Night cooling: a low-carbon office building retrofitting solution

The post-pandemic future of offices

The International Energy Agency[1] reports that cooling is the fastest-growing energy use in buildings, as its demand more than tripled between 1990 and 2018. A significant share of office buildings' energy consumption goes towards cooling, which remains a key challenge to achieving low- or zero-carbon commercial assets across Europe. With the increase in carbon taxes to incentivise carbon-neutral buildings, passive and bioclimatic solutions for cooling are a clear trend for building design. Reducing cooling loads, downsizing mechanical systems and using cooling agents can cut both operational and embodied carbon, and reducing reliance on mechanical cooling systems also increases the robustness of building services.

The COVID-19 pandemic has triggered a discussion on transforming office buildings from places to work into spaces to interact and engage with others, as a recent Arup study suggests.[2]

Night cooling: a future growth field

Open, zoned and activity-based office layouts support the implementation of night cooling, which uses the thermal mass of a building's primary structure (e.g. ceilings, walls, floors) as a heat sink during occupancy periods[3]. The structural components need to be exposed (e.g. concrete floor slabs, exposed brick walls) in order to absorb heat during the day; then, at night, the heat is discharged through convective heat transfer. This strategy enables the thermal comfort of building occupants during the day without using mechanical cooling, or with a reduced demand for it.

Arup's Research and Innovation team has investigated night cooling as a future growth field for suppliers of façade systems and Arup has pioneered the application of night cooling strategies on several low- and medium-rise office buildings since 2010, gaining insights on success factors. Simulations that accurately model cooling effects set the stage for wider acceptance and implementation, especially for refurbishments. The European Green Deal's 'renovation wave' initiative will increase the commercial viability of night cooling for deep office building retrofits, with reduced ventilation duct sizes increasing the clear floor height and market value of assets, thereby balancing additional expenditure on motorised windows.

A systemised approach

Due to the requirement of a minimum diurnal temperature range of 5° C for effective night cooling[4], this approach is currently most suitable for moderate climate zones (e.g. Benelux, Germany, Northern France, and southern parts of the United Kingdom). In dense urban areas night cooling models must consider local heat island effects as well as climate change scenarios[5]. Office spaces should be open plan, with no partitions blocking the air flow along exposed ceilings, thus facilitating higher air change rates. Both cross-ventilation (with inlets and outlets at opposite elevations on the floor plate) and stack ventilation (enabled by air extraction through vertical shafts) maximise air circulation and cooling effects[6,7].

Integrating opening vents into façade design can be an architectural challenge. However, Michael Stych, Director for Buildings Engineering at Arup London, states that "for night time vent, relatively small but well positioned opening at high level, with opportunity good cross-vent across a floor can be effective.".

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1 International Energy Agency, 2020, Tracking Buildings 2020, https://www.iea.org/reports/tracking-buildings-2020.
2 Arup, 2020, Future of offices in a post-pandemic world, https://www.arup.com/perspectives/publications/research/section/future-of-offices-in-a-post-pandemic-world.
3 A.B. Birtles, M. Kolokotroni, and M.D.A.E.S. Perera, 1996, "Night cooling and ventilation design for office-type buildings," Renewable Energy 8, no. 1–4, 259–263, https://doi.org/10.1016/0960-1481(96)88858-6.
4 N. Artmann, H. Manz, and P. Heiselberg, 2007, "Climatic potential for passive cooling of buildings by night-time ventilation in Europe," Applied Energy 84, no. 2, https://doi.org/10.1016/j.apenergy.2006.05.004.
5 N. Artmann, D. Gyalistras, H. Manz, and P. Heiselberg, 2008, "Impact of climate warming on passive night cooling potential," Building Research & Information 36, no. 2, 111–128, https://doi.org/10.1080/09613210701621919.
6 Mhuireach et al., 2020, "Lessons learned from implementing night ventilation of mass in a next-generation smart building," Energy and Buildings 207, 109547, https://doi.org/10.1016/j.enbuild.2019.109547.
7 B. Givoni, 1991, "Performance and applicability of passive and low-energy cooling systems," Energy and Buildings 17, no. 3, 177–199, https://doi.org/10.1016/0378-7788(91)90106-D.

With respect to suitable opening types, bottom-hung ‘hopper’ windows generally allow for effective air flow. Parallel-opening windows would have even better air circulation, but security concerns often exclude this opening type. Operable lamellas have been used in the past because of the cost-effectiveness of automation, but their generally poor airtightness impacts on the building envelope’s overall performance, so this opening type is no longer preferred.

Graham Dodd, Fellow at Arup London and a leading expert in the field of façade technology, sees the potential for systemised approaches following circular economy principles: “On the subject of window openers for night cooling, I would look for something compact, robust, solar powered, wireless controlled (Internet of Things ready), serviceable/repairable, and interchangeable in an open industry standard”.

Summary

In summary, a systemised solution for automated windows to enable night cooling is most attractive for low- and medium-rise office buildings in northwestern Europe. As the opening elements are a distinct feature of the façade, night cooling must be considered as part of a holistic building concept at an early design stage to facilitate architectural design integration. Key success factors for wider market adoption will be a maximised cooling effect and reduced automation costs; therefore, opening elements should be as compact as possible. With simple installation and low operation and maintenance costs being the key customer buying criteria, the market potential for robust, battery-powered, automated window systems should be investigated. Wireless controls that enable zone-by-zone activation will provide further operational cost savings.

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