Improving Indoor Air Quality

SENSIRION

Contents

98.6 %

of health damage from indoor air pollutants is caused by particulate matter, formaldehyde, and nitrogen dioxide.[I]

Beyond comfort

Improving indoor air quality is more than enhancing comfort; it's about protecting health, ensuring overall well-being, boosting productivity and improving energy efficiency. A recent report published in Environmental Science & Technology highlights that particulate matter (PM2.5 and PM10), formaldehyde, and nitrogen dioxide account for 98.6 % of total harm caused by typical indoor air contaminants. These pollutants not only represent the most significant threats to human health but are also among the most prevalent, making it essential to prioritize their removal to improve indoor air quality. [I]

People spend more than 90 % of their time indoors, where some pollutant concentrations can be 2 to 5 times higher than typical outdoor concentrations. Most people are aware of the risks implied with water contaminants including microorganisms, (in-)organic chemicals and disinfection byproducts. However, considering that the average person inhales about 11,000 liters of air per day compared to an intake of 3 liters of water – a factor of 3,600 times – it is crucial to recognize the significant impact of air quality on our health.

Indoor air quality standards

There are several bodies that provide guidelines for maintaining good indoor air quality including the European Commission (EC), the World Health Organization (WHO), the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the WELL Building Institute, RESET and California Title 24 (CA24).

Some thresholds such as those provided by the EC, are legally binding for EU Member States.

To illustrate, the WHO provides guidelines for short- and long-term exposures to formaldehyde, recommending a limit of 0.1 mg/m³ (80 ppb) at a 30-minute exposure. [II] Similarly, the EU Air Quality Standard issued by the EC sets the limit and target value for fine particles (PM2.5) as a 1-year average exposure at 25 and 20 µg/m³, respectively. [III]

RESET® and WELL® building standards

RESET® is a globally recognized benchmark for indoor air quality monitoring and certification. It focuses on real-time data-driven measurement of important indoor air quality parameters.

The WELL Building Standard®, developed by the International WELL Building Institute™, is a performance-based certification system that focuses on parameters such as air quality, lighting, acoustics and thermal comfort.

Indoor air quality

Prioritizing health

Poor indoor air quality can have immediate adverse health effects including allergic reactions such as sneezing, itching, and watery eyes. Exposure over longer time periods or relatively high concentrations can have more severe and long-lasting consequences, including asthma, bronchitis as well as cardiovascular problems and an increased risk of heart diseases and strokes. Some pollutants, such as formaldehyde, are even classified as carcinogenic.

Symptoms such as headaches, dizziness, and nausea, which occur in response to time spent in a building with inadequate air quality, can be characterizations of the Sick Building Syndrome. A study across 22 schools in the US found that a 1000 ppm increase in indoor carbon dioxide (CO_2) concentration above the outdoor concentration was associated with a corresponding relative 10-20 % increase in student absence. [IV]

21 % decrease in cognitive scores is observed with a 400-ppm increase in CO_2 levels. [V]

A study published in Environmental Health Perspectives investigated how varying indoor air quality conditions affected participants over a six-day period. The results revealed that cognitive function scores were 101 % higher in environments with low volatile organic compounds (VOC) and high ventilation compared to environments with high VOC levels. Additionally, elevated CO_2 levels negatively impacted cognitive performance, with a 400-ppm increase in CO_2 resulting in a 21% decrease in cognitive scores. These findings underscore the critical role that indoor air quality plays for cognitive function. [V]

Indoor air quality

Real-time data for healthier indoor environments

Integrating air quality sensors into residential smart home ecosystems – including air quality monitors, air purifiers, and smart speakers – is crucial to ensure optimal indoor air conditions and enhance productivity and well-being. These sensors provide real-time data that supports ventilation automation and features like pollen alerts, presence detection, and energy savings.

In offices and workspaces, air quality sensors integrated into HVAC systems maximize energy efficiency and enable proper ventilation and good air quality, ensuring a healthy and productive work environment. Employers and building owners can incorporate indoor air quality monitoring into well-being programs like WELL or RESET to enhance employee health and reduce absenteeism. In educational institutions, sensors contribute to student health and improve cognitive performance. Healthcare facilities rely on sensors to ensure clean air in waiting areas and patient rooms, which is essential for infection prevention, reducing virus spread, and supporting patient recovery.

