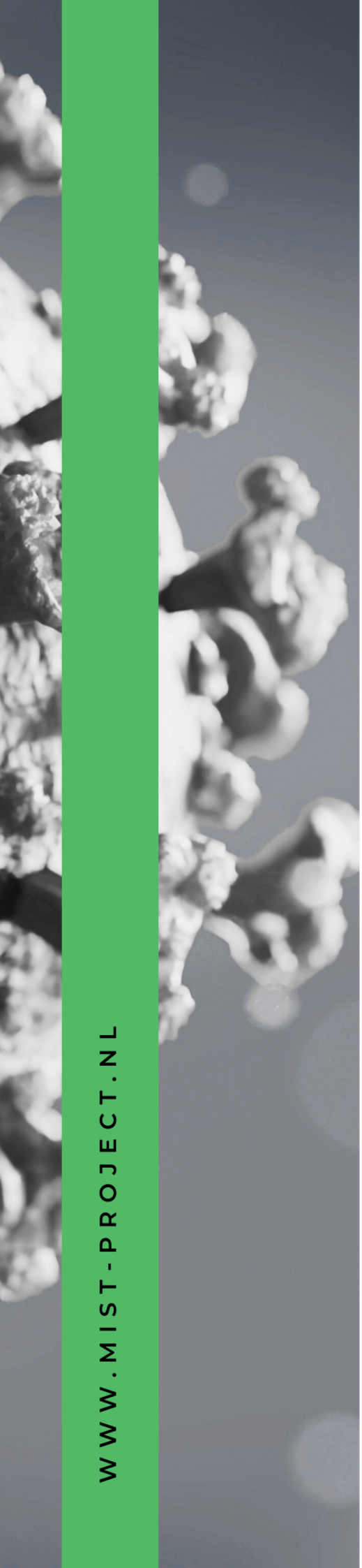

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Stakeholder Perspectives on Ventilation and Air Cleaning Strategies for Airborne Infection Control

-Report of workshops-

Deliverable
Work Package 5.2

Prepared by:
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2025

As a Part of project "MItigation STrategies for Airborne Infection Control" (MIST)

Funded by the Dutch Research Council (NWO)

Preface

This report is a deliverable of the research project **"MItigation STrategies for Airborne Infection Control" (MIST)**, funded by the Dutch Research Council (NWO). The MIST project aims to develop scientifically grounded and practically applicable strategies to reduce the risk of airborne transmission of infectious diseases in indoor environments.

The project is structured around a series of interconnected work packages that address various dimensions of airborne infection control, from technical analysis to behavioural insights. This report is part of **Work Package 5: Strategies for Infection Control** and specifically contributes to **Sub-Work Package 5.2: Interaction with Stakeholders, HVAC Professionals, and End-Users**.

The findings presented here are based on collaborative engagement with key actors in the field and reflect the importance of aligning scientific understanding with real-world practices and user needs. This report will support further dialogue, innovation, and implementation of effective mitigation strategies in the built environment.

Dr Elham Maghsoudi Nia
prof. dr.ir. Atze Boerstra
November 2025

This report is part of deliverable WP5.2 and the MIST project, project number P20-35, of the research programme Perspectief, which is financed by the Dutch Research Council (NWO).

Acknowledgments

This report was conducted as part of the MIST (MItigation STratgies for Airborne Infection Control) project funded by the Dutch Research Council (NWO). The authors gratefully acknowledge the financial support provided by NWO and the valuable contributions of all project partners. We would like to express our sincere gratitude to the many academics and practitioners across the Netherlands who generously supported us in organising the workshops for this study. Their valuable input, expertise, and commitment were instrumental in facilitating productive and insightful discussions. Their engagement and contributions have enriched our work and helped bridge research with real-world application.

Our thanks go to:

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This report is part of deliverable WP5.2 and the MIST project, project number P20-35, of the research programme Perspectief, which is financed by the Dutch Research Council (NWO).

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Summary

This report, developed as part of Deliverable WP5.2 of the MIST (MItigation STrategies for Airborne Infection Control) project, presents a synthesis of insights gathered from a series of stakeholder workshops. These workshops focused on identifying practical challenges encountered by various stakeholder groups, including technicians, manufacturers, and end users, regarding ventilation, HVAC systems, air cleaning technologies, and mitigation measures to control COVID-19 and other airborne pathogens.

Four workshops were conducted with a total of 26 participants. Across these sessions, a recurring theme was the lack of clear, actionable guidelines and reliable information on achieving "airborne infection-safe" indoor environments. Participants highlighted the need for specific technical advice and tools for risk assessment, emphasising that monitoring systems (beyond CO_2 sensors alone) are necessary to estimate airborne infection risks.

Several participants also stressed the importance of strategic governmental support, particularly in the form of guidelines and financial incentives for improving ventilation and deploying air cleaning technologies in public spaces such as schools. While some discussion focused on the availability and development of advanced technologies, many stakeholders underscored the importance of raising awareness among building owners, facility managers, and end users.

The findings presented in this report aim to support the development of new Dutch ventilation and air cleaning technology guidelines, targeting both technical and non-technical audiences. These guidelines will inform suppliers, decision-makers, and end users about airborne transmission routes and the role of ventilation and air purification in reducing infection risks.

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1. Introduction

Since the global outbreak of COVID-19, awareness of airborne disease transmission has increased significantly. Yet, even years later, the risk remains, and effective mitigation strategies remain crucial. While public attention has shifted, the need for clean and safe indoor air has not diminished. Ventilation and the introduction of air cleaning technologies do not only matter in relation to (transmission of) coronavirus, but also in relation to transmission of other airborne diseases like measles, tuberculosis, common colds, influenza, etc. Measures such as personal protective equipment (PPE), air filtration, and adequate ventilation continue to play a critical role in reducing the spread of airborne pathogens in indoor environments like offices, schools, hospitals, and elderly care facilities [1]. Among these measures, ventilation is a fundamental control measure to reduce the risk of airborne infection transmission of any pathogens [2]. It decreases the amount of viruses in people's breathing zones (coming from others), ensures the supply of clean outdoor air, and limits the recirculation of indoor air, factors known to reduce the likelihood of infection. Additional solutions like local exhaust systems, high-efficiency particulate filters, and local air cleaning or disinfection technologies, such as germicidal ultraviolet (GUV), offer further protection [1, 3]. Despite the availability of such technologies, their effective use often depends on the awareness, knowledge, and behaviour of the people who manage and occupy the spaces.

Mechanical HVAC systems, while technically capable, often underperform due to poor commissioning, limited user understanding, and insufficient maintenance [4]. End users frequently struggle with complex interfaces and a lack of clear guidance on properly ventilating their spaces. Meanwhile, technicians and manufacturers face their own challenges in translating scientific knowledge into practical, user-friendly solutions and implementation protocols.

The COVID-19 pandemic revealed society's vulnerability to infectious diseases. It exposed significant shortcomings in indoor air quality across the built environment, particularly in settings such as schools, where ventilation systems are often outdated or inadequately maintained. It also underscored the need for better public communication, multidisciplinary collaboration, and long-term investments in indoor air quality. Today, these lessons remind us that improving ventilation is not just a temporary pandemic measure but a lasting public health priority [2].

This report is one of the deliverables related to Work Package 5.2 of the MIST project (MItigation STrategies for Airborne Infection Control), funded by the Dutch Research Council (NWO). The project aims to develop:

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- *Mitigation strategies for controlling airborne infections related to HVAC technology, ventilation, and air cleaning.*
- *Evidence-based solutions and implementation protocols.*

The MIST project outputs target different stakeholder groups. Scientific results are translated into practical recommendations for implementing measures in the most efficient, cost-effective, and sustainable manner across various environments, including homes, hospitals, schools, and public transportation.

Following the project's goals, a series of stakeholder workshops was organised to explore how end users, technicians, manufacturers, and decision-makers perceive and interact with HVAC technologies, specifically ventilation and air cleaning systems. These workshops aimed to *identify practical challenges and to understand better the expectations and needs* of those involved in creating safe and healthy indoor environments.

2. Workshops' objectives

Within the MIST program, Delft University of Technology (TUD) is responsible for leading *Work Package 5 (WP5)*, which focuses on developing strategies for infection control. In line with Task 5.2, *Interaction with stakeholders, HVAC professionals, and end-users*, in the early stages of the project, all partners must gain insight into the perspectives of relevant stakeholder groups. These include HVAC professionals, system manufacturers, facility managers, and other professional end-users who may apply the outcomes of the MIST research.

To support this goal, a series of workshops involving diverse stakeholders and key decision-makers was organised. The purpose was to find the real-world challenges they face when designing, operating, and maintaining ventilation, air cleaners, and HVAC systems, particularly in airborne infection mitigation (e.g., COVID-19 and other pathogens). In addition, participants were encouraged to share their preferences for how they would like to receive future guidance and findings from the project, for example, through infographics, videos, interactive websites, white papers, or webinars.

This report has been developed to ensure the timely, accurate, and targeted communication of insights gained through the workshops to various target audiences. It contains key messages, recommendations, and guidelines to keep each stakeholder group informed and engaged throughout the MIST project.

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3. Workshop methodology

As aforementioned, this report, as part of the MIST project in the Netherlands, aims to identify and address practical challenges in reducing airborne virus transmission in indoor environments. A qualitative research approach was adopted to explore real-world challenges stakeholders face in the design, operation, and maintenance of building installations, with a particular focus on mechanical ventilation and air cleaning technologies. To investigate these challenges, a series of structured stakeholder workshops and a managed focus group were conducted [5] for stakeholder engagement and participatory inquiry.

3.1 Workshop structure

Four workshops titled "*MIST Workshop – Issues in Practice*" were organised between April and July 2024. Each session was designed to engage stakeholders, including HVAC professionals, end-users (e.g., facility managers), manufacturers, and consultants. The workshops were structured around the central research question:

"*What practical challenges do different stakeholders face in relation to ventilation and HVAC systems when creating and maintaining healthy indoor environments?"*

Each session followed a semi-structured format and included a combination of the following interactive activities:

- Sharing personal and professional experiences;
- Identifying key barriers and challenges in current practice;
- Expressing specific needs, expectations, and information gaps;
- Group discussions to explore risk mitigation strategies and solutions.

The format allowed for flexible discussion while maintaining consistency across sessions, enabling comparative analysis. To achieve precise outcomes, the workshops' activities were designed in line with some concrete sub-objectives (Table 1).

