



# SMART VENTILATION WHITE PAPER

ADVANCING ENERGY EFFICIENCY AND INDOOR AIR  
QUALITY FOR SUSTAINABLE BUILDING PRACTICES

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## Executive summary

Mechanical Ventilation is critical for maintaining indoor air quality (IAQ), reducing pollutant concentrations, and ensuring occupant health and well-being, as well as optimising the heating or cooling needs of buildings. Conventional ventilation systems operate on fixed schedules or manual adjustments regarding air flows, often leaving room to further optimise air replacement within enclosed spaces. Smart ventilation systems use sensors and automation to optimise airflow dynamically, balancing health and comfort, energy efficiency, and operational sustainability.

### A smart ventilation system:

- **Monitors air quality** (CO<sub>2</sub>, humidity, volatile organic compounds, and particulate matter).
- **Adjusts ventilation** in real-time based on occupancy, pollutant concentrations, and indoor and outdoor conditions.
- **Enhances efficiency** by minimising energy waste while ensuring regulatory compliance.
- **Provides user feedback** to improve system longevity and performance.

### Key Benefits:

- **Optimized IAQ:** Removes pollutants and maintains healthy humidity levels.
- **Energy Savings:** Reduces unnecessary energy use by improving the efficiency of air renewal.
- **Improved Comfort:** Adapts ventilation to maintain an adequate indoor environment.
- **Cost Efficiency:** Lowers maintenance costs and extends system lifespan.

### Challenges:

- **Initial Investment:** Requires digital technology.
- **System Complexity:** Needs careful design and sometimes integration.

### Smart Ventilation in Residential vs. Non-Residential Buildings:

- **Residential:** Focuses on IAQ and energy efficiency challenges, ensures a healthier environment while minimising energy consumption.
- **Non-residential:** Focuses on significant energy savings for larger systems with opportunistic smart grid integration to support demand-side flexibility while providing, at the same time, healthy indoor air quality.

For the industry to unlock the full potential of smart ventilation, collaboration among manufacturers, policymakers, and researchers is essential. Standardisation, AI-driven optimisation, and sustainability initiatives will drive future innovations in this field. Smart ventilation has a prominent role in future-proofing buildings, ensuring healthier indoor environments, energy efficiency, and regulatory compliance. EVIA actively positions itself as a strategic partner for European policymakers in the rollout and refinement of regulations such as the EPBD, Ecodesign Lot 6, and the Zero Pollution Action Plan objectives.

**Now is the time to act and embrace smart ventilation as a key component of sustainable building design.**

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# 1. Establishing a common framework

A common framework for understanding smart ventilation is essential to align industry perspectives across residential and non-residential applications. This framework includes key definitions, technological foundations, and regulatory environments, serving as a neutral grounding for all stakeholders. By defining the principles and advantages of smart ventilation, this white paper aims to foster a shared understanding of how these systems contribute to energy efficiency, occupant well-being, and regulatory compliance.

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## 1.1 Defining smart ventilation in the industry context

### → THE ROLE OF SMART VENTILATION

Mechanical ventilation is a fundamental aspect of building design. It ensures a continuous supply of fresh air while extracting pollutants, moisture, and excess heat, providing a healthy and productive indoor environment. The transition from conventional, manually operated systems to smart ventilation represents a paradigm shift in indoor environmental control. Traditional ventilation systems rely on static configurations, pre-set schedules, or manual user adjustments regarding air flows, which are not dynamic. This leaves room to further optimise air replacement within enclosed spaces to adapt to fluctuating indoor conditions.

### → WHAT MAKES A VENTILATION SYSTEM 'SMART'?

A smart ventilation system utilizes **advanced algorithms and real-time sensor data** to dynamically regulate airflow in response to environmental conditions. By leveraging demand-control ventilation, these systems optimise indoor air quality (IAQ) without unnecessary energy consumption by providing just the needed air flow. Smart ventilation embodies a **balance between occupant health, energy efficiency, and operational sustainability**, ensuring that fresh air is delivered precisely where and when it is needed.

