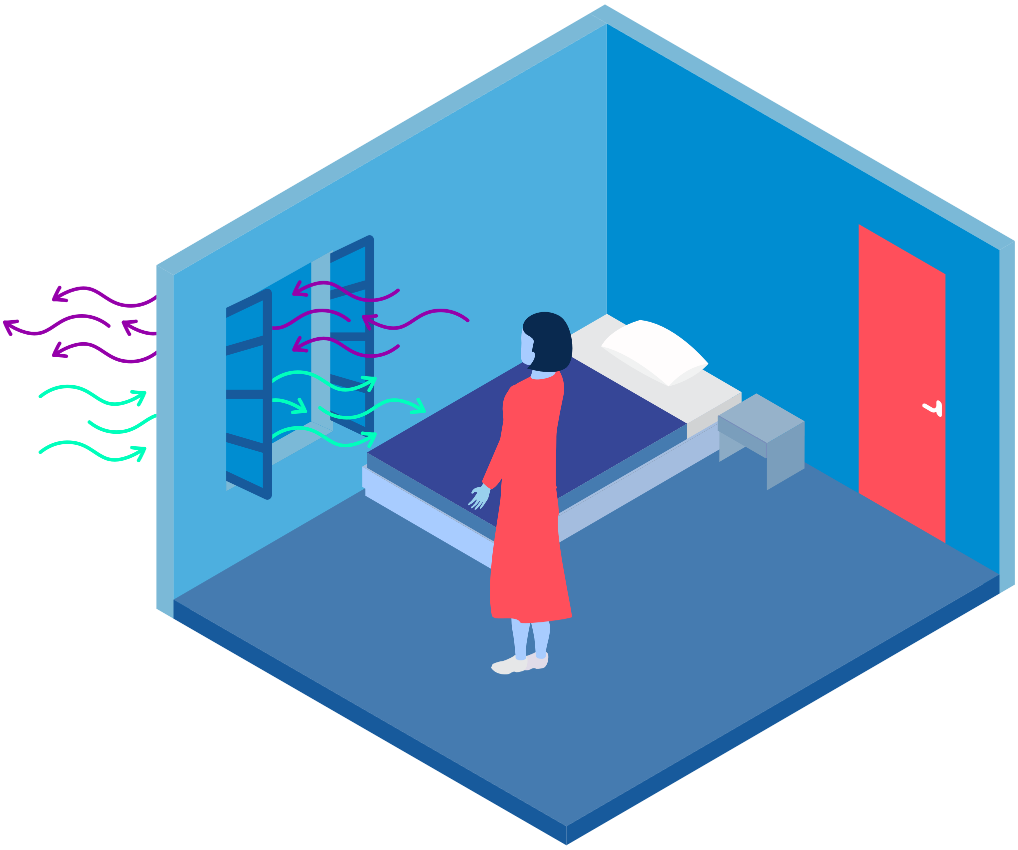
World Health Organization

Roadmap to improve and ensure good indoor ventilation in the context of COVID-19



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Contents

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Abbreviations

ACH	Air Changes per Hour
AGP	Aerosol-Generating Procedures
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CADR	Clean Air Delivery Rate
ECAP	Environment and Engineering Control Expert Advisory Panel
HCW	Health Care Worker
HEPA	High-Efficiency Particulate Air
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IPC	Infection Prevention and Control
MERV	Minimum Efficiency Reporting Value
PM	Particulate Matter
REHVA	Federation of European Heating, Ventilation and Air Conditioning Associations
WHO	World Health Organization

Glossary

Aerosol-generating procedures (AGP): Defined as any medical procedures that can induce the production of aerosols of various sizes (e.g. tracheal intubation, non-invasive ventilation, tracheostomy, cardiopulmonary resuscitation, manual ventilation before intubation, bronchoscopy, dental procedures) *(1)*.

Age of air, local: The time it takes for supply air to reach a certain indoor point *(2)*.

Air changes per hour (ACH): Ventilation airflow rate (m^3/hr) divided by room volume. It indicates how many times, during 1 hour, the air volume of a space is fully replaced with outdoor air *(2)*.

Air cleaner: Device used for removal of airborne particulates and/or gases from the air. Air cleaners may be added to heating, ventilation and air-conditioning systems (HVAC) systems or stand-alone room units *(2)*. Single-space air cleaners with high-efficiency particulate air (HEPA) filters (either ceiling mounted or portable) can be effective in reducing/lowering concentrations of infectious aerosols in a single space. The effectiveness of portable HEPA filters will depend on the airflow capacity of the unit, the configuration of the room including furniture and persons in the room, the position of the HEPA filter unit relative to the layout of the room, and the location of the supply registers or grilles *(3)*. Note that air cleaners do not replace normal ventilation as they are only able to remove a particular part of the indoor air contamination.

Air conditioning: Form of air treatment in which temperature is controlled, possibly in combination with the control of ventilation, humidity and air cleanliness *(2)*. Note that air-conditioning units in the case of, for example, split units often have no ventilation component. Therefore, ventilation requirements are to be put in place in addition to the use of air conditioning.

Air diffusion, mixing: Air diffusion where the mixing of supply air and room air is intended *(2)*.

Air, exhaust: Air removed from a space and discharged to the atmosphere by means of mechanical or natural ventilation systems *(2)*.

Air extract, mechanical: The process of extracting air with the aid of powered air movement components, usually fans *(2)*.

Air extract, natural: The process of extracting air by means of wind forces or density differences or a combination of the two *(2)*.

Air, indoor: Air in the treated room or zone *(2)*.
Air, mixed: The mixture of outdoor air and recirculated air *(2)*.

Air, outdoor: Controlled air entering the system or opening from outdoors before any air treatment *(2)*.

Air, recirculation: A part of extracted air which is not exhausted from the building, but it is recirculated back into spaces *(2)*. The air can be treated before being recirculated (thermal, air quality).

Air, supply: Air delivered by mechanical or natural ventilation to a space, composed of any combination of outdoor air, recirculated air or transferred air *(2)*.

Air transportation: Transportation of a specified airflow to or from the treated space generally by means of ducts. Along the ducts, devices for the purpose of treating the air (e.g. cleaning, heating, cooling, humidifying or dehumidifying, etc.) and known as air treatment devices, may be inserted *(2)*.

Clean air delivery rate (CADR) (m^3/hr): Usually used in relation to portable air cleaner devices.
Cross ventilation: Cross ventilation occurs where there are ventilation openings on both sides of the space. Air flows in one side of the building/room and out the other side through, for example, a window or door. Cross ventilation is usually wind driven *(4)*.

Fan coil: A component of a HVAC system containing a fan and a heating or cooling coil, used to distribute heated or cooled air. Where the unit does not include a ventilation component, ventilation in the room has to be taken care of in parallel.

Filter: Device for removing particulate matter from a fluid or gas *(2)*.

Flow rate, ventilation: Volume flow rate (m^3/hr) (l/s) (ACH) at which ventilation air is supplied or removed from a room or a building through the ventilation system or infiltration through the building envelope *(2)*.

Heat exchanger: A device in which heat is transferred between two mediums which do not come in contact *(2)*.

Heat exchanger, air-to-air plate: Heat exchanger designed to transfer thermal energy from one air stream to another without moving parts. Heat transfer surfaces are in the form of plates. This exchanger may have a parallel flow, cross flow or counter flow construction or a combination of these *(2)*.

Heat exchanger, rotary: A device incorporating a rotating cylinder or wheel for the purpose of transferring energy from one air stream to the other. It incorporates heat transfer material, a drive mechanism, a casing or frame, and includes any seals which are provided to retard the bypassing and leakage of air from one air stream to the other *(2)*.

Heat exchanger, twin coil: Heat exchanger designed to transfer thermal energy from one air stream to another without moving parts. Heat transfer surfaces are in the form of tubes. This exchanger may have a parallel flow, cross flow or counter flow construction or a combination of these *(2)*.

Heat recovery: Heat utilized from a heating system, which would otherwise be wasted *(2)*.

High-efficiency particulate air (HEPA): HEPA air filter classes H10 to H14, according to EN 779 *(2)*. Facilities that choose to use HEPA filters should follow the manufacturer's instructions, including on recommended cleaning and maintenance procedures for HEPA filters. Otherwise, portable air cleaners with HEPA filters can lead to a false sense of security as their performance decreases due to filter loading *(3)*.

Minimum efficiency reporting value (MERV): Minimum reported efficiency in specified particle size ranges during the test *(2)*.

Pressure difference: Difference between pressures measured at two points or levels in fluids or gases *(2)*.

