Module 1
Chapter 1
Indoor Air, Thermal and Daylight Quality

Training Material

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Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 10	Ventilation rate	[l/(sm2)]	4.1 Level(s)

Objective

- The rate of ventilation is one of the most effective strategies for controlling the exchange of air, CO2, and humidity. It includes the provision of a minimum rate of air exchange to avoid levels of CO2 that are not suitable for health, humidity, and pollutant substances derived from materials inside the environment

Applicability (applicable only to buildings equipped with a mechanical ventilation)

Building use:

- Residential
- Non-residential

Project stage:

- Design
- Construction / As Built
- In Use

KPI 10 Ventilation Rate

Description

- This indicator measures the ventilation rate in each main room of the building, in relation to the expected use patterns.
- The assessment boundary of the ventilation rate is the building equipped with a mechanical ventilation
- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 10 Ventilation Rate

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to buildings equipped with a mechanical ventilation

KPI 10 Ventilation Rate

Unit of measure

- The Ventilation rate (air flow) is measured as: [l /s/m2]

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

where

q_{tot} = total ventilation rate for the breathing zone, l/s

n = design value for the number of the persons in the room,

q_p = ventilation rate for occupancy per person, l/(s person)

A_R = floor area, m^2

q_B = ventilation rate for emissions from building, $l/(s \cdot m^2)$

KPI 10 Ventilation Rate

Reference Standards

- Ventilation rate indicator is developed in accordance with Level(s) (the European framework for sustainable buildings) indicator 4.1: Indoor air quality.
- The main reference standard for the calculation of the ventilation rate at the design phase is the EN 16798-1: 2019 Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics“.
- When considering ventilation needs, the expected use patterns should be considered, especially if occupant densities might vary significantly from one zone to another or in the same zone, but during different times of day or week.
- CEN/TR 16798-2 is the reference for the identification of the four categories of indoor environmental quality, which correspond to different expectation levels.
- The reference standard for the measurement of the ventilation rate is EN 12599: 2012 - Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems. This European Standard enables the choice between simple test methods, when sufficient, and extensive measurements, when necessary. It applies to mechanically operated ventilation and air conditioning systems.
- The measuring methods in this European Standard can be used in the frame of the energy inspection of air conditioning systems according to EU Directive 2010/31/EU "Energy performance of buildings Directive" (see EN 15239, EN 15240).

KPI 10 Ventilation Rate

Helpful links

https://www.youtube.com/watch?v=bEyOnYPDY0U

1 – Indoor Air Quality

KPI 11 CO_2 Concentration

1 – Indoor Air Qutaliy

Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 11	CO_2 concentration	[PPM]	4.1 Level(s)

Objective

- To ensure an adequate level of indoor air quality (IAQ), it is necessary to ensure that the concentration of CO2 falls within safety limits. Moreover, the measurement of CO2 concentration is an indirect measure that allows us to understand if the mechanical ventilation is functioning correctly and if there are any anomalies

Applicability (applicable only to In-use Buildings)

Building use:

- Residential
- Non-residential

Project stage:

- In Use

KPI 11 CO2 concentration

Description

- This indicator measures the CO2 concentration in the use stage of the building.
- The measurement should be made in building rooms in which its known that users spend most of their time in and cover various representative periods of time, as defined in EN 15251: 2007.
- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 11 CO2 concentration