Smart home ecosystems include everything from lighting automation and smart speakers to fully integrated homes with numerous connected IoT devices. The Matter™ communication protocol supports a seamless connection between these devices, no matter what brand. Data originating from Sensirion sensors perfectly blend into Matter ecosystems, ensuring smooth and efficient integration.

Matter for smart home devices

To enable interoperability with various smart devices, the open source protocol Matter connects compatible devices and systems, offering a complete toolkit.

As a member of the Connectivity Standards Alliance™, Sensirion is supporting Matter's adoption and growth.

Compatible with healthy building standards

Most of Sensirion's environmental sensors are compatible with the relevant healthy building standards RESET, WELL, California Title 24 and LEED. For building owners, adherence to healthy building standards ensures the creation of healthier and more comfortable spaces for occupants, contributing to overall well-being and productivity. For device manufacturers, compatibility with the healthy building standards is essential for developing solutions that are compatible with regulatory requirements and meet market expectations. It also ensures a swift time to market and maintains an efficient cost structure.

	Sensors	RESET®	WELL®	California Title 24	LEED
RH/T	SHT40, SHT41, SHT45 Also included in SEN54, SEN55, SEN63C, SEN65, SEN66, SEN68	✓	✓	✓	
PM2.5	SPS30, SEN50, SPS60 SEN60 Also included in SEN54, SEN55, SEN63C, SEN65, SEN66, SEN68	✓	✓		✓
VOC	SGP40 Also included in SEN54, SEN55, SEN65, SEN66, SEN68	✓*	✓*		
CO_2	SCD30 SCD41 Also included in SEN66	✓ (Grade A) ✓ (Grade B) ✓ (Grade B)	✓ ✓ ✓	✓ ✓ ✓	
HCHO	SFA30, SFA40 Also included in SEN68		✓		✓

* Conversion from VOC Index to TVOC necessary

Measure what matters

To support efforts in creating safer and healthier indoor environments, Sensirion offers advanced sensing solutions that accurately measure and monitor air quality pollutants. Given our increasingly indoor-oriented lifestyle, understanding the factors that affect poor indoor air quality is essential.

Common conditions that contribute to indoor pollution include excessive humidity, temperature fluctuations, particulate matter, volatile organic compounds, nitrogen oxides, formaldehyde, and carbon dioxide. Additionally, concerns like the recent COVID-19 pandemic, pollen and smoke from wildfires have further highlighted the importance of air quality management.

Comfortable

Relative humidity and temperature

SHT4x

Relative humidity and temperature play a significant role in the comfort, health, and well-being of building occupants. Most people feel comfortable in environments with a relative humidity between 40 and 60 % and temperature between 20 and 25° C. Rising temperatures can increase the release of volatile organic compounds while consistent high humidity leads to the growth of mold, mildew, and dust mites, all of which can cause health issues such as allergies and asthma. Conversely, low humidity can cause respiratory dryness and an environment favorable for viruses.

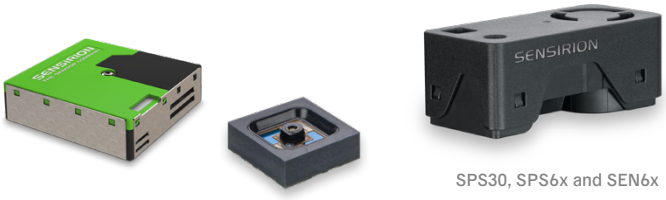
As one of the market leaders for environmental sensing, Sensirion offers a broad portfolio of humidity and temperature sensors, including the most advanced SHT4x series. Our sensors are used in devices such as smart thermostats or humidifiers and with that, contribute to climate management in millions of households worldwide.