Pressure, negative: Condition that exists when less air is supplied to a space than is exhausted from it, so the air pressure within that space is less than that in the surrounding areas. Under this condition, if an opening exists, air will flow from the surrounding areas into the negatively pressurized space *(2)*.

Pressure, positive: Condition that exists when more air is supplied to a space than is exhausted from it, so the air pressure within that space is greater than that in the surrounding areas. Under this condition, if an opening exists, air will flow from the positively pressurized space outward to the surrounding areas *(2)*.

Single-sided ventilation: Single-sided ventilation relies on opening(s) on one side only of the ventilated enclosure. It is possible to get buoyancy-driven exchanges through a single opening if the opening is reasonably large in the vertical dimension *(4)*.

Source control: A preventive strategy for reducing airborne contaminant levels in the air through removal of the material or activity generating the pollutants *(2)* or through removing the pollutant at source by means of localized exhausted strategy.

Split system: A two-component heating and cooling or cooling only system. The condensing unit is installed outside, the air handling unit is installed inside. Refrigerant lines and wiring connect them together *(2)*. Generally, this system has no ventilation component and recirculates conditioned air.

Stack effect: Pressure difference caused by the difference in density between indoor and outdoor air due to indoor/outdoor buoyancy forces *(2)*.

Ventilation: Ventilation is the process of supplying outdoor air to and removing indoor air from a space, for the purpose of controlling air contaminant levels, potentially accompanied by humidity and/or temperature, by natural or mechanical means *(5)*.

Ventilation, mechanical: The active process of supplying air to or removing air from an indoor space by powered air movement components *(2)*.

Ventilation, natural: Ventilation occurring as a result of only natural forces, such as wind pressure or differences in air density, through doors, windows or other intentional openings in the building *(2)*.

Ventilation system: A combination of appliances designed to supply interior spaces with outdoor air and/or to extract polluted indoor air *(2)*.

Whirlybird: A wind-driven turbine located on a roof to improve extraction of air from a building.

Executive summary

Context
The risk of getting COVID-19 is higher in crowded and inadequately ventilated spaces where infected people spend long periods of time together in close proximity. These environments are where the virus appears to spread by respiratory droplets or aerosols more efficiently, so taking precautions is even more important.

Understanding and controlling building ventilation can improve the quality of the air we breathe and reduce the risk of indoor health concerns including prevent the virus that causes COVID-19 from spreading indoors.

Methods
The roadmap was developed after conducting a scoping review of the available literature and an assessment of the available guidance documents from the major internationally recognized authorities on building ventilation. The available evidence and guidance were retrieved, collated and assessed for any discrepancies by international expert members of the World Health Organization (WHO) Environment and Engineering Control Expert Advisory Panel (ECAP) for COVID-19. The roadmap development process included two expert consultation sessions via virtual meetings, and two rounds of written submissions, to gather technical contributions and to ensure consensus building for the adaptation of recommendations. This process considered infection prevention and control (IPC) objectives, resource implications, values and preferences, ethics, and research gaps within the roadmap development.

Outcomes
This process resulted in a roadmap on how to improve ventilation in indoor spaces. The roadmap is divided into three settings – health care, non-residential and residential spaces – and takes into account different ventilation systems (mechanical or natural). The roadmap is aimed at health care facility managers, building managers, as well as those members of the general public who are providing home care or home quarantine.

1. Introduction

Knowledge about transmission of the SARS-CoV-2 virus is continuously evolving as new evidence accumulates. According to available evidence, SARS-CoV-2 mainly spreads between people when an infected person is in close contact with another person. Transmissibility of the virus depends on the amount of viable virus being shed and expelled by a person, the type of contact they have with others, the setting and what IPC measures are in place. The virus can spread from an infected person's mouth or nose in small liquid particles when the person coughs, sneezes, sings, breathes heavily or talks. These liquid particles are different sizes, ranging from larger "respiratory droplets" to smaller "aerosols". Close-range contact (typically within 1 m) can result in inhalation of, or inoculation with, the virus through the mouth, nose or eyes *(6–11)*.

Aerosol transmission can occur in specific situations in which procedures that generate aerosols are performed. The scientific community has been actively researching whether the SARS-CoV-2 virus might also spread through aerosol transmission in the absence of aerosol-generating procedures (AGP) *(12, 13)*. Some studies that performed air sampling in clinical settings where AGP were not performed found virus RNA, but others did not *(14)*. The presence of viral RNA is not the same as replication and infection-competent (viable) virus that could be transmissible and capable of initiating invasive infection. A limited number of studies have isolated viable SARS-CoV-2 from air samples in the vicinity of COVID-19 patients *(15, 16)*. Outside of medical facilities, in addition to droplet and fomite transmission, aerosol transmission can occur in specific settings and circumstances, particularly in indoor, crowded and inadequately ventilated spaces, where infected persons spend long periods of time with others *(10)*. High-quality research is required to address the knowledge gaps related to modes of transmission, infectious dose and settings in which transmission can be amplified. Currently, studies are under way to better understand the conditions in which aerosol transmission or superspreading events may occur.

1.1 Public health and social measures

WHO has published numerous recommendations for measures *(17–21)* to prevent spread of COVID-19, among which is ensuring good ventilation in indoor settings, including health care facilities, public spaces and residential areas. A well-designed, maintained and operated system can reduce the risk of COVID-19 spread in indoor spaces by diluting the concentration of potentially infectious aerosols through ventilation with outside air and filtration and disinfection of recirculated air. Proper use of natural ventilation can provide the same benefits. The decision whether to use mechanical or natural ventilation should be based on needs, resource availability and the cost of systems to provide the best control to counteract the risks.

This document accompanies the published recommendations cited above. It elaborates and expands on recommended actions targeting ventilation as listed in the above cited documents and provides health care facility managers, building managers (including long-term care, non-residential and residential facilities) as well as for the general public when implementing home care and home quarantine, with an operational tool to enhance indoor ventilation as an environmental and engineering control for the COVID-19 pandemic and beyond. It is neither prescriptive nor exhaustive and should be adapted to national regulatory frameworks and local social, cultural and economic contexts. The roadmap is not intended to replace other guidance and plans, but rather to complement them by helping facility managers ensure that key considerations are addressed.

1.2 Scope of the document

SARS-CoV-2 transmission is particularly effective in crowded, confined indoor spaces where there is poor or no ventilation *(22)*. Therefore, ensuring adequate ventilation may reduce the risk of COVID-19 infection *(23)*. This roadmap aims to define the key questions users should consider to assess indoor ventilation and the major steps needed to reach recommended ventilation levels or simply improve indoor air quality (IAQ) in order to reduce the risk of spread of COVID-19. It also includes recommendations on how to assess and measure the different parameters, specifically in health care, non-residential and residential settings. It is meant to be a technical document helping users to analyse building HVAC systems in order to implement, if required, the different strategies proposed to improve HVAC's ability to mitigate and reduce the risk of COVID-19 transmission.

Note: Indoor ventilation is part of a comprehensive package of prevention and control measures that can limit the spread of certain respiratory viral diseases, including COVID-19. However, ventilation alone, even when correctly implemented, is insufficient to provide an adequate level of protection. Correct use of masks, hand hygiene, physical distancing, respiratory etiquette, testing, contact tracing, quarantine, isolation and other IPC measures are critical to prevent transmission of SARS-CoV-2.

The roadmap provides guidance for health care facility managers, building managers (including long-term care, non-residential and residential facilities) as well as for the general public when home care and home quarantine are required.

2. Methodology

The methods used to develop the roadmap included two stages. First, a scoping rapid review on building ventilation and transmission of SARS-CoV-2 was undertaken. A search (see Annex 1 for the search strategy) of the WHO COVID-19 database and existing COVID-19 rapid review collections up to 2 December 2020 identified 1174 citations, 99 of which were reviewed at the full-text level. Six articles met broad inclusion criteria on ventilation systems and transmission of SARS-CoV-2 (three peer-reviewed articles and three preprint articles – see Annex 1 for details). Of the peer-reviewed studies, one was a validation study of an isolation space created by modifying a HVAC system in a hospital in Pennsylvania, United States of America. A second study evaluated transmission between patients and health care workers (HCW) in negative pressure isolation rooms in Daegu, Republic of Korea. The third study was an outbreak investigation in an air-conditioned restaurant in Guangzhou, China. Of the included preprint studies, two were studies of SARS-CoV-2 transmission on the Diamond Princess cruise ship. A third preprint study evaluated the role of HVAC systems in transmission in an academic medical centre in Oregon, United States of America.