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Table 1. Alignment of Workshops' Objectives and Activities

Interaction with stakeholders	Activity Alignment
1. Inventory the wants and needs of stakeholders	Activity for sharing personal experiences and technical issues during the Pandemic Activity for identifying/prioritising challenges and issues - Group discussion
2. Determine preferred dissemination format	Activity for prioritising dissemination format

Three workshops were organised at the Faculty of Architecture and the Built Environment, TU Delft, providing a setting for in-depth discussions with professionals. One of the workshops took place during the CLAIRE Congress on June 5th, 2024, in Zoetermeer, hosted in collaboration with the CLAIRE project (CLAIRE – Clean air for everyone (claireproject.nl)), a partner aligned with MIST in its focus on indoor air quality and pathogen mitigation. This joint session was held at the 'Bouwhuis' of Binnenklimaat Nederland, offering a platform to engage a broader professional audience in the ventilation, air purification, and indoor climate sector.

Participants were invited through various channels, including academic networks, professional associations, mailing lists, and personal invitations (Table 2). Before each session, the participants were provided with background information detailing the workshop's objectives, structure, and interactive activities. A summary of the workshop dates, locations, and participant profiles is presented in Table 3.

Table 2. Stakeholder workshops: information and announcement Channels

Channel	Number of Engagement
Emails	6
Other events	13
Consortium Network	7

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Table 3. The workshops and participants' details

Workshop date	Location	Participants profile
8 April, 2024	TU Delft, Faculty of Architecture and the Built Environment	• Manufacturers (Extreme air products, Virobuster International GmbH / University of Twente, Kuijpers) • Technicians (Arcadis, VFA Solutions B.V., Hiensch Engineering B.V.) • End users (Radboud University, TU Delft)
22 May, 2024		• Manufacturers (Orange Climate) • Technicians (BBA Binnenmilieu, TNO) • End users (Amsterdam UMC)
5 June, 2024	'Bouwhuis' of Binnenklimaat Nederland	• Manufacturers (PURETi) • Technicians (Universiteit Utrecht/IRAS, RIVM, University of Twente, Leiden University); • End user (PO/VO Raad)
8 July, 2024	TU Delft, Faculty of Architecture and the Built Environment	• Manufacturers (Innovation Handling, Novaerus, Versuni) • Technicians (NLR, Active Technology Transfer Europe) • End user (Sport Innovator)

3.2 Workshops' procedure

The sessions opened with a welcome, an introduction to the MIST project, and an explanation of the workshop's goals. Following this, participants engaged in different activities.

3.2.1 Workshop 1 and 2 procedures

The procedures of these two workshops were the same and included three structured rounds of activities:

- **Round 1 - Personal reflections (activity 1):** Participants shared their personal experiences as well as the organizational and technical challenges they faced during the COVID-19 pandemic.

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- **Round 2 - Identifying and prioritising issues (activities 2 and 3):** Through group discussions, participants identified main challenges, prioritised the most demanding ones, presented their findings, and responded to feedback from other groups.
- **Round 3 - Dissemination strategies (activity 4):** Workshop participants evaluated and prioritised potential formats for disseminating future MIST project findings to various audiences.

The workshop concluded with a summary of key takeaways, a discussion of next steps, and reflections on the collaborative process. An overview of the workshop structure is further illustrated in Figure 1.

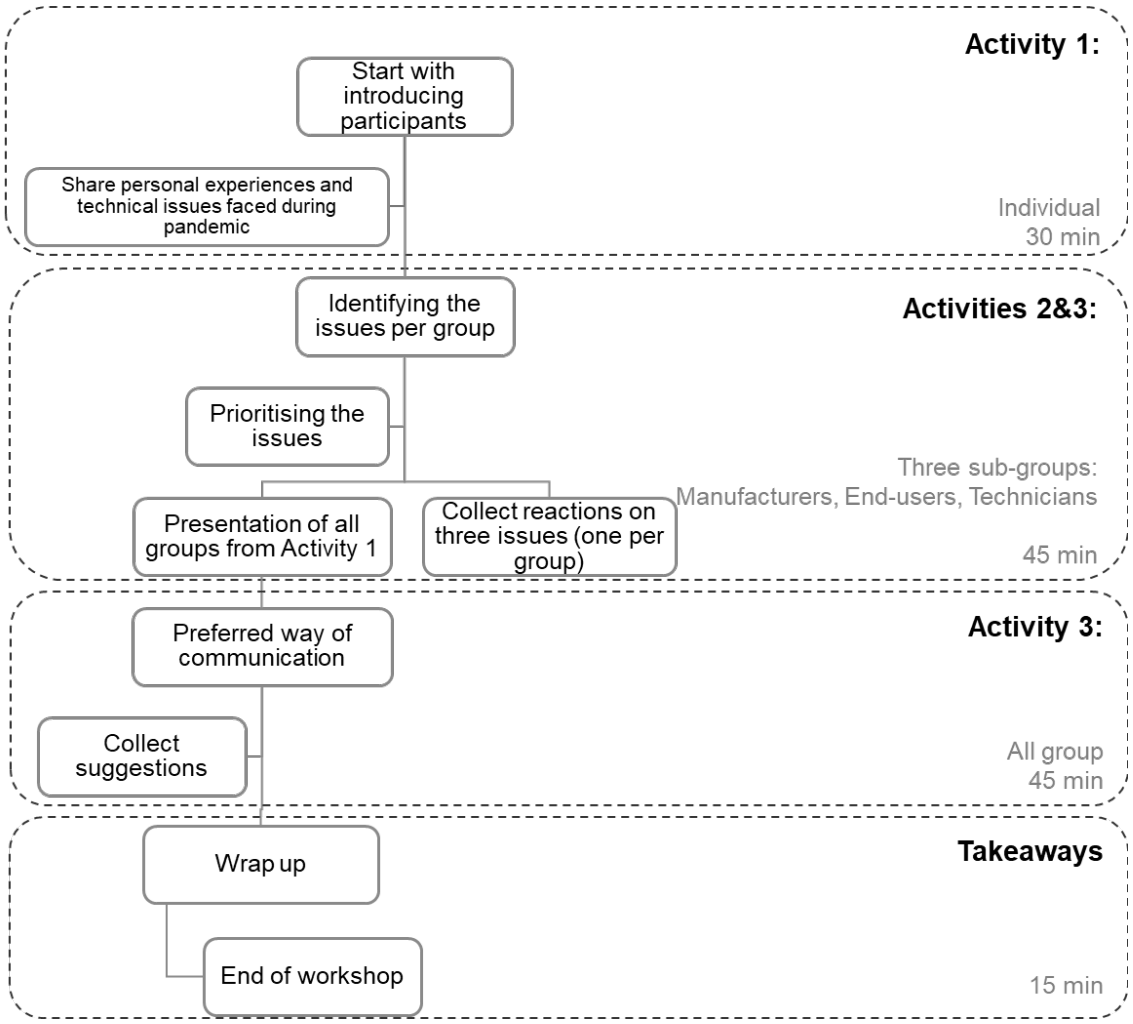

Figure 1. Process of workshops 1 & 2

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The activities for workshops 1 and 2 are described below:

Activity 1: Sharing experiences with technical challenges during the pandemic

During the first activity, participants were invited to reflect individually on and share their experiences with organizational and technical challenges related to ventilation and air cleaning issues during the COVID-19 pandemic. They were encouraged to express their stories using various formats, such as writing, sketching, or visual representations. Participants were prompted to categorise their experiences into four timeframes:

- **Past** - Challenges faced during the pandemic;
- **Present** - Relevant challenges they are currently dealing with;
- **Future** - Anticipated challenges in the near future;
- **Personal role** - How they perceive their own involvement or position within these challenges.

Activity 1 aimed to identify diverse perspectives and set the stage for deeper group discussions. An example of the format used during this activity is illustrated in Figure 2.

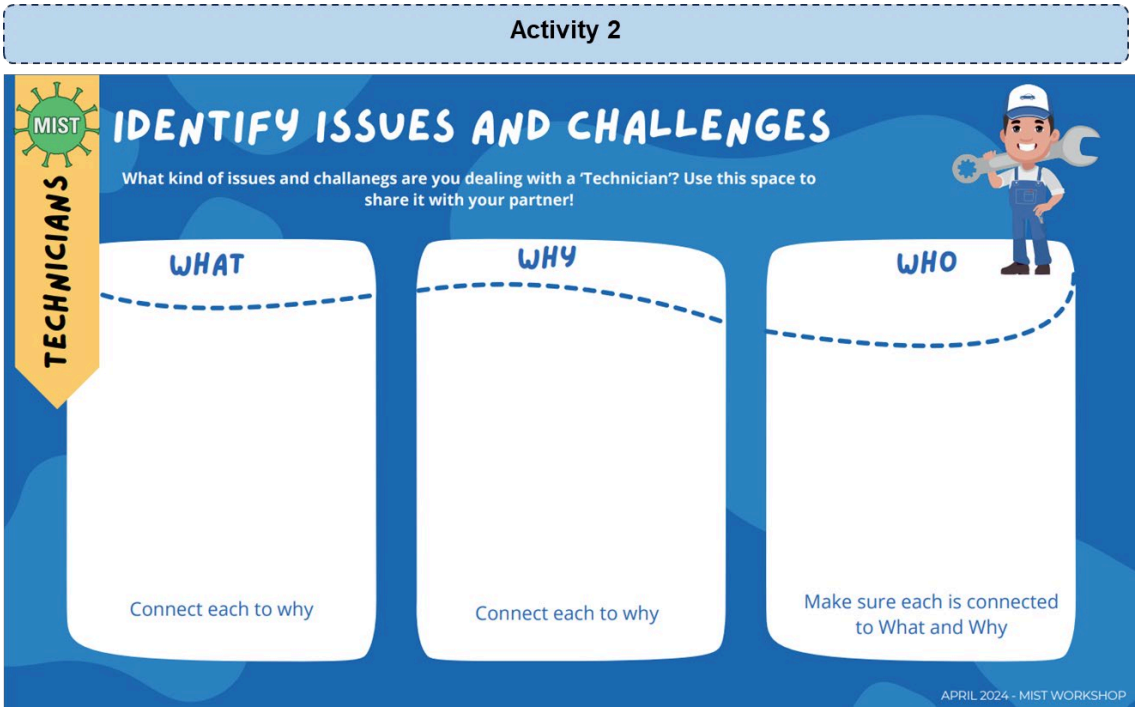

Figure 2. Activity 2 for workshops 1 & 2

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Activity 2: Group discussion on the challenges

During the second activity, participants engaged in three small-group discussions (1. Manufacturers, 2. Technicians, and 3. End users) to explore the challenges they are facing in more depth. Each group was asked to consider three key questions:

- **What** types of challenges are they currently dealing with?
- **Why** are these challenges occurring? What are the underlying causes or contributing factors?
- **Who** are the key actors or drivers influencing these challenges?

