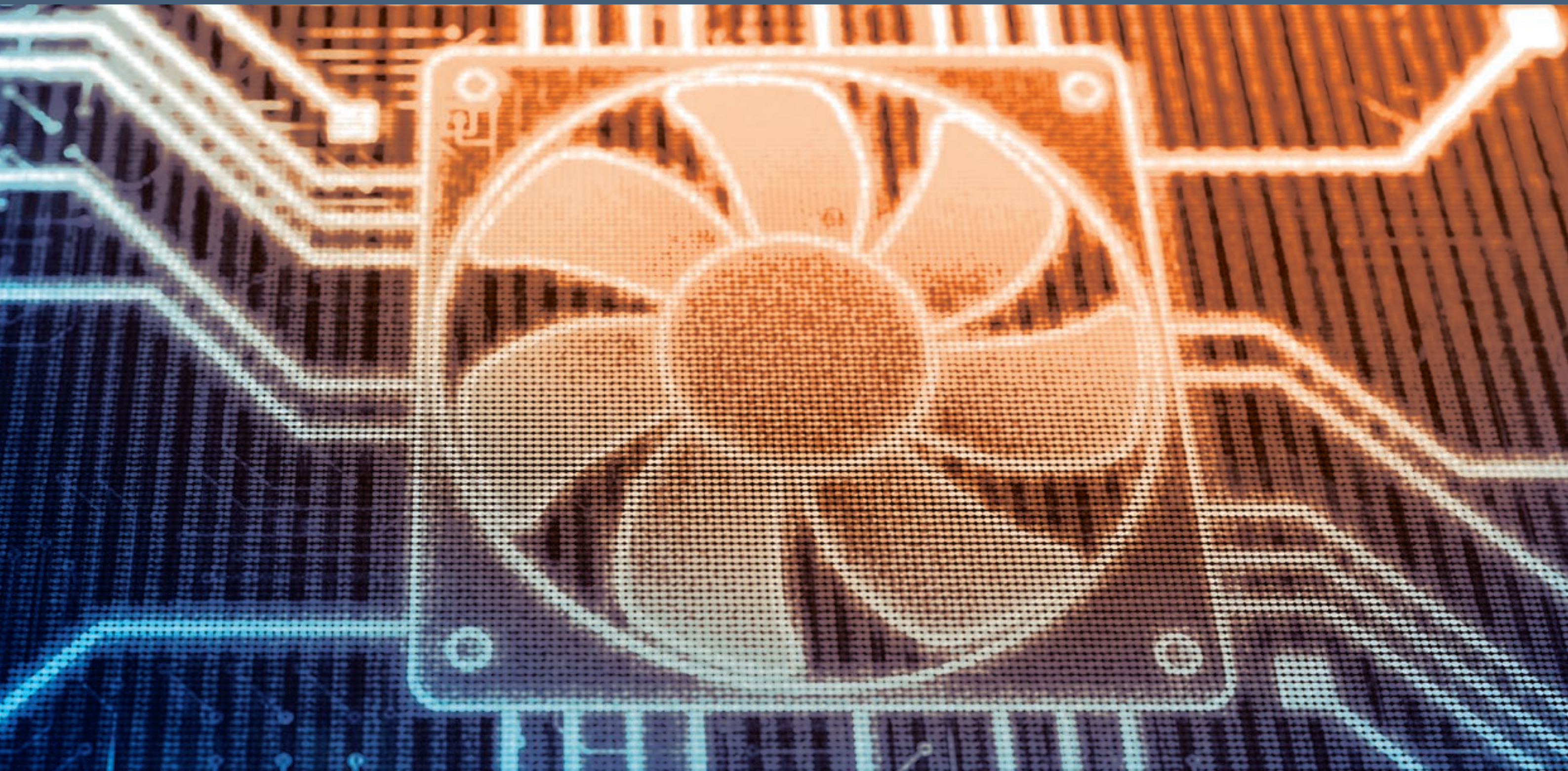
Air Quality Solutions



Intelligent Air Quality beyond CO_2

Ventilation energy savings while maintaining premium air quality. A contradiction?