### → KEY FUNCTIONS OF A SMART VENTILATION SYSTEM

A truly intelligent ventilation system continuously assesses air quality and system performance, adjusting in real-time to optimize outcomes. The core functionalities include:

- **Continuous Air Quality Monitoring:** Detects fluctuations in key air quality parameters, especially CO<sub>2</sub> levels and humidity.
- **Automated Adaptation:** Adjusts ventilation rates dynamically based on occupancy, outdoor conditions, and pollution levels.
- **User Awareness & Predictive Maintenance:** Notifies occupants, owners, or facility managers of system performance, identifies malfunctions, and anticipates maintenance needs.
- **Energy Optimization & Cost Efficiency:** Minimizes wasteful energy use while ensuring compliance with IAQ regulatory requirements.

## → KEY IAQ PARAMETERS USED IN SMART VENTILATION ALGORITHMS

### PRIMARY

**Indoor CO<sub>2</sub> level:** A widely accepted indicator of human presence and ventilation rates.

**Indoor humidity:** Excessive humidity can damage buildings, encourage mold growth, and diminish comfort levels, while insufficient humidity is equally undesirable.

### SECONDARY

**Particulate matter:** It is acknowledged as a health hazard. It comes from both indoor and outdoor sources, and because of its complexity, it is rarely used as a control parameter. However, its importance in system control is growing in Europe.

**Total Volatile Organic Compounds (TVOC):** Although many VOCs pose health risks, others are harmless. Because TVOCs come from many sources and are complex to manage, they are not suitable for automatic ventilation control and are best used in specific areas.

## → ADDITIONAL PARAMETERS FOR SMART VENTILATION

Smart ventilation systems might use advanced parameters and strategies to optimize:

- Comfort (e. g. temperature) and presence detection
- Energy Recovery and Energy Consumption
- Reaction to outdoor conditions (e.g. outdoor air for free cooling)
- Outdoor pollution (Particulate Matter PM2.5, Pollen, Ozone)

Users often struggle to manually operate ventilation systems or manage window airing in a way that consistently meets conflicting requirements, preventing balanced operation. While installers may deliver systems that perform well under design and contractual specifications, these systems often fail to maintain optimal performance during regular partial-load conditions. Smart Ventilation Systems address these challenges by enhancing performance in all scenarios.

### Outputs to be maximized

- |   |   |
|---|---|
| <b>01</b> Fresh air supply  | + |
| <b>02</b> Reduction of indoor air pollution and removal of excessive humidity | + |
| <b>03</b> Energy and humidity recovery (heat/cold)                            | + |
| <b>04</b> Filtering   | + |
| <b>05</b> Passive heating and cooling   | + |

### Outputs to be minimized

- |   |   |
|---|---|
| <b>01</b> Energy consumption and costs  | - |
| <b>02</b> Underperformance due to incorrect installation or malfunctioning system | - |
| <b>03</b> Incorrect use of the system by occupants                                | - |
| <b>04</b> Noise and discomfort due to excessive ventilation (draught)             | - |
| <b>05</b> Maintenance cost (system cleaning, filter replacement)                  | - |

## → STRATEGIC INVESTMENTS FOR ENHANCED RETURNS

- Modern sensor and control technology make smart ventilation easy to use and manage.
- Upfront costs are higher, but energy savings and health gains offset the investment quickly.
- Standard communication protocols and data models make the interaction with BACS simple.

# 2. Smart ventilation for healthy IAQ & wellbeing

Ensuring optimal IAQ in buildings is essential for occupant health and well-being. Since people spend most of their time indoors, the air they breathe directly affects their overall health. Smart ventilation systems play a crucial role in maintaining a good IAQ, contributing to a healthier indoor environment.