Following the discussion, each group was tasked with prioritising the identified challenges based on perceived urgency, impact, or relevance to their practice.

This structured dialogue aimed to facilitate collective sense-making and to help uncover patterns across different stakeholder perspectives. The format of the second activity is illustrated in Figure 3.

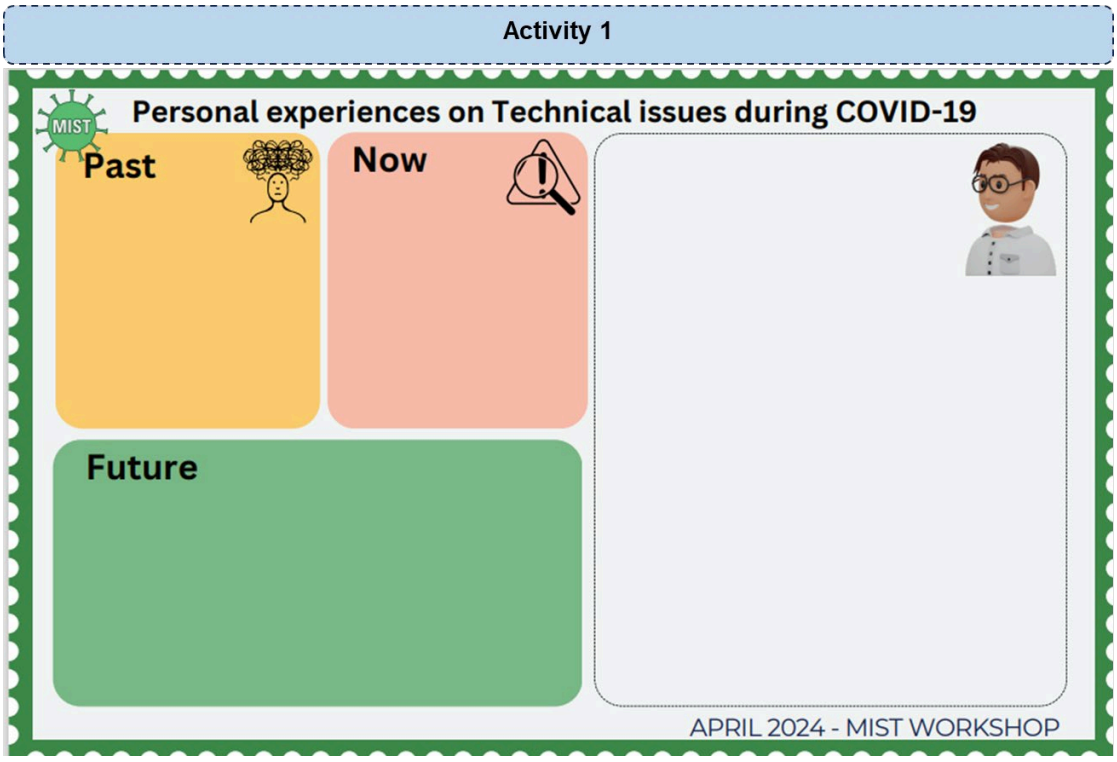

Figure 3. Activity 1 for workshops 1 & 2

Takeaways of activity 2: To conclude the second activity and create a transition to the next, each group (involved in activity 2) identified the top three challenges ("What") they were facing. These challenges were then compared across three groups to identify patterns and overlaps. Specifically:

- The three main challenges identified by each group were recorded.

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- Shared challenges between any two groups were recognised.
- One common challenge present across all three groups was highlighted.

This comparison helped to establish a shared understanding of the most pressing issues and provided a foundation for the last workshop activity. The outcome of this analysis is illustrated in Figure 4.

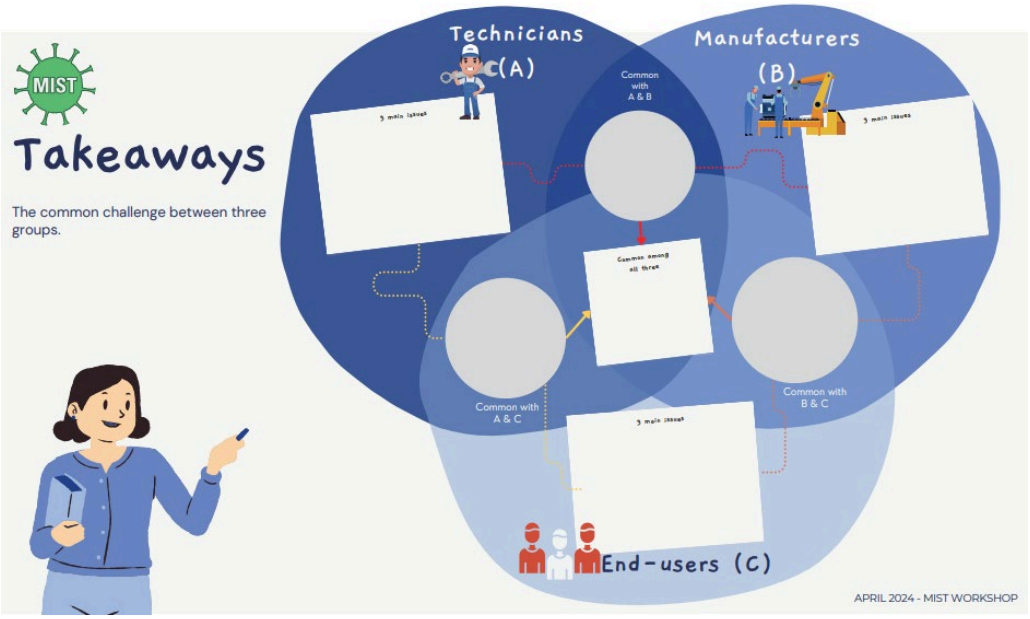

Figure 4. The format of activity 2 in workshops 1 & 2

Activity 3: Identifying actions for target groups

During the third activity, participants discussed the necessary actions required to address the prioritised challenges identified in the previous sessions. For each challenge, participants explored potential interventions and strategies tailored to specific target groups.

This activity aimed to translate identified issues into actionable steps by considering the roles and responsibilities of different stakeholders involved in ventilation and indoor climate practices.

The structure and outcomes of the third workshop activity are illustrated in Figure 5.

Activity 4: Prioritising formats for future guideline dissemination

During the fourth and final activity, participants were invited to share their preferences on how they would like to receive MIST project information and updates about future guidelines. A range of potential dissemination formats was presented, and participants used coloured stickers to indicate their top three choices. In addition to selecting from the given options, participants were encouraged to suggest alternative or complementary formats they believed would be effective or more accessible

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for their context. This activity provided insights into communication strategies that align with stakeholder needs and preferences. The format of this activity is illustrated in Figure 6.

Figure 5. Activity 3 form used during workshops 1 & 2

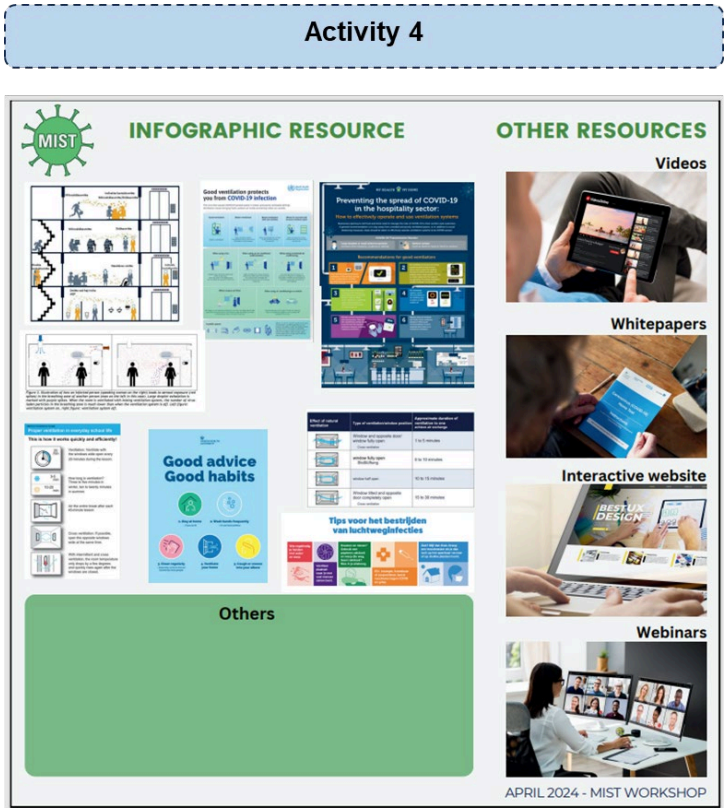

Figure 6. The format of activity 4 for workshops 1 - 3

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3.2.2 Workshop 3 procedure

There was a difference between the activities in workshop 3 and those in the two previous workshops due to the limited time available. The workshop process is illustrated in Figure 7.

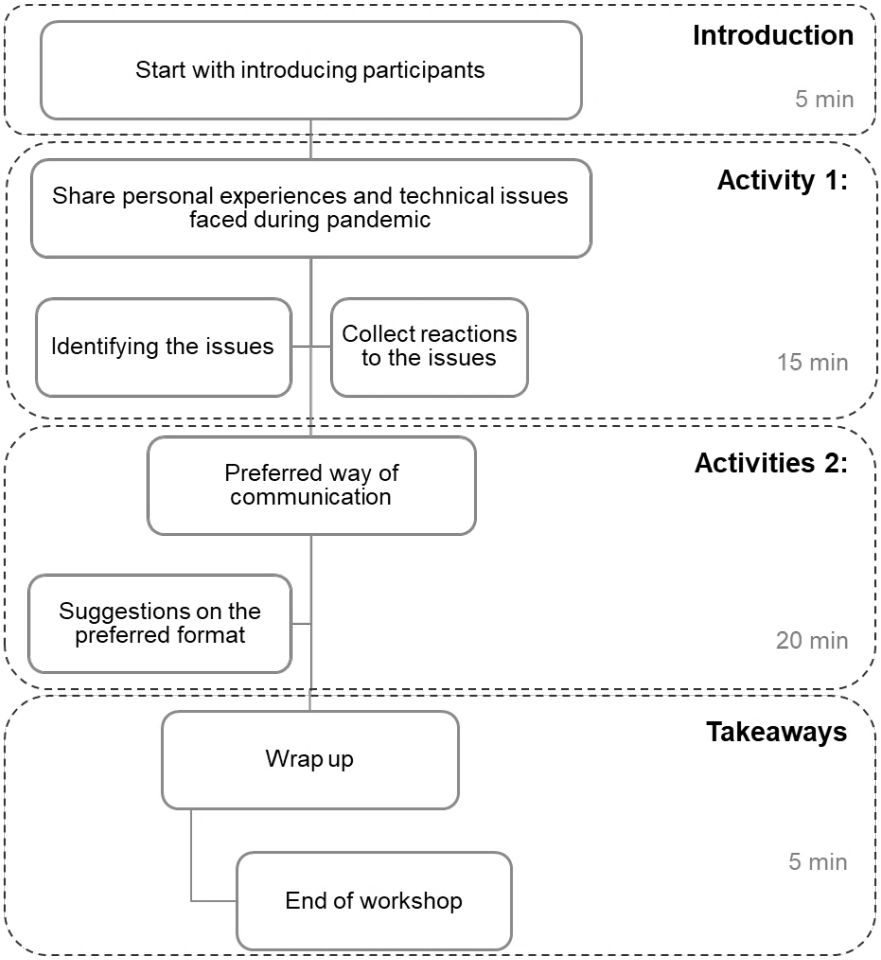

Figure 7. Process of workshop 3

Workshop 3 comprised only two activity rounds:

