

International Energy Agency

## Subtask A: Energy Benefits of Using Gas-Phase Air Cleaning (Annex 78)

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Energy in Buildings and Communities  
Technology Collaboration Programme



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Technology Collaboration Programme

June 2025

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Published by ICIEE-SUSTAIN Technical University of Denmark, Nils Koppels Alle, build. 402, DTU, DK-2800 Lyngby, Denmark

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ISBN 97887-93478-22-0

Participating countries in the EBC TCP: Australia, Austria, Belgium, Brazil, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Türkiye, United Kingdom and the United States of America.

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# Preface

## The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

## The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
- the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:

- the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
- benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
- improving smart control of building services technical installations, including occupant and operator interfaces;
- addressing data issues in buildings, including non-intrusive and secure data collection;
- the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

## The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following

projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (\*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

- Annex 1: Load Energy Determination of Buildings (\*)
- Annex 2: Ekistics and Advanced Community Energy Systems (\*)
- Annex 3: Energy Conservation in Residential Buildings (\*)
- Annex 4: Glasgow Commercial Building Monitoring (\*)
- Annex 5: Air Infiltration and Ventilation Centre
- Annex 6: Energy Systems and Design of Communities (\*)
- Annex 7: Local Government Energy Planning (\*)
- Annex 8: Inhabitants Behaviour with Regard to Ventilation (\*)
- Annex 9: Minimum Ventilation Rates (\*)
- Annex 10: Building HVAC System Simulation (\*)
- Annex 11: Energy Auditing (\*)
- Annex 12: Windows and Fenestration (\*)
- Annex 13: Energy Management in Hospitals (\*)
- Annex 14: Condensation and Energy (\*)
- Annex 15: Energy Efficiency in Schools (\*)
- Annex 16: BEMS 1- User Interfaces and System Integration (\*)
- Annex 17: BEMS 2- Evaluation and Emulation Techniques (\*)
- Annex 18: Demand Controlled Ventilation Systems (\*)
- Annex 19: Low Slope Roof Systems (\*)
- Annex 20: Air Flow Patterns within Buildings (\*)
- Annex 21: Thermal Modelling (\*)
- Annex 22: Energy Efficient Communities (\*)
- Annex 23: Multi Zone Air Flow Modelling (COMIS) (\*)
- Annex 24: Heat, Air and Moisture Transfer in Envelopes (\*)
- Annex 25: Real time HVAC Simulation (\*)
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- Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (\*)
- Annex 28: Low Energy Cooling Systems (\*)
- Annex 29: ☼ Daylight in Buildings (\*)
- Annex 30: Bringing Simulation to Application (\*)
- Annex 31: Energy-Related Environmental Impact of Buildings (\*)
- Annex 32: Integral Building Envelope Performance Assessment (\*)
- Annex 33: Advanced Local Energy Planning (\*)
- Annex 34: Computer-Aided Evaluation of HVAC System Performance (\*)
- Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (\*)
- Annex 36: Retrofitting of Educational Buildings (\*)
- Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (\*)
- Annex 38: ☼ Solar Sustainable Housing (\*)
- Annex 39: High Performance Insulation Systems (\*)
- Annex 40: Building Commissioning to Improve Energy Performance (\*)
- Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (\*)
- Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (\*)
- Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (\*)
- Annex 44: Integrating Environmentally Responsive Elements in Buildings (\*)
- Annex 45: Energy Efficient Electric Lighting for Buildings (\*)
- Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (\*)
- Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (\*)
- Annex 48: Heat Pumping and Reversible Air Conditioning (\*)
- Annex 49: Low Exergy Systems for High Performance Buildings and Communities (\*)
- Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (\*)
- Annex 51: Energy Efficient Communities (\*)
- Annex 52: ☼ Towards Net Zero Energy Solar Buildings (\*)
- Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (\*)
- Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (\*)
- Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (\*)
- Annex 56: Cost Effective Energy and CO<sub>2</sub> Emissions Optimization in Building Renovation (\*)
- Annex 57: Evaluation of Embodied Energy and CO<sub>2</sub> Equivalent Emissions for Building Construction (\*)

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (\*)

Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (\*)

Annex 60: New Generation Computational Tools for Building and Community Energy Systems (\*)

Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (\*)

Annex 62: Ventilative Cooling (\*)

Annex 63: Implementation of Energy Strategies in Communities (\*)

Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (\*)

Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (\*)

Annex 66: Definition and Simulation of Occupant Behavior in Buildings (\*)

Annex 67: Energy Flexible Buildings (\*)

Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (\*)

Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings (\*)

Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale (\*)

Annex 71: Building Energy Performance Assessment Based on In-situ Measurements (\*)

Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings (\*)

Annex 73: Towards Net Zero Energy Resilient Public Communities (\*)

Annex 74: Competition and Living Lab Platform (\*)

Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables (\*)

Annex 76: ✨ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO<sub>2</sub> Emissions (\*)

Annex 77: ✨ Integrated Solutions for Daylight and Electric Lighting (\*)

Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications

Annex 79: Occupant-Centric Building Design and Operation

Annex 80: Resilient Cooling

Annex 81: Data-Driven Smart Buildings

Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems

Annex 83: Positive Energy Districts

Annex 84: Demand Management of Buildings in Thermal Networks

Annex 85: Indirect Evaporative Cooling

Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings

Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems

Annex 88: Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings

Annex 89: Ways to Implement Net-zero Whole Life Carbon Buildings

Annex 90: ✨ EBC Annex 90 / SHC Task 70 Low Carbon, High Comfort Integrated Lighting

Annex 91: Open BIM for Energy Efficient Buildings

Annex 92: Smart Materials for Energy-efficient Heating, Cooling and IAQ Control in Residential Buildings

Working Group - Energy Efficiency in Educational Buildings (\*)

Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (\*)

Working Group - Annex 36 Extension: The Energy Concept Adviser (\*)

Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (\*)

Working Group - Cities and Communities (\*)

Working Group - Building Energy Codes

# Summary

As data show ventilation accounts for 20% of global energy use with 35% of the total energy use in residential and commercial buildings resulting from heating, ventilation, and air conditioning (HVAC) [5], [7], [8], air cleaning could represent a critical energy conservation device for the green energy transition [9]. Air cleaning can be applied in new and existing buildings to either improve indoor air quality or reduce energy use [3], [7]. However, for building designers to adopt air cleaners as a potential energy saving solution, aside from proving their air quality performance, there is a need for a convenient method to evaluate the energy impact [9], [10]. Subtask A in IEA EBC Annex 78 addressed the challenge of balancing indoor air quality (IAQ) and energy efficiency in buildings by exploring the application of gas-phase air cleaning technologies. This task focused on how integrating gas-phase air cleaners and, thus, increasing indoor air recirculation can minimize heating and/or cooling requirements while upholding acceptable IAQ standards. Furthermore, the clean air effectiveness (CAE), is recommended as a new key performance indicator (KPI), which can be used to include the energy benefits for substituting outdoor air supply of air cleaners in the design process of ventilation systems.