Safe

Particulate matter

Particulate matter (PM) consists of a mixture of particles and liquid droplets suspended in air. The smaller the particles, the deeper they can penetrate our lungs, and potentially enter our bloodstream. This increases the risk of respiratory issues, cardiovascular disease, and premature mortality. Research indicates that PM accounts for more than 90 % of all health-related impacts of indoor air pollutants.[1]

Accurate, real-time PM data empowers informed decisions, such as optimizing air filtration, (automatically) operating air purifiers, or opening windows. For accurate, effective system-control and monitoring Sensirion offers the SPS and SEN sensor series.



SPS30, SPS6x and SEN6x

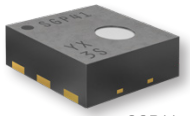
Indoor air quality

SGP40

Volatile organic compounds

Volatile organic compounds (VOC) is the collective term for carbon-containing substances that are volatile at room temperature. VOC are emitted from various materials, such as furniture, paints, or common household consumables. Short-term exposure can lead to eye, nose, and throat irritation, headaches, dizziness or worsening of asthma. The risks escalate with prolonged exposure, potentially leading to lung cancer or damage to vital organs.

VOC accumulation to dangerously high concentrations underscores the importance of monitoring VOC with sensors such as Sensirion's metal oxide (MOX) sensor SGP40. MOX sensors are inherently sensitive to all VOC, which is a challenge addressed by Sensirion's unique VOC index. It tracks what truly matters: relative changes to an adaptive baseline.



SGP41

Nitrogen oxides

Nitrogen oxides (NOx), a group of highly reactive gases, primarily consisting of nitric oxide and nitrogen dioxide (NO_2), are formed during combustion reactions. Indoors, NOx may originate from gas stove cooking or infiltration of outdoor air contaminated by sources like car exhaust. High concentrations of these gases, particularly NO_2, irritate and damage the respiratory system and can therefore have a negative effect on lung function.

Continuous monitoring of NOx levels indoors with sensors such as Sensirion's SGP41 allows for a safe and healthy indoor environment. One key advantage of the SGP41 is its excellent resistance to siloxanes, providing long-term reliable monitoring.

Formaldehyde

Formaldehyde poses serious health risks even at extremely low concentrations. Common sources include wood-based furniture and flooring, paint, and cosmetics. Classified as both a respiratory irritant and a carcinogenic chemical, formaldehyde ranks among the key indoor pollutants according to the WHO[(II)], EPA[(VI)], and European Commission.[(VII)] Because the gas is undetectable by sight and hardly detectable by smell at low concentrations, dedicated sensors are necessary for detection.

Accurately measuring formaldehyde requires distinguishing it from other common indoor volatile organic compounds, which are typically present at much higher concentrations. Sensirion's SFA is designed for this purpose, offering high sensitivity, ultra-low cross-sensitivity, and an accuracy as low as +/-20 ppb or +/-20 % (whichever is higher). To illustrate its accuracy: detecting formaldehyde at 20 ppb is like finding a single grain of rice in a collection of 80 bags, each weighing 10 kg (22 lbs).

SFA30 and SFA40

Fresh

Carbon dioxide

Carbon dioxide (CO_2) is an important parameter for maintaining healthy and comfortable residential and commercial spaces. Since human exhalation is the primary source of CO_2 in indoor environments, its concentration correlates with human activity, occupancy, and viral load. Research found statistically significant declines in cognitive function scores when CO_2 concentrations were increased to levels that are common in indoor spaces (approximately 950 ppm).[(V)] For reference, fresh outdoor air typically contains around 400 ppm of CO_2. High levels of CO_2 are also found to be associated with lower sleep efficiency, leading to sleep disruption and irregular sleep patterns.[(VIII)]

