THE INDOOR CLIMATE BRIEFING

Highlighting the importance of healthy indoor air and sustainable buildings

Lindab®

Take a deep breath

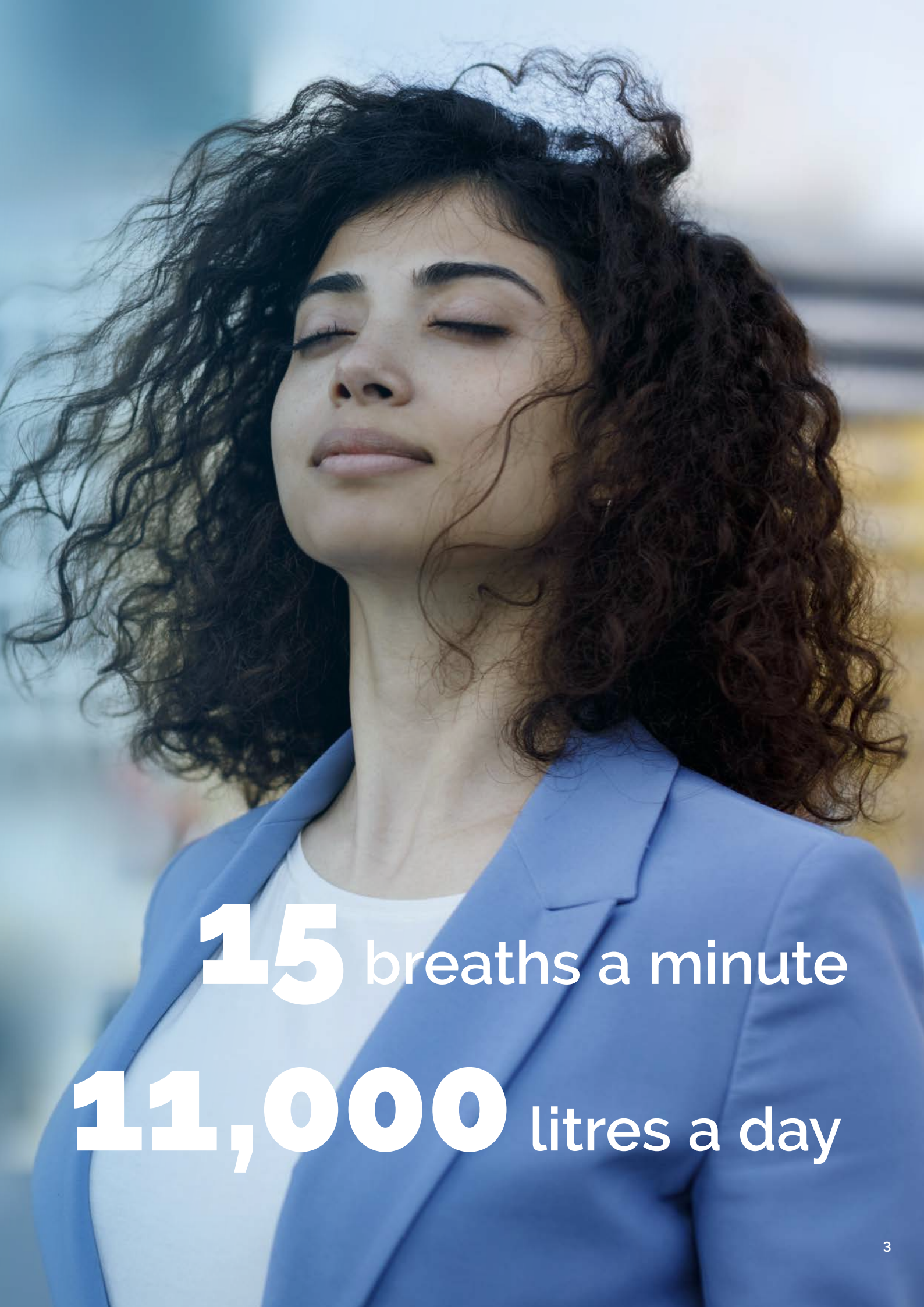
Within 10 seconds of being born we take a breath of air. Then we continue for the rest of our lives, 15 breaths a minute, 11,000 litres a day[1].