In industrial countries adults drink 2-3 liters of liquids and eat 1-2 kg of food per day. While hygiene and quality of edibles are attracting interest, air quality is of minor attention although an average human inhales 15 kg of air – 80% thereof indoors!

From the classroom to the cubicle, the benefits of maintaining good indoor air quality extend beyond protecting the occupant's health. Students in schools with healthy air are more proficient at retaining information and teachers have fewer sick days. For employers, improving indoor air quality directly correlates with higher productivity and a more satisfied workforce, as studies have shown.

Green building's and emission-dependent energy tax's reverberation finally created awareness for both, indoor air quality, and ventilation energy costs. Hence in modern or reconstructed buildings, no, or permanent ventilation are a luxury of past times due to poor air quality on the one and skyrocketing ventilation budgets on the other hand. As always, the truth lies in between and is called "demand controlled ventilation" (DCV). DCV, however is a world of its own, whose background with a focus on indoor air quality, the various ventilation control options, and cost is being discovered here.

Introduction

This brochure provides background information on indoor air as well as sources of air contaminants. It also introduces ams air quality solutions based on VOC detection used in various indoor air quality applications in consumer and building automation industries.

Anatomy of indoor air

Clean air simply comprises of 21% oxygen and 79% nitrogen. However in real life and in particular indoors this looks rather different: various components i.e. noble gases, carbon monoxide (CO), carbon dioxide (CO_2), and mixed gases / volatile organic compounds (VOCs) add with different prominence, whereof the latter two are the most important ones: CO_2, due to its HVAC (heat, ventilation, and air conditioning) industry awareness level and VOCs, due to their criticality.

The role and impact of VOCs in indoor air

About 5,000 to 10,000 different VOCs exist. They are two to five times more likely to be found indoors than outdoors. Indoor VOCs are various types of hydrocarbons from mainly two sources: bio-effluents, i.e. odors from human respiration, transpiration, and metabolism and building material as well as furniture. VOCs are known to cause eye irritations, headache, drowsiness or, even dizziness, all summarized under the term SBS (sick building syndrome). Besides industrial applications and comfort aspects (e.g. temperature) VOCs are the one and only root cause for the need to ventilate! Some typical indoor contaminants and their sources are shown in table 1, in which VOCs caused by humans have the lion's share over building material, furniture and office equipment, hence rule the demand for ventilation.

Typical indoor air contaminants

Indoor Air		Typical Substance		Cure
Contamination Source	Emission Source	VOCs	Others	
Human Being	Breath	Acetone, Ethanol, Isoprene		demand controlled ventilation
			CO_2	
			Humidity	
	Skin respiration and transpiration	Nonanal, Decanal, α-Pinene		
			Humidity	
	Flatus	Methane, Hydrogen		
	Cosmetics	Limonene, Eucalyptol		
	Household Supplies	Alcohol Esters, Limonene		
	Combustion (Engines, Appliances, Tobacco Smoke)		CO	
			CO_2	
			Humidity	
Building Material, Furniture, Office Equipment, Consumer Products	Paints, Adhesives, Solvents, Carpets	Formaldehyde, Alcanes, Alcohols, Carbonyls, Ketones, Sloxanes		permanent, 5-10% ventilation
	PVC	Toulene, Xylene, Decane		
	Printers/Copiers, Computers	Benzene, Styrene, Phenole		

Table 1

CO_2 [ppm]	Air Quality
2100	**bad** heavily contaminated indoor air ventilation required
2000	
1900	
1800	
1700	
1600	
1500	**mediocre** contaminated indoor air ventilation recommended
1400	
1300	
1200	
1100	
1000	**fair**
900	
800	**good**
700	
600	**excellent**
500	
400	