Subtask A quantified the energy performance of integrating air cleaning into ventilation systems. The baseline for assessing energy benefits included both the energy use associated with heating or cooling the ventilation air along with the electrical power required to operate the fans.

Subtask A was further divided into:

- A.1. Reducing energy use through indoor air cleaning (recirculation) vs. cleaning outdoor air in environments with inadequate outdoor air quality for ventilation
- A.2. Enhancing energy efficiency through decreased outdoor air utilization via air cleaning
- A.3. Enhancing energy efficiency through the integration of air cleaning with personalized ventilation systems: a workplace-centric approach
- A.4. Setting a performance standard for air cleaners: introducing the efficiency metric clean air delivery rate (CADR)/kWh for evaluating energy-efficient air cleaning

The results show that energy savings can be obtained by implementing air cleaning, however dependent on climate and the heating, ventilation and air condition (HVAC) system. It is essential however to consider all energy flows, including heating, cooling, and fan energy use to accurately assess the energy efficiency of gas-phase air cleaners.

For building designers to adopt air cleaners as a potential energy saving solution, aside from confirming their air quality performance, there is a need for a convenient method to evaluate the energy impact. The clean air effectiveness (CAE) combines both the air cleaning and energy savings performance into a single indicator which can be used to select the optimum air cleaning device and assessing if substituting a share of the total outdoor ventilation can lead to energy savings.

Further research is required however to comprehensively understand the energy implications of gas-phase air cleaners, requiring field studies to validate current findings. Establishing standardized baselines for key performance indicators will facilitate consistent evaluation and comparison of air cleaning systems and their integration in buildings.

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# Abbreviations

Nomenclature	Meaning	Unit
<b>CAE</b>	Clean air effectiveness	[-]
<b>CAE<sub>GPAC</sub></b>	Clean air effectiveness of the gas-phase air cleaner	[-]
<b>CAE<sub>MV</sub></b>	Clean air effectiveness of mechanical ventilation system	[-]
<b>CADR</b>	Clean air delivery rate	[m <sup>3</sup> /h]
<b>CCM</b>	Cumulative clean mass	[mg]
<b>E<sub>AUX</sub></b>	Energy use for delivering air	[kWh]
<b>E<sub>COOL</sub></b>	Energy use for cooling	[kWh]
<b>E<sub>HEAT</sub></b>	Energy use for heating	[kWh]
<b>E<sub>USE</sub></b>	Energy use	[kWh]
<b>E<sub>USE,GPAC</sub></b>	Energy use of the gas-phase air cleaner	[kWh]
<b>E<sub>USE,MV</sub></b>	Energy use of mechanical ventilation system	[kWh]
<b>n<sub>OH</sub></b>	Number of operating hours	[h]
<b>P<sub>GPAC</sub></b>	Electrical power of the gas-phase air cleaner	[kW]
<b>SPE</b>	Single pass efficiency	[-]

Acronyms	Meaning
<b>AHU</b>	Air handling unit
<b>CAV</b>	Constant-air-volume
<b>DCV</b>	Demand control ventilation
<b>EBC</b>	Energy in Buildings and Community
<b>HEPA</b>	High efficiency particulate air filters
<b>HVAC</b>	Heating, ventilation, and air conditioning
<b>IAQ</b>	Indoor air quality
<b>IEA</b>	International Energy Agency
<b>KPI</b>	Key performance indicator
<b>MV</b>	Mechanical ventilation
<b>PAQ</b>	Perceived air quality
<b>PECS</b>	Personalised environmental control system
<b>VAV</b>	Variable-air-volume
<b>VOC</b>	Volatile organic compound
<b>WHO</b>	World Health Organization

# Definitions

Definitions of energy performance according to EN 15603:2008 (Official Journal of the EU, 19.4. 2012, p. C 115/9) and econcept (embodied energy):

**Energy source:** source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process.

**Energy carrier:** substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes.

# 1. Introduction

Gas-phase air cleaners are equipped with either activated carbon filters, chemisorbent media filters, photocatalytic oxidation, ion generation, ozone generators or a combination of these solutions [1], [2]. They are challenged by sorbent regeneration, particle deposition, high pressure drops, byproduct generation, and incomplete pollutant breakdown depending on the technology employed [1]. Still, they remove a broad range of volatile organic compounds (VOCs) and odours, thereby removing bio-effluents and building emissions and cleaning the air, with a moderate to high efficiency [1], [3], [4], [5]. They also perform effectively when challenged with VOCs at low concentration [3], [4], [5]. There is, however, a high uncertainty about lifetime of gas-phase air cleaners [3]. Despite the emergence of wide array of air cleaning technologies, investigations into effectiveness is generally limited to media filtration [6], with the air cleaning effectiveness of gas-phase air cleaning being largely unreported [5].

## 2. Gas-phase air cleaning implementation in buildings

### 2.1 Air cleaning usage

Air cleaning can be used to treat the outdoor air if it represents the primary pollution source [11]. For urban air pollution and extreme events (e.g. wildfires, volcanic eruptions, sandstorms) [12], filtration and air cleaning represent the only effective solution for reducing pollution indoors [13], [14], [15]. In these situations, high efficiency particulate air (HEPA) filters can dramatically reduce indoor concentrations [13].

On the other hand, gas-phase air cleaners make possible recirculation and reuse of indoor air [16]. Thus, they can be used in buildings to substitute ventilation or to improve IAQ by removing VOCs and odours [17], [18], [19]. Furthermore, by cleaning the indoor air, gas-phase air cleaning can reduce the outdoor to indoor entrainment of pollutants due to the reduction in outdoor air supply [20].

Similar to specific pollutant targeted ventilation [21], gas-phase air cleaning can improve energy efficiency through the reduction of outdoor ventilation rates. This is because significant amount of energy is utilized to heat, cool, and run the circulation fans [16]. However, the performance of gas-phase air cleaning on air quality and the energy implications is largely unreported [16].