This makes you realise the vast amount of air that goes through our bodies in a lifetime. Now, consider that "the rest of our lives" is spent 90 percent indoors[2] and you begin to understand how important the quality of indoor air really is. All air contains pollutants to different degrees, but indoor air can be up to five times as polluted as outdoors[3]. Much is done to lower the emissions that make our outdoor air bad. Not as much focus, however, is put on indoor air.

How can we tell if the air we breathe is good or bad? What health risks are associated with poor indoor air quality, and how is healthy air defined? How do sustainable buildings contribute to better indoor environments, and vice versa?

To answer these questions, we have gathered insights from a wide range of sources and compiled them into a clear, educational, and accessible document.

Think of it as an indoor climate briefing, designed to shed much-needed light on the invisible air around us — and why it matters.


15 breaths a minute
11,000 litres a day

Key insights

Indoor air matters

Indoor air quality has a major impact on our health, productivity, and building longevity —but it's often overlooked compared to outdoor air.

→ *Learn more on page 2*

Regional differences

In Europe, the indoor air quality varies by region due to differences in climate, insulation, and ventilation. Northern Europe has both cleaner outdoor air and better mechanical ventilation, while Eastern and Southern Europe face greater challenges.

→ *Learn more on page 6*

Five factors of healthy air

Five key factors define healthy indoor air: carbon dioxide, temperature, humidity, particulate matter, and volatile organic compounds. Poor air quality can lead to headaches, fatigue, respiratory issues, and reduced cognitive performance.

→ *Learn more on page 9*

Policy drives change

EU policies like the Energy Performance of Buildings Directive aim to improve energy efficiency, indoor climate, and building sustainability, supporting the EU Green Deal goal of a climate-neutral building stock by 2050.

→ *Learn more on page 18*

Healthy buildings perform better

Healthier buildings are more durable and efficient. Proper insulation, ventilation, and noise control reduce illness, boost well-being, and cut emissions. Smart, demand-controlled solutions can reduce energy use by up to 50%.

→ *Learn more on page 19*

Everyone has a role

Ultimately, good indoor air benefits everyone—and it's not just up to regulations. Individuals and organisations can and should demand healthier indoor environments at home, work, and beyond.

→ *Learn more on page 21*

How is the air we breathe in Europe?

While there isn't enough research to fully compare indoor air quality across Europe, outdoor air is better documented — and that matters, as it directly affects the air we breathe indoors. We need a steady inflow of outdoor air to replace stale indoor air, which is more likely to accumulate pollutants and reduce comfort[4]. But what if the outdoor air is polluted?

Air enters buildings in three ways: through cracks and gaps (infiltration), open windows or doors (natural ventilation), or controlled systems (mechanical ventilation). This is why insulation and ventilation methods matter. The higher the rate at which outdoor air replaces indoor air, the lower the risk of pollutants[4]. Infiltration has the lowest air exchange rate while mechanical ventilation has the highest, often also combined with some kind of filter taking care of pollution in the outdoor air.

Air quality, insulation, and ventilation all influence indoor air—and highlight differences in conditions and needs across European regions. To get a good overview, we've focused on four regions: North, West, South, and East. We have chosen to compare air quality in terms of the amount of dust particles *(called PM2.5)* present in the air on an annual basis, since studies show stronger and more consistent health effects from these compared to others[5].