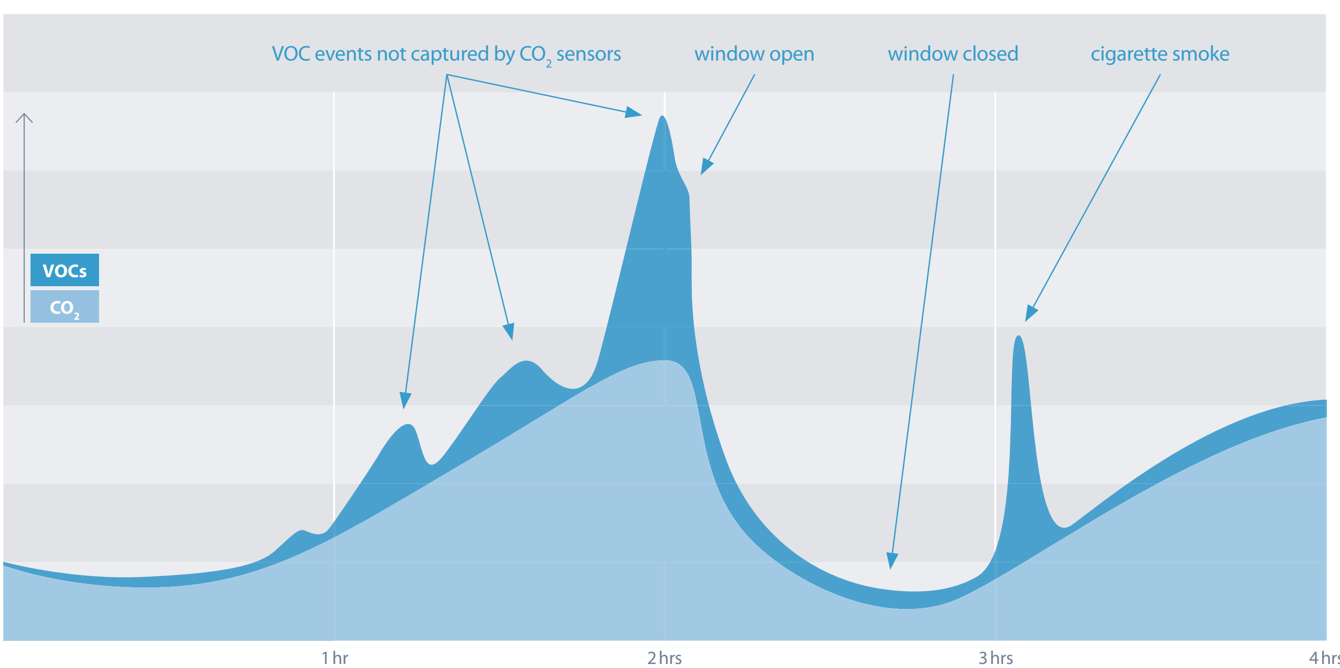
Table 2

The role and impact of CO_2 in indoor air

Although CO_2 is represented twice in table 1 and although it plays a major role in modern ventilation control, sole CO_2 has no real impairment on humans as decades of submarine experience and ISS (International Space Station) experiments confirm: even heavy CO_2 concentrations of 1% (10,000ppm) show no impact on our well-being. Nonetheless, due to the lack of suitable VOC sensing devices, historically CO_2 values have served as adequate air quality indicator, reflecting the total amount of VOCs (TVOCs) since the amount of CO_2 is proportional to the amount of VOCs, produced by human respiration and transpiration! At least in average, as diagram 1 with CO_2 and VOC measurements from a typical meeting session shows.

Therefore the ease of reduction to one single parameter, compared to consideration of some 1,000s VOCs, and the availability of suitable CO_2 measuring technology made it the surrogate of inhabitant generated pollution in confined living spaces i.e. today's standard indoor air quality reference for DCV with tangible air quality definitions (table 2) as initially introduced by Max von Pettenkofer and picked up by most HVAC industry standards.

