lightricity

Wireless Sensing of CO_2

Monitoring the level of CO_2 in the environment enables the improvement in air quality and occupancy sensing

Every minute of every day we breathe in air, but what gases make up the air that we breathe? Well, the majority is Nitrogen (N_2) at 78.09%, followed by Oxygen (O_2) at 20.95%, Argon (Ar) at 0.93%, Carbon Dioxide (CO_2) at 0.04% and a few other gases in very small concentrations.

However, why do we want to measure or monitor the CO_2 level in the air we breathe?

Indoor air quality is a significant issue as people spend 90% of their time indoors [1], furthermore, as buildings become better insulated to improve energy efficiency this reduces the ingress of fresh air. Recent studies [2] have shown that exhaled CO_2 affects human health at lower levels than previously thought effects can include; inflammation, dizziness, breathing issues, reduced cognitive performance, kidney and bone problems caused by exposure at levels as low as 1,000 ppm. This level of CO_2 can be observed in crowded, poorly ventilated rooms e.g. classrooms, offices, bedrooms and air-conditioned public transport and planes. As a consequence, many countries are setting maximum Permissible Exposure Limits.

This issue has been brought to our attention as the recent Covid-19 pandemic has increased the amount of time many people, but especially the vulnerable, spend indoors. Moreover, the return to work has resulted in the expectation for more careful monitoring and control of building occupancy and indoor air quality. CO_2 levels are an excellent proxy for air quality and hence the effectiveness of ventilation and room occupancy.

As human beings we breathe in oxygen and breathe out carbon dioxide (CO_2) and so if we know the concentration of CO_2 we can use the information to help inform air conditioning systems on their operations as in a room full of people the CO_2 level will increase over time in proportion to the number of people in the room (occupancy level). Furthermore, CO_2 level is also of importance in some industrial processes. CO_2, water and sunlight are key components for plants growth and the process of photosynthesis and so monitoring CO_2 levels in greenhouses is important for efficient production.

CO_2 is a greenhouse gas and hence as we become more aware of the challenges presented by global warming, the importance of CO_2 emissions has grown.

In summary, the level of CO_2 in the air is very important and hence the ability to accurately monitor the concentration of CO_2 is of relevance in a number of environments.

So how easy is it to measure CO_2 level?

There are a number of sensor systems capable of monitoring the concentration of CO_2 in the air:

- Electrochemical sensors measure the conductivity or electrical current which changes in proportion to the level of CO_2 in the air sample.
- Non-dispersive Infrared (NDIR) sensors work by monitoring the amount of light absorbed and this is proportional to the CO_2 level in the sample.
- Metal oxide semiconductor (MOS) sensors have a metal strip or film that is exposed to the air being tested. As the air comes into contact with the metal there is a change in chemical composition and hence the conductivity of the metal changes and this is proportional to the concentration of the target gas.

CO_2 is measured in parts per million (ppm) and hence accuracy and sensitivity are very important, typical levels are shown in the table below:

Environment	CO_2 Concentration (ppm)
Outdoor	350-450
Indoor	<600
Level that causes drowsiness	1000-2500
Adverse Health Effects	>2500

NDIR sensors offer the following benefits; they are not sensitive to humidity and water vapour, they are low energy, less susceptible to drift, have a lifetime of 10 years+ and are relatively low cost.

Benefits of Wireless CO_2 Sensors:

In the introduction we touched briefly on why CO_2 is measured, let us now look in more detail at the pros and cons of using wireless sensors.

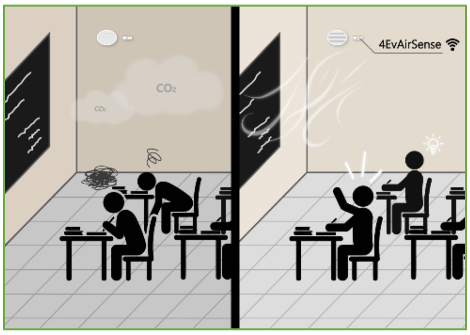
The advent of NDIR sensors and wireless technology has enabled more applications and benefits from being able to monitor and measure CO_2 levels.