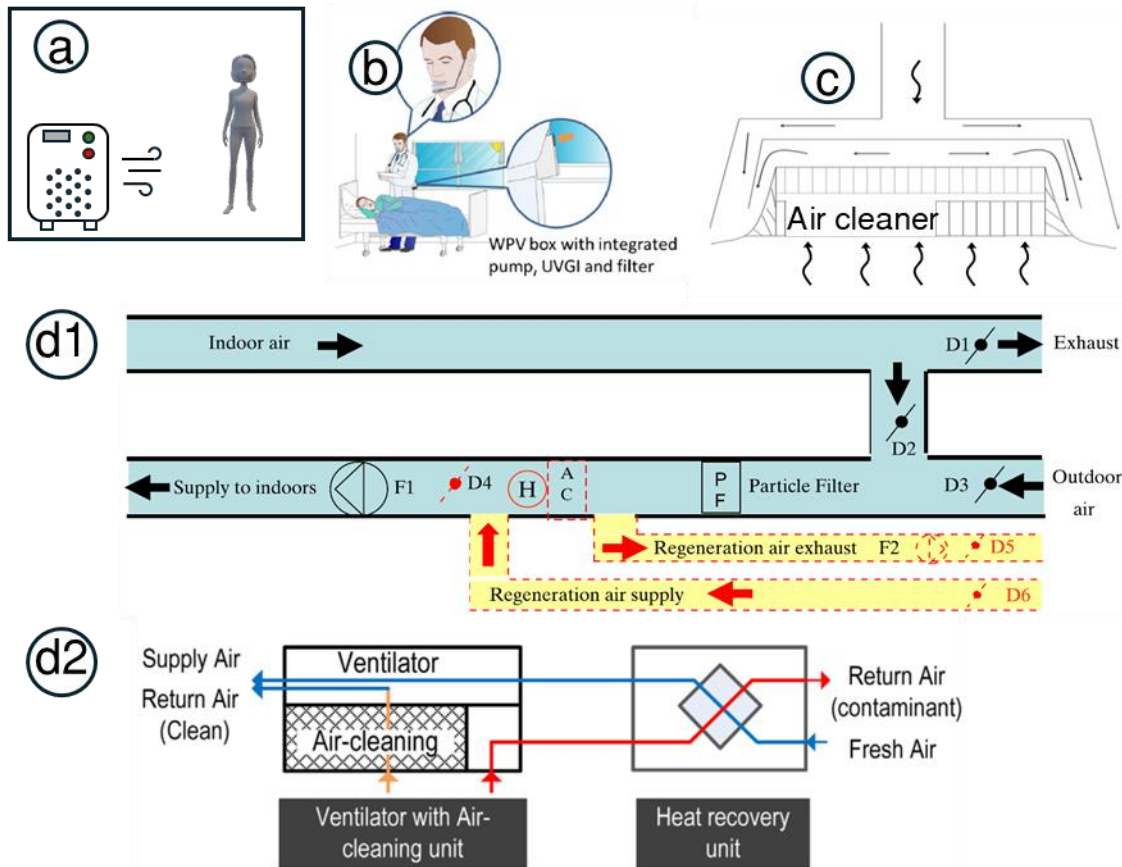
### 2.2 System configuration

Gas-phase air cleaning can be implemented in buildings a) as stand-alone units, b) in personal ventilation systems, c) in chilled beams, or d) on the primary air supply. Figure 1 provides examples of such implementations [22], [23], [24].

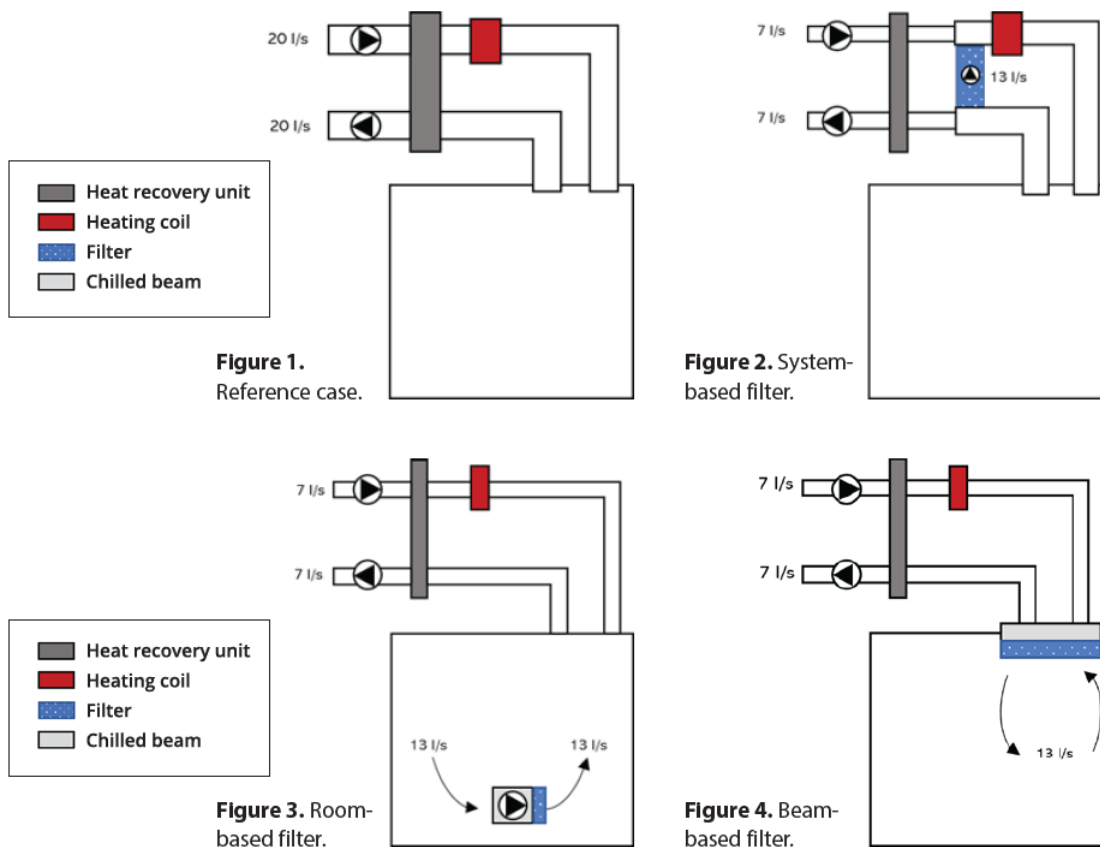
The location of the air cleaner can impact indoor air quality. If positioned on the primary air supply, air cleaners can directly reduce outdoor to indoor pollutant entrainment [11], [20]. However, this may require HVAC system adjustments, such as additional ducting for regeneration purposes in the case of adsorptive devices (Figure 1, d1) [25]. Other systems such as the one presented by Cho et al. [22] (Figure 1, d2) rely on air-cleaning units mounted close to the air supply diffuser which cleans recirculated indoor air prior to mixing it with the outdoor air supply.

According to Ebrahimifakhar et al. [26] pollutant concentrations can be controlled locally using portable air cleaners (also known as air purifiers). Portable air cleaners (Figure 1b) are installed in the vicinity of occupants and are used for cleaning recirculated indoor air, with their location being a determining factor on air distribution and hence air quality [27]. Personal ventilation systems with air cleaning systems (Figure 2b) have the advantage of supplying clean recirculated air directly in the occupant breathing zone, thus ensuring high effectiveness and requiring significantly lower air flow rates [24]. A beam-based implementation (Figure 1c, air cleaning combined with chilled beam) has the advantage of cleaning the recirculated air with no impact on air distribution [23].

The location of the air cleaner with respect to the ventilation system was also shown to have an impact on energy use. According to Afshari et al. [28] who investigated multiple configurations (fig. 2), even though implementing air cleaning centrally or as a stand-alone device leads to energy savings, the lowest energy use is achieved by a beam-based implementation due to the efficient recirculation of air through induction. However, air cleaning reduces the effect of free cooling by lowering the outdoor airflow rate. This was also reported by Zaatari et al. [20] when investigating lowering air delivery in retail stores due to HEPA implementation.