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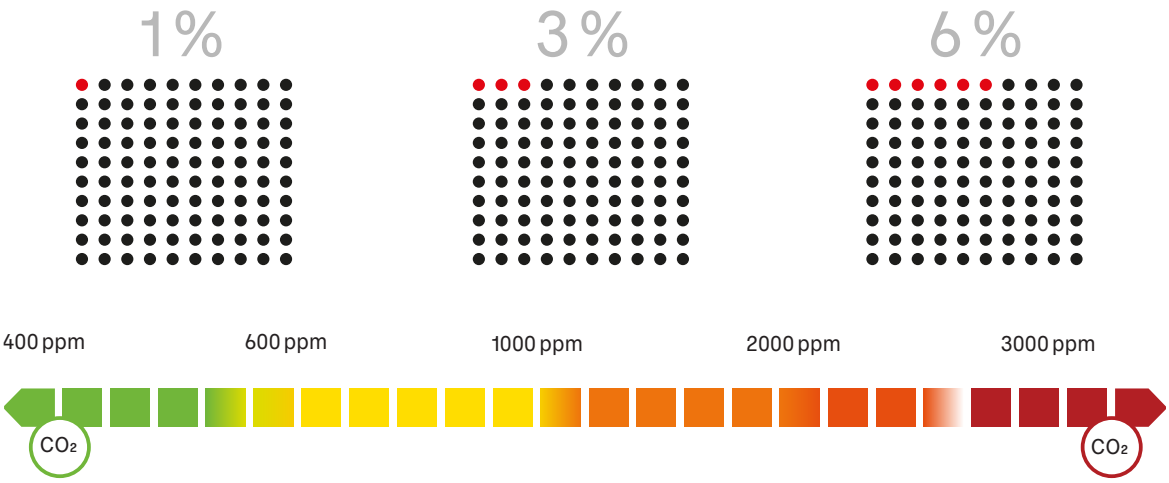
Significant worsening of sleep quality and stress levels after a night's rest already occur when comparing bedrooms with differences as little as from 750 to 1000 ppm. At even slightly higher CO_2 concentrations (1300 ppm), deep sleep duration decreases along with a significant increase in salivary cortisol after waking, suggesting increased stress and sympathetic activity.[IV]

SCD30, SCD41 and STCC4

When indoor CO_2 concentration reaches 1500 ppm, 3 % of breath inhalations contain 100 % air that has been previously exhaled by other occupants (see illustration below). This is equivalent to a lungful of exhaled air from other occupants every two minutes. Such a level of CO_2 can be dangerous because the amount of aerosols in the air is a good proxy for viral load.

Sensirion addresses these needs with a range of sensor solutions based on different technologies. The transmissive nondispersive infrared (NDIR) sensor SCD30 features best-in-class accuracy and excellent stability, while the photoacoustic NDIR sensor SCD41 offers a smaller footprint and high accuracy for compatibility with healthy building standards such as RESET and WELL. On the other hand, the thermal conductivity-based STCC4 is designed for applications that require miniature size, low cost and low power consumption at consumer-grade accuracy, such as smart thermostats and household indoor air quality monitors.

Fraction of previously inhaled air in relation to CO2 concentrations



Visualization of the fraction of previously inhaled air in relation to the air's CO_2 concentration.

The all-in-one solution

Sensirion's SEN6x offers comprehensive sensing capabilities for indoor air quality monitoring in a compact plug-and-play design. This saves precious development resources, enables a short time-to-market and reduces time and costs during assembly. It measures up to nine different parameters using a single interface, with Sensirion having addressed all sensor design-in challenges including optimal airflow, temperature compensation algorithms, and acceleration engines.

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Additional applications empowered by sensor fusion

Pollen

While pollen is essential for plant reproduction, these microscopic grains can have adverse effects on human health. With an increasing number of people being allergic to pollen and with pollen seasons extending due to climate change,[IX] there is an increase in allergy-related issues. When inhaled, pollen can trigger allergic reactions, leading to symptoms such as sneezing, coughing, congestion, and itchy eyes. These allergic reactions can be particularly problematic for people with asthma or other respiratory conditions.

As pollen particle size and concentration pose challenges for physical sensing solutions, Sensirion builds up expertise with virtual sensing, addressing specific use cases with sensor fusion and large datasets.