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to in-use buildings

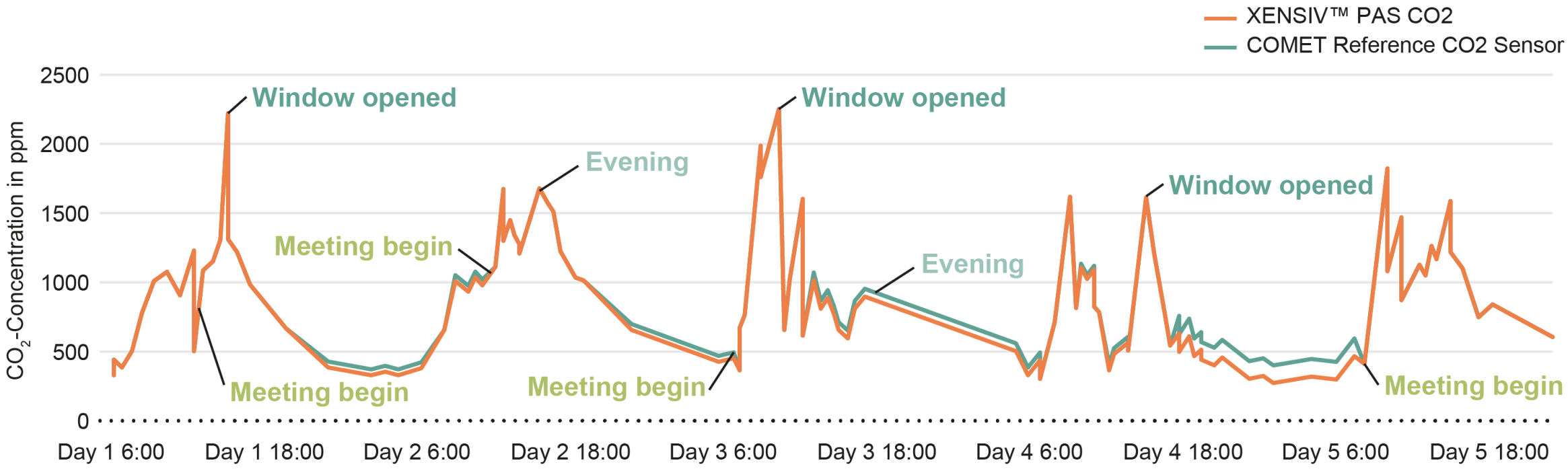
400ppm 0.04%	Normal outdoor air
400-1,000ppm 0.04-0.1%	Typical CO2 levels found indoors
1,000-2,000ppm 0.1-0.2%	Common complaints of drowsiness or poor air quality
2,000-5,000ppm 0.2-0.5%	Headaches, fatigue, stagnant, stuffiness, poor concentration, loss of focus, increased heart rate, nausea
> 50,000ppm > 5%	Toxicity due to oxygen deprivation occurs
> 100,000ppm > 10%	Oxygen deprivation in seconds: convulsions, coma, and death

https://www.co2meter.com/en-de/blogs/news/carbon-dioxide-indoor-levels-chart

KPI 11 CO2 concentration

Unit of measure

- CO2 concentration is measured as: particle per million [ppm].



https://assonina.it/2021

KPI 11 CO2 concentration

Reference Standards

- CO2 concentration indicator is developed in accordance with Level(s) (the European framework for sustainable buildings) indicator 4.1: Indoor air quality.

- The main reference standard for the measurement of the CO2 concentration is the EN 15251: 2007 Indoor Environmental Criteria. The standard identifies parameters to be used by monitoring and displaying the indoor air quality in existing buildings. It specifies criteria for measurements which can be used, if required, to measure compliance by inspection.

- The other reference standard for the measurement of the ventilation rate is the EN 16798-1: 2019 Energy performance of buildings - Ventilation for buildings

KPI 11 CO2 concentration

Helpful links

https://www.youtube.com/watch?v=_hMOKDxOyEo

1 – Indoor Air Quality

KPI 12 Relative Humidity

1 – Indoor Air Qutaliy

Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 12	Relative humidity	[%]	4.1 Level(s)

Objective

- Relative humidity level is an important factor that influences the comfort of occupants. High relative humidity (> 90%) increases the perception of the intensity of hot or cold temperatures, while excessively low humidity (<20%) can cause irritation to the eyes, nose, and throat. Poor control of the humidity of can create ideal conditions for mold growth.

Applicability (applicable only to In-use Buildings)

Building use:

- Residential
- Non-residential

Project stage:

- In Use

KPI 12 Relative Humidity

Description

- The relative humidity is the amount of water vapour present in air expressed as a percentage of the amount needed for saturation at the same temperature. The relative humidity can't be calculated, only measured in the in-use phase.

