New IAQ sensor for demand controlled ventilation

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People spend ~90% of their lifetime indoors and providing the right environment takes energy and resources. Many efforts have been undertaken to reduce energy consumption of buildings and today's regulations require strict airtightness of buildings. In parallel to the improvements of the building envelope, the request for sufficient and energy-efficient ventilation increased. Energy-efficient ventilation schemes have to be applied as heat losses caused by ventilation are getting more and more pronounced in conjunction with reduction of the overall energy demand of buildings. Several studies of today's airtight buildings showed that sufficient ventilation is necessary to provide a healthy and comfortable indoor environment and to maintain building integrity. Measures to improve indoor air quality are cost-effective, considering potential benefits of reduced sick leave, reduced medical costs and better performance at work gained at improved indoor air quality.

Today's ventilation schemes are mainly based on time-scheduled ventilation. However, fixed ventilation schemes often do not account for the right ventilation demand and can lead to a waste of energy. More advanced active systems apply demand controlled ventilation (DCV) using sensors for indoor air quality (IAQ) control. Bad IAQ is often related to humans and their bio-effluents and the most common indicator is carbon dioxide (CO_2), whose production is proportional to the human metabolic rate. Nevertheless, the use of CO_2 as indicator and state-of-the-art sensors for CO_2 quantification, mainly based on non-dispersive infrared adsorption technology, are limited. Events coming along with more complex mixtures of gaseous compounds, mainly volatile organic compounds (VOCs), released by human bio-effluents, cooking odours, outdoor pollutants, cleaning supplies as well as building material and furniture emissions, cannot be detected with CO_2 as indicator, but play a pronounced role for human air quality perception and some are even a hazard to human health.

AppliedSensor

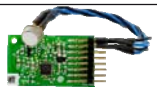
AppliedSensor is an international supplier of gas sensing solutions for air quality, comfort, control and safety applications. Improved reproducibility and stability together with low cost potential led to application-driven developments of micro-machined metal oxide semiconductor (MOS) gas sensors for industrial and commercial products in everyday life.

Intelligent Indoor Air Quality Monitoring beyond CO_2

AppliedSensor developed a family of low-cost and compact products for IAQ monitoring and energy-efficent DCV (**Table 1**). These sensor modules close the gap between direct CO_2 and VOC only detection. The detection of relevant indoor VOCs and potentially harmful substances (e.g. CO) is faciliated by the MOS sensing element. An empirical algorithm correlating proportionality of CO_2 production rate and metabolic VOC generation allows the iAQ-modules to provide measures of both, CO_2 and VOC related events at the same time, and makes the modules applicable in almost every indoor environment. The correlation between human CO_2 and VOC production provides a standardized output signal in CO_2 equivalent units [ppm] according to the request of HVAC planners and ventilation standards refering DCV settings to CO_2 concentrations above outdoors.

The professional iAQ-modules (iAQ-100, iAQ-2000, iAQ-engine, iAQ-Duct Kit) can be used for exhaust/supply air flow control in suitable centralized and decentralized ventilation systems and for automatic window

Table 1. AppliedSensor's iAQ modules.

Sensor modules		Measurement range	Interface	Dimension/weight	Characteristics
iAQ-2000		450-2000 ppm CO_2-eqivalents	I²C, 0-5 V, PWM, RS232	43 x 22 x 7 mm/4 g	Broad application range
iAQ-engine			I²C, 0-5 V	17 x 10 x 4 mm/3 g	Smallest design
iAQ-100			PWM	56 x 29 x 14 mm/10 g	Protection class IP 67
iAQ-Duct Kit			I²C, 0-5 V, PWM	43 x 22 x 7 mm/4 g	iAQ-2000 with cable, sensor on TO39 for probe-tip integration
iAM			USB	-	Personal IAQ monitor enables manual ventilation

actuation. In addition, AppliedSensor offers the personal indoor air quality monitor (iAM). Plugged to the computer or USB adapter the iAM makes building occupants aware of indoor air conditions signaling ventilation demand by three LEDs (green, yellow, red). The application software can be downloaded from www.appliedsensor.com.

Field Studies – VOC vs. CO2 Approach

The developed iAQ-modules have been optimized based on case studies in a variety of environments such as offices, meeting rooms, schools, kitchens, restrooms and bedrooms.

The benefit of VOC-based IAQ control compared to CO_2-based DCV becomes obvious in indoor spaces where changes of CO_2 are too small for ventilation control but indoor air is dominated by odorous events, affecting perceived air quality to a large extent (e.g. kitchens, restrooms, smoking areas). The iAQ-module allows capture of CO_2 concentrations and odorous events at the same time, whereas NDIR sensors are only able to measure the CO_2 production linked to the grade of occupancy. The main signals caused by cooking activities, that can be attributed to VOCs are only detected by the iAQ-module in the background of CO_2 (**Figure 1**, right hand side: cooking event).

