation of the building and its HVAC system and controls, with a time step of one hour or less, should be undertaken to predict heating and cooling demands. The level of simulation proposed for ALDREN differs from current practices but is not ground-breaking, in the sense that it has become routine practice in Australia [10], and is used to some extent in the US under the guidance of ASHRAE 90.1 [11]. ASHRAE also offers an accreditation scheme for "Building Energy Modelling Professionals": the BEMP Certification [12].

There are several key objectives of more advanced simulation:

- To understand how the HVAC system would operate for each hour of the year and thereby confirm plant capacity requirements more robustly and enable designers to identify how much time would be spent in more or less efficient operating modes
- To confirm that the proposed design is capable of meeting the target energy performance
- To use 'off-axis scenarios' to check the resilience of the energy performance to plausible future scenarios for hours of use, intensity of use (people and equipment) and weather
- To inform the development of a Verification Plan which identifies necessary sub-metering and produces monthly targets for each sub-meter and each sub-system (heating, hot water, cooling, fans, etc.).
- To inform the optimisation of HVAC control.

B. Independent design review

An independent design review (IDR) should be undertaken by an independent and experienced energy efficiency professional who has been assessed for high levels of expertise in relation to:

- deep retrofit building projects and the design of HVAC services and their controls
- commissioning/tuning of buildings
- energy auditing and energy efficiency improvement of existing buildings
- simulation of building performance.

The IDR scrutinises the design, Control Plan, Validation Plan, a functional description of the controls and the simulation outputs with the overarching objectives of checking the risk the building will not achieve its target performance and recommending improvements. The final design should consolidate into the design package any changes arising from the IDR.

C. Continual alignment of actual building with the simulation model

At the start of the design stage, a Control Plan should be agreed which specifies which parties will be able to control the HVAC (landlord, tenants, hotel guests, etc.). By the end of the final design stage, a simple description of the controls which implements the control plan should be articulated in plain English in a Description of Operations (DesOps).

The DesOps should be made available to tenderers for the controls engineering and used as an input into the design and functional description of the HVAC

controls. Any refinements introduced to the control strategy should be reflected in a revised version of the DesOps that emerges on completion and handover.

During the tendering and construction stages, it is important to keep the simulation model and DesOps up to date with any significant design changes. For example, if any changes threaten the achievement of the target rating after a value engineering process, further modelling may be needed to demonstrate that the target would not be compromised.

A key objective of commissioning should be to ensure the control algorithms in the completed building are consistent with the functional description of the HVAC controls, the simulation model of the final design and the revised DesOps.

Once the building is in occupation, measured energy use data should be collected, following the Validation Plan, and monthly monitoring reports prepared comparing sub-metered performance to simulated predictions. The reports should highlight any risks that the energy performance will fail to meet the target, and identify potential remedial actions.

Performance based maintenance contracts for managing agents and facilities managers are likely to produce the best chance of achieving the target energy performance. Meters should be treated as maintainable assets and the tasks of meter data collection and processing should be requirements of the maintenance contract.

Four BMS tuning exercises should be undertaken during the defects liability period to check controls are working optimally during different seasons of the year [13].

A performance verification tool developed by the ALDREN project acts as a repository for data generated during the various protocol stages described above and presents a side-by-side comparison of predicted and measured energy consumption data in order to verify the renovated building's energy performance in operation is in line with design targets.

Conclusions

ALDREN proposes an energy performance verification protocol for deep retrofits of offices and hotels. It is anticipated that using detailed simulation of HVAC systems and their controls, alongside the dynamic thermal simulation of the building itself, for prediction and target setting, will enable performance outcomes to come close to matching design aspirations in air-conditioned buildings. ■

References

[1] ALDREN (ALliance for Deep RENovation in buildings) https://aldren.eu/.

[2] European Parliament Energy efficiency of buildings A nearly zero energy future? May 2016.

[3] European Union: Directive 2012/27/EU of the European Parliament and of the Council on Energy Efficiency, Recital 16 October 2012.

[4] The Economist, Investing in energy efficiency in Europe's buildings. A view from the construction and real estate sectors, 2013.

[5] The Renovate Europe campaign https://www.renovate-europe.eu/.

[6] Bordass, WT, Cohen, RR and Bannister, P "Design for performance: UK Commitment Agreements: Making measured energy in-use the objective for new office buildings, Feasibility Study Final Report, published by the Better Buildings Partnership (BBP), May 2016.

[7] Tsoutsos T, Tournaki S and Frangou M, Nearly Zero Energy Hotels in Europe (NEZEH), Technical University of Crete, 2016 www.nezeh.eu.

[8] 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.

[9] To determine precise hours and density of use over a year throughout a building could be time intensive.

[10] New South Wales Office of Environment and Heritage, Handbook for estimating NABERS ratings Version 1.2, July 2019.

[11] ASHRAE Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, 2016.

[12] U.S. affiliate of the International Building Performance Simulation Association (IBPSA-USA) and the Illuminating Engineering Society (IES), BEMP – Building Energy Modelling Professional Certification.

[13] The ALDREN performance verification protocol also offers an alternative approach promoted by another H2020 project, the QUANTUM 'performance test bench' tool [14]. The contractor defines how to test the control of each data point is happening correctly and once the building is in operation, an independent verifier checks and produces a robust defects list for the contractor to resolve.

[14] Mechanical and Electrical Engineering Working Party of National, Regional and Local Authorities (AMEV) for QUANTUM project, Technical Monitoring as an Instrument for Quality Assurance, 2017.