Unlike traditional constant flow ventilation, which operates on fixed schedules or manual adjustments, smart ventilation uses sensors, algorithms, and automation to continuously monitor and control air quality and adapt air flows accordingly. These systems efficiently maintain carbon dioxide (CO<sub>2</sub>) and humidity (H<sub>2</sub>O) levels at appropriate levels, and remove pollutants such as volatile organic compounds (VOCs) by dynamically adjusting ventilation rates. This proactive approach enhances comfort, reduces respiratory risks, and mitigates other health concerns.

Smart ventilation systems effectively regulate humidity, preventing mold, mildew, and other moisture-related issues by maintaining optimal indoor conditions. Moreover, they enhance energy efficiency by adjusting ventilation rates based on occupancy patterns, pollutant levels and outdoor air quality, minimizing unnecessary energy use while ensuring adequate air circulation.

Communication with other smart home technologies or BACS further optimizes indoor environmental quality. Together, these systems provide a holistic IAQ solution, improving residents' health and comfort.



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## 2.1 Smart ventilation is key in IAQ management

1. Health and Well-being: By integrating all aspects of IAQ and the relevant indoor environmental quality (IEQ), smart ventilation systems contribute significantly to the health, comfort, and productivity of building occupants.
2. Advanced Contaminant Management: Utilizes high-efficiency filters and sensors to avoid occupant exposure to harmful pollutant concentrations.
3. Humidity Control: Prevents mould growth and the effects of dry or overly humid conditions.
4. Efficient Ventilation Management: Supplies outdoor air at the right amount and time to balance IAQ with energy efficiency.
5. Temperature Control: Ensures stable and comfortable indoor conditions by dynamically adapting airflow rates.

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## 2.2 Smart ventilation in residential and non-residential applications

The parameters outlined in the definition of Smart Ventilation, along with their associated positive effects, can vary significantly depending on the system's design and application. Larger, more complex systems typically consider a wider range of factors, allowing for a more advanced balance between desired outcomes and costs. Smaller systems, due to their simpler design and lower cost, tend to focus on prioritizing the core aspects of smart ventilation.

### → IMPORTANT ASPECTS OF SMART VENTILATION

	RESIDENTIAL	NON-RESIDENTIAL
<b>Interventions of the occupants</b>	Temporary manual override of the automatic function is typically necessary to allow users to manage specific situations and maintain confidence in the system.	Optional. It depends on the interactions between the building owner/ facility manager and the occupants.
<b>Connectivity</b>	Connectivity is not a requirement for classifying a smart ventilation system in a residential context. However, it can prove beneficial for larger systems with enhanced functions.	Connectivity is frequently necessary, as smart ventilation systems commonly communicate with building management systems when such infrastructure exists.
<b>Energy Consumption and savings (Smart Grid readiness)</b>	Energy consumption of residential ventilation systems is typically low. Also, the energy buffer capacity of ventilation in a residential context is very limited. Demand-side flexibility offers too little potential energy	Energy consumption of larger ventilation systems can be higher, especially if combined with HVAC and BACS functions. A certain energy buffer function might be achievable and time shifting of ventilation might

savings to justify efforts in this direction.

make sense and could be implemented if IAQ requirements during occupation of the building is respected.