- **First round:** Participants were invited to express agreement or disagreement with a series of statements presented on cards. They then shared personal experiences and opinions to identify current challenges and practical issues, while also responding to input from other participants. During the first activity, participants were asked to reflect on their experiences with technical challenges during and after the pandemic. They were provided with 22 cards,

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each displaying a statement from earlier workshop participants. The cards were written in both Dutch and English. Each participant was invited to select up to two cards and share the extent to which they agreed or disagreed with each statement (Figure 8). They were also encouraged to elaborate on their own experiences, current challenges, anticipated future issues, and their role in addressing these challenges.

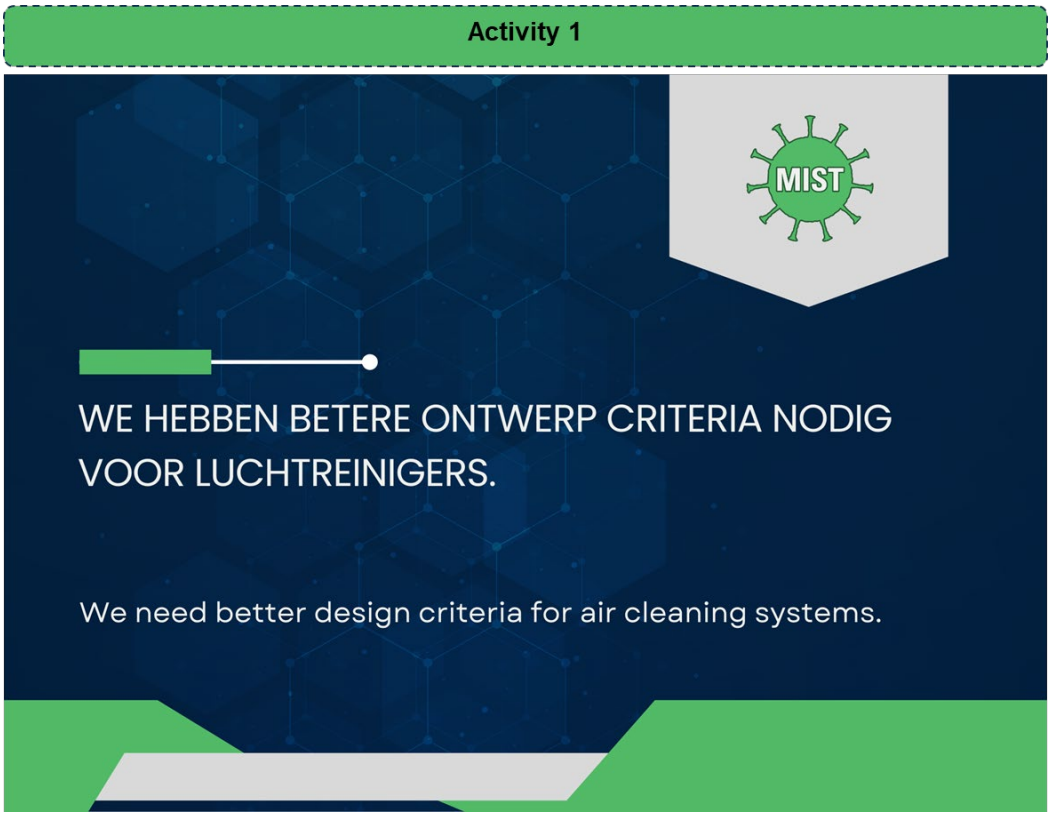

Figure 8. Example of a 'statement chart' as used during workshop 3

The 22 statements used in this activity are listed below:

1. We hebben betere ontwerpcriteria nodig voor luchtreinigers.

   We need better design criteria for air cleaning systems.

2. We zouden meer gebruiken moeten maken van CO2 stoplichten (indicatoren) om te bepalen of ruimtes veilig zijn of niet.

   We should use CO_2 indicators more to determine whether spaces are safe or not.

3. Er is behoefte aan verbetering van ventilatiesystemen in scholen.

   There is a need to improve the school's ventilation systems.

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4. Er is behoefte aan verbetering van de ventilatiesystemen in gezondheidszorggebouwen.

   There is a need to improve ventilation systems in healthcare buildings.

5. Er is behoefte aan verbetering van de ventilatiesystemen in horecagebouwen (bars, restaurants, nachtclubs).

   There is a need to improve ventilation systems in Horeca (catering) buildings (bars, restaurants, nightclubs).

6. Ik geloof niet dat de lucht infectie route uitmaakt.

   I do not believe that the airborne infection route really matters.

7. Beleidsmakers zijn vooral geïnteresseerd in energieprestatie van gebouwen in plaats van gezondheidsprestatie.

   Policymakers are mainly interested in the energy performance of buildings, rather than the health performance.

8. Bij het ontwerpen van ventilatiesystemen nemen ingenieurs en architecten de overdracht van infectieziekten via de lucht niet mee.

   When engineers and architects design ventilation systems, they unfortunately do not take infectious disease airborne transmission into account.

9. Ik heb geen idee hoe of hoeveel ik een ruimte moet ventileren om het ‘gezond genoeg’ te maken.

   I have no idea how or how much to ventilate to make a room 'healthy enough'.

10. Het is een probleem dat overheidsbeleid zich het meest focust op buitenlucht en niet op binnenlucht.

    It is a problem that most policies still focus on outdoor air and not indoor air.

11. De volgende pandemie is pas ver in de toekomst dus het is niet nodig om verder onderzoek te doen naar tegenmaatregelen zoals ventilatie en filteren van de lucht.

    The next pandemic is far in the future, so there is no need to further explore countermeasures like ventilation and air cleaning.

12. Ik geloof dat we niets hebben geleerd van de COVID-19 pandemie.

    I believe that we have learned nothing from the COVID-19 pandemic.

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13. Ik heb een duidelijk beeld van wat ik moet doen en wat ik moet ontwijken tijdens een pandemie (om jezelf veilig te houden).

    I have a clear idea about what to do (to keep oneself safe) during a pandemic and what to avoid.

14. We moeten de ventilatie eisen veranderen in het Bouwbesluit (BBL).

    We should change the ventilation requirements in the Dutch building code (BOUWBESLUIT/ BBL).

15. De overheid moet financiële ondersteuning beiden zodat scholen en verpleeghuizen mobiele luchtreinigers kunnen aanschaffen.

    The government should provide financial support so schools and nursing homes can purchase mobile air cleaners.

16. “Covid is voorbij”, dus we hoeven niets meer te doen om ons binnenklimaat veilig te houden.

    “COVID is gone”, so we no longer have to do anything to keep our indoor environments safe.

17. Het verbeteren van ventilatie impliceert een hoger energiegebruik, we moeten deze verbetering dus niet overdrijven.

    Improving ventilation implies higher energy consumption, so we should not ‘overdo’ it.

18. Eindgebruikers hebben geen basiskennis over ventilatiesystemen en luchtreinigers.

    End users have no basic knowledge of ventilation and air cleaning systems.

19. Er is zijn niet genoeg evidence based tools om strategieën voor risicobeperking van overdracht via de lucht te onderzoeken.

    There is a lack of scientific evidence-based tools to explore airborne risk mitigation strategies.

20. Een praktisch hulpmiddel is nodig voor risico-identificatie en -beperking bij het ontwerpen van gebouwen.

    A practical tool for risk identification and mitigation in building design is needed.

21. Ik geloof dat luchtreinigers niet werken.

    I do not believe that air cleaning systems work.

22. We leggen te veel nadruk op mechanische ventilatie maar te openen ramen zijn ook belangrijk.

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We put too much emphasis on mechanical ventilation; operable windows are also very important.

- **Second round:** Participants prioritised preferred dissemination formats and provided suggestions for effective communication of outcomes. During the second activity, participants were invited to share their preferences for how they would like to receive information about future guidelines. Using coloured stickers, they could indicate their top three preferred formats from a predefined list. Additionally, participants were encouraged to suggest alternative or complementary dissemination formats they considered effective or relevant (Figure 9).

The session concluded with a summary of key takeaways and an outline of the proposed next steps.