- The measurement should be made in building rooms in which its known that users spend most of their time in and cover various representative periods of time, as defined in EN 15251: 2007.

- The level of relative humidity is an important influencing factor on occupant comfort. Excessively high humidity (> 90%) increases the intensity of hot or cold temperatures, while excessively low humidity (< 20%) can cause irritation of the eyes, nose and throat

- Poor control of humidity from outdoor air or from kitchen and bathroom areas can create ideal conditions for mold growth, which in turn can provoke respiratory or allergenic health issues

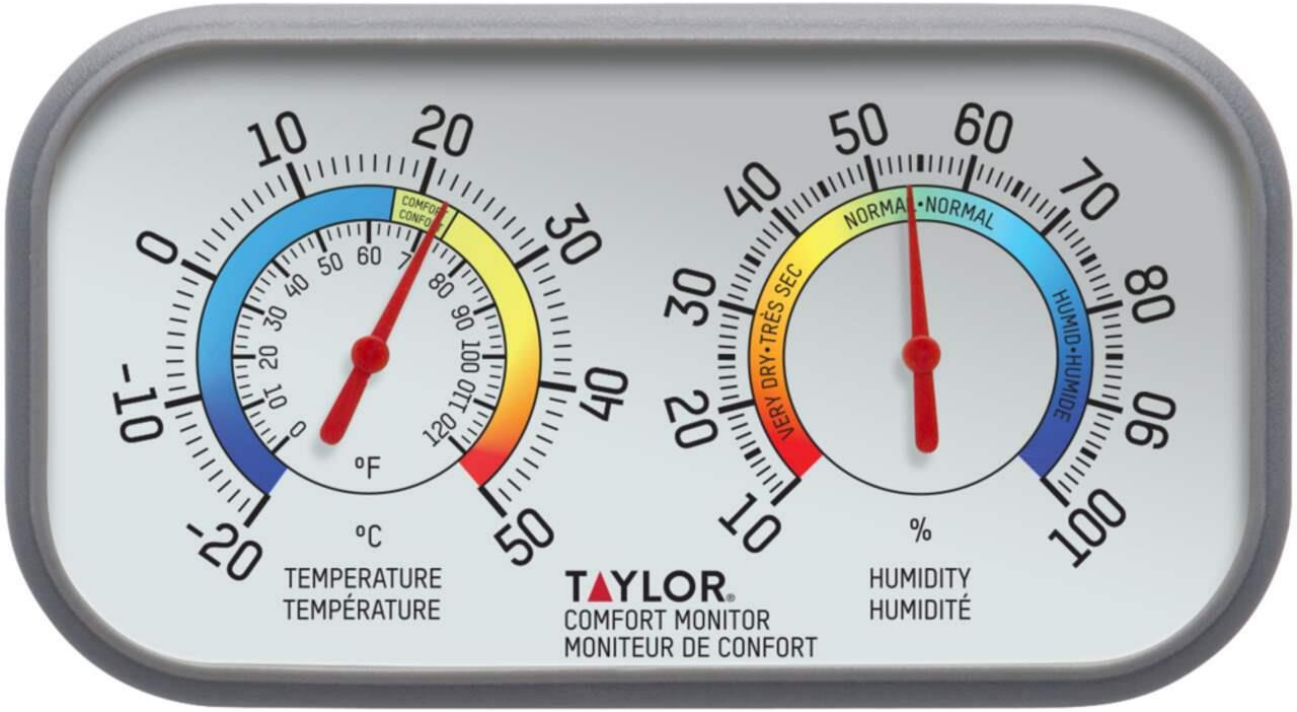
- The measurement of the relative humidity is an indirect measure that allows to understand if the mechanical ventilation works properly and if there are anomalies not identified at the design stage

- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 12 Relative Humidity

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to in-use buildings



KPI 12 Relative Humidity

Unit of measure

- Relative humidity is measured as: [%].

https://atuncampos.com.ec/room-relative-humidity-an-overview-sciencedirect-topics-ee-6Lo7x9cl

KPI 12 Relative Humidity

Reference Standards

- Relative humidity indicator is developed in accordance with Level(s) (the European framework for sustainable buildings) indicator 4.1: Indoor air quality.
- The main reference standard for the measurement of the ventilation rate is the EN 15251: 2007 Indoor Environmental Criteria. The standard identifies parameters to be used by monitoring and displaying the indoor air quality in existing buildings. It specifies criteria for measurements which can be used, if required, to measure compliance by inspection.
- The other reference standard for the measurement of the ventilation rate is the EN 16798-1: 2019 Energy performance of buildings - Ventilation for buildings.