In addition, a review and adaptation of all relevant technical guidance published by the globally recognized leading international and regional heating, refrigerating and air-conditioning associations and federations, namely the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA), and review and adaptation of the available guidance on HVAC systems in the context of COVID-19 published by the US Centers for Disease Control and Prevention and the European Centre for Disease Prevention and Control was undertaken. Links to the technical documents and guidelines considered are available in Annex 2.

Key findings from the identified studies and the relevant recommendations from the existing guidance were extracted and collated. Discrepancies in the extracted findings and recommendations were then reviewed in consultation with national and international expert members of the ECAP for COVID-19.

The ECAP constitutes an ad-hoc advisory panel supporting the WHO's World Health Emergencies preparedness, readiness and response to COVID-19 and includes, amongst other, members of the Global Infection Prevention and Control Network, engineers and architects from relevant professional engineering and architecture networks, organizations and institutions specialized in health care settings, technical experts from ministries of health and similar institutions (see Acknowledgements); and WHO staff and consultants from different departments including Environment, Climate Change and Health, Infection Prevention and Control, and Operations Support and Logistic.

The roadmap development process included two expert consultation sessions, via virtual meetings, to gather technical contributions and consensus building for the adaptation of recommendations taking IPC objectives, resource implications, values and preferences, ethics and research gaps into account. In addition to the virtual meetings, two rounds of written input by contributors were used to finalize the roadmap.

All authors contributing to this document and members of the external and internal review panels signed conflict of interest statements. No conflicts of interest were declared.

3. Key information

Ventilation is the intentional introduction of clean air into a space while the stale air is removed. Ventilation moves outdoor air into a building or a room and distributes it within the building or room. If local outdoor conditions require, e.g. high particulate matter (PM) concentration, treatment of the outdoor may be needed before introducing it into the building.

The general purpose of ventilation in buildings is to ensure that air in the building is healthy for breathing. At present this is achieved mainly by diluting pollutants originating in the building with clean air, and by providing an airflow rate to change this air at a given rate thus removing the pollutants. Ventilation is also used for odour control, containment control and often combined with climatic control (temperature and relative humidity).

Building ventilation has three basic elements:

- ventilation rate (m³/hr, l/s or ACH) – the volume of outdoor air that is provided into the space;
- airflow direction – the overall airflow direction in a building and spaces, which should be from clean zones to dirty zones; and
- air distribution or airflow pattern – the external air should be delivered to each part of the space in an effective and efficient manner and the airborne pollutants generated in each part of the space should also be removed in an effective and efficient manner.

There are three methods that may be used to ventilate a building: natural, mechanical and hybrid (mixed mode) ventilation. This roadmap only considers mechanical and natural ventilation as all key questions and strategies described can also be adopted for hybrid ventilation.

4. Settings

To provide maximum utility of a ventilation system and provide greater general dilution of air contaminants throughout the space, mechanical and natural systems can be used independently of the settings. However, each setting has specific ventilation requirements defined by national and international regulatory bodies which differ according to the ventilation objectives. For instance, ventilation systems in medical facilities are in place as an environment and engineering control for infection prevention *(24)* while, for residential buildings, they are mainly to create a thermally comfortable indoor environment with acceptable indoor air quality *(25).*

The roadmap focuses on three different settings according to specific IPC objectives. Each setting is described below to facilitate understanding and knowledge of implementation strategies in all contexts.

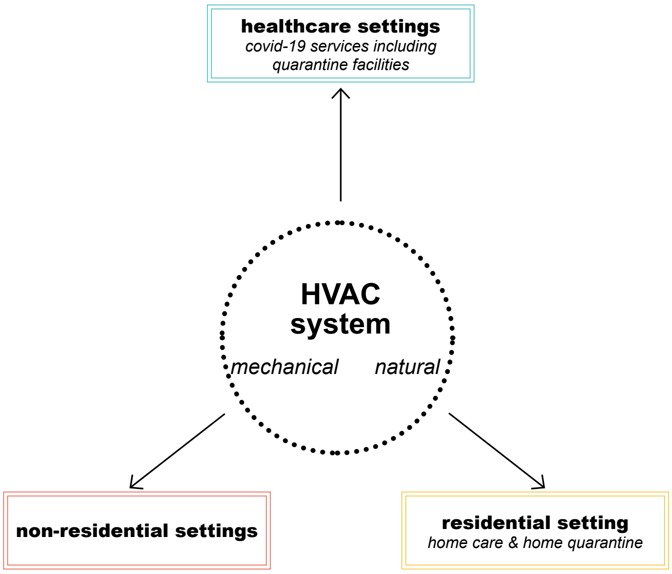
4.1 Health care settings

Adequate ventilation in all patient care areas plays a key role to help prevent and reduce infections. Nevertheless, this document specifically targets COVID-19 structures such as COVID-19 treatment centres and wards including quarantine, community facilities and long-term care facilities. Some risk factors, such as the presence of confirmed and suspected cases, the proximity required to provide medical care, AGP potentially performed, and visitor influx, make these settings particularly vulnerable. For the above reasons, together with other IPC measures described in their specific guidance, these settings require strict ventilation requirements to enable a safe working environment and reduce the risk of health care associated infections amongst HCWs, patients and visitors.

4.2 Non-residential setting

For this document “non-residential setting’’ refers to public and private indoor spaces characterized by a heterogeneous occupancy rate with people not belonging to the same household, such as workplaces *(26)*, schools *(19)* and universities, accommodation sector buildings *(27)*, and religious and commercial spaces. The load of air pollution or infectious aerosol potentially released in a building depends on the activities performed inside, the number of occupants and whether or not the occupants are wearing masks.

National, regional or international requirements are available for each setting and several interim guidance documents have been developed. However, in order to strengthen proposed IPC measures, simplify the COVID-19 risk assessment and facilitate the implementation of corresponding countermeasures, a minimum ventilation rate per person is proposed. This figure, directly linked to space occupancy, will allow the assessment and improvement of ventilation and, if not possible, the adjustment of maximum building occupancy. Note that buildings repurposed in community and quarantine facilities are included in the chapter “4.1 Health care settings”.



4.3 Residential settings

In the context of the current COVID-19 outbreak, WHO recommends the rapid identification of COVID-19 cases and their isolation and management either in a medical facility or an alternative setting, such as the home. Additionally, in many contexts, health services are delivered at community level and in the home by community health workers, traditional medicine practitioners, social care workers, or a variety of formal and informal community-based providers. Specific guidance for safe home care *(20)* and home quarantine *(28)* are already available and provide recommendations on IPC measures including how to assess a potential isolation area space in residential settings. This roadmap aims to strengthen the use of ventilation as an environment and engineering control measure to reduce the risk of COVID-19 transmission amongst household members whenever a person is under home care or home quarantine and should be considered as a complementary part for the already existing IPC guidance.

5. Important considerations

5.1 Vector-borne diseases

Vector-borne diseases are human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors; the commonest one being mosquitoes, the vector for malaria, dengue, and yellow fever. Other flying vectors also contribute to human illness such as human African trypanosomiasis and leishmaniasis.

Every year more than 700 000 deaths result from these diseases. The burden of these diseases is highest in tropical and subtropical areas, and they disproportionately affect the poorest populations *(29).*

One of the most used, affordable and sustainable measures to prevent and reduce the incidence for some vector-borne diseases is the installation of mosquito screening on windows, doors and other entry points. Unfortunately, simple mosquito screening on windows may reduce the natural ventilation rate significantly and this should be taken into account when calculating air changes.

For the above reasons, especially where vector-borne diseases are endemic, it is essential to consider strengthening vector control activities while improving indoor ventilation.

5.2 Outdoor air pollution

Outdoor air pollution is a major environmental health problem affecting all countries. Ambient (outdoor) air pollution in both cities and rural areas is estimated to cause about 4 million *(30)* premature deaths worldwide per year. People living in low- and middle-income countries disproportionately experience the burden of outdoor air pollution.

Avoiding air pollution through staying indoors may be beneficial but the effect largely depends on the level of indoor risks (e.g. indoor and household air pollution, presence of sick persons). Also, there is uncertainty about the reduction in exposure of populations, and the health benefits of staying indoors are not clear or may be reversed, depending on various circumstances, and the potential benefits and harms depend from specific local factors. As shown in a recent report, efficacy of portable indoor air filters (or portable indoor air cleaners) in real-world situations (i.e. not laboratory or occupational settings) showed that they are efficient to reduce indoor particulate matter (PM2.5) concentration by 40–82% but that little improvement of health effects were demonstrated *(31)* (mainly for healthy adults). It would, however, be premature to recommend the use of portable air filters as a public health measure to protect from air pollution for many reasons. Thus, the use of portable indoor air filters might be proposed for people with pre-existing conditions, such as chronic obstructive pulmonary disease, heart failure or lung transplants, who should stay at home and be protected from exposure to air pollution. Yet, given the current COVID-19 pandemic, indoor air filtration and recirculation should be carefully considered, taking into account the COVID-19 mitigation measures. If appropriate, consider outdoor air pollution levels while assessing and improving indoor ventilation by using natural ventilation and outdoor air filtration. For example, in areas constantly experiencing high levels of outdoor air pollution or at times/episodes of air pollution, (outdoor) air filtration may be more appropriate than increasing ventilation rates.