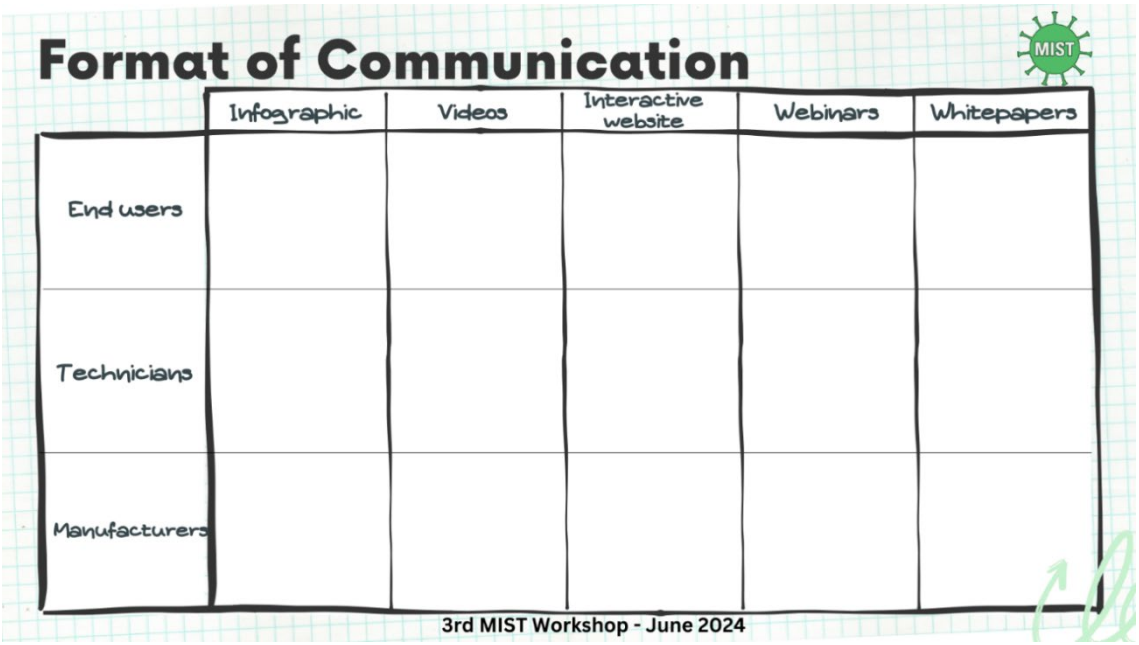

Figure 9. Core graph used during Workshop 3

3.2.3 Workshop 4 procedure

The programme consisted of three structured rounds of activities, which built upon and combined the formats used in the previous workshops:

- **Round 1:** Participants reviewed and responded to selected cards by expressing agreement or disagreement with the core statements that were derived from workshops 1 and 2 (see section 3.2.2 for a presentation of those statements). They also shared personal experiences and discussed technical issues encountered in practice.

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- **Round 2:** Through group discussions, participants identified key challenges and issues, prioritised them collaboratively, presented their outcomes to the larger group, and collected feedback from other participants.
- **Round 3:** Participants discussed and prioritised preferred dissemination formats for the presentation of future MIST project outcomes.

The workshop concluded with a summary of key takeaways and an outline of next steps. The full process of the workshop is illustrated in Figure 10.

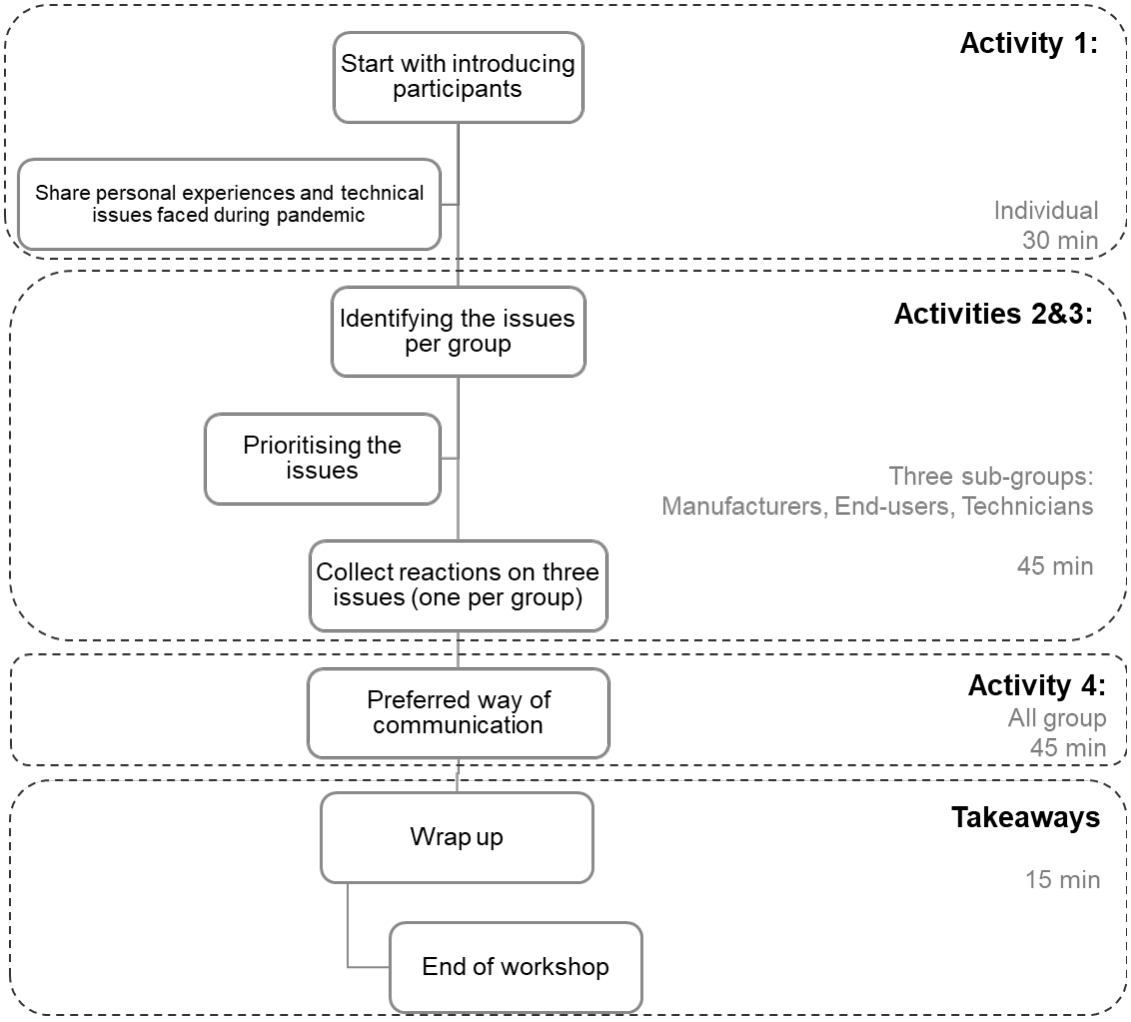

Figure 10. The process of workshop 4

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The structure of workshop 4, combined with the structure of all previous sessions, results in four distinct activities:

- **Activity 1:** This activity mirrored the approach used in Workshop 3. Participants were asked to select one or two cards (see Fig. 8 for an example), each containing a statement derived from earlier workshops. They then expressed their agreement or disagreement with the selected statements. Other participants reacted to these perspectives, allowing for a group discussion through which key concerns and shared challenges were identified.
- **Activity 2:** Based on the format used in Workshops 1 and 2, participants worked in subgroups to discuss the following questions:
    - What types of challenges are they currently facing?
    - Why do these challenges exist, and
    - Who or what drives these challenges?

Each group then prioritised the challenges identified (see Figure 3 as an example).

- **Takeaways from Activity 2:** To conclude the second activity and facilitate a transition to the next round, each group highlighted their top three challenges (What). In addition, common challenges were identified across two subgroups, and one overarching issue shared by all three subgroups was recognised (see Figure 4 as an example).
- **Activity 3:** Participants discussed appropriate actions required to address the previously identified challenges, tailored to the specific needs of each stakeholder group (Figure 5).
- **Activity 4:** Following the approach from workshop 3, participants indicated their preferences for how future MIST project results and future guidelines should be communicated. Using coloured stickers, they marked their top three preferred dissemination formats and were encouraged to propose additional formats or methods (see Figure 9).

3.2.4 Focus group facilitators

Three facilitators supported the workshop by guiding participants throughout the sessions. The focus group facilitators played a key role by allowing us to observe the discussions passively and take notes without interfering with the dialogue. This approach enabled us to capture insights into participant interactions and the dynamics of their conversations around specific topics, highlighting the socially constructed nature of the dialogue [5]. Moderator guides were also prepared and provided for each activity to ensure consistency and focus during the sessions.

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3.3 Method of analysis

Data gathered from the workshops was analysed using thematic analysis, a qualitative method that identifies, analyses, and reports patterns (themes) within data. Notes and transcripts were reviewed to extract recurring issues and insights, which were then grouped into main themes.

The analysis process consisted of:

- Coding and categorisation of participant responses;
- Identification of core challenges and recurring patterns;
- Validation of findings through in-session feedback and participant reflection.

This iterative approach accurately reflected stakeholders' perspectives and real-world experiences. The analysis also helped develop practical recommendations and communication strategies for future dissemination.

4. Output per workshop

The details of each workshop, including participants, outputs, and key messages, are described in the following sections.

4.1 Output of workshop 1

The first workshop was held on April 8th, 2024, at the Faculty of Architecture and the Built Environment, TU Delft, for three hours.

- **Target participation.** At the first MIST workshop, eight people participated. Participation was nearly equally divided between manufacturers and technicians, each representing 37.5% of attendees (see Figures 11 and 12).

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Figure 11. Participants' engagement in workshop 1

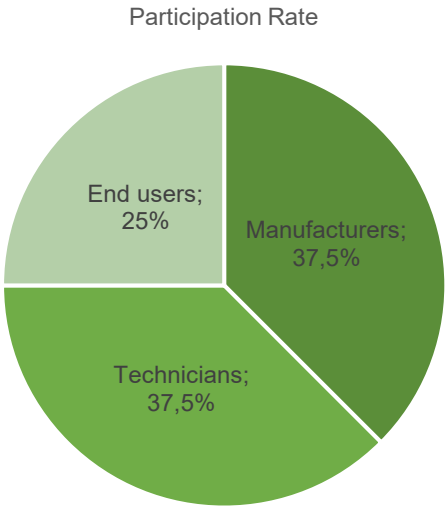

Figure 12. Rate of participation of different types of groups in workshop *1*

- **Key messages from participants.** During Activity 1, participants shared their past experiences, current situations, and expectations for the future regarding mitigation strategies. Table 4 presents the extracted key messages, highlighting the need for integrated and practical guidelines, regulations, and evidence-based tools. These insights underscore the necessity of cross-sector collaboration among stakeholders and governmental bodies.

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Table 4. Participant reflections from activity 1 in workshop 1

Participant	Key Message	Past	Now	Future
1	- Insufficient data for different types of spaces, policies, and collaborations	- Insufficient data when it comes to the importance of ventilation in education, meeting rooms, and offices	- Policy for a minimum of m3/h that guarantees 'virus-safety' is still not determined	- 100% of the data is available in relation to space through a Dashboard - Further cooperation with advisors is needed - Actions in relation to the use of different spaces
2	- Lack of knowledge, scientific evidence-based tools, and guidelines	- Lack of knowledge of mitigation strategies and risk reduction	-Lack of scientific, evidence-based tools -Considering triangulation of comfort (Celsius + % RH), virus-safety (CO_2-concentration), and health (ppm)	- Approved official guidelines for virus airborne transport routes
3	- Too many different guidelines, a lack of energy-efficient and proven technologies, and limited knowledge of end users	- Contradictions in advice (Different countries → Different guides)	- More air and/ or filtration can use more energy and more space, which will cost more. - No basic knowledge of HVAC among users. -No need to handle it. → 'Covid is over'.	- Many solutions and products, more than now -Basic knowledge available among end users - Energy-efficient filtration systems availability - Proven technology - What risk is acceptable?