1 – Indoor Air Quality

KPI 13 Total VOCs

1 – Indoor Air Qutaliy

Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 13	Total VOCs	[µg/m3]	4.1 Level(s)

Objective

- To ensure an adequate level of indoor air quality (IAQ), it is necessary to reduce exposure to Volatile Organic Compounds (VOCs) as they have adverse impact on human health, VOCs emissions can be limited through the careful selection of products and construction materials.

Applicability (applicable only to In-use Buildings)

Building use:

- Residential
- Non-residential

Project stage:

- In Use

KPI 13 Total VOCs

Description

- This indicator measures the VOCs concentration in the use stage of the building.
- Total VOCs is measured according to what stated in EN 16516 and in the ISO 16000-6:2021. Reference limit values for TVOCs concentration in indoor air are indicated within the WHO Guidelines.
- Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products numbering in the thousands
- Organic chemicals are widely used as ingredients in household products. Paints, varnishes and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds while you are using them, and, to some degree, when they are stored
- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 13 Total VOCs

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to in-use buildings.

- The Total Volatile Organic Compound (TVOC) is the sum of the concentrations of the identified and unidentified volatile organic compounds (as defined in 3.1.3.11 of EN 16516), calculated by summing the reference room concentrations in relation to the external values of these pollutants.

- The reference limit values for TVOCs concentration in indoor air are indicated within the WHO Guidelines.

KPI 13 Total VOCs

Unit of measure

- Total VOCs is measured as: [µg/m3].

Table B.17 —Criteria for the different building types

SOURCE	Low emitting products for low polluted buildings	Very low emitting products for very low polluted buildings
Total VOCs TVOC (as in EN 16516)	< 1 000 µg/m³	< 300 µg/m³
Formaldehyde	< 100 µg/m³	< 30 µg/m³
Any C1A or C1B classified carcinogenic VOC	< 5 µg/m³	< 5 µg/m³
R value (as in EN 16516)	< 1,0	< 1,0

The R value includes the pollutants with limit values that have been identified.

B.7 WHO health-based criteria for indoor air

Table B.21, 2nd column gives suggested guideline values for indoor and outdoor air pollutants as formulated by the WHO. For some pollutants no indoor air requirements have been defined yet by WHO. For those values only WHO outdoor requirements are presented, see the 3rd column.

Table B.21 — WHO guideline values for indoor and outdoor air pollutants

Pollutant	WHO Indoor Air Quality guidelines 2010	WHO Air Quality guidelines 2005
Benzene	No safe level can be determined	-
Carbon monoxide	15 min. mean: 100 mg/m³ 1 h mean: 35 mg/m³ 8h mean: 10 mg/m³ 24 h mean: 7 mg/m³	-
Formaldehyde	30 min. mean: 100 µg/m³	-
Naphthalene	Annual mean: 10 µg/m³	-
Nitrogen dioxide	1 h mean: 200 µg/m³ Annual mean: 20 µg/m³	-
Polyaromatic Hydrocarbons (e.g. Benzo Pyrene A B[a]P)	No safe level can be determined	-
Radon	100 Bq/m³ (sometimes 300 mg/m³, country-specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 µg/m³	
Sulfure dioxide	-	10 min. mean: 500 µg/m³ 24 h mean: 20 µg/m³
Ozone	-	8 h mean: 100 µg/m³
Particulate Matter PM 2,5	-	24 h mean: 25 µg/m³ Annual mean: 10 µg/m³

KPI 13 Total VOCs

Reference Standards

- TVOCs indicator is developed in accordance with Level(s) (the European framework for sustainable buildings) indicator 4.1: Indoor air quality.