## → RESIDENTIAL SMART VENTILATION

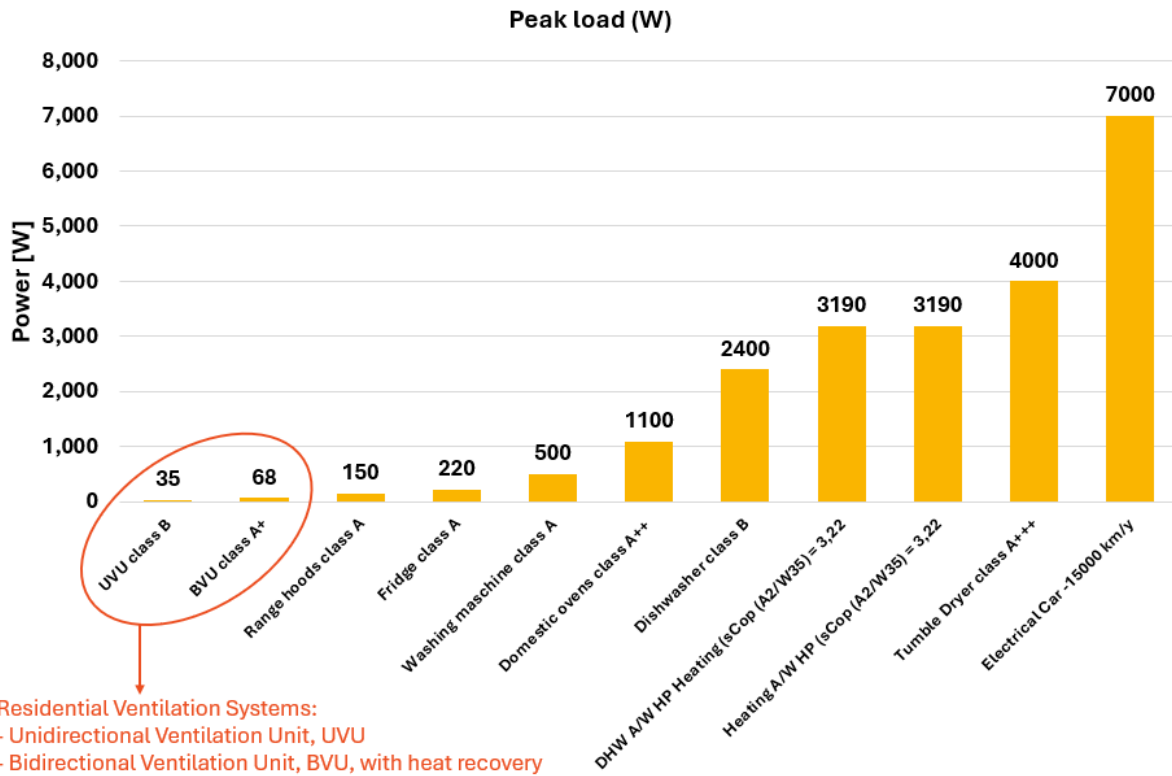
Mechanical ventilation ensures the supply of fresh air to maintain acceptable IAQ while minimizing energy needs and cost for buildings. National regulations establish ventilation flow requirements based on minimum IAQ targets, which vary across countries: in some, ventilation can be temporarily halted, while in others, it is mandatory to keep them running permanently. Certain countries allow multiple fan speeds, whereas others mandate a constant minimum airflow or require demand-controlled ventilation to ensure IAQ is maintained even when airflow is reduced.

Reducing ventilation based on an external signal is ineffective because ventilation systems lack the ability to store or buffer air quality improvements. Increasing airflow when a home is unoccupied wastes energy unnecessarily, while reducing ventilation below the minimum threshold required for acceptable Indoor Air Quality (IAQ) poses serious health risks.

**For a typical 100 m<sup>2</sup> house, ventilation energy consumption is as follows:**

- Motor consumption: 10 to 80 W (year-round)
- Fresh air heating demand: 100 W to 1 kW (during the heating season)

The most efficient systems consume minimal energy, meaning the potential energy savings for the grid are very limited (less than 100 W). External grid control would only introduce additional costs for the integration without delivering energy savings, as ventilation must always meet the minimum IAQ standards set by national regulations. In residential buildings, smart ventilation systems that adapt airflow to actual needs or recover energy from exhaust air can deliver meaningful energy savings, despite the low electricity use of these products. By optimizing ventilation performance and ensuring compliance with IAQ standards, these systems remove the need for grid integration. Continuous, demand-based ventilation is essential to maintain indoor air quality while keeping household energy use low.