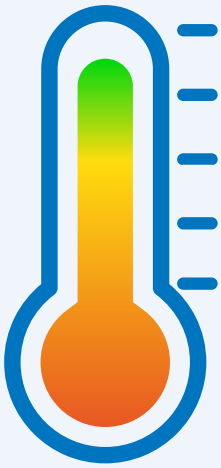
Insulation & ventilation

In Northern Europe, homes are well-insulated with airtight construction and triple-glazed windows, requiring mechanical ventilation to maintain air quality[9]. In Western Europe insulation is generally good, especially in Germany and the Netherlands, though older homes often rely on passive ventilation[10, 11, 12].
In Southern Europe, insulation has traditionally been poor due to the warm climate, and natural ventilation is still the norm, though mechanical systems are becoming more common in newer buildings[13, 14]. Eastern Europe shows a mix—newer buildings have better insulation, but older ones often lack proper ventilation, leading to issues like moisture and mold[15].

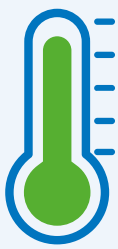
EU wants to raise the standards

Interestingly, we can see that the regions with the poorest outdoor air quality are also those with the lowest access to mechanical ventilation. These regions generally have a warmer climate, while colder climates traditionally mean better insulation to keep heat in, and better insulation places higher demands on ventilation. EU directives such as the Energy Performance of Buildings Directive, are pushing all regions toward better building insulation and increased use of mechanical ventilation to improve energy efficiency and indoor air quality.

Healthy air indicator



** The thermometer is our own illustration, based on the World Health Organization's healthy air recommendation of a maximum of five micrograms of PM2.5 in each cubic meter of air on average per year[6], and the European Environment Agency's measurement of the PM2.5 annual mean concentrations[7,8].*



Northern Europe
Sweden, Norway, Finland, Denmark, Iceland, Estonia, Latvia, Lithuania

Western Europe
Germany, France, Netherlands, Belgium, Austria, United Kingdom, Ireland, Luxembourg

Southern Europe
Italy, Spain, Portugal, Greece, Cyprus, Malta

Eastern Europe
Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Serbia, Bosnia and Herzegovina, North Macedonia, Croatia, Slovenia, Albania, Kosovo, Montenegro