CO_2 and VOCs from business meeting session

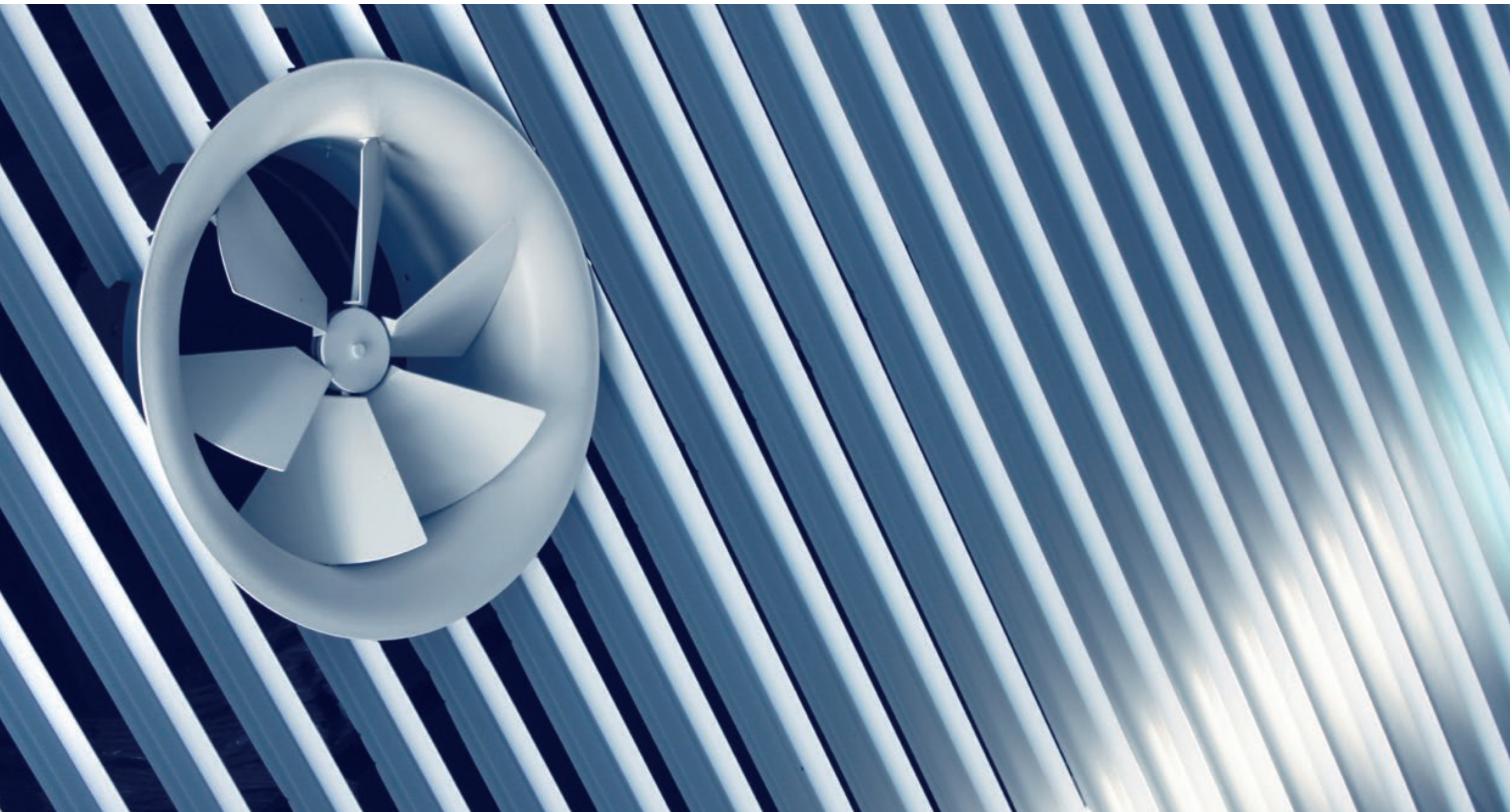


The volatility of volatile organic compounds

Moreover the diagram on page three teaches us more than just the correlation trend between VOCs and CO_2. It shows that VOCs are much more volatile in their concentration, i.e. sudden in their occurrence, than CO_2. The reason can be found in the dynamics of human behavior (activity, excitement, etc.), sudden bio-effluents and the intermittent use of odorous materials e.g. cleaning supplies, perfumes or cigarette smoke. Thus exclusively relying on plain CO_2 as ventilation reference would lead to unsatisfactory results since ventilation should react flexibly on the contamination source and ventilation should ventilate only as needed i.e. as short as necessary. This simple formula unveils all mysteries of DCV and optimizes ventilation energy savings to a maximum whilst reducing the impact on human occupants to a minimum.