6. How to use the roadmap

Owners and building managers should consider evaluating their building systems to check that they are operating in proper order (per design or current operational strategies), are capable of being modified to align with HVAC mitigation strategies, and to identify deficiencies that should be repaired. Several recommendations should be considered in consultation with HVAC professionals.

The finalized roadmap is divided into three settings: health care, non-residential and residential spaces such as private houses. For each category there is a further stratification according to the ventilation system – mechanical or natural ventilation. After identifying the correct setting and ventilation system, the reader should start from the top, beginning with the central column labelled “step – key questions”. On the left side, the minimum requirements and standards are proposed for each key question, while on the right side, the different strategies to improve the specific matter. Strategies are listed in order of preference from the most effective to the least effective, i.e. if more than one strategy can be implemented, the first one, the one on top, should be preferred. However, it is worth highlighting that neither the cost nor the time required for implementation were considered. As a rule of thumb, the strategies at the top of the list, while being the most effective, can be the most expensive and take the longest to implement. When implementing the roadmap, building owners and managers should consider, amongst other factors, weather conditions and outdoor air pollution. For a few specific cases, it is preferable to implement two or more strategies simultaneously. Those cases are marked with a plus (+) symbol in between the strategies to be combined.

6.1 Health care settings including quarantine facilities

natural ventilation

Minimum requirements

Steps – key questions

Strategies

Ventilation rate minimum requirements *(32)*:

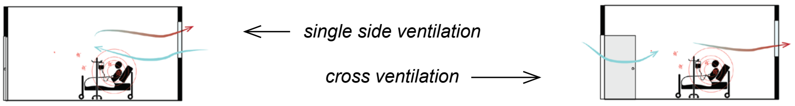
- 160 L/s/patient or 12 ACH where AGP are performed
- 60 L/s/patient or 6 ACH other

Does the ventilation rate meet WHO minimum requirements?
To estimate the ventilation rate consult point 2.

NO

+ Assess the opening locations and opening surfaces considering potential new openings (add/modify window or door dimensions).

+ Consider enabling cross ventilation rather than single-sided ventilation.
Note: Cross ventilation should not be implemented in these specific cases:
• within a room or ward for COVID-19 suspected cases where AGP may take place and when the exhaust air is not properly managed;
• when the airflow is moving from a less clean to a clean area.



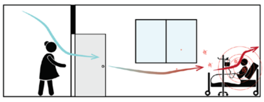
If the system does not allow increasing ventilation to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/patient standard.

+ If no other (short-term) strategy can be adopted, consider using a stand-alone air cleaner with HEPA filters. Pay attention to the airflow direction (from clean to less clean areas) when positioning. The air cleaner should be positioned in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Stand-alone air cleaners should be operated continuously and air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate.
Note: Consider that stand-alone air cleaners do not replace ventilation in any circumstance.

YES

The airflow direction should be from clean to less clean area *(32)*

Does the airflow move from clean to less clean area?
To evaluate the airflow consult point 3.



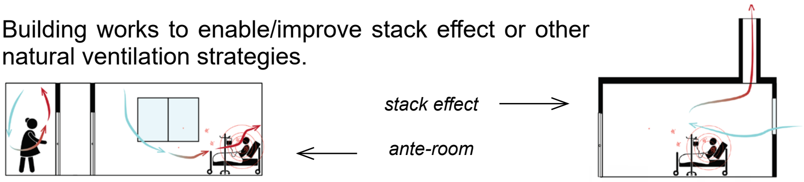
NO

+ Consider modifying the functional distribution regarding airflow directions to minimize exposure of HCWs, i.e. changing patient and staff areas in order to have natural negative pressure (i.e. due to stack effect) close to patient rooms, if a clear airflow direction is identified.

+ Installation of wall or window air extractors or whirlybirds *(33)*.

+ The use of a pedestal fan placed close to an open window could enable ventilation. A pedestal fan facing towards the window (i.e. facing outside) serves to pull the room and exhaust air to the outside; a fan facing towards the interior of the room (i.e. facing inside) serves to pull in the outdoor air and push it inside the room. The orientation of the pedestal fan should be chosen according to the desired airflow direction.

+ Building works to enable/improve stack effect or other natural ventilation strategies.



+ In rooms, where AGP are performed: add ante-rooms in order to have strict control on airflow direction. Double doors in ante-rooms should not be open at the same time in order to clearly separate the air between patient room and corridor (clean area). Note: In most cases, this strategy cannot be combined with cross ventilation, therefore the minimum ventilation rate should be attained with other strategies.
A cost-effective solution is the use of a plastic door zipper as a partition to create an ante-room.

YES

Air should be exhausted directly to the outside away from air intake vents *(34)*

Is the exhausted air correctly managed?

NO

Use of fences to avoid passage of people close to openings (windows and doors), keeping people or animals at a distance at least of 4 m.
No action is needed if the air is exhausted from the roof or 2 m higher than people (i.e. due to stack effect, whirlybirds).

YES

Heating and air conditioning with recirculating units should be used carefully and after assessment

Air conditioning and heating are performed by non-ducted (with indoor air recirculation) convectors such as split or fan coil units.

YES

Use of split system and fan coil units is discouraged because they are difficult to maintain, provide poor filtration and contribute to turbulence, potentially increasing the risk of infection *(35)*.
Avoid use of split system and fan coil units for COVID-19 patients *(36)*, especially where AGP are performed and consider using alternative heating and cooling systems and local exhaust systems.
Split systems can be used only in single room (suspected or confirmed cases) and in shared room hosting cohorted confirmed inpatients.
Note: Non-ducted recirculating units do not replace ventilation in any circumstance.

Whenever in-room recirculating units with poor filtration are used, consider creating a negative pressure relative to the corridor to reduce the potential for aerosols to escape from the room. Negative pressure can be created by increasing the airflow of extracted air from the room by installing extractor fans or devices. Units should be cleaned carefully in between patients *(36)*.

\+

If alternative air conditioning and heating are not available/feasible, consider running the air-conditioning and heating units at minimum velocity to reduce turbulence where AGP are performed. Where thermal conditioning (high temperatures) is needed, ensure that direct airflows between individuals are avoided.
Except for single room (suspected or confirmed cases) and shared room hosting cohorted confirmed inpatients.
Note: Consider non-ducted recirculating units do not replace ventilation in any circumstance

\+

Considering modifying the position of the heating/cooling unit to direct the airflow to the less clean zone or install an extractor to control the airflow where AGP are performed.

NO

END

mechanical ventilation

Minimum requirements

Steps – key questions

Strategies

Ventilation rate minimum requirements *(32)*:

- 160 L/s/patient or 12 ACH where AGP are performed
- 60 L/s/patient or 6 ACH other

Does the ventilation rate meet WHO minimum requirements?
To assess the ventilation rate consult point 1.

NO

In consultation with a HVAC professional assess the opportunity to increase the ventilation rate according to system capabilities.
Disable demand-control ventilation controls that reduce air supply based on temperature or occupancy (CO_2 concentration).

If the ventilation rate cannot be increased mechanically, consider maximizing ventilation by using natural ventilation through opening windows *(37)* (see natural ventilation section for more strategies).

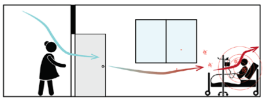
If the system does not allow increasing the ventilation to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/patient standard.

If no other (short-term) strategy can be adopted, consider using a stand-alone air cleaner with HEPA filter. Pay attention to the airflow direction (from clean to less clean areas) when positioning. The air cleaner should be positioned in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Stand-alone air cleaners should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate.
Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.

YES

The airflow direction should be from clean to less clean area *(32)*

Does the airflow move from clean to less clean area?
To evaluate the airflow consult point 3.



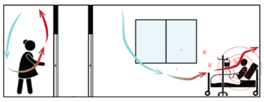
NO

Consider modifying the functional distribution regarding airflow directions to minimize exposure of HCWs, i.e. swapping patient and health care staff areas, if a clear airflow direction is identified.