- The main reference standard for the measurement of the TVOCs is the EN 16516, according to it, the Total Volatile Organic Compound (TVOC) is the sum of the concentrations of the identified and unidentified volatile organic compounds (as defined in 3.1.3.11 of EN 16516), calculated by summing the reference room concentrations in relation to the external values of these pollutants.

- Another key standard to be referred to, is the ISO 16000-6:2021 - Indoor air — Part 6, this document specifies a method for determination of volatile organic compounds (VOC) in indoor air and in air sampled for the determination of the emission from products or materials used in indoor environments (according to ISO 16000-1) using test chambers and test cells. The method uses sorbent sampling tubes with subsequent thermal desorption (TD) and gas chromatographic (GC) analysis employing a capillary column and a mass spectrometric (MS) detector with or without an additional flame ionisation detector (FID).

- The reference limit values for TVOCs concentration in indoor air are indicated within the WHO Guidelines.

KPI 13 Total VOCs

Helpful links

https://www.youtube.com/watch?v=u6W_06qbFPI&list=PL3EGWMSHI12Yp64Snr36_x2168tTqui3N&index=7

1 – Indoor Air Quality

KPI 14 CMR VOCs concentration

1 – Indoor Air Qutaliy

Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 14	CMR VOCs concentration	[µg/m3]	4.1 Level(s)

Objective

- To ensure an adequate level of indoor air quality (IAQ), it is necessary to reduce exposure to (CMR VOCs) Carcinogen, Mutagen, Reprotoxic. CMR VOCs refers to substances which are chronically toxic and have very serious impacts on health are classified as Carcinogenic, Mutagenic or toxic for Reproduction according to Regulation (EC) No 1272/2008 as they have adverse impact on human health.

Applicability (applicable only to In-use Buildings)

Building use:

- Residential
- Non-residential

Project stage:

- In Use

KPI 14 CMR VOCs concentration

Description

- This indicator measures the CMR VOCs concentration in the use stage of the building.
- CMR VOCs is measured according to what stated in EN 16516 and in the ISO 16000-6:2021. In addition to Total VOCs estimation, a value for total CMR VOCs is necessary to separately identify the more hazardous substances that may be emitted.
- CMRs entering routes into organisms include inhalation (of dust, fumes, gas, vapours), ingestion (by eating, drinking, smoking with dirty hands or by accidental ingestion) and penetration through (intact or damaged) skin and mucous membranes
- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 14 CMR VOCs concentration

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to in-use buildings.

- CMR VOCs is measured according to what stated in EN 16516 and the ISO 16000-6:2021. Reference limit values for CMR VOCs concentration in indoor air are indicated within the WHO Guidelines..

KPI 14 CMR VOCs concentration

Unit of measure

- CMR VOCs is measured as: [µg/m3].

KPI 14 CMR VOCs concentration

Reference Standards

- CMR VOCs concentration indicator is developed in accordance with Level(s) (the European framework for sustainable buildings) indicator 4.1: Indoor air quality.

- The main reference standard for the measurement of the CMR TVOCs is the EN 16516, according to it, the Total Volatile Organic Compound (TVOC) is the sum of the concentrations of the identified and unidentified volatile organic compounds (as defined in 3.1.3.11 of EN 16516), calculated by summing the reference room concentrations in relation to the external values of these pollutants.

- Another key standard to be referred to, is the ISO 16000-6:2021 - Indoor air — Part 6, this document specifies a method for determination of volatile organic compounds (VOC) in indoor air and in air sampled for the determination of the emission from products or materials used in indoor environments (according to ISO 16000-1) using test chambers and test cells. The method uses sorbent sampling tubes with subsequent thermal desorption (TD) and gas chromatographic (GC) analysis employing a capillary column and a mass spectrometric (MS) detector with or without an additional flame ionisation detector (FID).

- The reference limit values for CMR VOCs concentration in indoor air are indicated within the WHO Guidelines.