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Table 4. Participant reflections from activity 1 in workshop *1*

Participant	Key Message	Past	Now	Future
4	- Information on protection factors, preparation guides, and the lack of standards	- Role of facemasks: personal protection and/or protecting others	- How to derive a standard? - How to determine a protection factor for face masks	- How should we prepare for the next pandemic? - How to better balance decisions with a large impact (e.g., lockdown) on society and individually
5	- Practical guidelines, regulations, and protocols for now and the future - Communication gap	- Confusion and lack of knowledge, and lack of government governance - Poor communications and minimal guidelines	- Development of guidelines (future use) and strategies	- Practical tool(s) and guidelines - Protocols (what to do or not to do) and protocols of what to do if a new pandemic occurs - Better communications strategies - Regulations (obligatory by law) - Development of flex strategies
6	- Regulation is needed for ventilation and air cleaning, also paying attention to recirculation	- Disorder in the market: Many new suppliers with different techniques, with little knowledge of virus transmission aspects aspects	- Covid is not in attention - End-users are waiting for the government to make decisions	- Regulation is needed for ventilation and air cleaning to ensure a level of quality in the air in the building.

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Table 4. Participant reflections from activity 1 in workshop 1

Participant	Key Message	Past	Now	Future
7	- Academic-based solutions, protocols, and regulations on preventive measures are important	-Lack of knowledge/awareness about the relation of COVID to air among the public, decision makers, academia, and users - Lack of validation of the effectiveness of different air cleaning techniques	-The market is waiting for regulations and a budget - Believe in 'COVID is gone'- 'I don't need to do anything.' - Lack of awareness -Validation is still required and essential	- Mitigation Protocols - Regulation of solutions/technologies as preventive measures - New hygiene rules - New 'Building Decree' - Policy needs to consider comfort, health, safety, and cost
8	- Insufficient Building Decree	Building design rules weight is triangulated for comfort for offices (°C/RH%), virus-safety for schools (CO2/O2), and health for hospitals (CFU/PPM)	The Building Decree is mainly dedicated to keeping, e.g., a teaching room clean and fresh. Is this sufficient to mitigate virus infection?	Building design rules will consider sustainability aspects, adding circularity, cost, and energy to the triangulation of comfort, health, and virus-safety

- **Challenges and required actions**

The main challenges practitioners are facing, and the recommended actions, are summarised in Table 5. The common challenge across all groups is a lack of awareness and effective guidelines/approach; the required action is effective communication on airborne infection control.

This report is part of deliverable WP5.2 and the MIST project, project number P20-35, of the research programme Perspectief, which is financed by the Dutch Research Council (NWO).

Table 5. The three main issues that different types of stakeholders are dealing with, identified in workshop 1

Stakeholder type	Three main issues (prioritised) of each stakeholder	Required actions
Manufacturers	1. Common sense approach vs 100% proof approach of solutions/products 2. Trade-offs, e.g., health effects of intervention vs costs + energy use 3. m3/h approach vs “effectivity” approach	▪ Define one message in terms of risk mitigation vs virus mitigation ▪ Invite a good, strategic, risk communication specialist ▪ Consensus within MIST-compliant terms and core message
Technicians	1. Lack of awareness (sense of urgency) 2. Lack of clear guidelines and consequences 3. Technology and applications	▪ Communication (Virus inclusive) beyond SARS-CoV-2 ▪ Invite politicians, GGD, employees, popular scientists, ▪ Develop KISS approach (two-track approach): give back to society
End users	2. Resistance in society 3. Means for creating a safe environment 4. Private vs. public domain	▪ Reduce fear vs empowering citizens ▪ Create trust between the general public and the government

- **Preferred dissemination formats**

During the final activity, stakeholders discussed how they would prefer the outcomes and recommendations to be communicated. Table 6 outlines these preferences, tailored to each stakeholder group. There is a consistent preference for accessible, visual, and interactive materials, such as videos, infographics, and practical guidebooks.

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Table 6. The preferred format of dissemination by stakeholders in workshop 1

Stakeholder type	Preferred format	Comments
Manufacturers	Videos, Interactive website, Infographic (differs per target group)	Simple (Readable at a glance)
Technicians	Videos, Webinars, Practical guidelines book (including Tables, visualisation, and illustrations)	Dedicated to the target group (general public, technicians, asset managers, and scientists)
End users	Videos (influencers), Whitepapers (engineers, elderly group), Interactive websites (young people, video games), Infographics (different according to the target group: public domain, medical professionals, etc.), Webinars (technicians, and engineers)	Social media, Teaching packages (Primary and high school)

4.2 Output of workshop 2

The second workshop took place on 22 May 2024 and lasted for three hours. It was held at the Faculty of Architecture and the Built Environment, TU Delft (see Figure 13).

Figure 13. Participants' engagement in the workshop 2

This report is part of deliverable WP5.2 and the MIST project, project number P20-35, of the research programme Perspectief, which is financed by the Dutch Research Council (NWO).

- **Target participation.** At the second MIST workshop, four people participated. Participation in the second workshop was evenly distributed between manufacturers and technicians, each representing approximately 40% of the total participants (see Figure 14).

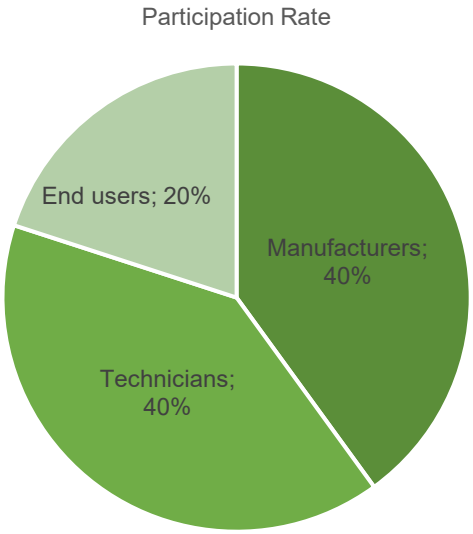

Figure 14. The rate of participation of different types of groups in workshop 2

- **Key messages from participants.** The key messages are derived from Activity 1, by sharing the experiences of the participants in the past and now, and their expectations for the future (Table 7). The key messages show that there is a need for extra guidelines, standards, and mitigation strategies for better indoor air quality and ventilation, and combining health with other aspects of sustainability.

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Table 7. Participant reflections from activity 1 in workshop 2

Participant	Key Message	Past	Now	Future
1	Guidelines for ventilation	- Choice of short-term measures - Priority of building types and activities - Need for evidence-based info on the role of ventilation - Schools with proper ventilation already have a relatively low risk in normal situations (without COVID-19)	- Ventilation is improved and needs to be continued until all buildings are equipped with some mechanical ventilation due to COVID-19 - CO_2 monitoring is more recognized as important	- Extra guidelines to 'remember' the pandemic and the need for extra ventilation
2	Mitigation strategies, including energy efficiency, comfort, and health	- Old Mitigation measures - Statement (initially) of the government that COVID-19 was not airborne was counterproductive	- Sharing awareness and investments in ventilation systems due to their relation to health and ventilation - Outgoing Ongoing debate about rotary heat exchangers vs plate heat exchangers/twin coil solutions - Institutional organizations work on 'pandemic preparedness'	- How can we identify 'air health' in a way that is clear to non-technicians - Air cleaning approach (value for air handling) - Define mitigation strategies that have congruent objectives for energy, comfort, health, cost, and sustainability: it would be new

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Table 7. Participant reflections from activity 1 in workshop 2

Participant	Key Message	Past	Now	Future
3	Guidelines and standards on ventilation systems and air cleaners	- Filtering or not (air going outside directly) - Which face masks are effective and when - How to move a patient through hospitals in a safe way	- Use or non-use of the rotary heat exchangers - Which filtering to use - When to allow recirculation - Energy saving versus 'virus-safety'	- Do's and don'ts during pandemic
4	Improving ventilation quality and related guidelines	- Many questions on transmission and mitigation	- Development of (more evidence-based) guidelines	- Ventilation quality is also important

- **Challenges and required actions**

The key challenges faced by practitioners, along with the corresponding recommended actions, are summarised in Table 8. A shared challenge across all stakeholder groups is the lack of scientific knowledge, technical specifications, and clear standards. The primary action recommended to address this challenge is the implementation of effective communication strategies tailored to different types of stakeholders.

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Table 8. The three main issues that different types of stakeholders are dealing with, identified in workshop 2

Stakeholder type	Three main issues (prioritised)	Required actions
Manufacturers	1. Lack of specifications (issue of professionalism with clients) 2. Client-focused design 3. Lack of business case	1. Engage clients early to capture users' perspectives, demands, and requirements 2. Apply the V-model to verify that the design meets client expectations 3. Map business objectives onto the V-model, linking high-level goals to measurable outcomes
Technicians	1. Lack of scientific knowledge: (Too much Copy-paste, more practical information than scientific) 2. Lack of engineering standards (Evidence-based)	1. Collaboration and knowledge sharing between researchers, engineers, and practitioners 2. Mixed-group communication to share evidence-based methods and co-develop engineering standards
End users	1. Clear product description (effectiveness of solutions) 2. Lack of knowledge amongst manufacturers, consultants, or end-users 3. Lack of information on side effects	1. Discuss with end-users what they want and need 2. Engage all stakeholders early to understand knowledge gaps and provide targeted guidance 3. Consult end-users to identify potential concerns or side effects

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- **Preferred dissemination formats**

The preferred formats for disseminating the outcomes, as discussed during the final activity of the workshop, are summarised in Table 9.

Table 9. The preferred format of dissemination in workshop 2

Stakeholder type	Preferred format	Comments
Manufacturers	Whitepapers, webinars, and interactive websites	- Webinars take time, but are good for interaction
Technicians	Whitepaper (for those who need to know more), webinars, interactive websites, infographics, videos (short, graphical)	- An interactive website is a good library for all types of output for different target groups - Programma van Eisen (PvE's) (schedule of requirements: detailed document) - Evaluate projects: e.g., using certification methods like Binnenklimaat Label
End users	Infographics, white papers (for results of research), interactive websites (with checklists), and podcasts	- Personal: all types of information are needed to meet personal preferences. Depending on the type of info. And the type of target group - Infographics are best for end users: quick info, and to communicate with experts

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4.3 Output of workshop 3

The third workshop was held on 5 June 2024, with a duration of 45 minutes, during the CLAIRE Congress at Binnenklimaat Nederland in Zoetermeer (see Figure 15).