Factors for healthy indoor air

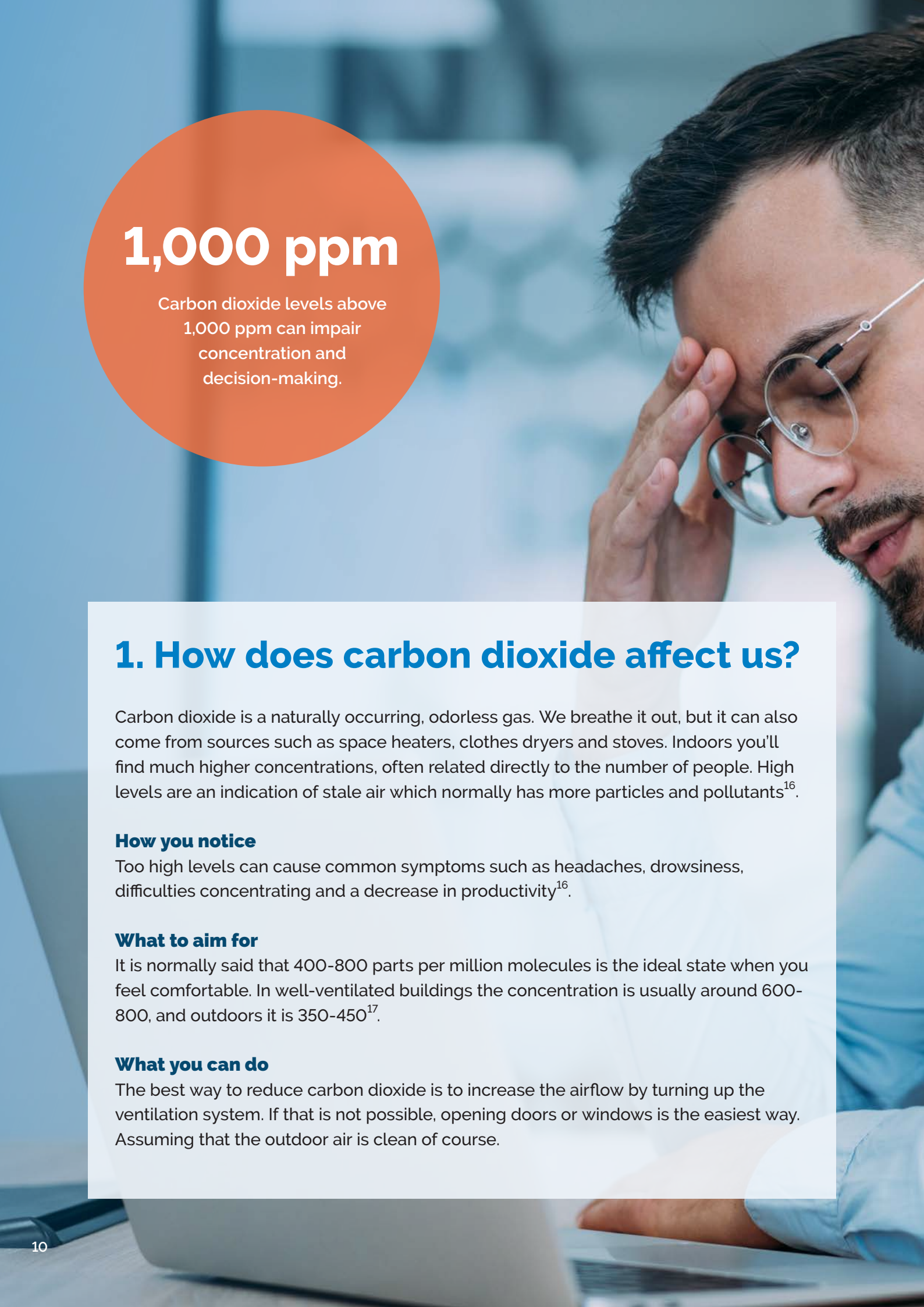
What constitutes good and healthy indoor air? In this briefing we will primarily focus on the common international stated factors defining indoor air quality.

These are:

1. Carbon dioxide
2. Relative humidity
3. Temperature
4. Particulate matter
5. Volatile organic compounds

Thanks to digitisation and sensor technology, all these factors can now be continuously monitored in real-time, often integrated into building management systems or indoor air quality monitors.

In other words: we can visualise the invisible



1,000 ppm

Carbon dioxide levels above 1,000 ppm can impair concentration and decision-making.

1. How does carbon dioxide affect us?

Carbon dioxide is a naturally occurring, odorless gas. We breathe it out, but it can also come from sources such as space heaters, clothes dryers and stoves. Indoors you'll find much higher concentrations, often related directly to the number of people. High levels are an indication of stale air which normally has more particles and pollutants[16].

How you notice

Too high levels can cause common symptoms such as headaches, drowsiness, difficulties concentrating and a decrease in productivity[16].

What to aim for

It is normally said that 400-800 parts per million molecules is the ideal state when you feel comfortable. In well-ventilated buildings the concentration is usually around 600-800, and outdoors it is 350-450[17].

What you can do

The best way to reduce carbon dioxide is to increase the airflow by turning up the ventilation system. If that is not possible, opening doors or windows is the easiest way. Assuming that the outdoor air is clean of course.

2. Relative humidity – an absolute health factor

Relative humidity shows how much moisture is in the air compared to the maximum it can hold at the current temperature. Warm air holds more moisture than cold air, so when the temperature rises, the relative humidity drops and vice versa. Low humidity is more common during winter when cold air heats up indoors, making the air very dry.

How you notice

Low levels can irritate the mucous membrane and make us more likely to catch cold viruses. It is also a common cause of nosebleeds, dry eyes, dry skin and sinus discomfort. High levels can cause molds and other biological contaminants to thrive, resulting in symptoms like sneezing, runny nose, red eyes and skin rashes while also triggering asthma attacks[23, 24].