**Figure 1:** Air cleaning implementation: a) stand-alone unit, b) in personalized environmental control systems (PECS) [24], c) beam based [23], d) on the primary air supply [22], [25].

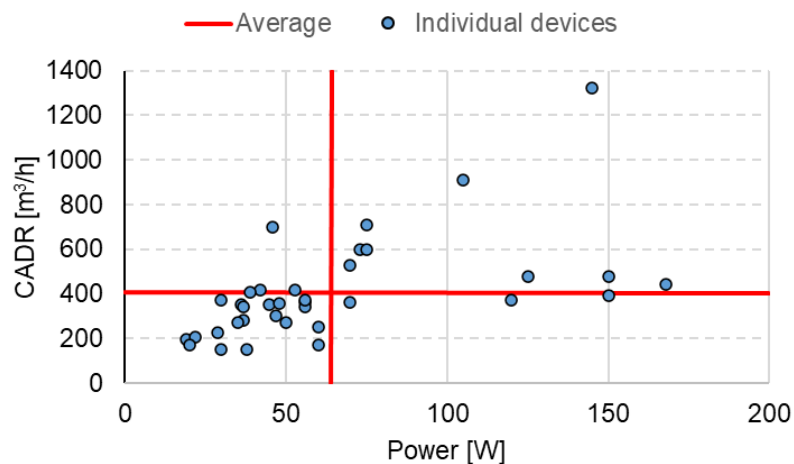


**Figure 2:** Different HVAC system configurations with air cleaners 1) Reference case, 2) system-based filter, 3) room-based filter, 4) beam-based filter. Afshari et al. [28].

# 3. Energy efficiency through air cleaning integration

## 3.1 Stand-alone gas-phase air cleaner energy use

Figure 3 shows the Clean air delivery rate (CADR) as a function of electrical power of stand-alone gas-phase air cleaners. The data was based on the gas-phase air cleaning systems selected from the air cleaner survey made by Ji et al. [29] and additional devices identified on the European market. Further details on the data are available in Appendix A – Stand-alone gas-phase air cleaner list. Except for an air cleaner which was designed for high room areas (2100 m<sup>2</sup>), the average design room size was 55 m<sup>2</sup>.



**Figure 3:** CADR as a function of electrical power for stand-alone gas-phase air cleaners based on market data (adapted from Li et al. [29]).

No air cleaner provided the rated CADR based on sensory ratings of perceived air quality. The electrical power at rated conditions ranged from 19 to 168 W. The rated CADR was between 150 and 1325 m<sup>3</sup>/h, however dependent on the pollutant of interest. The blue dots represent individual air cleaning devices while the red lines indicate average values for the CADR and power. On average a stand-alone air cleaner can provide a CADR of 400 m<sup>3</sup>/h. This is 200 m<sup>3</sup>/h higher than the value suggested by Ebrahimifakhar et al. [26] for an average electrical power of 65 W. Most air cleaners operate below 100 W with varying CADR values, while few high-power models (>100 W) provide significantly higher CADR.

## 3.2 Energy savings in buildings

Table 1 provides an overview of energy savings obtained from gas-phase air cleaning implementation in scientific literature. Estimations were derived from numerical and simulation studies in either office or residential settings with floor areas ranging from 16 to 3000 m<sup>2</sup>. The framework for determining the energy savings from air cleaning implementation consisted of assuming or deriving an air cleaner efficiency and implementing it as a reduction in the outdoor air flow rate of the ventilation system.

Except for Cho et al. [22] and Bogatu et al. [9], who also investigated air cleaning combined with demand control ventilation (DCV) and variable air volume (VAV) strategies, the rest of the studies employed a constant air volume (CAV) strategy for the mechanical ventilation (MV) system. The influence of heat recovery on the energy savings generated by the air cleaner was usually investigated, while assuming heat

recovery effectiveness of 80% or above. Simulations were conducted in both hot and humid climates with varying humidity levels.

The outdoor air flow rate reductions investigated were up to 60%. The air cleaners used to derive the reduction in air flow rate were usually equipped with an activated carbon filter and additional filters, e.g. HEPA. Out of all the studies, 36% investigated air cleaners implemented on the primary ventilation systems, 45% investigated portable air cleaners, while 20% did not specify the selected air cleaning system configuration. The effectiveness of the air cleaner was either determined on the single-pass efficiency as a function of a specific pollutant of interest, e.g. formaldehyde, or based on the perceived air quality of a panel. The majority of studies reported significant energy savings (up to 50%) when implementing gas-phase air cleaning technologies in buildings, however dependent on climate. This is primarily due to the significant reduction in heating and cooling energy needs generated by the lower outdoor air supply. Air cleaning can significantly reduce heating energy use in cold climates. The use of heat recovery significantly reduces the energy savings effect of air cleaning. Moreover, a reduction in the outdoor air flow rate due to air cleaning implementation may increase cooling energy use by eliminating the effect of free cooling in cold climates. Critical metrics such as CADR and purification efficiency are essential for assessing the effectiveness of air cleaning systems. Furthermore, studies incorporating dynamic control based on real-time air quality monitoring demonstrate higher energy savings and better indoor air quality management.