1 – Indoor Air Quality

KPI 15 R value

1 – Indoor Air Qutaliy

Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 15	R value	[decimal ratio]	4.1 Level(s)

Objective

- To ensure an adequate level of indoor air quality (IAQ), it is necessary to reduce exposure to toxic substance . the R value normalizes each individual VOC concentration with respect to the "lowest concentration of interest“ LCI value specific for that single VOC. This creates a coefficient for each VOC and, when the coefficients for VOCs identified individually in the same sample are summed together, it is possible to generate the composite R value

Applicability (applicable only to In-use Buildings)

Building use:

- Residential
- Non-residential

Project stage:

- In Use

KPI 15 R value

Description

- This indicator measures the R value. The R value normalizes each individual VOC concentration with respect to the "lowest concentration of interest“ LCI value specific for that single VOC.

- Since each individual VOC has the potential toxicity in case of human exposure, the value R has been developed, trying to translate data from total VOC measurements into potential health risks.

- An R value >1 means that the content of VOCs in the indoor air can be a risk to human health.

- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 15 R value

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to in-use buildings.

- The R value is a metered indicator, it can be measured during the in-use phase.

- Concerning the LCI values, the main document to which refer to is the Agreed EU-LCI values , developed by the European Commission, released in December 2021

- The measurement must be in compliance with what stated in EN 16516: construction products: Assessment of release of dangerous substances - Determination of emissions into indoor air . This European Standard specifies a horizontal reference method for the determination of emissions of regulated dangerous substances from construction products into indoor

KPI 15 R value

Unit of measure

- R value is measured as: [decimal ratio].
- R value is measured according to what stated in EN 16516 and in ISO 16000-6.
- The R value is the main metric that links to the **EU LCI (Lowest Concentration of Interest) values. The R value for an individual VOC is the ratio of the measured concentration to the EU-LCI value**.
- For example, a measured concentration of 24 µg/m3 and an EU LCI value of 200 µg/m3 would correspond to an R value of 0.12. When more than one substance with an EU-LCI value is measured, the R values of each substance are added together.

1 – Indoor Air Quality

KPI 16 Formaldehyde concentration

1 – Indoor Air Qutaliy

Thematic area	Key Performance Indicator (KPI)		Unit	Reference framework
Indoor air quality	KPI 16	Formaldehyde concentration	[decimal ratio]	4.1 Level(s)

Objective

- Indoor exposure to formaldehyde pollutant through inhalation is a dominant contributor to cause adverse health effects. Due to its serious health risk, as it is classified as carcinogenic, it is necessary to prevent human health from exposure to the contaminant; in that sense, it is preferable the use of low-emitting building materials and products. Ventilation can reduce indoor exposure to formaldehyde

Applicability (applicable only to In-use Buildings)

Building use:

- Residential
- Non-residential

Project stage:

- In Use

KPI 16 Formaldehyde concentration

Description

- This indicator measures the Formaldehyde concentration in indoor air. Formaldehyde is also a VOC but is generally reported separately from other CMR VOCs because of its serious health risk (it is classified as carcinogenic.

- Formaldehyde is a commonly used resin in the surface treatment of textile fabrics, as a binder in wood-based panels and in numerous other applications. Upon contact with moisture, formaldehyde resins can break down, releasing continual small quantities of formaldehyde to the indoor air.

- Reference limit values for formaldehyde concentration in indoor air are indicated within the WHO Guidelines and in the AFSSET document.

- The AFSSET , the French agency for health safety of the environment, which has developed a in depth analysis concerning the limit values in indoor air of formaldehyde concentration..

- The indicator is alighted with the Level(s) indicator 4.1: Indoor air quality

KPI 16 Formaldehyde concentration

Scope

- The KPI addresses both residential and non-residential buildings, but it is important to point out that this KPI is only applicable to in-use buildings.