What to aim for

Reviewing research, our overall assessment is that the right level is between 40-60 percent. It is a healthy level both for people and buildings, not causing mold or irritation and virus transmissions[25].

What you can do

The easiest solution when the air is too dry is to lower the temperature somewhat. When humidity reaches too high levels, increase the ventilation to bring it back down. A dehumidifier can work for specific situations like water damage or to keep a very precise humidity. If you have really high humidity levels you may want to check your pipes and plumbing for water leaks.

40–60%

The ideal indoor humidity range is 40–60 percent – balancing comfort and health.

3. Temperature
– cold facts on a hot topic

Temperature is often the starting point when we talk about indoor air—and for good reason. It's the most noticeable and adjustable factor. But what we're really aiming for is thermal comfort, defined as "that condition of mind that expresses satisfaction with the thermal environment"[18]. What feels comfortable varies depending on age, clothing, health, and personal preference. While temperature plays a central role, thermal comfort depends on more than that. Radiant temperature, air movement, humidity, clothing, and activity level all contribute to how we experience comfort indoors.

How you notice

At too high temperatures we get tired and have difficulties concentrating. It can also aggravate pollution that is already present. At too low temperatures, we find it difficult to do things physically. Both high and low temperatures can affect mental ability, work capacity, strength and mobility[19].

What to aim for

In general terms, a suitable indoor temperature in the summer is 23-26˚C and in the winter 20-24˚C[20, 21]. Summer indoor temperatures need to be warmer because light clothing and a big difference from outside temperatures would make us feel cold indoors otherwise. Our body's temperature naturally drops as you sleep so a cooler room makes it easier to fall and stay asleep. Set the thermostat between 16-20˚C for the most comfortable sleep[22].

What you can do

First off: You probably know what temperature you prefer. If we are talking about setting the temperature for a larger space with group of people, there are tools available to calculate thermal comfort. Indicators such as Predicted Mean Vote (PMV), Percentage of Dissatisfied (PPD), and Draught Rate are used to estimate how people will feel in a space — whether it's too warm, too cold, or affected by airflow. These help designers create environments that feel comfortable for most occupants.

Reducing indoor pollutants starts with **ventilation**, **smart materials** and **awareness**

4. Why particulate matter, matters

Particulate matter (PM) are dust particles that floats in the air around us. These particles are created in nature by sandstorms and forest fires for example, but also by fossil fuels in vehicles, fireworks, tobacco smoke and so on. They are usually categorised according to their size, PM10 being particulate matter smaller than 10 micrometer and so forth.

How you notice

Most particulate matter usually gets stuck in the lungs, but really small pieces can enter the bloodstream where it can spread to other organs. High levels of particulate matter may cause short-term health effects such as eye-, nose-, throat- and lung irritation, coughing, sneezing, runny nose and shortness of breath[26].

What to aim for

WHO guidelines recommend 5 micrograms of PM2.5 per cubic meter of air or less, annually[6]. This can be measured with sensor devices for your indoor spaces.

What you can do

First and foremost, make sure to keep your premises clean and dust free. If you have a ventilation system, a majority of the particles from outside can be removed. Make sure to have a good quality HEPA filter. For the particles already indoors, you may also consider buying an air purifier with HEPA filters.

5. The thousand gases of our everyday lives

Volatile organic compounds (VOC) are the collective name of thousands of different gases produced and used in our everyday life. Concentrations can be up to ten times higher indoors than outdoors[27]. They can be found in cleaning products and perfume, generated from day-to-day activities such as cooking and smoking but also come from furniture and various building materials too.

How you notice

Possible short-term effects may include headache, nausea, cough and dizziness as well as nose, throat and skin irritation. Long-term effects may be hidden as seemingly normal symptoms, such as an allergic skin reaction or leg cramps[28].

What to aim for

An ideal concentration is 300 micrograms per cubic metre of air or less. Levels between 300 and 500 are considered acceptable, but above that, irritation and discomfort may begin to occur[29].