Wildfires

Wildfire smoke originates from the combustion of organic materials such as trees, grasses, and other vegetation. These pollutants include particulate matter, carbon monoxide, harmful volatile organic compounds and other toxic gases. When wildfires occur near populated areas, these pollutants can infiltrate indoor spaces through windows, doors, and ventilation systems, leading to a range of health issues. This can vary from relatively minor issues like eye and respiratory tract irritation to more severe consequences such as exacerbation of asthma and heart failure. As climate change contributes to more frequent and intense wildfires, it becomes increasingly important to implement effective indoor air quality measures, such as air filtration systems, to mitigate the impact of wildfire pollutants and safeguard indoor environments.

Filter monitoring

Air quality in a polluted city center or in a region that is occasionally exposed to wildfires is different compared to a remote location in the mountains. With that, filter clogging speed also differs from region to region. Adding a flow or differential pressure sensor is one way to accurately measure filter performance. Using large datasets and smart algorithms is another. By retrieving accurate data from highly accurate laser operated particulate matter sensors, Sensirion can support developing algorithms to measure and predict filter performance drop. By using smart output from predictive algorithms instead of the prescribed regular filter change periods, filters are only replaced when necessary. This saves money and contributes to a better environment.

Energy savings

Every year, substantial amounts of money and energy are wasted due to inefficient heating, ventilation and air conditioning, with open windows being a significant contributor. Most smart thermostats fail to account for open windows, resulting in unnecessary heating and cooling expenses. Integrating Sensirion sensors allows for accurate open-window detection. Data is continuously processed with embedded machine learning to adjust settings accordingly. Dashboards provide real-time insights, enabling manual overrides and detailed analytics.

Sensirion support

If you require assistance for design-in, algorithm development or data analysis, Sensirion's field application engineering teams cover all continents and are ready to support.

With excellent sensor and design-in experience, testing setups and applications insights, you can comfortably rely on Sensirion to bring solutions successfully to market.