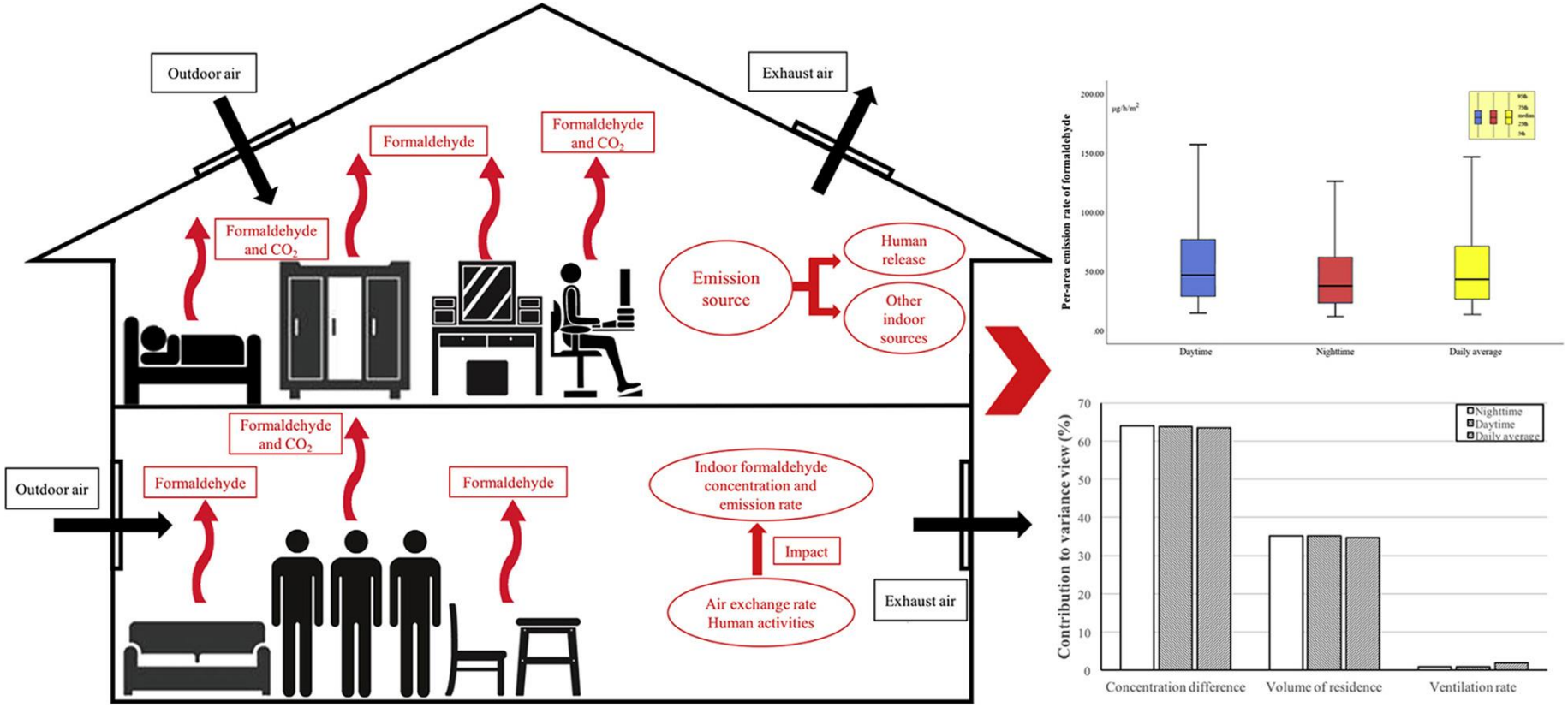
- The Formaldehyde concentration is a metered indicator, it can be measured during the in-use phase.

- Formaldehyde is measured according to what stated in EN 16516 and the ISO 16000-6:2021. Reference limit values for formaldehyde concentration in indoor air are indicated within the WHO Guidelines and in the AFSSET document.

KPI 16 Formaldehyde concentration

Unit of measure

- Formaldehyde concentration is measured as: [µg/m3]



Li, Baizhan, et al. "An investigation of formaldehyde concentration in residences and the development of a model for the prediction of its emission rates." Building and environment 147 (2019): 540-550.