Residential smart ventilation features:

- **Demand-based operation:** Adjusts airflow dynamically according to occupancy patterns and real-time IAQ.
- **Regulatory compliance:** Adheres to national requirements, ensuring that minimum ventilation rates are maintained even when external control is applied.
- **Minimal smart grid Impact:** Ventilation systems operate at low energy levels, making grid interaction negligible compared to energy-intensive appliances such as electric vehicles and water heaters.
- **Reduced heating demand:** By limiting thermal losses to what is strictly necessary for adequate IAQ, ventilation systems indirectly support grid stability; humidity-based demand-control UVU systems can achieve 15–26% energy savings compared to buildings without mechanical ventilation.

## ➔ NON-RESIDENTIAL SMART VENTILATION

In non-residential buildings, mechanical ventilation requirements are often significantly higher than those in residential settings due to larger spaces and higher occupancy rates. For instance, offices commonly aim for a CO<sub>2</sub> concentration target of 1000 ppm to ensure adequate air quality, and heat recovery systems are frequently employed to improve energy efficiency. Smart ventilation systems, whether demand-controlled or not, usually communicate with Building Automation and Control Systems (BACS). This integration allows monitoring of the dynamic adjustments carried out by the ventilation system to optimize energy use while maintaining indoor air quality at the desired level.

Smart ventilation systems in non-residential applications focus on:

- **Communication with BACS.**
- **Adaptive IAQ Settings:** Adjusts air exchange rates based on real-time occupancy data, indoor pollutant concentrations and outdoor air conditions.
- **Grid-responsive ventilation:** Modulates airflow to contribute to demand-side energy flexibility while complying with IAQ requirements.

Depending on the typical application, the yearly average outdoor air volume flow can be reduced by 20% to 60%, leading to annual electrical energy savings of more than 40% regarding the electricity consumption of the ventilation unit.