**Table 1:** Examples of energy savings from gas-phase air cleaning implementation.

Author	Study purpose	System configuration	Research type/test procedure	Air cleaner	Results
Afshari et al. [28]	Impact on energy use of air cleaning as a function of different system configuration	<ul style="list-style-type: none"> <li>MV with heat recovery (eff. 80%) as baseline</li> <li>Three additional configurations: i) integrated air cleaner, iii) portable air cleaner, and iv) air cleaner incorporated in chilled beam</li> </ul>	<ul style="list-style-type: none"> <li>Building energy simulation</li> <li>16 m<sup>2</sup> office space</li> <li>Pressure drop adjusted according to configuration</li> </ul>	<ul style="list-style-type: none"> <li>Assumed 80% efficiency</li> <li>Not physically implemented; outdoor air flow rate reduced</li> </ul>	<ul style="list-style-type: none"> <li>Reducing outdoor air flow rate limits potential for free cooling</li> <li>All configurations led to savings in fan and heating energy use compared to baseline</li> <li>Energy use reduced by 26% when a beam-based filter is employed compared to baseline</li> </ul>
Bogatu et al. [30], [31]	Estimate energy savings from substituting outdoor air with gas-phase air cleaning	<ul style="list-style-type: none"> <li>CAV mechanical ventilation system</li> <li>With and without heat recovery (85%)</li> <li>20 m<sup>2</sup> office space</li> </ul>	<ul style="list-style-type: none"> <li>Building energy simulation</li> <li>Cold and humid and hot and humid climates</li> <li>Varied required air flow rate according to building pollution level</li> </ul>	<ul style="list-style-type: none"> <li>Air cleaner not physically implemented</li> <li>CADR determined based on PAQ in laboratory measurements</li> <li>Air cleaner: prefilter, HEPA filter, activated carbon filter, platinum catalytic converter</li> </ul>	<ul style="list-style-type: none"> <li>Energy savings increase with the required outdoor air flow rate</li> <li>Energy savings are subject to climatic conditions</li> <li>Gas-phase air cleaning could improve air quality for a lower energy use than the equivalent increase in outdoor air flow rate</li> </ul>
Bogatu et al. [10]	Establish a metric and framework for selecting air cleaning systems	<ul style="list-style-type: none"> <li>VAV mechanical ventilation system</li> <li>With and without heat recovery (85%)</li> <li>1661 m<sup>2</sup> office building module</li> </ul>	<ul style="list-style-type: none"> <li>Building energy simulation</li> <li>Hot and humid (Tokyo, Japan) and cold and humid (Copenhagen, Denmark) climates</li> <li>0 to 50% reduction in required outdoor air flow rate</li> </ul>	<ul style="list-style-type: none"> <li>Air cleaner not physically implemented</li> <li>CADR based on PAQ in laboratory measurements</li> <li>Air cleaner: prefilter, HEPA filter, activated carbon filter, platinum catalytic converter</li> </ul>	<ul style="list-style-type: none"> <li>Air cleaning may be a competitive energy saving solution even for low CADRs (e.g. 20% of total required air flow rate)</li> <li>Energy savings of up to 3.9-4.4 kWh/m<sup>2</sup> per year depending on climate</li> </ul>
Chen et al. [27]	Real-time monitoring and optimization for portable air cleaner operation to reduce energy use while maintaining air quality	<ul style="list-style-type: none"> <li>Open-space office</li> <li>Mechanical ventilation system without recirculation</li> <li>Constant supply air temperature</li> <li>Portable air cleaners</li> </ul>	<ul style="list-style-type: none"> <li>CFD model</li> <li>Ammonia used as surrogate pollutant</li> <li>ACH 0.5, 1, 1.5, or 2</li> <li>Optimize on/off operation and placement of portable air cleaners</li> </ul>	<ul style="list-style-type: none"> <li>Assumed to remove ammonia</li> <li>Purification efficiency 99%</li> </ul>	<ul style="list-style-type: none"> <li>Average reduction of energy use of 35%.</li> <li>For an 81 m<sup>2</sup> office space an optimum of 3 air cleaners was determined</li> </ul>
Cho et al. [22]	Energy-saving potential of a ventilation system with an air-cleaning unit and demand control	<ul style="list-style-type: none"> <li>CAV or DCV mechanical ventilation system</li> <li>Heat recovery effectiveness 80-90%</li> </ul>	<ul style="list-style-type: none"> <li>Building energy simulation</li> <li>DCV controlled according to CO<sub>2</sub> and formaldehyde level</li> <li>Residential</li> <li>Korea climate</li> </ul>	<ul style="list-style-type: none"> <li>Fine-mesh pre-filter, ionizer, electrostatic filter, and HEPA filter</li> <li>Assumed CADR of 35%</li> </ul>	<ul style="list-style-type: none"> <li>Proposed control reduced ventilation system operation time by 50% and energy use by 20%</li> <li>Concentration of CO<sub>2</sub> and formaldehyde may exceed limits</li> </ul>
Cui et al. [32]	Reduce energy use of mechanical ventilation systems	<ul style="list-style-type: none"> <li>CAV mechanical ventilation system</li> <li>Air cleaner integrated in the primary air supply system</li> </ul>	<ul style="list-style-type: none"> <li>Building energy simulation</li> <li>Singapore climate</li> </ul>	<ul style="list-style-type: none"> <li>Air cleaner consisted of i) oxygen production device, ii) ozone-based oxidation</li> </ul>	<ul style="list-style-type: none"> <li>Outdoor air flow rate reduction from 10 to 2 L/s per person led to 23.4% cooling energy savings</li> </ul>

Author	Study purpose	System configuration	Research type/test procedure	Air cleaner	Results
	by purifying recirculated air	<ul style="list-style-type: none"> <li>• 3000 m<sup>2</sup> five-storey office building</li> </ul>		<ul style="list-style-type: none"> <li>• device, and iii) activated carbon filter</li> <li>• Not physically implemented; outdoor air flow rate reduced</li> </ul>	<ul style="list-style-type: none"> <li>• Air cleaner implementation led to a reduction in total energy use compared to an MV running at 8 L/s per person</li> </ul>
Han et al. [33]	Investigate energy savings from dynamically adjusting outdoor air intake and air cleaner operation based on outdoor air quality and thermal conditions	<ul style="list-style-type: none"> <li>• Mechanical ventilation system</li> <li>• Low energy office building (2471 m<sup>2</sup>)</li> </ul>	<ul style="list-style-type: none"> <li>• Validated building model</li> <li>• Compare to a prescriptive minimum ventilation rate and a 50% reduction in ventilation rate</li> <li>• Four US climates (Syracuse, Houston, Los Angeles, Duluth)</li> </ul>	<ul style="list-style-type: none"> <li>• Not physically implemented</li> <li>• Modelling transient indoor/outdoor air pollution</li> <li>• Eighteen compounds of concern representative of office environments were used</li> </ul>	<ul style="list-style-type: none"> <li>• Dynamic control led to 11% annual energy savings</li> <li>• Energy savings came from the reduction in energy use for conditioning outdoor air and increase ventilation rate for daytime cooling</li> <li>• Most energy savings do not necessarily translate into cost savings because of cost difference between energy sources</li> </ul>
Li et al. [34]	Determine total equivalent ventilation rate with portable air cleaners (MV-PAC) system under regular and respiratory infectious disease (RID) scenarios	<ul style="list-style-type: none"> <li>• Open-space office</li> <li>• Mechanical ventilation system without recirculation</li> <li>• Two portable air cleaners</li> </ul>	<ul style="list-style-type: none"> <li>• Optimization of MV-PAC operation for i) IAQ (PM2.5 and CO<sub>2</sub>), ii) mitigation of RID, and iii) energy use</li> <li>• Use of non-dominated sorting genetic algorithm II (NSGA-II) with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)</li> </ul>	<ul style="list-style-type: none"> <li>• Air cleaner consisted of HEPA, activated carbon filter, photocatalytic reactor</li> <li>• CADR 800 m<sup>3</sup>/h for PM2.5 and 530 m<sup>3</sup>/h for formaldehyde</li> </ul>	<ul style="list-style-type: none"> <li>• By substituting ventilation using air cleaners, the energy use was reduced by 50%</li> <li>• During periods with high outdoor air pollution, the energy use increased by 38.9% due to the increased use of air cleaners</li> </ul>
Nourozi et al. [16]	Reducing building energy use by partially substituting outdoor air ventilation with gas-phase air cleaning	<ul style="list-style-type: none"> <li>• CAV mechanical ventilation system</li> <li>• Heat recovery effectiveness 60-95%</li> </ul>	<ul style="list-style-type: none"> <li>• Building energy simulation</li> <li>• Stockholm, Sweden climate</li> <li>• Office and residential buildings</li> <li>• Recirculation morning and evenings</li> <li>• Recirculation rate of 0 to 60%</li> </ul>	<ul style="list-style-type: none"> <li>• Assumed efficiency of 60-65%</li> <li>• Not physically implemented; recirculation increased</li> </ul>	<ul style="list-style-type: none"> <li>• A 60% recirculation rate decreased heating demand by up to 9% and 24% in residential and office buildings, respectively.</li> <li>• No energy savings were registered in the residential setting when heat recovery was employed</li> </ul>
Sidheswaran et al. [25]	Evaluation of air cleaning filter for VOC removal during work hours with periodic in-situ regeneration	<ul style="list-style-type: none"> <li>• Air cleaner integrated in the primary air supply system</li> <li>• Filter regeneration realized by secondary loop with heated/unheated outdoor air</li> </ul>	<ul style="list-style-type: none"> <li>• Experimental assessment of air cleaner in a 19 m<sup>3</sup> stainless steel chamber</li> <li>• Numerical estimation of ventilation energy cost</li> </ul>	<ul style="list-style-type: none"> <li>• Activated carbon filter</li> <li>• 1.4-g single-layer specimen of 80 mm diameter and 0.4 mm thickness</li> </ul>	<ul style="list-style-type: none"> <li>• Use of air cleaner reduced VOCs by 60 to 80% and formaldehyde by 12 to 40%</li> <li>• Heating the filter to ~150 °C improved regeneration leading to VOC removals of 70-80%</li> <li>• Reduction of 50% outdoor air can lead to ventilation energy cost reduction of 35%</li> </ul>