In consultation with a HVAC professional, assess the opportunity to modify airflow direction, i.e. modifying the location of supply and exhaust (return) air devices.

+

In rooms where AGP are performed: add ante-rooms in order to have more strict control of airflow direction. Doors in ante-rooms should not be open at the same time in order to clearly separate the air between the patient room and the corridor (cleaner area).
A cost-effective solution is the use of a plastic door zipper as a partition to create an ante-room.



YES

Air should be exhausted directly to the outside and away from air-intake vents, people and animals *(34)*

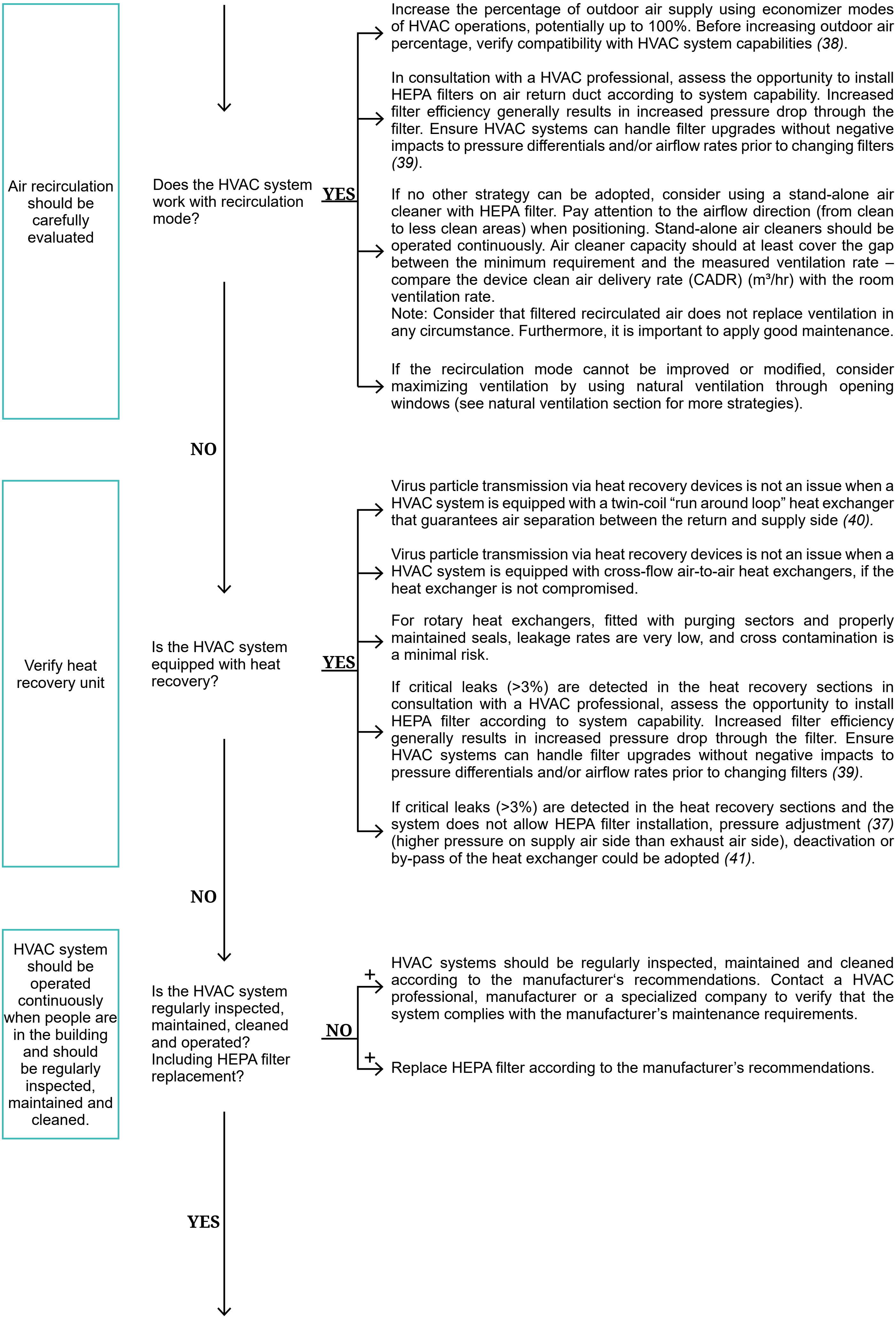
Is the exhausted air correctly managed?

NO

Consider fencing the area near the exhaust outlet keeping people or animals at a distance at least of 4 m. The air intake should be at least 2 m if the air outlet is above and 4 m if air outlet is below (EN 16798-4) from the exhaust.

If fencing the area is not feasible, in consultation with a HVAC professional, assess the opportunity to install HEPA filters according to system capability.

YES



Air recirculation should be carefully evaluated

Does the HVAC system work with recirculation mode?

YES

- Increase the percentage of outdoor air supply using economizer modes of HVAC operations, potentially up to 100%. Before increasing outdoor air percentage, verify compatibility with HVAC system capabilities *(38)*.
- In consultation with a HVAC professional, assess the opportunity to install HEPA filters on air return duct according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If no other strategy can be adopted, consider using a stand-alone air cleaner with HEPA filter. Pay attention to the airflow direction (from clean to less clean areas) when positioning. Stand-alone air cleaners should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate.
  Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. Furthermore, it is important to apply good maintenance.
- If the recirculation mode cannot be improved or modified, consider maximizing ventilation by using natural ventilation through opening windows (see natural ventilation section for more strategies).

NO

Verify heat recovery unit

Is the HVAC system equipped with heat recovery?

YES

- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin-coil “run around loop” heat exchanger that guarantees air separation between the return and supply side *(40).*
- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with cross-flow air-to-air heat exchangers, if the heat exchanger is not compromised.
- For rotary heat exchangers, fitted with purging sectors and properly maintained seals, leakage rates are very low, and cross contamination is a minimal risk.
- If critical leaks (>3%) are detected in the heat recovery sections in consultation with a HVAC professional, assess the opportunity to install HEPA filter according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If critical leaks (>3%) are detected in the heat recovery sections and the system does not allow HEPA filter installation, pressure adjustment *(37)* (higher pressure on supply air side than exhaust air side), deactivation or by-pass of the heat exchanger could be adopted *(41)*.

NO

HVAC system should be operated continuously when people are in the building and should be regularly inspected, maintained and cleaned.

Is the HVAC system regularly inspected, maintained, cleaned and operated? Including HEPA filter replacement?

NO

- \+ HVAC systems should be regularly inspected, maintained and cleaned according to the manufacturer‘s recommendations. Contact a HVAC professional, manufacturer or a specialized company to verify that the system complies with the manufacturer’s maintenance requirements.
- \+ Replace HEPA filter according to the manufacturer’s recommendations.

YES

Heading and air conditioning with recirculating units should be used carefully and after assessment.

Air conditioning and heating are performed by non-ducted (with indoor air recirculation) convectors such as split system or fan coil units at room level.

YES

Use of split system and fan coil units is discouraged because they are difficult to maintain, provide poor filtration and contribute to turbulence, potentially increasing the risk of infection *(35)*.
Avoid the use of split system and fan coil units for COVID-19 patients *(36)*, especially where AGP are performed and consider using alternative heating and cooling systems.
Split systems can be used only in single room (suspected or confirmed cases) and in shared room hosting cohorted confirmed inpatients
Note: Non-ducted recirculating units (at room level) do not replace ventilation in any circumstance.

Whenever in-room recirculating units with poor filtration must be used, consider creating a negative pressure relative to the corridor to reduce the potential for aerosols to escape from the room. Negative pressure can be created by increasing the airflow of extracted air from the room using an extractor fan or similar. Units should be cleaned carefully in between patients *(36)*.

+

If alternative conditioning and heating systems are not available/feasible, consider running the air-conditioning and heating units at the minimum velocity allowed, in order to reduce turbulence when AGP are performed. If for thermal conditioning (high temperatures) is needed, at least ensure that direct airflows between persons are avoided.
Except for single room (suspected or confirmed cases) and shared room hosting cohorted confirmed inpatients.Note: Consider non-ducted recirculating units do not replace ventilation in any circumstance.

+

Consider modifying the position of the heating/cooling unit to direct airflow to the less clean zone or install an extractor to control the airflow when AGP are performed.