The benefit of having wireless sensors is that installation is simple and easy, with no need for hard wiring this enables the retrofitting of monitoring systems in both old/historic and new buildings. However, there is a disadvantage and that is the use of batteries to provide the power that enables the sensors to operate. Due to their limited lifetime when batteries lose charge they will need to be changed, this maintenance involves 'down-time' during battery change periods; in addition, the disposal of large numbers of batteries raises issues of sustainability. The development of energy harvesting has alleviated the cost and sustainability issues with batteries as we will discover later on, but firstly let us consider the applications.

Applications of Wireless CO_2 Sensors:

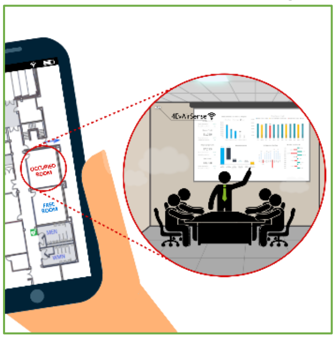
Energy Savings / Ventilation

Productivity / Health & Safety



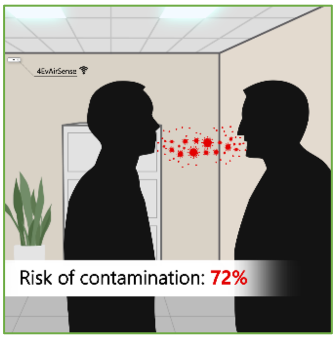
Green Houses

Occupancy Sensing



Air Quality and Wellness

Airborne Pathogen Reduction



Air Quality:

CO_2 sensing is very important in heating, ventilation and air conditioning (HVAC). Sophisticated high-cost Building Management Systems (BMS) for Demand-Controlled Ventilation (DCV) use wired CO_2 sensor measurement inputs but many systems lack this. Due to high installation and maintenance cost many people live and work with much less sophisticated ventilation options e.g. just opening windows and using fans. CO_2 sensor technologies were too power hungry for battery or energy harvesting use until the new generation of LED-based NDIR sensors were introduced. Hence the use of wireless CO_2 sensors has enabled BMS to monitor the CO_2 level alongside temperature and humidity as indicators of the air quality. Legislation is regulating the air quality in buildings and public spaces and this requires a simple and cost-effective method for ascertaining the levels of CO_2. In addition, in many instances the air must be either heated or cooled which has an impact on the energy costs of the business. Therefore, accurate and reliable monitoring of CO_2 level, temperature and humidity are of importance. Traditionally the CO_2 sensor was positioned in the return ductwork of the air circulation system and as the CO_2 level increased more fresh air would be introduced into the building thereby enabling a consistent supply of good quality air.

Occupancy Sensing:

As mentioned earlier as the number of people in a room increases, so does the CO_2 level and hence this can be used to monitor the occupancy level. This is important for a number of reasons, it can be used to determine the usage level of meeting rooms, identify vacant rooms, improving occupancy rates etc.

With the introduction of IoT systems then wireless CO_2 sensors can be used in a variety of settings to monitor occupancy levels and this offers benefits in public spaces such as lecture theatres, hospitals, cinemas, hotels and also can be an important component in smart home systems. The 'wireless' capability is particularly important as it means there is no inconvenience or unsightly cabling and the costs of installation will be minimal. However, to date wireless sensors have been powered by batteries and despite battery powered sensors being reliable there is a cost associated with the replacement of the battery at the end of its life and the matter of sustainability. These were discussed in detail in the following white papers [3-5].

Generating Data for a Digital Twins:

A digital twin is an immersive model of a physical space and can be applied to both residential and commercial properties. Landlords are seeing the benefits of developing a digital twin of the properties in their portfolio in order to assess the 'well-being' of the spaces. The value is early identification of issues such as mould generation or damp, improving the efficiency of heating and ventilation and also for monitoring the rate or pace of damp and mould growth so that preventative action can be taken promptly. The model can also be used to understand the usage by occupants which can be of value to landlords and the social housing community; educating the tenants on the need for ventilation and efficient living in the property.