### 3.3 Air cleaning and personalised environmental control systems

According to IEA EBC Annex 87 [35], a Personalised environmental control system (PECS) is a system that can provide an individually controlled environment in the immediate surroundings of an occupant, without affecting directly the space and other occupants. Compared to total volume heating, ventilation, and air-conditioning systems, PECS can enhance comfort at low energy expense while being able to address interpersonal differences.

PECS can also be used to supply clean air in the breathing zone of the occupants with effectiveness greater than total-volume ventilation systems [36], [37], [38]. Thus, personalised ventilation systems have the potential to significantly reduce the amount of airflow required to fulfil indoor air quality recommendations, leading to improved air quality and energy savings [24]. For this, the PECS can be connected to an outdoor air supply duct, or it can be equipped with air cleaning (e.g. Shinoda et al. [39]) to recirculate and clean the room air before being supplied to the breathing zone [9], [40]. PECS would thus substitute outdoor ventilation reducing the energy use for heating and cooling the outdoor air. This would result in energy savings if the total volume system and the PECS do not have a conflicting operation (e.g. the PECS does not generate a cooling load that must be removed by the air handling unit) [24], [41], [42].

According to Schiavon et al. [42] in hot and humid climates reducing the outdoor air flow rate due to PECS implementation generated energy savings of up to 11% compared to a mixing ventilation strategy. This was mostly due to a reduction in cooling the supply air in the air handling unit (AHU). However, these savings are representative for open-space offices with high occupant density and where people are stationary, e.g. at workstations. In cold climates [41], reducing the air flow rate does not always imply a reduction of the energy use when implementing PECS compared to mixing ventilation. This is because for a constant PECS supply air temperature the supplied air provides a free cooling effect which is lost by reducing the air flow rate. For a comfort-based approach however, where the supply air temperature of the PV is controlled inversely to the room temperature, energy savings should be achieved with approximately 8% as reported by Schiavon et al. [41].

# 4. Metrics for assessing air cleaner efficiency in relation to energy

## 4.1 Air cleaner performance characterization

Air cleaners are characterized based on their pollutant removal performance and the energy use of the device. Factors to be taken into account when selecting the most effective air cleaning system include target pollutant, long-term performance, energy use, and the formation of unwanted by-products [6]. The indicators used for characterizing the pollutant removal performance are [43], [44]:

- The clean air delivery rate (CADR), [m<sup>3</sup>/h], which expresses the pollutant removal efficiency.
- Single pass efficiency (SPE), [-], which represents the fraction of pollutants removed from the airstream passing through the air cleaner determined in laboratory tests.
- Air cleaner effectiveness, [-], which is a comparison of pollutant concentrations in a space with and without air cleaners determined under field tests or in situ evaluations.

The indicators can be determined for pollutants such as smoke, dust, pollen, specific volatile organic compounds, particles, microorganisms, pathogens, or surrogate pathogens and as a function of the perceived air quality (PAQ) based on sensory tests [44], [45], [46]. According to Afshari et al. [43], the CADR, SPE, and air cleaner effectiveness do not account for long-term air cleaner performance [43] and instead the cumulative clean mass (CCM) which takes into account the CADR degradation could be used.

According to Zhang et al. [18], most studies focus on air cleaner SPE, particle removal, CADR, but energy is often overlooked. The energy use of the device is a function of the required air flow rate and the elements included in the air stream (e.g. filters) which generate pressure drop [1]. The CADR and energy use are interconnected as a higher airflow rate and hence energy use, will increase the CADR [43], [44].

## 4.2 Clean air effectiveness

The use of either CADR, effectiveness, SPE or electrical power does not offer a holistic assessment of a device compared to an alternative for providing clean air, i.e. the building HVAC system or an alternative air cleaner. Therefore, the clean air effectiveness (CAE) is proposed as a key performance indicator (KPI) [10], [30] which combines the clean air delivery rate and the required energy use. The CAE represents the equivalent energy use for providing one L/s of clean air and can be determined for the entire period of interest, e.g. day, month, or year. The CAE is equal to:

$$CAE = \frac{CADR}{E_{USE}} \quad [L/s \text{ per } kWh] \quad (1)$$

where the *CADR* represents the clean air delivery rate in L/s and *E<sub>USE</sub>* the energy use for providing the respective amount of clean air in kWh. The CAE is versatile by allowing to account for any energy use associated with the air stream such as heating, cooling, and air delivery. The CAE can be used under two scenarios namely, to select the optimum device as a supplement to the mechanical ventilation (MV) system in the interest of air quality or for assessing if a share of the total ventilation rate can be substituted by air cleaning in the interest of energy savings for the same resulting air quality. In both scenarios, the solution with the highest CAE should be selected.

For an equitable comparison the CAE should be computed over the same timeframe, e.g. yearly, for all compared systems [10]. The CADR should be representative of the same pollutant of interest and ideally for the same PAQ. Moreover, primary energy factors should be applied according to the energy source, i.e. district heating, electric cooling, by region [10].