Indoor air quality references from the past to the present

As we have learned, historically, and despite all its deficiencies there has been no other option but a CO_2 measurement due to said ease of detection and its role as a reasonable reference value. So-called mixed gas / VOC detectors that have flooded the HVAC market in recent history already suffered their first setbacks due to serious long-term stability problems and lack of useful output units to calibrate to. Consequently HVAC planners did not know when and how to invoke ventilation due to absence of suitable threshold values, furthermore the entire ventilation system functionality was unpredictable. Although the motivation to measure the root cause of contaminated air was honorable, its implementation was questionable.

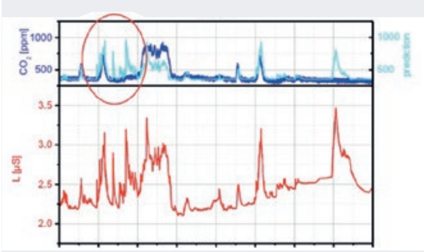


Perceived air quality – ams' approach as close to the nose

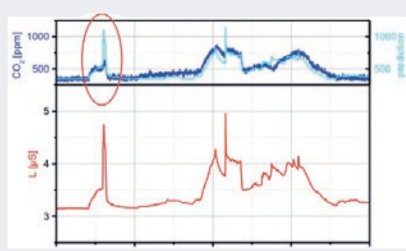
Taking the drawback of non-established VOC standards into account ams' iAQ (intelligent Air Quality) sensor, takes advantage of its implemented RMR (reversed metabolic rule) technology, reversing the proportional correlation of VOCs and CO_2, as described before, by providing a standardized output signal in ppmCO_2 equivalents from measured VOCs, thus adhering to today's CO_2-standards, while considering all volatile VOC behavior i.e. capturing odors and bio-effluents that are completely invisible to CO_2-sensors as the set of real-life measurements in diagram 2 demonstrates. Needless to say, that proven control-algorithms discipline sensor drift and ageing, thereby providing reliable readings for a lifetime.

The iAQ sensor straightens all deficiencies of modern CO_2–measurement technologies by detecting the true root-cause of ventilation demand. Furthermore it remedies all deficiencies of modern VOC sensing technologies by signal-adherence to established CO_2–standards and stringent drift compensation for extended sensor lifetime. The iAQ-sensor mimics the human nose and even detects substances not sniffable by it, but hazardous in their effect on humans (e.g. carbon monoxide).

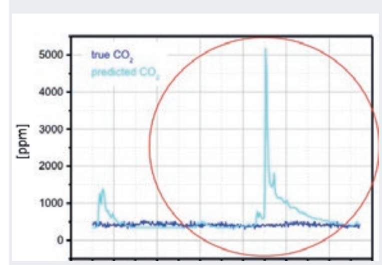
Typical scenarios where CO_2 sensors fail as DCV reference



Cantina/Restaurant



Gym



Restroom

What reference to follow?

Today there are various types of DCV sensors available: Besides occupation detection these are CO_2-, humidity- and VOC-sensors. Table 3 compares the performance of the latter three air quality sensor technologies over various applications and clearly depicts the advantage of ams' intelligent Air Quality technology.

Application	Commercial					Residential			
	Office	Conference Room	Restaurant	Gym	Restroom Toilet	Kitchen	Livingroom	Bedroom	Bathroom
Predominant Events	breath, odors	breath, odors	breath, odors, humidity	odors, breath	odors	odors, humidity	breath, odors	breath, odors	humidity
Humidity Sensor	poor	poor	fair	poor	poor	fair	poor	fair	excellent
CO_2 Sensor	good	good	good	fair	poor	poor	good	good	poor
iAQ Sensor	excellent	excellent	excellent	excellent	excellent	excellent	excellent	excellent	fair

Table 3

When and how to ventilate

There is an easy answer to this: on demand. As we have learned most VOC–events are rather unpredictable, as they are dominated by human metabolism and behavior, i.e. require a ventilation system that reacts flexibly on their occurrence. A model that holds true for more than 85% of all ventilation cases. The remainder is material emissions as they are common in new buildings, after refurbishments or, with new furniture. To sufficiently dilute any such emitted substances, low-rate permanent ventilation at 5-10% of the maximum rate is adequate. Table 1 provides examples of relevant substances and recommended ventilation scenarios. Any such case will rarely occur solely, hence the combination of both ventilation types is the silver bullet!