Figure 15. Participants' engagement in workshop 3

- **Target participation.** At the third MIST workshop, eight people participated in total. The majority of participants in the third workshop were technicians, representing 75% of the attendees (Figure 16).
- **Key messages from Workshop 3 participants.** The key messages were derived from Activity 1, in which participants shared their thoughts by selecting one or two cards and reflecting on the statements. These messages highlight the need to draw policymakers' attention to indoor air quality, raise awareness among end users, improve school ventilation systems, and develop scientifically validated tools. The identified challenges, practitioner demands, and recommended actions are summarised in Table 10.

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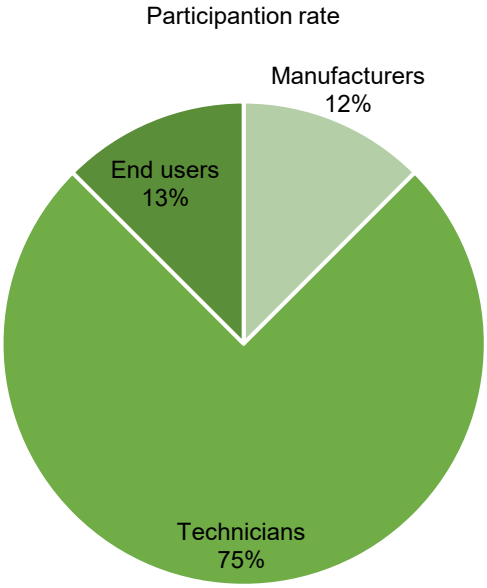

Figure 16. Participation rate in workshop 3

Table 10. The identified challenges and required actions, derived from the first activity in the third workshop

Participant	Card No.		Key message	Identified challenge required action
1	10	Agree	Policy: Less attention is given to the existing policy on indoor air	Bringing the attention of policymakers towards indoor air quality
	18	Agree	Knowledge: Unawareness of teachers of ventilation and air cleaning systems	Increasing the awareness of educational institutions
2	11	Disagree	Knowledge: The next pandemic is not far; however, there is an unawareness of it	Increasing the awareness of the next pandemic.
	19	Disagree	Scientific evidence-based tools: There is a tool to assess the risk, but no tool for transmission risk	Developing scientific evidence-based tools on the transmission risk of airborne
3	6	Disagree	Knowledge: The airborne infection route	The airborne infection route needs to be identified
4	15	Agree	Government role: The government's financial support for schools in improving air quality	The government should provide financial support for schools and nursing homes so they can purchase mobile air cleaners
	7	Agree	Policy: The main focus is still on the energy performance of buildings, rather than the health performance	Bringing attention to policymakers towards the health performance of buildings, in addition to the energy performance

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Table 11. The identified challenges and required actions, derived from the first activity in the third workshop

Participant	Card No.		Key message	Identified challenge required action
5	13	Agree	Knowledge: Awareness of keeping oneself safe during a pandemic and what to avoid	Initiate better communication campaigns about 'virus safety'
6	18	Agree	Knowledge: Lack of knowledge of end users on ventilation and air cleaning systems	Increasing the awareness of end-users towards ventilation and air cleaning systems
	15	Agree	Government role: The government's financial support for schools in improving air quality	Bringing attention to policymakers towards the health performance of buildings
7	14	Agree	Building code: The Dutch building code for new schools is quite good, but the requirements for older schools and renovations are insufficient	Improving the air quality of educational buildings and developing related codes for older buildings and post-occupancy
	3	Agree	Need to improve the school's ventilation systems: The air quality in schools is poor	(General) improvement of the school's ventilation systems
8	15	Agree	Government role: There is a problem with the air quality in schools	Bringing attention to policymakers towards the health performance of buildings
	7	Agree	Policy: Policymakers are more interested in the energy performance of buildings, rather than in the health performance	Bringing attention to policymakers towards the health performance of buildings, in addition to the energy performance

- **Preferred dissemination formats**

The preferred formats for disseminating outcomes, as discussed during the final activity of Workshop 3, are presented in Table 11. These reflect the participants' suggestions on how information should be shared effectively across different stakeholder groups at the end of the MIST project.

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Table 12. The preferred format of dissemination in workshop 3

Stakeholder type	Preferred format	Comments
Manufacturers	Interactive website, webinars, white papers	Webinars to answer core questions
Technicians	Videos, live contact, whitepapers, interactive website, infographics, webinars	Suggestion to not focus on a single format for technicians
End users	Videos, live contact, infographic, interactive website, webinar	Depending on people's preferences: - Infographics as daily reminders, and an infographic for teachers - For policymakers: infographics and whitepapers - Interactive website: can search/in-depth later

4.4 Output of workshop 4

The fourth and final workshop was held on 8 July 2024, with a duration of three hours, at the Department of Architectural Engineering and Technology (AE+T), Faculty of Architecture and the Built Environment, TU Delft (see Figure 17).

Figure 17. Participants' engagement during workshop 3

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- **Target participation.** At the fourth MIST workshop, a total of six people participated. The majority of participants in the fourth workshop were manufacturers, accounting for 50% of the total group (Figure 18).

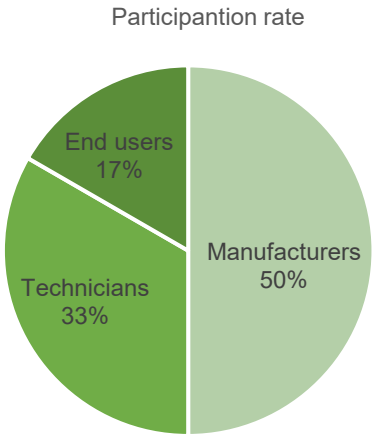

Figure 18. The rate of participation in workshop 4

- **Key messages from participants.** The key messages were derived from Activity 1, during which participants selected one or two cards and shared their perspectives on the card statements. Through this discussion, several recurring themes emerged, highlighting the following needs:
    - Greater attention to health-related concerns among policymakers, architects, designers, and engineers.
    - Government financial support to implement effective ventilation and mitigation measures.
    - Increased awareness among installers and end users regarding air quality and infection prevention.
    - Improved ventilation systems in healthcare environments.
    - Enhanced design criteria for air cleaning systems.
    - Development of scientific, evidence-based tools to support decision-making and implementation.

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The identified challenges, professional demands, and recommended actions are summarised in Table 12.

Table 13. The identified challenges and required actions, derived from the first activity of workshop 4

Participant	Card No.		Identified challenge	Required action
1	4	Agree	Need to improve ventilation systems in healthcare buildings: There is a need to improve ventilation systems and risk calculation in healthcare centres (this is not properly included in the building decree)	Introduction of good air cleaners and mechanical ventilation systems
	15	Agree	Government role: More funding is needed to buy ventilation systems	Establish subsidies (the government's financial support for schools and nursing homes), starting with subsidies for air cleaners
2	15	Agree	Government role: The government's financial support is needed	The government's financial support for schools and nursing homes can be used to purchase, e.g., mobile air cleaners
	7	Agree	Policy: Policymakers and building owners are often interested in energy and cost, and not in occupational health, etc.	Bringing attention to policymakers towards the health performance of buildings, in addition to the energy performance
3	19	Agree	Lack of scientific evidence on tools to reduce infection risk via the airborne route	Develop scientific evidence-based tools to explore airborne risk mitigation strategies
	1	Agree	Design improvement: There is a need for better performance criteria for air cleaners	Better design criteria for air cleaning systems and developing international standards for assessment of safe space, e.g., criteria for clean air delivery rate, filter type and efficiency, side effects, and reactive technology (air cleaning techniques)
4	18	Agree	Knowledge: Even the installers have no knowledge of ventilation and air-cleaning systems	Provide installers with adequate measurement equipment
	11	Disagree	Knowledge: People think the next pandemic is far away due to the lack of knowledge	Increase people's awareness of the next pandemic

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Table 12. The identified challenges and required actions, derived from the first activity of workshop 4

Participant	Card No.		Identified challenge	Required action
5	2	Disagree	Uncertainty in using CO_2 indicators	Use the appropriate type of indicator to determine whether spaces are safe or not
	18	Agree	Knowledge: Sporters have little knowledge about the importance of adequate ventilation and how to ventilate	Help, e.g., sports instructors with simple information
6	16	Disagree	Knowledge: There will be other issues with infectious diseases and allergies, such as mould and fungi exposure	Communicate better about the importance of prevention and purification
	8	Agree	Knowledge: Architects and engineers do not consider infectious diseases, and no growth of bacteria and pathogens in their design (recirculation is poor, extraction is good)	Develop design guidelines that assist building professionals in cleaning the air

- **Challenges and required actions**

The primary challenges encountered by practitioners, as identified during workshop 4, along with the corresponding recommended actions, are summarised in Table 13. These insights were gathered through group discussions and collaborative analysis during the workshop activities, reflecting the perspectives of various stakeholder groups. A common set of challenges emerged across all stakeholder groups, including a lack of knowledge, an absence of clear standards and regulations, and insufficient communication. The shared priority action identified by participants is the development of comprehensive guidelines, standards, principles, and certification systems to support effective and consistent practices.

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Table 14. The three main issues that different types of stakeholders are dealing with, mentioned in the fourth workshop

Stakeholder type	Three main issues (prioritised) of each stakeholder	Required actions
Manufacturers	1. Long process of research 2. Lack of standards 3. Lack of knowledge	1. Shorten the path from research to developing evidence-based guidelines/standards 2. Develop test protocols for air cleaners 3. Develop evidence-based specifications like ASHRAE
Technicians	1. Lack of techniques/Measurement methods 2. Lack of regulations 3. Lack of a clear vision/purpose for different parameters	1. Develop guidelines/KPI's 2. Developing evidence-based standards (What, where, when) 3. Develop design principles
End users	1. Lack of motivation/communication 2. Need a certification 3. Need to pilot a project	1. Develop Awareness video/actions 2. Develop certification/sticker: e.g., MIST stamps 3. Develop a pilot project to test usability in practice

- **Preferred dissemination formats**

The preferred formats for disseminating the outcomes, as discussed during the final activity of workshop 4, are presented in Table 14.

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Table 15. The preferred format of dissemination in workshop 4

Stakeholder type	Preferred format	Comments
Manufacturers	Webinars, interactive websites, whitepapers, mass media	Whitepapers with detailed content
Technicians	Mass media, infographic, interactive website, webinars	Mass media for all target groups
End users	Videos (most practical way), interactive websites, whitepapers (standards and for educated end users), mass media, webinars, (simple) infographic, video (visualisation of the invisibles), symposium for target groups, and logical data	Well-researched whitepapers are the foundation of communication (other formats cascade from whitepapers). Videos can be seen quickly, are readable, and are not complicated.