What you can do

One simple action is to remove or reduce the number of products that emit these gases. Read labels to make sure which products have no or little emissions. Increase ventilation when using products that emit volatile organic compounds. If no ventilation system is available, opening doors and windows can serve as a temporary solution — helping to remove stale air and bring in fresh outdoor air.

10x

Indoor air can contain up 10x higher concentration of gases compared to outdoor air — especially in poorly ventilated spaces.

Good air do us good

Creating environments with healthy indoor air keeps us stay active, happy and high functioning. It is not all about reducing negative health effects – it is just as much about enhancing positive effects. Quite often they go hand in hand. Let us look at some of the advantages with a healthy indoor air environment.

Frees up time

Improving ventilation and using HEPA filtration is likely to reduce airborne infections, e.g. shown by a study where healthy indoor air at workplaces can see up to 35 percent less sick leave than those with poor air quality[30]. Not being sick as often gives us opportunity to do the things we love as well as the things we must.

Boosts cognitive performance

Research shows that our ability to understand and use information can increase by 172 percent, and the ability to handle crises can increase by 97 percent in a good indoor air environment[31]. And with good ventilation pupils' cognitive performance can improve by up to 15 percent[32]. The better the air quality, the better we get at processing information!

Enhances comfort & well-being

In environments with healthy indoor air, there is no mold or odors, no irritation of eyes, nose, and throat etc. It's safe to say that an overall positive effect is the general feeling of comfort and well-being indoors. It is a mental as well as physical thing, not worrying about headaches in meetings or nosebleeds when eating for example. A recent study on elderly people in China suggests that a high frequency of indoor ventilation lowers the levels of depression and anxiety[33].

Sustainable buildings and energy-efficiency

Sustainable buildings are designed for long-term durability and comfort with a minimal environmental impact. In Europe, sustainable buildings are guided by the Energy Performance of Buildings Directive, which sets Minimum Energy Performance Standards and supports the EU Green Deal's goal of a climate-neutral building stock by 2050.

Healthy indoor air, healthy buildings

A healthy indoor air not only keeps people healthy, but also buildings. High humidity and poor ventilation can lead to condensation on walls, windows, and insulation materials. This creates conditions for mold and mildew to grow, which can damage wood, drywall, and insulation[34]. Volatile organic compounds and other gases can degrade paints and furnishings, while dust and other particulate matter can clog filters and corrode coils[35]. Over time, poor indoor air quality wears down buildings and their systems. Healthy buildings, on the other hand, are more durable and thus more sustainable.

Reduce the noise

Creating a healthy indoor environment isn't just about temperature and air quality —noise matters too. Excessive noise affects comfort, well-being, concentration, and sleep[36], making sound reduction vital in homes, schools, and workplaces. Mechanical ventilation systems can cause indoor noise, but proper design and sound control can minimise it. Good acoustics also contribute to building health and sustainability, often recognised in certifications like LEED and BREEAM. Reducing ventilation noise improves comfort and supports a healthier, more productive indoor environment[37].

Saving energy, money and emissions

Heating and ventilation systems account for about 34% of energy use in commercial buildings[38] — the largest share — making energy efficiency in this segment especially important. A demand-controlled ventilation system uses sensors to deliver fresh air only where and when it's needed, avoiding unnecessary energy use. Combined with products in recycled or decarbonised steel, such systems can reduce both energy use and CO_2 emissions, while also offering durability and a high degree of recyclability.

Final thoughts

Outdoor air and its level of pollution occupy the thoughts of both the public and our governing bodies. It's an important issue that is strongly connected to another matter we find is often forgotten or overlooked: indoor air. Considering how much time we spend indoors in the Western world, indoor air should receive at least as much attention as outdoor air — especially from a health perspective.

The EU has introduced directives and goals to accelerate the renovation rate of sustainable, energy-efficient buildings. While the incentives may primarily be driven by the aim of reducing climate impact and electricity costs, the health benefits are many — as these renovations also impose higher requirements on ventilation and other elements that improve our indoor air quality.