#### 4.2.1 Selecting the optimum air cleaner

Two or more air cleaners may be compared to select the appropriate solution for improving air quality. The goal is to identify the most effective air cleaner. When determining the CAE of the gas-phase air cleaner (GPAC), the CADR is equal to the amount of clean air provided, i.e. fraction of the total air cleaner flow rate that is free of targeted pollutants and has no negative effect on the air quality of the space. The CADR may be representative of a specific target pollutant [43] or as a function of the perceived air quality [45] depending on the application. Unless specified by the manufacturer, the CADR can be determined based on a standardized method. The energy use of each air cleaner can be determined based on the expected air cleaner operation time and the fan power at the rated setting for maintaining the air quality under prescribed conditions. The air cleaner effectiveness ( $CAE_{GPAC}$ ) is equal to:

$$CAE_{GPAC} = \frac{CADR}{E_{USE,GPAC}} = \frac{CADR}{P_{GPAC} \cdot n_{OH}} \quad [L/s \text{ per kWh}] \quad (2)$$

where  $E_{USE,GPAC}$  equals to the electrical power ( $P_{GPAC}$ ) of the air cleaner in kW multiplied by the number of operating hours ( $n_{OH}$ ) within the investigated period. The entire occupancy period could be used as the air cleaner operation time unless designed for a specific use, e.g. only during periods with high outdoor air pollution levels where the use time should be estimated based on frequency and duration of the specific event. If multiple air cleaners are assumed in the space, e.g. to reach the required CADR with multiple devices or for an improved air distribution, the CAE should reflect the total energy use of all devices included in the proposed solution.

#### 4.2.2 Substituting a share of the total outdoor ventilation

In order to substitute a share of the total outdoor ventilation with the use of a stand-alone air cleaner, the proposed air cleaning solution must be more effective than the mechanical ventilation system at supplying that share of clean air.

In this case, the CAE can be computed for both the air cleaning and the MV system for the same reference period. The CAE of the air cleaning solution is equal to the ratio between its CADR and its energy use as described in 5.2.1. The CAE of the MV system ( $CAE_{MV}$ ) is equal to:

$$CAE_{MV} = \frac{CADR}{E_{USE,MV}} = \frac{CADR}{E_{HEAT} + E_{COOL} + E_{AUX}} \quad [L/s \text{ per kWh}] \quad (3)$$

where the CADR represents the reduction in outdoor ventilation rate and the total energy use of the MV system ( $E_{USE,MV}$ ) represents the energy use for heating ( $E_{HEAT}$ ), cooling ( $E_{COOL}$ ), and delivering ( $E_{AUX}$ ) the air.

If the CAE of the air cleaning solution is higher than the MV system, the air cleaner represents a more effective solution for supplying clean air. However, the air cleaning solution can only be used as a substitution solution during periods without extreme outdoor pollution levels if the remaining outdoor ventilation rate is above 4 L/s per person and the World Health Organization (WHO) guidelines are met [47]. If the MV system must be turned off to prevent the intake of high concentration of pollutants from outdoors during extreme events, the air cleaning solution may always be used if the IAQ can be improved.

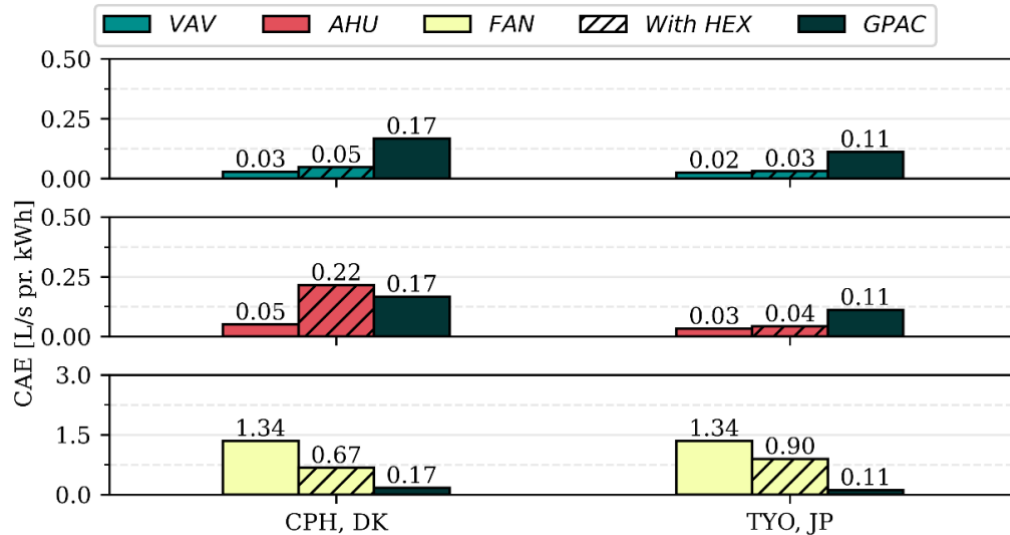
#### 4.2.3 CAE use case example

A use case example of the CAE was presented by Bogatu et al. [10]. In the study, air cleaning was used as a substitute for a share of the total outdoor ventilation of a medium office building module. The building performance simulation was performed under two climates, Copenhagen (CPH), Denmark (DK) and Tokyo (TYO), Japan (JP) categorized as cold and humid and warm and humid, respectively.

The building office module was equipped with a VAV ventilation system with dedicated electrical heating coils. The energy savings generated by substituting the outdoor ventilation air with stand-alone gas-phase air cleaners (GPAC) were investigated. The CADR of the GPAC, 15 L/s, was determined under laboratory settings using sensory assessments. The air cleaner was assumed operational only when the VAV was not in cooling mode (maximum ventilation rate) and for the entire occupancy schedule. A sensitivity analysis was performed where the minimum required outdoor air flow rate of the VAV was reduced by 0 L/s (no air cleaning), 536 L/s, and 893 L/s under two air handling system configurations namely with and without a heat

recovery unit (85% effectiveness). The number of stand-alone GPACs was adjusted according to the total required air flow reduction and the area of the space.

Figure 4 shows the resulting values for the CAE for the highest CADR of 893 L/s where a total of 62 GPACs were used. The CAE of the air cleaner was equal to the ratio between the sensory assessment based CADR and its energy use. The CAE of the ventilation system was calculated while considering different system components. It was broken down into a) the energy use of the heating and cooling coils of the air handling unit, electrical heating coils, and fan (VAV), b) only considering the AHU, i.e. excluding the electrical heating coils, and c) only considering the energy use for delivering air (FAN). The energy savings generated by the heat recovery unit (HEX) were also considered if the component was included in the AHU.



**Figure 4:** Clean air effectiveness (CAE) according to the assumed boundary conditions a) VAV only, b) AHU only, and c) air delivery (FAN) only compared to the one of the air cleaner (GPAC). Values are provided for two configurations, with and without heat recovery (HEX). Bogatu et al. [10].

Figure 4 shows that when only the fan energy use is considered, the air cleaner does not represent a competitive solution. Similarly, when only the AHU energy use is considered, namely excluding the independent demand of each building zone, the air cleaners are still not competitive if a large amount of energy could be recovered (CPH, DK). However, the air cleaner becomes a competitive solution for substituting outdoor air ventilation if the energy use over the entire VAV is considered.