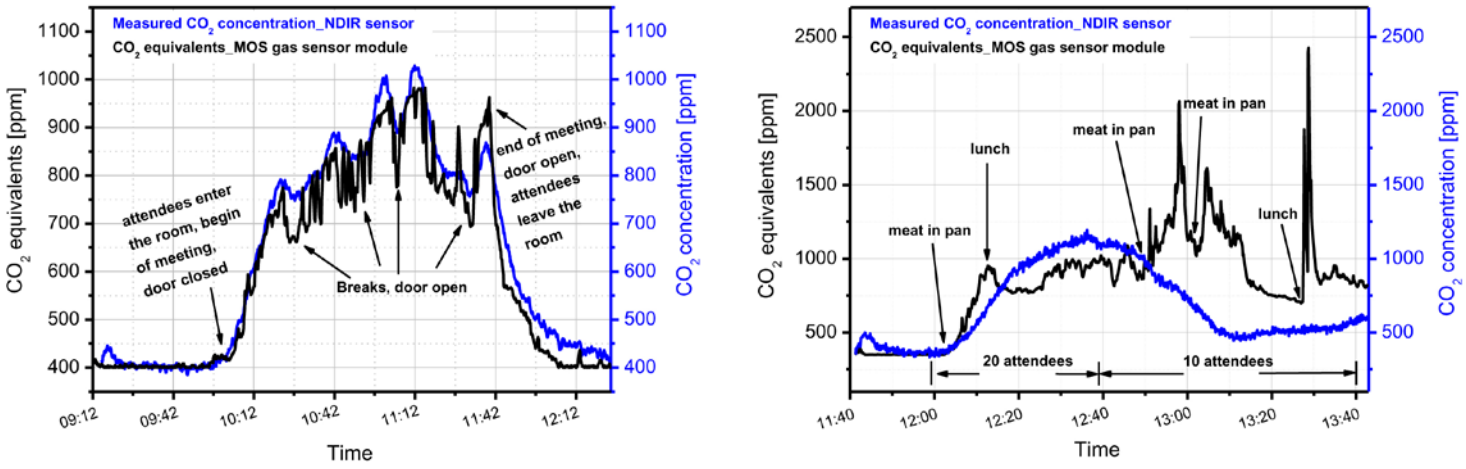


Figure 1. VOC vs. CO_2 approach: predicted and measured CO_2 concentrations (meeting room/kitchen).

Implementation of the empirical algorithm for CO_2 prediction based on anthropogenic VOC detection allows reliable correlation of predicted and measured CO_2 concentrations in indoor spaces where no appreciable human activity takes place. The perfect correlation of predicted CO_2 equivalents calculated from the detected VOC level compared to the measured CO_2 concentration using NDIR technology is shown by means of a meeting room on the left hand side of **Figure 1**.

Long-term stability

For long-term stabilty testing, iAQ-modules are permanently operated in the field for more than seven years. Real-life tests comparing long-term operated modules with new sensor modules showed, that perfect functionality in the field is guaranteed even for iAQ-modules with more than 60.000 operating hours (**Figure 2**).

Best practice examples

DCV - office

The iAQ-modules have been tested in various centralized and decentralized commercial ventilation systems for DCV. The main focus has been on energy demand and resulting IAQ compared to natural and time-scheduled ventilation. DCV ensures that fresh air is supplied to interior spaces whenever necessary. When defined threshold limits are exceeded, the module alerts the climate control system to increase ventilation. When VOC levels are minimized, the module instructs the system to decrease ventilation, thereby saving energy and lowering building operation costs.

The results when triggering the supply air rate with the iAQ module instead of applying time-scheduled ventilation are very promising: In a 80 m³ office with two employees, the supply air rate could be reduced by 60% compared to time-scheduled ventilation according to DIN EN 15251 (**Figure 3**, left hand side) while maintainig good air quality (CO_2 concentrations did not exceed 1000 ppm for the design value of 2 people in the office). The ventilation settings can be taken from **Table 2**.

Table 2. Ventilation settings - office.

Ventilation Strategy	Description
Time-scheduled ventilation	Ventilation according to EN 15251 (assuming IAQ category II, low polluting building material and equipment, 2 attendees) • Total air flow rate: 125 m³/h (Mo-Fr 08:00 a.m. to 06:00 p.m.) • 6 m³/h otherwise
DCV using iAQ-module	Sensor output, 450-2000 ppm CO_2 equivalents serves to trigger the ventilation rate in linear scale from 6 m³/h to 125 m³/h

60% less supply air resulted in 70% less power consumption for the fan and 15% less heating energy demand during heating period 2009/2010 (**Figure 3**, right hand side).