Indoor air quality

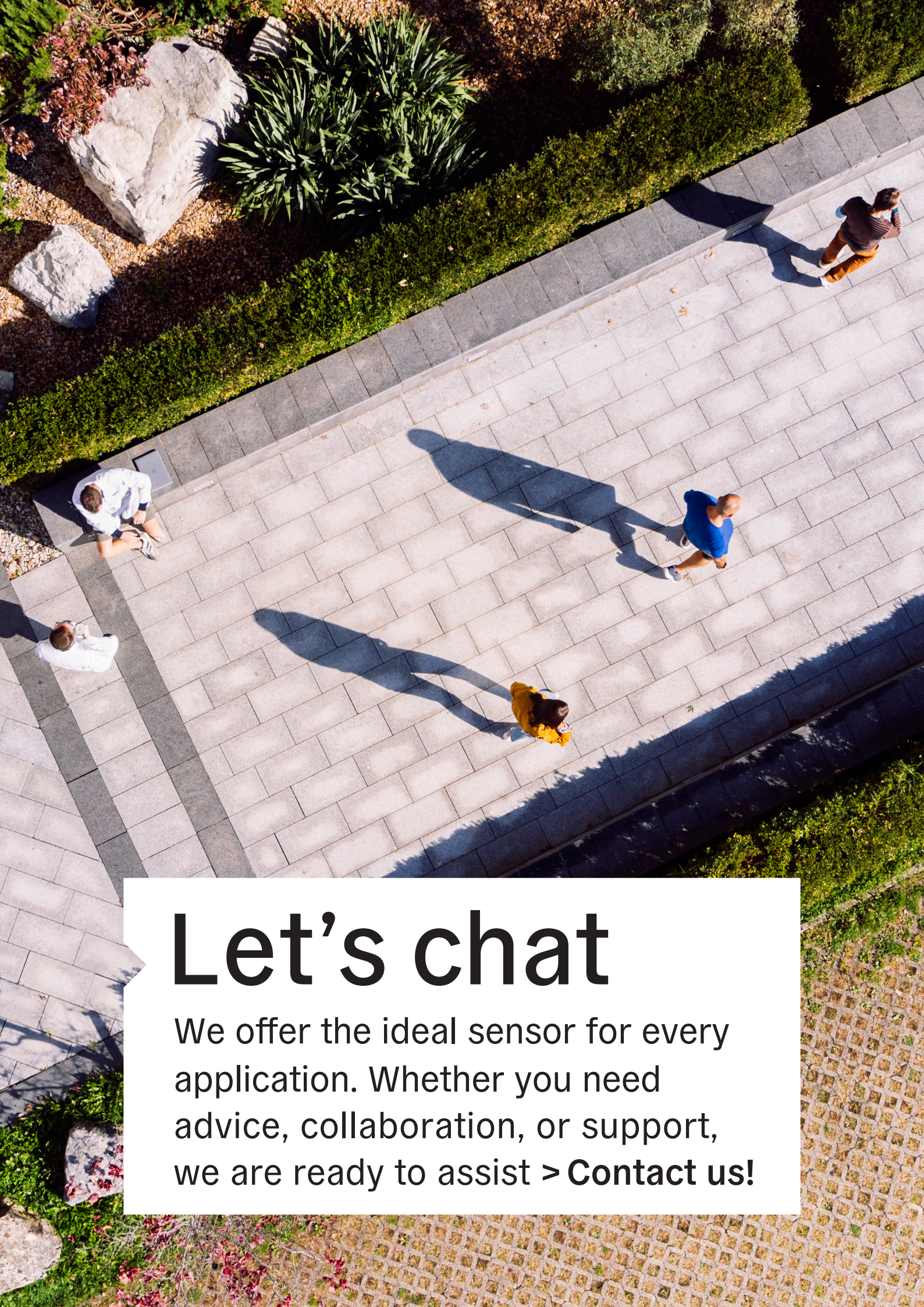
Battery operation

Sensirion supports the trend towards an increasing number of indoor air quality monitors being battery operated. By combining several strategies, indoor air quality monitors can operate efficiently, saving energy and prolonging battery lifespan. With smart sleep modes supported by selective sensor activation, intelligent algorithms can trigger specific sensors based on priority. For example, when monitoring particulate matter, relative humidty, temperature, carbon dioxide and formaldehyde levels, sensors can be activated either continuously or periodically. Periodical measurements (duty cycling) can be automated with algorithms and machine learning, which optimizes energy efficiency based on event-dependent sampling intervals.

Viral index

The RESET viral index serves as a valuable tool for assessing the likelihood of airborne virus transmission within indoor spaces. The index is based on parameters including temperature, humidity, particulate matter, and carbon dioxide levels. By analyzing these readings, it calculates the potential risk of infection. Sensirion's participation to this initiative supports a healthier indoor environment by improving ventilation, filtration, and air circulation.

Sensirion can overlap the viral index with an algorithm to accommodate air purifier performance of cleaning the air from viruses. Read more about the viral index on the RESET International Standard website.



Let’s chat

We offer the ideal sensor for every application. Whether you need advice, collaboration, or support, we are ready to assist **> Contact us!**

Indoor air quality

About Sensirion

At Sensirion, we are committed to being the number one partner for sensors and sensor solutions. Our mission is to excel in design and reliability, using our technological expertise to advance sensor technology. Through our innovative products, we aim to enhance sustainability, efficiency, health, safety, and quality of life. Our wide range of sensors measure humidity, temperature, gas concentrations, gas and liquid flow, catering to various markets. Central to our products is our patented CMOSens® Technology, which integrates sensor and analysis electronics into a single chip, ensuring high reliability and precision. By continuously refining our products and services, we uphold the highest standards, ensuring exceptional performance even in the most demanding applications.

Our journey

Founded in 1998 as a spin-off from ETH Zurich, Sensirion has grown to employ more than 1,200 dedicated individuals across the globe. Our headquarters in Stäfa, Switzerland, and our international subsidiaries across Europe, the US, China, Taiwan, South Korea and Japan are home to sales and application engineering teams that are constantly innovating and looking for ways to overcome challenges with smart sensor solutions.

Join us

Reach out and support shaping the future by exploring new possibilities with Sensirion. Whether you're looking to improve air quality, advance healthcare, or enhance safety in autonomous driving, our sensors are ready to make a difference.

Let's work together to create a sustainable future.

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