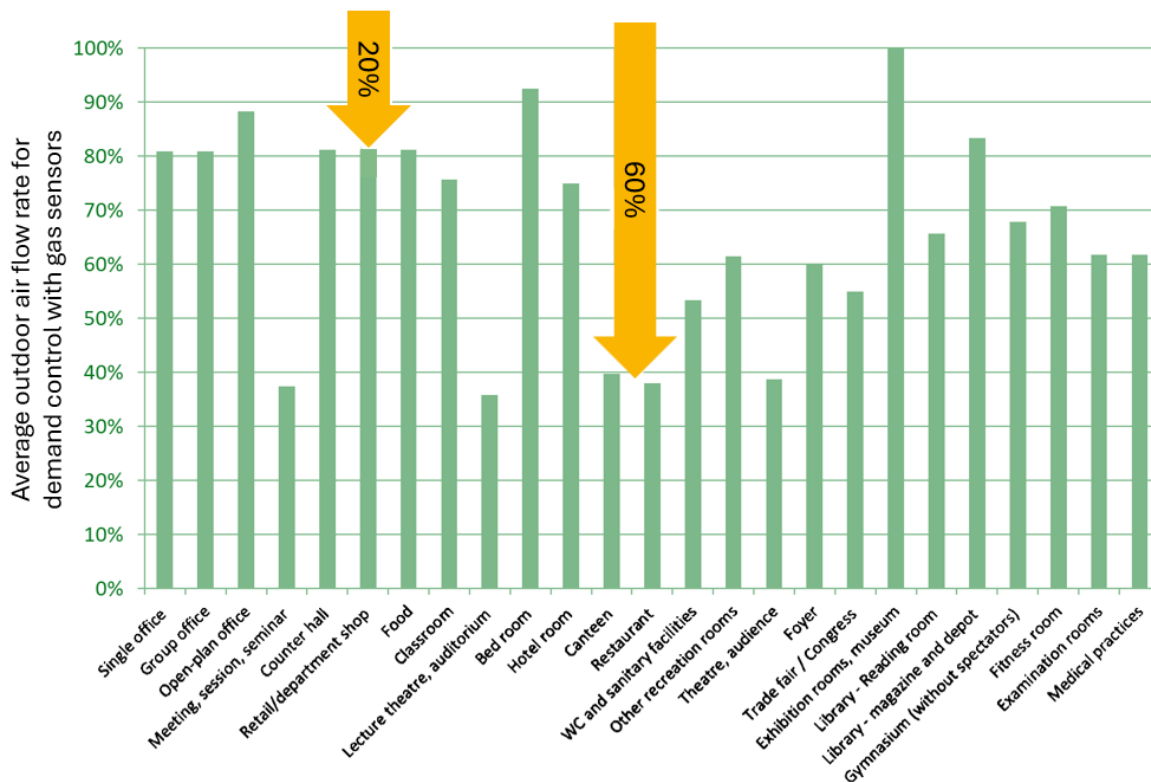


Table 1 Extracted from TGA Report, Technische Universität Dresden nr. 11 09/2024

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## 2.3 Standards, policies, and regulatory frameworks

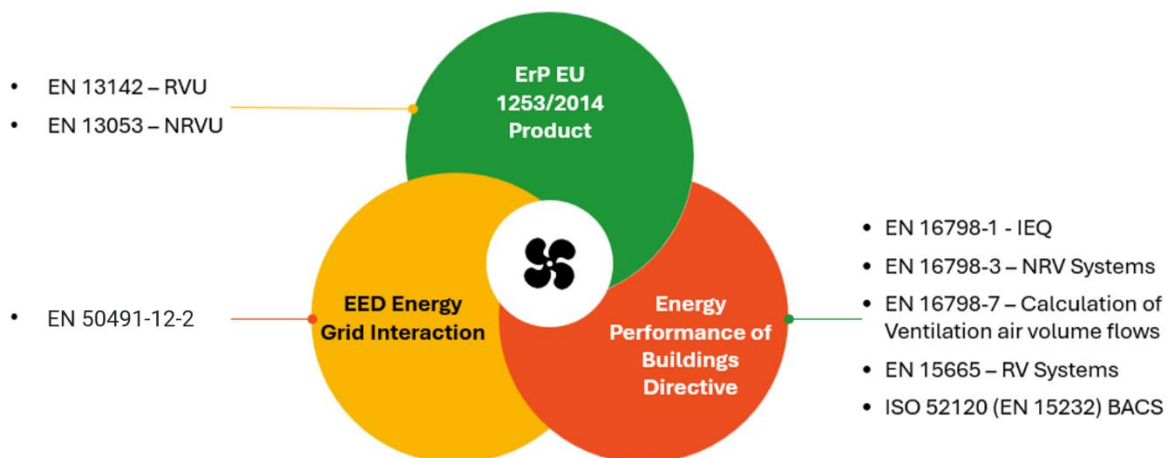
EVIA is eager to contribute to the European initiatives that recognise smart functionalities as valid tools for improving energy efficiency.

In addition, smart ventilation helps meet the EU's 2030 climate goals under the Green Deal. EVIA supports coordinated policies on energy efficiency, air quality, and building digitalisation.

Smart ventilation systems must align with key legislative frameworks to ensure both compliance and industry-wide consistency. These include:

- **Energy Performance of Buildings Directive (EPBD) Revision:** includes the Smart Readiness Indicator (SRI), a methodology for assessing building smartness, including aspects such as benchmarking and flexibility. Separately, the EPBD demands member states to set mandatory IAQ requirements for all buildings as well as IAQ monitoring obligations for non-residential ones.

For the first time, the EPBD explicitly requires Member States to establish requirements for healthy IEQ in all buildings. Smart ventilation systems are essential for achieving the IEQ objectives outlined in the EPBD revision, as IEQ is defined as follows: “Indoor Environmental Quality refers to the outcome of an assessment within a building based on parameters such as temperature, humidity, ventilation rate, and the presence of contaminants, which influence the health and well-being of its occupants.”