Today, we can see a significant difference in both building techniques and the use of ventilation throughout Europe. This is a natural result of our varied climates, but also of our previous lack of knowledge about how indoor air affects our health, what makes up indoor air quality, and how we influence it.

The mentioned directives help streamline both construction methods and ventilation and thereby improve the quality of our indoor air. But not everything is up to the EU or national governments. We can all demand better air quality in our workplaces, gyms, schools, hotels — and above all, in our homes. After all, it's our health that's at stake if the indoor air is poor.

We can all demand better air quality in our gyms, schools, hotels - and above all, in our homes.

Reference list:

1) Lung Basics – Lung Care Foundation
https://lcf.org.in/lung-basics/#:~:text=We%20%E2%80%A6

2) Indoor Air Quality (IAQ) – OSHwiki, EU OSHA
https://oshwiki.osha.europa.eu/en/themes/indoor-air-quality-iaq

3) Report on the Environment: Indoor Air Quality – U.S. EPA
https://www.epa.gov/report-environment/indoor-air-quality

4) Introduction to Indoor Air Quality – U.S. EPA
https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

5) Assessing Indoor Air – CEUR WS Conference Paper
https://ceur-ws.org/Vol-3309/short13.pdf

6) WHO Indoor Air Quality Guidelines – WHO
https://iris.who.int/bitstream/handle/10665/345329/9789240034228-eng.pdf

7) Annual PM2.5 Concentrations in Europe – European Environment Agency
https://www.eea.europa.eu/en/analysis/maps-and-charts/concentrations-pm2.5-annual?activeTab=8a280073-bf94-4717-b3e2-1374b57ca99d

8) PM2.5 Annual Mean in European Countries – European Environment Agency (EEA)
https://www.eea.europa.eu/en/analysis/maps-and-charts/pm2-5-annual-mean-in-2

9) Appendix: Nordic Energy Research Report
https://pub.norden.org/nordicenergyresearch2025-01/appendix-2.html

10) Cooling of Residential Buildings in Germany – REHVA Journal
https://www.rehva.eu/rehva-journal/chapter/cooling-of-residential-buildings-in-germany

11) Energiesprong (retrofit initiative) – Wikipedia
https://en.wikipedia.org/wiki/Energiesprong

12) Net-Zero Historic Building Stock – UK Parliament Post
https://post.parliament.uk/net-zero-and-the-uk-historic-building-stock/#:~:text=%E2%80%A6

13) Thermal Insulation in Southern Europe Housing – ScienceDirect
https://www.sciencedirect.com/science/article/abs/pii/S0306261924007700

14) Climate Change & Thermal Comfort in Southern Europe Housing – NOVA Research
https://novaresearch.unl.pt/en/publications/climate-change-and-thermal-comfort-in-southern-europe-housing-a-c

15) Eastern Europe Building Energy Performance – Springer
https://link.springer.com/article/10.1007/s12053-024-10215-y

16) CO_2 Monitoring & Indoor Air Quality – REHVA Journal
https://www.rehva.eu/rehva-journal/chapter/co2-monitoring-and-indoor-air-quality

17) Ventilation & Health Protection – Public Health Agency of Sweden (Folkhälsomyndigheten)
https://www.folkhalsomyndigheten.se/livsvillkor-levnadsvanor/miljohalsa-och-halsoskydd/halsoskydd/ventilation/

18) ASHRAE 55 and ISO 7730 – Thermal Comfort Standards

19) Thermal Climate at Work: Heat Risks – Swedish Work Environment Authority (AV)
https://www.av.se/inomhusmiljo/temperatur-och-termiskt-klimat-pa-arbetsplatsen/varme-kan-paverka-kroppen-negativt-och-oka-risken-for-olycksfall/