DCV - meeting room

In a highly frequented meeting room designed for 8 people and time-scheduled centralized ventilation of 70 l/s from 08:00 a.m. to 6 p.m., 50% supply air rate could be saved within one week applying a 3-step DCV scheme

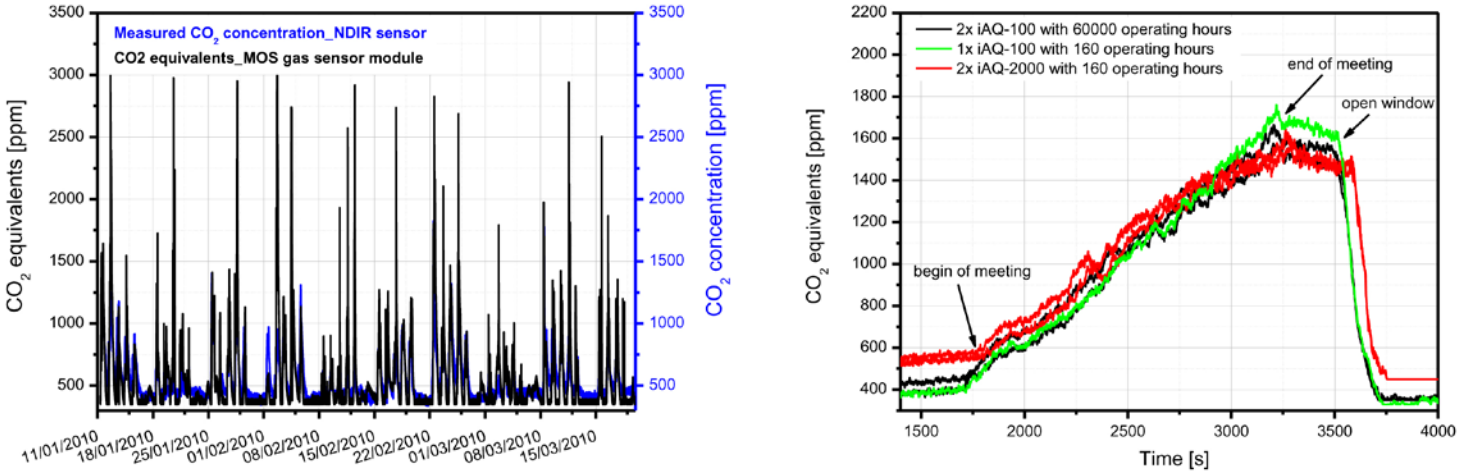


Figure 2. Long-term stability: Left: 10 weeks IAQ monitoring data of permanently operated iAQ-2000 module. Right: Real-life test after 60.000 operating hours (iAQ-100).