Table 2 shows the CAE in litres per second per watt (L/s pr. W) by CADR for each climate and AHU configuration for 10 to 50% reductions in outdoor air flow rate. The values are only provided with respect to the energy use of the entire VAV system. The results show the CAE of the VAV remains constant irrespective of the reduction in the outdoor air flow rate due to the linear relationship between the CADR and the total energy use. In contrast, the CAE of the GPAC increased for an increase in the CADR, as a higher amount of air was cleaned by the GPAC. Notably, energy savings were achieved for the assumed air cleaner as soon as the CADR reached 20% even if a HEX was present in the AHU.

**Table 2:** Clean air effectiveness (CAE) in L/s pr. W by air flow rate reduction, Bogatu et al. [10].

CADR [L/s]	CADR [%]	CAE					
		VAV <sup>1</sup>		GPAC CPH	VAV <sup>3</sup>		GPAC TYO
		CPH [L/s pr. W]	CPH, HEX [L/s pr. W]	CPH [L/s pr. W]	TYO [L/s pr. W]	TYO, HEX [L/s pr. W]	TYO [L/s pr. W]
179	10			0.07			0.05
357	20			<b>0.14</b>			<b>0.09</b>
536	30	0.06	0.09	0.21	0.04	0.05	0.14
714	40			0.28			0.19
893	50			0.35			0.23

<sup>1</sup>Determined for ~2000 hours of VAV operation at the minimum air flow rate in CPH, DK.

<sup>3</sup>Determined for ~1500 hours of VAV operation at the minimum air flow rate in TYO, JP.

## 5. Conclusion

To accurately assess the energy efficiency of gas-phase air cleaners, it is essential to consider all energy flows, including heating, cooling, and fan energy use. In cooling load-dominated climates, the potential for free cooling without air cleaners can result in substantial energy savings, potentially superior to the savings from reduced heating and transportation of outdoor air. In heating load dominated climates, air cleaning systems can substantially reduce energy use especially in buildings without heat recovery systems.

The energy savings are dependent on the system and control employed, which require further investigation. The integration of gas-phase air cleaning with Personalised Environmental Control Systems (PECS) shows promising potential; however, current research is limited, emphasizing the need for more extensive studies. A wide range of air cleaning systems are available on the market with varying CADRs and power use for a wide range of applications. Establishing standardized baselines for key performance indicators such as the clean air delivery rate (CADR), clean air effectiveness (CAE), and overall energy use will facilitate consistent evaluation and comparison of air cleaning systems and their integration in buildings. These efforts will contribute to a more robust understanding of the energy benefits and operational efficiencies of gas-phase air cleaning technologies, ultimately guiding the development of more effective and sustainable indoor air quality management strategies.

Further research is required to comprehensively understand the energy implications of gas-phase air cleaners, requiring field studies to validate current findings. The long-term resilience and performance with respect to air quality and energy use of gas-phase air cleaning systems under various conditions warrant additional investigation.

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# Appendix A – Stand-alone gas-phase air cleaner list

**Table 3:** List of stand-alone gas-phase air cleaners. Retrieved from Ji et al. [29] and producers available on the European market.

Producer	Model	Components	Power [W]	CADR [m <sup>3</sup> /h]	Room size [m <sup>2</sup> ]
Honeywell	KJ305F-PAC1101W	HEPA, high-silica hydrophobic molecular sieve	38	150	
Blueair	211i Max	Main filter, activated carbon layer	46	700	60 to 140
352	X88 C	Pre-filter, H11 filter paper, Aldehyde lifting molecular sieve, UVGI, activated carbon, H13 Filter paper, Plasma jet	120	373	45 to 78
352	X86C	Pre-filter, F6 Filter paper, activated carbon, Deodorization module, H13 Filter	150	390	45 to 78
SHARP	KC-Z380SW	Pre-filter, Ordor Filter, Formaldehyde Filter, HEPA	56	361	38
Panasonic	F-PDF35C-G	Activated carbon, HEPA	19	196	-
SHARP	KC-W280SW	-	37	280	17 to 30
Honeywell	KJ450F-Z21WS	Pre-filter, HEPA, high-silica hydrophobic molecular sieve	-	150	-
PHILIPS	AC4026	-	30	153	-
PHILIPS	AC4374	-	56	340	-
Blueair	270E Slim	HEPASilent (charged particle filters and activated carbon)	60	250	-
A.O.Smith	KJ-400A01	-	36	350	50 to 99
A.O.Smith	KJ455f-C15-PFWi	Pre-filter, activated carbon, H13 Filter HEPA, reverse antimicrobial layer	-	270	-
DAIKIN	MC70KMV2	Pre-filter, Plasma jet, Filter paper, Catalytic Filter	42	420	-
LIFAair	LA350	Pre-filter, acid-proof activated carbon, HEPA cartridge	45	350	23 to 39
Blueair	550E	HEPASilent (charged particle filters and activated carbon)	73	600	-
Blueair	503	HEPASilent (charged particle filters and activated carbon)	75	600	-
PHILIPS	AC6608	-	75	710	70
IQAir	Health Pro 250	HyperHEPA, V5 cellular particulate activated carbon, Pre Max particulate filtration	145	1325	-
Midea	KJ210G-C42	-	22	205	20
SHARP	KC-CE50-N	-	48	358	35
Austin	Mecent HM230	-	35	270	-
PHILIPS	AC4080	-	60	171	-
DAIKIN	MC71NV2C-W	Pre-filter, Plasma jet, Filter paper, Catalytic Filter	53	419	-
Blueair	Pro M	HEPASilent (charged particle filters, activated carbon)	70	360	-
DAIKIN	MCK38RV2C-W	Pre-filter, Plasma jet, Filter paper, Catalytic Filter, Humidifier layer	29	228	-
Lenovo	X500	Activated Carbon, 3M-HEPA, UV LED, Negative Ions	70	526	2100
AirProce	AI600	Pre-filter-F7 V3, activated carbon, H13 Filter GF	150	480	-
A.O.Smith	KJ800f-C15-PFWi	Pre-filter, activated carbon, H13 Filter HEPA, reverse antimicrobial layer	125	480	-
DAIKIN	MCK57LMV2-N	Pre-filter, Plasma jet, Filter paper, Catalytic Filter, Humidifier	37	342	-
PHILIPS	AC4086	-	50	270	-
Allerair	AirTube S V	Carbon filter, HEPA, pre-filter	20	170	25
aura	aura	Pre-filter, HEPA, smart copper fabric, activated carbon, UV LED	168	441	-

Producer	Model	Components	Power [W]	CADR [m <sup>3</sup> /h]	Room size [m <sup>2</sup> ]
PHILIPS	AC8612	-	105	910	-
Midea	KJ400G-E33	-	39	405	-
SHARP	KC-W380SW-W	-	56	370	-
PHILIPS	AC4076	-	47	302	-
ReFinAIR	AP-C460A	-	30	370	50 to 100

ANNEX **78**



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