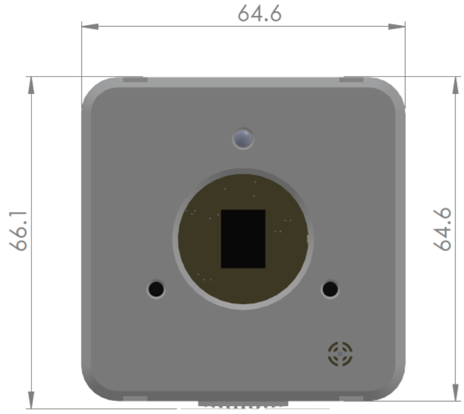
Agriculture:

With the growing global population, climate change and the demand for land for housing there is a move to increase the efficiency of farming and agriculture. Certain foodstuffs can be grown in large greenhouses, some covering the space of several football pitches. For example, there is a greenhouse in Norfolk, UK that uses rainwater capture from a roof the size of 17 football pitches, in addition it recycles CO_2 from an adjacent factory to grow tomatoes. This is typical of a new generation of growing facilities labelled as 'precision agriculture'. [6]
Due to the nature of these large-scale plant factories, it is essential that the CO_2 level is closely monitored and controlled. The adoption of wireless sensors is an efficient method for monitoring and as the light is a prerequisite for plant growth, this is an ideal environment for light energy harvester powered sensors.

Battery-Free Wireless CO_2 Sensors:

For many years the conversion of light from the sun to electricity has been commonplace and solar cells on the roofs of buildings or solar farm installations are now seen in many countries. However, these silicon-based cells have relatively poor conversion efficiency when converting indoor ambient light to electricity. Fortunately, there are new materials that have been optimised to operate efficiently under indoor lighting conditions and these will work down to low light levels. When combined with low power electronics it is now a reality to power sensors, including CO_2 sensors, without the need for primary batteries. This offers the opportunity for long life, no maintenance, cost effective wireless CO_2 sensors that can be utilised for the range of applications detailed above.

Lightricity's maintenance-free, self-powered wireless CO_2 sensor:



Lightricity has previously demonstrated the feasibility of powering short-range BLE wireless CO_2 sensor with its indoor PV technology and subsequent reductions in power needs for both sensors and RF modules means PV-powered sensor devices able to communicate on useful duty cycles and much longer range (e.g. LoRaWAN® protocol with >1 km range) are now possible in miniaturised packages (with 1 cm^2 high-efficiency indoor PV).

In Summary:

The employment of wireless CO_2 sensors serves to enhance sustainability, optimising ventilation control and reducing wasted energy. Solar energy harvesters avoid the environmental impact of massive battery waste, addresses battery-use regulation restrictions and encourages long-term thinking on wireless technologies. Overall, the solution ensures equitable access to information, health and habitable shelter especially in environments such as care/residential homes and social housing linking air quality notifications to smart phones prompting simple actions (e.g. open windows) at reasonable cost ensuring better health for all.

Contact Information:

For further information, product enquiries and order information please visit:
www.lightricity.co.uk

Lightricity PV technology

Our technology is the world's most efficient indoor PV technology (though it works outdoors too). It converts indoor light sources to energy with up to 35% efficiency – a more than six-fold improvement on conventional PV, as validated by the UK's National Physical Laboratory (NPL).

A panel the size of your fingertip will power your IoT device forever. Even in extremely low indoor light. Our technology can be sealed in the device and operate at temperatures from -40 to +200 degrees, opening possibilities to power devices not previously thought possible with indoor IoT.

We offer two solutions. For those designing new connected devices, our customisable PV panels can be integrated into any low-power IoT device as an alternative to batteries. For IoT systems integrators, we offer off-the-shelf, easy-to-integrate, completely battery-free PV-powered sensors for many common measurement and tracking applications.

References:

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