What to save by DCV

There are many options to tackle energy savings in ventilation. Ventilation systems can be operated permanently with constant air volume (CAV), statistically with variable air volume (VAV), and on-demand (DCV). DCV, however has many facets i.e. control options to choose from: occupation, CO_2, VOC, and humidity are today's typical reference variables in use.
Test results of the iAQ–sensor against timer-control, installed in an air handling unit supplying a gymnasium show 24% less operating time whereof a least square approximation confirmed the equivalent of 60% cost savings. In post-installation surveys, visitors to the gym gave the air quality good ratings.

Demand controlled ventilation with ams' iAQ technology means maintaining excellent indoor air quality and occupants health at minimal cost!

Typical iAQ applications

There are many possibilities in improving indoor air conditions and energy budgets by deployment of iAQ sensors. Even retrofit of legacy infrastructure can be possible. The following table helps identifying the most suitable iAQ ventilation scenarios.

Consumer/Residental	Consumer/Residental	Residental/Commercial
iAQ-integrated in IoT smart home products	iAQ-integrated air cleaner	iAQ-integrated de-centralized ventilation system
Description - AQ indication in 3 levels - Top level w/ addt'l buzzer - For manual ventilation **Application** - All rooms w/o automatic ventilation systems	**Description** - Air cleaner w/ a/c filter - Invoked by AQ level **Application** - Mainly residental rooms (i.e. living room)	**Description** - Single room ventilation - W/ or w/o heat recuperation - Invoked by IAQ level **Application** - Residental rooms - Commercial rooms

Residental/Commercial	Commercial/Residental	Commercial/Residental
iAQ-integrated bathroom ventilation system	iAQ-integrated standalone air handling unit	iAQ-integrated wall controller reporting to central AHU or building automation system
Description - Control of bathroom duct vent - Invoked by IAQ level - Fresh air from door-slot **Application** - Residental and commercial bathrooms	**Description** - Single room ventilation - W/ or w/o heat recuperation - Invoked by IAQ level **Application** - Residental rooms - Commercial rooms	**Description** - Single/multi room vent. control - Invoked by IAQ level to central unit or BAS **Application** - Commercial rooms - Residental rooms

Commercial/Residental	Commercial	Residental/Commercial
iAQ-integrated duct controller reporting to central AHU or building automation system	Duct controller reporting to central AHU or building automation system	iAQ-integrated wall controller for automated window ventilation
Description - Single/multi room control - Invoked by IAQ level to central unit or BAS **Application** - Commercial rooms - Residental rooms	**Description** - Single room control - Invoked by IAQ level to local damper actuator of exhaust air duct - Optional master/slave control of fresh air duct **Application** - Commercial rooms	**Description** - Single room window control - Autom. window opening and closure invoked by wall controller **Application** - Residental rooms - Commercial rooms

Customer feedback

"Besides the small module size it is the mixed gas plus the CO_2-equivalent signal that offer significant cost benefit for us and our customers."

Walter Goetschi, Managing Director, Sensortec GmbH, Switzerland on ams' iAQ-100

"A good correlation to CO_2-sensors was observed (…)."

Dr. Mari-Liis Maripuu, Chalmers University of Technology, Sweden – Conclusion of an evaluation of Functional Requirements on Systems and Components for Demand Controlled Ventilation Systems in Commercial Buildings where ams' iAQ-100 was evaluated.

"We compared the fan-speeds of our air handling unit alternately controlled by an occupancy sensor and ams' indoor air quality sensor. The indoor air quality sensor reduced the operating time by 24 percent."

Erik Edvardsson, Development Engineer, Swegon AB, Sweden

"To verify the overall performance of one of our decentralized ventilation systems with integrated ams indoor air quality module, designed to meet the demand for controlled ventilation, an independent institute has been employed. As expected, the module demonstrated sound correlation to CO_2 and even responded to emissions from furniture and office materials. We are very satisfied with its performance and additional benefits in terms of comfort and improved air quality."