20) Thermal Climate at Work: Cold Risks – Swedish Work Environment Authority (AV)
https://www.av.se/inomhusmiljo/temperatur-och-termiskt-klimat-pa-arbetsplatsen/risker-med-kyla/

21) ISO 15251 Table on Operative Temperature – NCBI
https://www.ncbi.nlm.nih.gov/books/NBK553920/table/ch1.Tab2/

22) Best Sleep Temperature – SleepFoundation.org
https://www.sleepfoundation.org/bedroom-environment/best-temperature-for-sleep#:~:text=%E2%80%A6

23) PubMed Study on Thermoregulation (1975)
https://pubmed.ncbi.nlm.nih.gov/3709462/

24) Effects of Indoor Air Humidity – REHVA Journal
https://www.rehva.eu/rehva-journal/chapter/effects-of-indoor-air-humidity

25) ASHRAE Technical Resources – Indoor Air Quality & Healthcare
https://www.ashrae.org/technical-resources/healthcare

26) Toxicological Profile for Particulate Matter – ATSDR/CDC
https://www.atsdr.cdc.gov/pha-guidance/resources/atsdr-particulate-matter-guidance-508.pdf

27) What Are VOCs? – U.S. EPA
https://www.epa.gov/indoor-air-quality-iaq/what-are-volatile-organic-compounds-vocs

28) Information on VOCs – Minnesota Dept. of Health
https://www.health.state.mn.us/communities/environment/air/toxins/voc.htm

29) IAQM Interim Indoor Air Assessment Levels
https://iaqm.co.uk/wp-content/uploads/2013/02/Interim-PS-IAQ-Assessment-Levels-Appendix_20200617-1.pdf

30) Sick Leave & Indoor Air Quality – Indoor Air Journal (2000)
Title: IAQ Risk of Sick Leave Associated with Outdoor Air Supply Rate, Humidification, and Occupant Complaints. Indoor Air 2000;10.

31) Green Office Environments & Cognitive Function – Harvard T.H. Chan School
https://www.hsph.harvard.edu/news/press-releases/green-office-environments-linked-with-higher-cognitive-function-scores/

32) Ventilation, Symptoms, and Performance – ScienceDirect (2011)
https://www.sciencedirect.com/science/article/abs/pii/S0360132311002617?via%3Dihub

33) Indoor Air Quality and Work Performance – Wiley Online Library (2024)
https://onlinelibrary.wiley.com/doi/10.1155/2024/9943687

34) HVAC Health Hazard Evaluation – NIOSH/CDC (2022)
https://www.cdc.gov/niosh/hhe/reports/pdfs/2022-0077-3422.pdf

35) Agents of Deterioration – Wikipedia
https://en.wikipedia.org/wiki/Agents_of_deterioration

36) Ventilation Noise & Sleep Quality – PubMed (2021)
https://pubmed.ncbi.nlm.nih.gov/34085318/

37) Effect of Ventilation on Viral Transmission – PMC (2020)
https://pmc.ncbi.nlm.nih.gov/articles/PMC7183564/

38) Commercial Building Energy Consumption – ElectricityRates.com
https://electricityrates.com/business-electricity/commercial-building-energy-consumption/

39) Energy Performance of Buildings Directive – European Commission
https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/energy-performance-buildings-directive_en

40) DCV Systems Performance in European Dwellings – REHVA Journal
https://www.rehva.eu/rehva-journal/chapter/performance-of-automated-demand-controlled-mechanical-extract-ventilation-systems-for-dwellings-in-europe

41) EU Greenhouse Gas Emissions from Energy – EEA
https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-energy

Most of us spend the majority of our time indoors. Indoor climate is crucial to how we feel, how productive we are and if we stay healthy.

We at Lindab have therefore made it our most important objective to contribute to an indoor climate that improves people's lives. We do this by developing energy-efficient ventilation solutions and durable building products. We also aim to contribute to a better climate for our planet by working in a way that is sustainable for both people and the environment.

Lindab | For a better climate

Lindab®
For a better climate