NO

END

6.2 Non-residential settings

natural ventilation

Minimum requirements	Steps – key questions	Strategies

Minimum requirements: Minimum recommended ventilation rate:

•10 L/s/person (EN 16798-1) *(42, 43)*

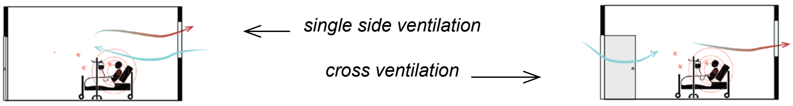
Steps – key questions: Does the ventilation rate meet the minimum requirement? To estimate the ventilation rate consult point 2.

NO

Strategies:

+ Assess the opening location and opening surface considering potential new openings (add/modify window or door dimensions).

+ Enable cross ventilation, if not yet present, instead of single-sided ventilation. Keep the doors open to allow air movement.



+ The use of a pedestal fan placed close to an open window could enable ventilation.

+ Installation of air extractors or whirlybirds *(33)*; building works to improve stack effect of other natural ventilation strategies.

+ If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14/F8 filters *(44)*. The air cleaner should be positioned in the areas used by people and close to people. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate.
Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.

YES

Minimum requirements: As a contaminant dilution strategy the indoor air should be changed as uniformly as possible

Steps – key questions: Is the air within the space well mixed?

NO

Strategies: The use of fans and/or fan coil or split units for cooling and heating as well as ceiling fans increase the air mixing within the room or the space *(44)*. This strategy should be implemented only if the minimum ventilation rate has been met.

1) pedestal fan
2) ceiling fan
3) split

YES

Minimum requirements: Occupancy and ventilation

Steps – key questions: Does the facility have periods of non-occupancy?

YES

Strategies: Open the windows to allow proper ventilation before and after occupied times. Windows should be opened for approximately 15 minutes when entering the room (especially when the room was occupied by others beforehand) *(37)*.

NO

Minimum requirements: Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Steps – key questions: Are air conditioning and heating performed by non-ducted (with indoor air recirculation) convectors such as split system or fan coil units?

YES

Strategies:

In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14/F8 or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

+ Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

NO

END

mechanical ventilation

Minimum requirements | **Steps – key questions** | **Strategies**

Minimum recommended ventilation rate:

- 10 L/s/person (EN 16798-1) *(42, 43)*

Does the ventilation rate meet the minimum requirement?
To assess the ventilation rate consult point 1.

NO

In consultation with a HVAC professional, assess the opportunity to increase the ventilation rate according to system capabilities.
Disable demand-control ventilation controls that reduce air supply based on temperature or occupancy.

If the ventilation rate cannot be increased mechanically, consider maximizing ventilation by using natural ventilation through opening windows *(37)* (see natural ventilation section for more strategies).

If the system does not allow increasing the ventilation up to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/person standard.

\+

If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14/F8 filters. The air cleaner should be positioned in the areas used by people and close to people. Stand-alone air cleaners should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate *(44)* – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate.
Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.

YES

As a contaminant dilution strategy, the indoor air should be changed as uniformly as possible.

Is the air within the space well mixed?

NO

The use of fans and/or fan coil units or split system units for cooling and heating increase the air mixing within the room or the space *(44)*. This strategy should be implemented only if the minimum ventilation rate has been met.

1) pedestal fan
2) ceiling fan
3) split

YES

Occupancy and ventilation

Does the facility have periods of non-occupancy?

YES

Operate the HVAC system with maximum outside airflow for 2 hours *(37)* at normal speed before and after occupied times.

NO

Verify air recirculation

Does the HVAC system work with recirculation mode?

YES

Increase the percentage of outdoor air as air supply, using economizer modes of HVAC operations, potentially up to 100%. Before increasing outdoor air percentage, verify compatibility with HVAC system capabilities *(38)*.

In consultation with a HVAC professional, assess the opportunity to install MERV 14/F8 filter on air return duct according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter *(45)*. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.

If no other strategies can be adopted, consider using stand-alone air cleaners (often called air purifiers) with particle filters. These should be operated continuously. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate. Use high-efficiency media filters (such as MERV 14/F8 or higher) *(44)*.
Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.

NO

Verify heat recovery unit

Is the HVAC system designed with heat recovery?

YES

Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin-coil "run around loop" heat exchanger that guarantees air separation between the return and supply side *(40)*.

Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with cross-flow air-to-air heat exchangers, if the heat exchanger is not compromised.

For rotary heat exchangers, fitted with purging sectors and properly maintained seals, leakage rates are very low, and cross contamination is a minimal risk.

If critical leaks (>3%) are detected in the heat recovery device, in consultation with a HVAC professional, assess the opportunity to install MERV 14/F8 filter according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.

If critical leaks (>3%) are detected in the heat recovery sections and the system does not allow MERV 14/F8 filter installation or the highest compatible with the filter rack, pressure adjustment *(37)* (higher pressure on supply air side than exhaust air side), deactivation or by-pass of the heat exchanger could be adopted *(41)*.

NO

HVAC system should be operated continuously when people are in the building and should be regularly inspected, maintained and cleaned

Is the HVAC system regularly inspected, maintained, cleaned and operated, including filter cleaning and replacement?

NO

HVAC systems should be regularly inspected, maintained and cleaned according to the manufacturer's recommendations. Contact a HVAC professional, manufacturer or a specialized company to verify that the system complies with the manufacturer's maintenance requirements.

Clean or replace the air filter according to the manufacturer's recommendations.

YES

Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Conditioning and heating is performed by non-ducted (with indoor air recirculation) convectors such as split or fan coil units.

YES

In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14/F8 or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

NO

Air should be exhausted directly to the outside away from air-intake vents, people and animals *(34)*

Is the exhausted air correctly managed?

NO

If the system does not allow air filter installation, consider fencing the area nearby the exhausted outlet, keeping people or animals at a distance at least of 4 m. The air intake should be at least at 2 m if air outlet is above and 4 m if air outlet is below (EN 16798) from the exhaust.

In consultation with a HVAC professional, assess the opportunity to install MERV 14/F8 filters according to system capability.

YES

END

6.3 Residential settings including homes and self-quarantine at home

This section refers specifically to the isolation area, space or room previously identified for home care or self-quarantine according to the available guidance. The recommendations proposed are based on the assumption that the house and the identified isolation area can be considered as separated spaces. Hence, the following strategies should not be considered for the whole residential area but for the isolation space only. Note: Long-term care facilities are not included.

natural ventilation

Minimum requirements

Steps – key questions

Strategies

Minimum recommended ventilation rate:

- 10 L/s/person *(42)* (EN 16798-1)

within the isolation area

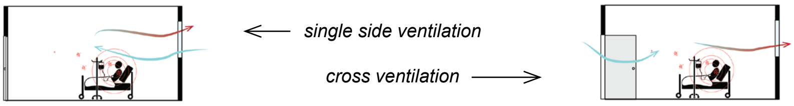
Does the ventilation rate meet the minimum requirement?
To estimate the ventilation rate, consult point 2.

NO

+ Assess the opening location and opening surface considering potential new openings (add modify window or door dimensions).

If available, exhaust fans in bathrooms, toilets and kitchen should be operated continuously within the isolation area *(44)*.

+ Ensure cross ventilation, if not yet present, instead of single-sided ventilation. Keep doors open to allow air movement.
Note: Consider step below prior to implementing cross ventilation.



Window-installable products are available to provide exhaust ventilation *(44)*.

The use of a pedestal fan placed close to an open window could enable ventilation. A fan facing towards the window (i.e. facing outside) serves to pull the room and exhaust air to the outside.

+ If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14/F8 filters *(44)*. The air cleaner should be positioned in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate.
Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.

YES

Separate the isolation area from the rest of the house *(44)*

The isolation area has a separate ventilation from the other rooms.

NO

If available, choose a room with a private toilet with an air extractor. That air extractor should run continuously at high speed.

+ Consider using stand-alone air cleaners with MERV 14/F8 filters. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate. The air cleaner should be positioned in areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection.
Note: Consider that filtered recirculated air does not replace ventilation in any circumstance.

YES

As a contaminant dilution strategy, the indoor air (within the isolation area) should be changed as uniformly as possible.

Is the air within the isolation area well mixed?

NO

The use of fans and/or fan coil or split system units for cooling and heating increases air mixing within the room or space. This strategy should be implemented only if the minimum ventilation rate has been met.

1) pedestal fan
2) ceiling fan
3) split

YES

Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Air conditioning and heating are performed by non-ducted (with indoor air recirculation) convectors such as split system or fan coil units.

YES

+

Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14/F8 or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.

Create negative pressure relative to the corridor (outside the room) by increasing general or toilet exhaust airflow. Carefully perform room unit cleaning and disinfection.