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## 2.4 Enhancing industry collaboration

Smart ventilation is governed by various regulations, including Ecodesign Lot 6 (energy efficiency), EPBD (IAQ requirements), and national health regulations. The industry is complex, with different systems across countries and between residential and non-residential buildings. Smart ventilation systems enable significant energy savings but require tailored regulatory frameworks. The primary goal is to ensure IAQ while minimizing ventilation heat and cool losses and reducing electricity consumption linked to heating and cooling needs. This lowers energy costs for users.

A smart ventilation system consists of a ventilation unit, control software, air distribution, and sensors that translate physical data (e.g., temperature, humidity, CO<sub>2</sub>) into actionable signals. Seamless integration requires expertise in IAQ, ventilation technology, and sensor development.

Specialized manufacturers provide holistic solutions that optimize IAQ and energy efficiency. Industry collaboration, informed decision-making, and a system-wide approach are essential to meeting regulations and achieving energy savings.

To fully unlock the potential of smart ventilation, the industry must:



## 2.5 Fostering innovation and adaptability in smart ventilation

Unlocking the full potential of smart ventilation requires industry-wide innovation at every stage of development and implementation. This demands a shift towards collaboration and experimentation with manufacturers, universities, and third-party entities. For instance, sharing monitoring data can drive comprehensive analysis and technological advancements.

A multidisciplinary approach is essential. Engineers, architects, environmental scientists, and software developers must work together to design systems that seamlessly integrate with building infrastructure while maximising efficiency and sustainability. Cross-disciplinary collaboration fosters diverse perspectives, enabling the industry to tackle complex challenges effectively.

Flexibility is also key. Advances in materials, sensor technology, and data analytics offer limitless opportunities for optimisation. Embracing modular designs and open-source platforms allows for rapid iteration and adaptation to evolving needs. Additionally, smart ventilation systems enhance usability by detecting faults and maintenance issues in real-time, ensuring optimal performance and reliability.

Sustainability must be a priority. Beyond optimising energy efficiency, the industry should consider the lifecycle impact of materials and technologies. Using renewable sources to meet energy demands, integrating recycled materials, and designing for longevity and recyclability contribute to a more sustainable built environment.

Smart ventilation represents a significant opportunity for innovation within the construction industry. By promoting collaboration, embracing adaptability, and prioritising sustainability, we

can design healthier, more energy-efficient buildings that not only meet but exceed future expectations.

Innovation only reaches its full potential when it is recognised in policy. EVIA is ready for a structured dialogue with DG ENER, DG CLIMA, and DG GROW on regulation, financing, and market access for smart ventilation technologies, particularly in the context of the Digital Decade program and the Chemicals Strategy for Sustainability.

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## 2.6 Comparative insights and future perspectives

This white paper emphasizes the critical need to include IAQ issue in smart grid integration and the potential of mechanical ventilation for achieving significant energy savings. Together with its partners, EVIA remains dedicated to advancing energy efficiency while addressing key considerations such as total cost of ownership and circularity. As sustainability initiatives drive the adoption of tighter building envelopes in both renovations and new constructions, effective ventilation becomes increasingly vital to maintain healthy indoor environments.

EVIA invites the European Commission to establish a structured dialogue platform on smart ventilation, with the goal of jointly shaping policies that integrate energy efficiency and indoor air quality. We propose holding the first roundtable in Q1 2026 with the relevant Directorates-General, Member State representatives, and the industry. EVIA is ready to serve as a knowledge partner, sounding board, and bridge-builder in shaping the future ventilation agenda.