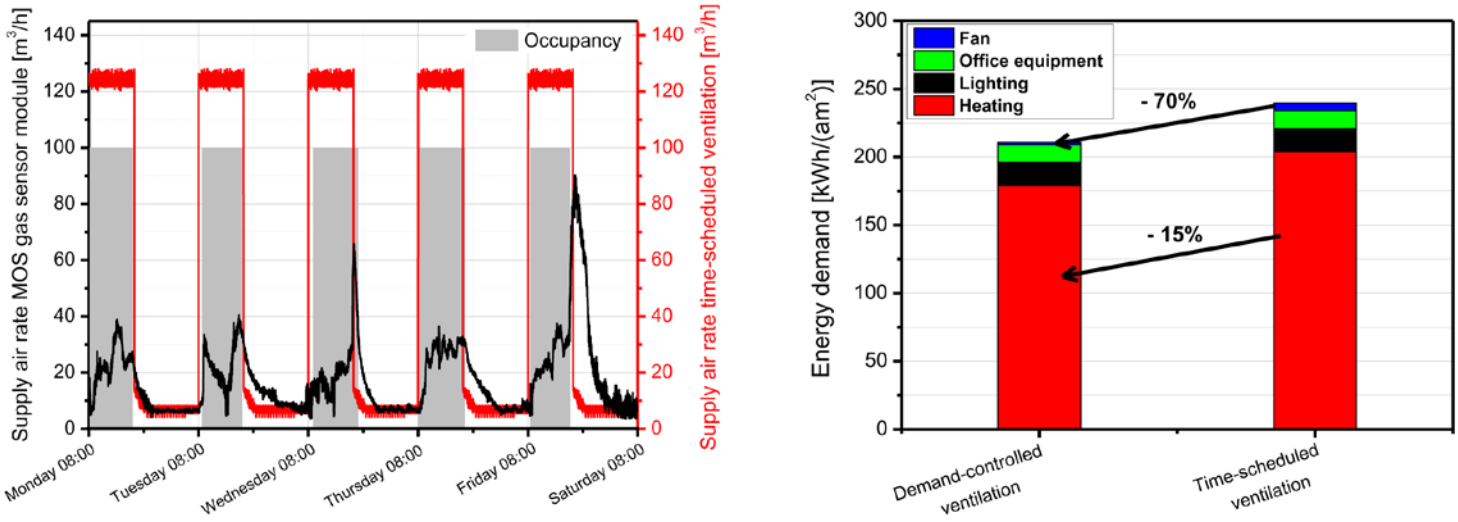


Figure 3. Left: Supply air rate [m³/h] - DCV compared to time-scheduled ventilation.
Right: Energy demand during winter period 2009/2010 for DCV and time-scheduled ventilation.

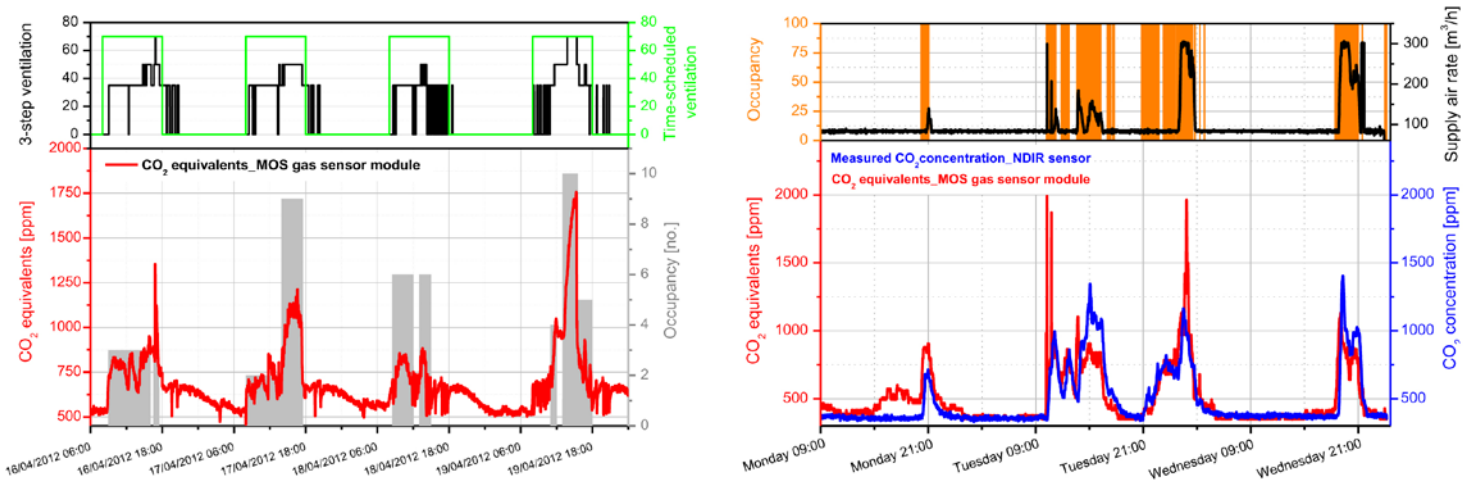


Figure 4. Left: DCV – meeting room. Right: DCV – fitness center.

as shown in **Figure 4**, left hand side. Step 1: 35 l/s, corresponding to sensor output > 700ppm, step 2: 50 l/s, corresponding to sensor output > 900ppm and step 3: 70 l/s, corresponding to sensor output > 1300 ppm.

DCV – fitness center

Installation of the sensor module in an air handling unit in a fitness center resulted in 24% less operating time, which translates to 60% energy cost saving with the overall IAQ rated good.

DCV using iAQ-modules vs. time-scheduled ventilation

The energy findings obtained by the case studies accentuate the need for DCV with AppliedSensor's iAQ-modules regarding actual load conditions in buildings. Human adaption often prevents air quality perception and results in high indoor pollution loads. Time-scheduled ventilation needs air flow rates to be adjusted before start-up depending on the average grade of occupancy or activity in the respective room which often results in a lack of overlap of operation time, ventilation demand, occupancy profiles and indoor pollution load. IAQ control with the developed iAQ-modules however ensures that fresh air is supplied to rooms whenever necessary minimizing the amount of supply air and hence the energy consumption compared to time-scheduled ventilation (**Table 3**).

Table 3. Case studies DCV - Supply air rate reduction.

Case study	Supply air rate reduction
Office	60%
Meeting room	50%
Fitness center	24%