NO

END

mechanical ventilation

Minimum requirements	Steps – key questions		Strategies
Minimum recommended ventilation rate: • 10 L/s/person *(42)* (EN 16798-1) within the isolation area	Does the ventilation rate meet the minimum requirement? To assess the ventilation rate, consult point 1.	**NO**	+ If the ventilation rate cannot be increased mechanically, consider maximizing ventilation by using natural ventilation through opening windows *(37)* (see natural ventilation section for more strategies). Forced air systems should be run as much as possible, such as by using “FAN ON” settings *(44)*. In consultation with a HVAC professional, assess the opportunity to increase the ventilation rate according to system capabilities. Disable demand-control ventilation controls that reduce air supply based on temperature or occupancy. If no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14/F8 filter *(44)*. The air cleaner should be positioned in areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m³/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 
	YES		
Separate the isolation area from the rest of the house *(44)*	The isolation area has a separate ventilation from the other rooms.	**NO**	+ If there is a forced air system that would mix the air between the household and the isolation space, return grilles or supply grilles within the isolation area should be sealed *(44)*. Therefore, the isolation area should switch the ventilation mode to natural (refer to the natural ventilation section for more strategies). + Portable room heaters or room air conditioners could be used in the isolation space *(44)* instead of heating and cooling based on air provided by the HVAC central system. Clean and disinfect the device once isolation is over. + Consider using stand-alone air cleaners (often called air purifiers) with particle filters. They should be operated continuously. Use high-efficiency media filters (such as MERV 14/F8 or higher) *(44)*. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance. 
	YES		
As a contaminant dilution strategy the indoor air (within the isolation area) should be changed as uniformly as possible	Is the air within the space well mixed?	**NO**	The use of fans and/or fan coil or split system units for cooling and heating increases the air mixing within the room or space. This strategy should be implemented only if the minimum ventilation rate has been met. Note: Air mixing should be enhanced within areas but considering the isolation area and the rest of the house separately.  1) pedestal fan 2) ceiling fan 3) split
	YES		

Verify air recirculation

Does the HVAC system work with centralized recirculation mode?

YES

- Increase the percentage of outdoor air as air supply, using economizer modes of HVAC operations, potentially up to 100%. Before increasing the outdoor air percentage, verify compatibility with HVAC system capabilities *(38)*.
- If there is a forced air system that would mix the air between the household and the isolation space, return grilles or supply grilles within the isolation area should be sealed. Therefore, the isolation area switches the ventilation mode to natural (refer to the natural ventilation section for more strategies).
- Update or replace existing air filters with MERV 14/F8 or the highest compatible with the filter rack on the air return duct. Make sure the HVAC system can overcome the additional pressure drop of the new filters.
- If no other strategy can be adopted, consider using stand-alone air cleaners with MERV 14/F8 filters *(44).* The air cleaner should be positioned in areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection. Pay attention to the airflow direction (from clean to less clean areas) when positioning.
  Note: Consider that filtered recirculated air does not replace ventilation in any case.

NO

Verify heat recovery unit

Is the HVAC system designed with heat recovery?

YES

- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin-coil "run around loop" heat exchanger that guarantees air separation between the return and supply side *(40)*.
- Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with cross-flow air-to-air heat exchangers, if the heat exchanger is not compromised.
- For rotary heat exchangers, fitted with purging sectors and properly maintained seals, leakage rates are very low, and cross contamination is a minimal risk.
- If critical leaks (>3%) are detected in the heat recovery sections, in consultation with a HVAC professional, assess the opportunity to install MERV 14/F8 or higher filter according to system capability. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters *(39)*.
- If critical leaks (>3%) are detected in the heat recovery sections and the system does not allow MERV 14/F8 filter installation or the highest compatible with the filter rack, pressure adjustment *(37)* (higher pressure on supply air side than in exhaust air side), deactivation or by-pass of the heat exchanger could be adopted *(41).*

NO

HVAC system should be regularly inspected, maintained, cleaned and operated continuously

Is the HVAC system regularly inspected, maintained, cleaned and operated, including filter cleaning and replacement?

NO

- HVAC systems should be regularly inspected, maintained and cleaned according to the manufacturer's recommendations. Contact a HVAC professional, manufacturer or a specialized company to verify that the system complies with the manufacturer's maintenance requirements.
- Clean or replace filter according to the manufacturer's recommendations.

YES

Heating and air conditioning with recirculating units should be assessed, maintained and cleaned

Conditioning and heating is performed by non-ducted (with indoor air recirculation) convectors such as split or fan coil units.

YES

- Air-conditioning and heating units performed by split system and fan coil units should be periodically cleaned and maintained. Filters should also be periodically cleaned or changed.
  Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
- In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14/F8 or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters.
  Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance.
- Create negative pressure relative to the corridor (outside the room) by increasing general or toilet exhaust airflow. Carefully perform cleaning and disinfection of room units.

NO

END

7. Evaluating ventilation

Ventilation rate and airflow direction are key elements to be assessed and evaluated before undertaking any action on the ventilation system. This first evaluation will provide the baseline and allow the user to better understand the gap between the ventilation system functionality and the proposed requirements. A second evaluation should be carried out once improvement strategies have been implemented. Comparing the second evaluation with the initial baseline will provide an overview of the effectiveness of the implemented improvement strategies and a clear understanding of the new ventilation rate and flow.
Mechanical and natural ventilation systems require different methods to evaluate the ventilation airflow rate.

Point 1) Minimum ventilation rate – mechanical ventilation system. How to assess it?

Each mechanical ventilation system is designed for specific airflow rates. Consult the technical manual to verify the system capacity.

Point 2) Minimum ventilation rate – natural ventilation system. How to estimate it?

As a rule of thumb, wind-driven natural ventilation rate through a room can be calculated as follows *(20)*:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

k = 0.05 in the case of single-sided ventilation
k = 0.65 in the case of cross ventilation
in the case of mosquito net presence = ventilation rate x 0.5
wind speed: the wind speed refers to the value at the building height at a site sufficiently away from the building without any obstructions (e.g. at an airport) *(32)*

Point 3) Airflow direction. How to evaluate it?

The airflow direction is usually assessed through a gas tracer. However, other cost-effective solutions can be used, such as incense sticks or other smoke generators – a smoke test can be used to highlight the direction of the airflow.

Annex 1:Search strategy and included studies

Search strategy

Concept	Search strategy	Results (2 December 2020)
Ventilation, filtration	hvac OR "air conditioning" OR "forced air" OR "air flow"~3 OR (enclosed AND (space* OR area*)) OR "forced ventilation" OR window* OR fans OR (air AND (recirculation OR recirculated OR ducted OR duct OR ducts OR filterat* OR purif* OR cleaner*)) OR "air exchange"~5 OR HEPA OR mh:("Air Microbiology" OR "Ventilation" OR "Air Filters" OR "Air Conditioning" OR "Filtration" OR "Air Pollution, Indoor" OR "Heating" OR "Air Movements" OR "Air Pollutants") OR MERV	1174

Included studies

Author	Title	Journal and date	Key findings
PUBLISHED LITERATURE			
SL Miller, et al.	Implementing a negative pressure isolation space within a skilled nursing facility to control SARS-CoV-2 transmission	Am J Infect Control 2 October 2020	Validation study of an isolation space at a skilled nursing facility in Pennsylvania, USA. Goal: minimize disease transmission between residents and staff. Isolation space was created by modifying an existing HVAC system; performed computational fluid dynamics and Lagrangian particle-based modelling to test containment and possible transmission. No transmission between residents isolated to the space occurred, nor any transmission to staff or other residents.
SY Lee, et al.	Crucial role of temporary airborne infection isolation rooms in an intensive care unit: containing the COVID-19 outbreak in South Korea	Crit Care 18 May 2020	In an academic hospital in Daegu, Republic of Korea, temporary airborne infection isolation rooms (AAIRs) were assembled. An air volume control damper was used to maintain a negative pressure gradient between pre-existing AIIRs and the ante-room (-5.0 Pa) at a level below the standard negative pressure (-2.5 Pa) recommended for these facilities. The common negative pressure isolation zone was equipped with five mobile negative-air machines that generated negative pressure (-5.0 Pa) compared with the ante-room. Airflow in isolation rooms reached 15–20 air exchanges per hour. Over a 4-week period, 7 patients were treated: 6 patients required mechanical ventilation, 2 patients were treated with extracorporeal membrane oxygenation, and continuous renal replacement therapy was provided to 1 patient. The COVID-19 team included 5 physicians and 40 nurses. All HCWs in the newly remodelled ICU were screened for COVID-19 after the first 2 weeks on duty; no tests were reported as positive.
J Lu, et al.	COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020	Emerg Infect Dis 2 April 2020	Epidemiological investigation in Guangzhou, China. During 26 January to 10 February 2020, an outbreak of COVID-19 occurred in an air-conditioned restaurant, involving 3 family clusters. From an examination of the potential routes of transmission, authors concluded that the most likely cause of the outbreak was droplet transmission prompted by air-conditioned ventilation.

