

Cleanrooms use far more energy than they should, and their ventilation design is a major reason.

Cleanrooms are an essential part of safe pharmaceutical manufacturing, but they come at a cost: extremely high energy use. This study highlights that the way air is supplied and conditioned can severely affect both costs and energy use.

Constant airflow, cooling, heating, and filtration are essential to keeping cleanrooms sufficiently clean to be used as manufacturing sites for pharmaceuticals and other, sometimes technologically cutting-edge products. This, on the other hand, makes them among the most energy-intensive indoor environments. Despite growing demands for a clean environment, there is no clear agreement on which ventilation strategy is more efficient. With this in mind, this study addresses the missing link by comparing two of the most common approaches: a centralized system, in which a single unit serves the entire air-conditioning process, and a decentralized system, in which smaller units control parts of the environment.

Using techno-economic analysis and airflow simulations, both systems are evaluated for energy use, indoor conditions, and long-term costs. The difference, however, is conspicuous. While the decentralized system in this specific application uses 218 MWh/year, the centralized system uses more than seven times as much, requiring 1 600 MWh/year. This is mainly due to extensive ducting used in a centralized system, which greatly increases resistance and thus, fan energy.

This study also reveals that even with very high air changes per hour, heat from machinery still approached design limits. This highlights the importance of correct cooling specifications rather than relying on ever-increasing airflow rates, which contribute to unnecessarily high energy use.

In practice, the findings of this study can guide cleanroom designers and engineers in making informed decisions regarding the right ventilation type for new cleanrooms. While a centralized system may look cheaper initially, the high operating costs make it less attractive over time. On the other hand, a decentralized system offers lower energy use and better long-term value.

As the number of cleanrooms continues to grow, improving their efficiency is becoming increasingly important. It not only lowers costs but also contributes to broader efforts to limit environmental impact.