Dirk Scherder, Manager FSL / Air-Water-Systems, TROX GmbH, Germany

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"A key function of the Home room monitor is to give the user a simple and credible measure of air quality. We felt that the integrity of Home's air-quality rating depended on very accurate measurements of the key pollutants: VOCs. This is why we chose to use the AS-MLV-P2 in Home. Not only is the sensor an excellent product, however, but also the hardware and software design expertise and support of the ams engineering team was outstanding, and this enabled us to integrate the AS-MLV-P2 into our product design with very little difficulty."

Cédric Hutchings, CEO of Withings

"ams' low-power VOC is exactly what we were looking for, when developing Cubesensors. There was really no alternative in VOC sensing units in terms of power consumption and performance. Cubesensors are battery-powered, multi-sensor units for indoor environment monitoring and VOC sensor is a crucial part of this product."

Cubesensors

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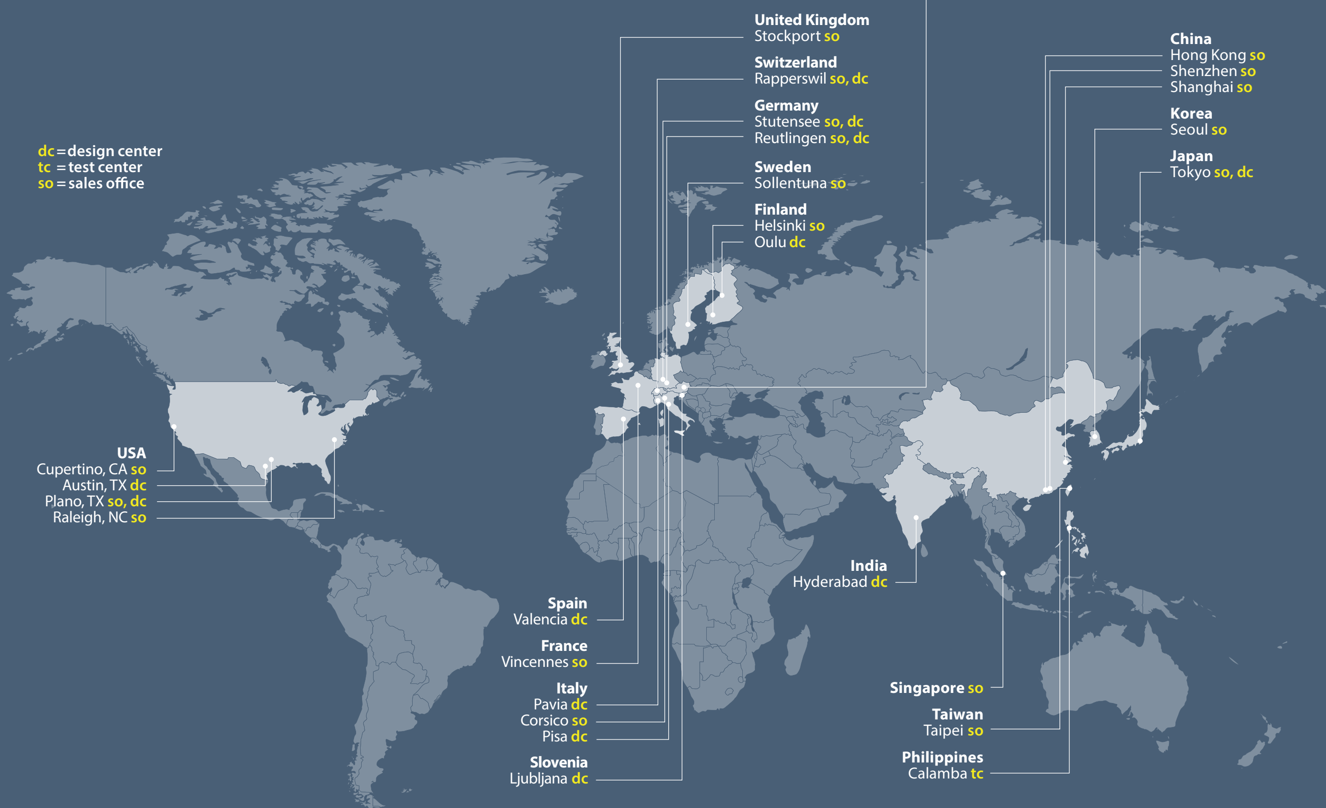

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