### → RESIDENTIAL

Achieving a balance between energy savings and maintaining a healthy indoor environment is a central focus for the ventilation industry. Advanced technologies such as geofencing and CO<sub>2</sub> detection optimize energy usage by tailoring ventilation to actual needs while ensuring an adequate IAQ. However, integrating residential ventilation systems into the Smart Grid would have minimal impact due to their low energy consumption. Residential ventilation typically operates at low speeds, using far less energy compared to high-demand devices like electric vehicles or water heaters. Additionally, interruptions in ventilation could negatively affect IAQ, as systems would need to work harder to compensate for rising CO<sub>2</sub> levels or temperature fluctuations. Moreover, in some countries, such as France, it is not allowed by regulation to stop ventilation systems.

The implementation of the EPBD measures requires support in translating SRI and IEQ requirements into practice, with smart ventilation playing a key role in both.

Ventilation systems balance energy savings with IAQ effectiveness. They consume such minimal electricity that their integration into the Smart Grid would be ineffectual, offering no meaningful contribution to energy savings for grid stability.

### → NON-RESIDENTIAL

In contrast, connecting non-residential buildings to the Smart Grid offers tangible benefits. When unoccupied, these buildings represent concentrated, high-energy systems that could be

leveraged within the Smart Grid. The HVAC industry already integrates energy-saving strategies through Building Management Systems, making smart grid deployment a logical next step. The ventilation sector can serve as a knowledge partner, helping to optimise these opportunities.

By systematically linking smart ventilation to Smart Grid objectives within the Green Deal, a direct policy connection is created with the implementation of the EU's 2030 climate commitments.

High-energy-use buildings can contribute significantly to Smart Grid stabilization by adjusting ventilation loads based on real-time demand. Air flow regulation by smart ventilation systems allows non-residential buildings to play a more proactive role in overall energy management.

## Conclusions and call to action

Smart ventilation is a critical component of future-proof building design, ensuring optimal indoor air quality while enhancing energy efficiency. In both residential and non-residential contexts, smart ventilation supports not only indoor air quality but also wider sustainability goals, with non-residential buildings offering greater potential for smart grid integration.

In residential spaces, smart ventilation strikes a balance between health and energy savings, leveraging advanced technologies to maintain air quality with minimal electrical consumption. While these systems contribute less to direct grid flexibility due to their low power use, they indirectly support energy system stability by significantly reducing heating demand. By limiting thermal losses to the minimum required for adequate indoor air quality, especially with humidity-based demand-control UVU technology, heating energy needs can be reduced by 15% to 26% compared to buildings without mechanical ventilation.

Non-residential buildings, on the other hand, offer additional opportunities for grid interaction, thanks to their higher energy use and frequent interaction with BACS, which allow for dynamic load management and demand-response strategies. For smart ventilation to reach its full potential, industry-wide collaboration is essential. Manufacturers, policymakers, and building professionals must work together to optimise ventilation strategies, align with regulatory frameworks, and drive innovation. This EVIA Smart Ventilation White Paper serves as a resource, fostering knowledge-sharing and informed decision-making across stakeholders.

Looking ahead, a holistic approach to smart ventilation—one that integrates both residential and non-residential perspectives—is key to achieving healthier, more sustainable, and energy-efficient buildings. By embracing smart technologies, regulatory advancements, and cross-sector collaboration, we can shape the future of ventilation and indoor environmental quality, ensuring long-term benefits for occupants, businesses, and the planet.

**Now is the time to act: advancing smart ventilation is not just an opportunity but a necessity for the next generation of building design.**



### KEY TAKEAWAYS

Smart ventilation is a cornerstone of sustainable building design, ensuring IAQ while optimizing energy consumption.

Regulatory frameworks should support and incentivize the adoption of smart ventilation through standardized guidelines.

The industry must foster a culture of collaboration and cross-learning to drive innovation and maximize efficiency.



### NEXT STEPS

Expand research and development in artificial intelligence-driven ventilation control.

Promote standardization efforts to streamline system integration.

Strengthen engagement with policymakers to ensure smart ventilation plays a central role in energy regulations.

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