PREPRINT LITERATURE			
Xu P, et al.	Transmission routes of Covid-19 virus in the Diamond Princess Cruise ship	medRxiv 14 April 2020	Diamond Princess cruise ship study. Collected the daily number of 197 symptomatic cases, and that of the 146 passenger cases in two categories (those who stayed and did not stay in the same stateroom). Infections started on 28 January and finished by 6 February for passengers except those who stayed in the same stateroom with infected individual(s). No other confirmed cases were identified among the disembarked passengers in Hong Kong, SAR, China, except an 80-year-old passenger. No confirmed cases were reported in three other stopovers between 27–31 January associated with disembarked passengers or visitors from the ship. However, two Okinawa taxi drivers became confirmed cases in association with driving the ship's passengers. Infection among passengers after 6 February was limited to those who stayed in the same stateroom with an infected passenger. Infections in crew members peaked on 7 February, suggesting significant transmission among crew members after quarantine on 5 February. Authors concluded that the central air-conditioning system did not play a role in transmission and that transmission appears to have occurred through close contact and fomites.
O Almilaji and PW Thomas	Air recirculation role in the infection with COVID-19, lessons learned from Diamond Princess cruise ship	medRxiv 9 July 2020	Diamond Princess cruise ship study. Analysis of count data published on 21 February 2020 and collected by the ship's onboard clinic. By using only passenger count data from the first prepared dataset of 115 symptomatic cases with symptom onset dates during the quarantine period of 6–17 February, analysis showed that 20% occurred in cabins with a previous case, and 80% occurred in cabins without a previous case. Results showed that symptomatic infection rate with recoded symptom onset in cabins with previously confirmed cases was not significantly higher than that in cabins without previously confirmed cases during the whole quarantine period. No evidence was found to conclude that SIRR in the cabins with previously confirmed cases was not significantly higher than that in cabins without previously confirmed cases on and after the median quarantine period day.
PF Horve, et al.	Identification of SARS-CoV-2 RNA in Healthcare Heating, Ventilation, and Air Conditioning Units	medRxiv 28 June 2020	Objective: to assess the potential role of HVAC systems in airborne viral transmission by determining the viral presence on air handling units in a setting where COVID-19 patients were treated (Oregon, USA). The presence of SARS-CoV-2 RNA was detected in 14/56 (25%) of samples taken from nine different locations in multiple air handlers. While samples were not evaluated for viral infectivity, the presence of viral RNA in air handlers raises the possibility that viral particles can enter and travel within the air handling system of a hospital, from room return air through high efficiency MERV 15 filters and into supply air ducts. No known transmission events were determined to be associated with these specimens; however, findings may suggest the potential for HVAC systems to facilitate transmission by environmental contamination via shared air volumes with locations remote from areas where infected persons reside.

Annex 2: Relevant technical guidance

Guidance developer	Reference	Hyperlink
ASHRAE	ANSI/ASHRAE/ASHE Standard 170-2017 Ventilation of health care facilities. 2017.	https://www.ashrae.org/technical-resources/standards-and-guidelines/standards-addenda/ansi-ashrae-ashe-standard-170-2017-ventilation-of-health-care-facilities
ASHRAE	HVAC design manual for hospitals and clinics (second edition). 2013.	https://www.ashrae.org/technical-resources/bookstore/hvac-design-manual-for-hospitals-and-clinics
ASHRAE	Handbook HVAC fundamentals. 2017.	https://www.ashrae.org/technical-resources/ashrae-handbook
ASHRAE	Technical resources for health care settings	https://www.ashrae.org/technical-resources/healthcare
ASHRAE	Technical resources for reopening of schools and universities	https://www.ashrae.org/technical-resources/reopening-of-schools-and-universities
ASHRAE	Technical resources for multifamily building owners/managers	https://www.ashrae.org/technical-resources/multifamily-buildings
ASHRAE	Technical resources for residential settings	https://www.ashrae.org/technical-resources/residential
ASHRAE	Technical resources for commercial settings	https://www.ashrae.org/technical-resources/commercial
ASHRAE	Filtration/Disinfection	https://www.ashrae.org/technical-resources/filtration-disinfection
US Centers for Disease Control and Prevention	COVID-19 employer information for office buildings. 4 January 2021.	https://www.cdc.gov/coronavirus/2019-ncov/community/office-buildings.html
European Centre for Disease Prevention and Control.	Heating, ventilation and air-conditioning systems in the context of COVID-19. 2020.	https://www.ecdc.europa.eu/en/publications-data/heating-ventilation-air-conditioning-systems-covid-19
REHVA	COVID-19 guidance document. 3 August 2020.	https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf
WHO	SARI treatment centers: interim guidance, 28 March 2020	https://www.who.int/publications/i/item/10665-331603
WHO	Natural Ventilation for Infection Control in Health-Care Settings: guidance 2009	https://www.who.int/water_sanitation_health/publications/natural_ventilation/en/
WHO	Considerations for quarantine of contacts of COVID-19 cases: interim guidance, 19 August 2020	https://www.who.int/publications/i/item/considerations-for-quarantine-of-individuals-in-the-context-of-containment-for-coronavirus-disease-(covid-19)
WHO	Home care for patients with COVID-19 presenting with mild symptoms and management of their contacts: interim guidance, 17 March 2020	https://apps.who.int/iris/handle/10665/331473
WHO	Infection prevention and control during health care when COVID-19 is suspected: interim guidance, 19 March 2020	https://www.who.int/publications/i/item/10665-331495
WHO	Aide-memoire: infection prevention and control (IPC) principles and procedures for COVID-19 vaccination activities, 15 January 2021	https://apps.who.int/iris/handle/10665/338715
WHO	COVID-19 management in hotels and other entities of the accommodation sector: interim guidance, 25 August 2020.	https://apps.who.int/iris/handle/10665/333992
WHO	Considerations for school-related public health measures in the context of COVID-19: Annex to Considerations in adjusting public health and social measures in the context of COVID-19,14 September 2020	https://www.who.int/publications/i/item/considerations-for-school-related-public-health-measures-in-the-context-of-covid-19
WHO	Rational use of personal protective equipment for COVID-19 and considerations during severe shortages: interim guidance, 23 December 2020.	https://apps.who.int/iris/handle/10665/338033
WHO	Laboratory biosafety guidance related to coronavirus disease (COVID-19): interim guidance, 28 January 2021.	https://apps.who.int/iris/handle/10665/339056

WHO	Prevention, identification and management of health worker infection in the context of COVID-19: interim guidance, 30 October 2020.	https://apps.who.int/iris/handle/10665/336265
WHO	Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19: interim guidance, 29 July 2020.	https://apps.who.int/iris/handle/10665/333560.
WHO	Infection prevention and control guidance for long-term care facilities in the context of COVID-19: interim guidance, 8 January 2021.	https://apps.who.int/iris/handle/10665/338481.
WHO	Mask use in the context of COVID-19: interim guidance, 1 December 2020.	https://apps.who.int/iris/handle/10665/337199
WHO	Transmission of SARS-CoV-2: implications for infection prevention precautions: scientific brief, 09 July 2020.	https://apps.who.int/iris/handle/10665/333114.

Note: Links accessed 12 February 2021.

Annex 3: Air filter category

Composite Average Particle Size Efficiency % in Size Range µm (ASHRAE standard 52.2-2012)			ASHRAE Standard (52.2-2012)	European standard (EN 779-2012|EN 1882:2009)	
Range E1	**Range E2**	**Range E3**	**Minimum Efficiency Reporting Value**	**Filter class**	**Efficiency at MPPS**
0.3 - 1.0 µm	**1.0 - 3.0 µm**	**3.0 - 10.0 µm**	**MERV**	**-**	**%**
50% ≤ E1	85% ≤ E2	90% ≤ E3	MERV13	F7	
75% ≤ E1	90% ≤ E2	95% ≤ E3	MERV14	F8	
85% ≤ E1	90% ≤ E2	95% ≤ E3	MERV15	F9	
95% ≤ E1	95% ≤ E2	95% ≤ E3	MERV16	E10	<85
				E11	<95
				E12	<99.5
				HEPA - H13	<99.95
				HEPA - H14	<99.995

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