Some quotes related to the challenges and required actions from all workshops combined are listed below:

Senior researcher / Applied technology company:

"There is a lack of scientific evidence and tools to objectively assess infection risks via airborne routes, leading to stubbornness among medical professionals. Additionally, there is a need for better performance criteria for air cleaners."

Senior vice president of international business development – Air quality technology company:

"*Policymakers and building owners are only interested in energy efficiency and cost reduction, and not in softer issues like occupational health. People should be prioritised."*

Senior researcher – Aerospace research organisation:

"In healthcare buildings, such as nursing homes (verpleeghuizen), there is often a lack of funding for purchasing ventilation systems."

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Medical and biodefense expert – Innovation and advisory organisation:

"There will surely be other issues with infectious disease, …, and prevention is important; the key is to remove the cause…however, architects unfortunately do not consider infectious disease."

Senior advisor and researcher – Applied research organisation:

"Current policies still focus too heavily on outdoor air quality, despite the fact that people spend 80–90% of their time indoors. Policy should be focused on prevention via good indoor air."

Innovation advisor – Innovation support organisation:

"*We need to help sports instructors by providing them with simple information*".

Founder & technical innovator – Technology development company:

"End users don't have any knowledge, nor do installers. This issue can be solved by providing them with adequate measurement equipment."

Senior medical researcher and specialist – University medical centre:

"*In the past, there was a significant focus on energy efficiency. During the pandemic, the priority shifted to health concerns. Now again, the focus is mainly on energy performance!"*

Technical director – Indoor climate solutions provider:

"It took too long to acknowledge the airborne route of transmission, and further discussion and exploration are still needed, as many people do not yet consider it a priority. Design criteria, such as maximum CO2 concentration, must be improved and more closely tied to actual health risks."

5. Overall outcomes of the four workshops

The collected data were analysed through thematic analysis, with key challenges identified and validated through participant confirmation during the workshops.

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5.1 Target participation

An effort was made to invite an equal number of participants from each stakeholder group. However, reaching end users proved challenging. As a result, out of the total 26 participants, the majority who attended the workshops were technicians and technical experts (Figure 19).

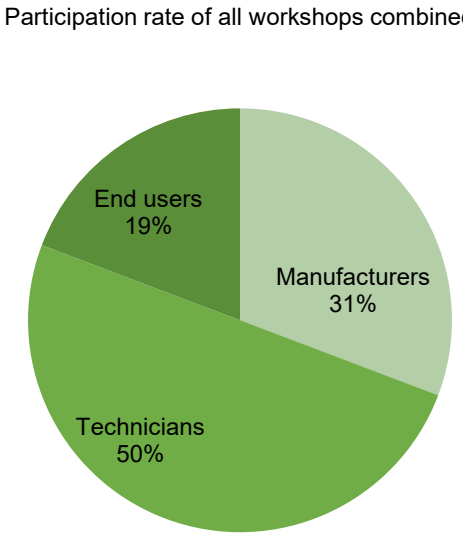

Figure 19. The total rate of participants across four workshops

5.2 Key messages from participants

Across the four workshops, participants consistently reflected on their experiences during the COVID-19 pandemic and the period immediately after. Their input highlights recurring challenges across knowledge, scientific evidence, technology, policy, and regulation. Rather than isolated issues, these challenges are interconnected and point to systemic weaknesses in how airborne infection risks are addressed in the built environment.

Main challenges experienced during the COVID-19 pandemic. Workshop participants described that, during the pandemic, a lack of clear, reliable, and accessible knowledge was a major challenge. End users, building operators, and even professionals often lacked an understanding of airborne transmission routes, ventilation principles, and the effectiveness of mitigation measures. Communication was perceived as fragmented and inconsistent, leading to confusion and reduced trust in the recommended measures. Participants also experienced a shortage of scientific, evidence-

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based tools and guidelines. Although many protocols, recommendations, and regulations were introduced rapidly, they were often academic in nature, difficult to translate into practice, or implement. The diversity of guidelines made it difficult for practitioners and decision-makers to determine which recommendations were reliable and evidence-based, and which should be prioritized.

Main challenges after the pandemic. Following the pandemic, participants observed that attention to indoor air quality and infection risk has declined. Policymakers and decision-makers are often perceived as primarily refocusing on energy performance and cost reduction, while health-related aspects of buildings receive lower priority. Participants noted that knowledge gaps persist, especially among end users, as well as among architects, engineers, installers, and facility managers. Awareness of airborne transmission and the role of ventilation and air cleaning is limited, which hinders the long-term adoption of preventive measures. From a technological perspective, participants highlighted the limited availability of proven, energy-efficient technologies for ventilation upgrades and air-cleaning solutions. Many available technologies lack transparent performance data, making it difficult to assess their effectiveness in real-world conditions.

At the policy and regulatory level, participants experienced a lack of clear standards and regulations for ventilation systems and air cleaners. Existing building codes and regulations were perceived as insufficient to address infection risks, especially regarding ventilation rates, air circulation, and the use of air-cleaning technologies. This regulatory gap was particularly evident during renovations of older buildings. The absence of comprehensive, integrated mitigation strategies remained a key concern. Participants emphasized the need for approaches that simultaneously address health, comfort, and energy efficiency, rather than treating these aspects separately. Additionally, participants highlighted the lack of tools to assess airborne transmission risk, as well as uncertainty about commonly used indicators such as CO_2 concentrations. This uncertainty reduced confidence in monitoring strategies and decision-making.

To address the challenges, participants argued that they can only be overcome through the development of clear, evidence-based, and practice-oriented tools and frameworks. This includes:

- Developing scientific evidence-based guidelines and standards that translate research findings into actionable recommendations for practice.
- Creating clear performance criteria and test protocols for air cleaning technologies, allowing stakeholders to compare solutions and understand their limitations.

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- Developing tools specifically aimed at assessing airborne infection risk, which can support decision-making for both design and operation of buildings.
- Reducing fragmentation by aligning guidelines and avoiding the proliferation of overlapping or contradictory recommendations.

Equally important is the need to improve communication and knowledge transfer. Participants stressed that information should be tailored to different target groups, including end users, professionals, manufacturers, and policymakers, and should clearly explain not only *what* measures are recommended, but also *why* and *under which conditions* they are effective.

The workshop outcomes indicate that **future MIST project results** should be presented in a way that explicitly bridges science and practice. Rather than producing academic outputs, results should be translated into:

- Clear guidance documents with practical examples,
- Transparent performance metrics,
- Tools and frameworks that support real-world decision-making.

It is crucial that MIST outputs clearly distinguish between evidence-based recommendations and assumptions, and explicitly address existing uncertainties. This will help users understand how and when results can be applied.

As the **general actions** needed, at the governmental level, participants emphasized the need for:

- Updated building codes and regulations that address ventilation and airborne infection risks, including in existing buildings;
- Financial support mechanisms to stimulate implementation and pilot projects;
- Clear regulatory frameworks that prioritize health alongside energy performance.

Participants with a manufacturing background, called for:

- Development of transparent, evidence-based product specifications;
- Standardized testing and reporting of system performance;
- Active collaboration with researchers and policymakers to align innovation with real needs.

Overall, participants argue for fewer, clearer, and better-aligned guidelines. During and after the COVID-19 pandemic, the abundance of diverse and sometimes conflicting guidelines created

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uncertainty and reduced effectiveness. The main message is therefore the need for **coherent, evidence-based, and user-oriented guidance**, supported by standards and shared understanding across all stakeholder groups.

5.3 Main challenges and required actions

The results of the workshops related to the main changes that stakeholders are dealing with are shown in Table 15.

Table 16. The main challenges that stakeholders are dealing with in practice

Stakeholder	Workshop 1	Workshop 2	Workshop 3	Workshop 4
Manufacturers	- Need for scientific validation vs practical implementation - Lack of cost-benefit trade-offs - Lack of measurement and an effectiveness approach	- Insufficient specifications and professional standards - Lack of business case development - Need a client-centric design approach	- Need for better performance criteria for air cleaners - Lack of scientific evidence and tools for infection risk via the airborne route - Less attention from architects and engineers to infectious diseases in the design	- Long process of research - Lack of standards - Lack of knowledge
Technicians	- Lack of awareness about airborne infection risks and a missing sense of urgency among stakeholders - Absence of clear guidelines - Technology and applications challenges	- Lack of scientific knowledge - Lack of engineering standards	- Lack of knowledge of installers on ventilation and air-cleaning systems - Uncertainty about using CO_2 indicators	- Lack of techniques/ Measurement methods - Lack of regulations - Lack of a clear vision/ purpose for different parameters

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Table 17. The main challenges that stakeholders are dealing with in practice

Stakeholder	Workshop 1	Workshop 2	Workshop 3	Workshop 4
End users	- Societal resistance and acceptance - Virus-safety verification frameworks - Domain-specific challenges (private vs public)	- Lack of clear product description - Lack of knowledge; Lack of information on side effects	- Need for the government's financial support - Little knowledge of end users about the importance of ventilation systems and how to ventilate properly. - Less attention from policymakers and building owners to occupational health	- Lack of motivation/ communication - Missing 'virus safe' certification scheme - No good pilot projects available / documented

5.3.1 Key thematic analysis: Issues identified

The needs and expectations of different stakeholders are summarised in Table 16.

Table 18. The key theme of needs and expectations that different stakeholders are facing

Type of stakeholder	**Needs and expectations**
Manufacturers	- Scientific validation vs practical implementation (scientific evidence tools provided in the short term) - Standards and professional guidelines - Measurement and effectiveness approach (better performance criteria) - Cost-benefit trade-offs and business case development - Knowledge and awareness (client-centric design approach)

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Table 19. The key theme of needs and expectations that different stakeholders are facing

Type of stakeholder	Needs and expectations
Technicians	- Awareness and stakeholder engagement - Standards and regulations (clear guidelines and engineering standards) - Scientific and technical knowledge gaps (knowledge of installers) - Measurement and effectiveness approach (techniques/measurement methods and clear vision) - Technology and application challenges
End users	- Need to overcome societal resistance and acceptance (motivation/communication) - Knowledge and information gaps (clear product description, information on side effects) - Domain-specific challenges: attention of policymakers and the government's financial support) - 'Virus-safety' verification frameworks (need a certification) - Need for successful pilot project buildings that are well-documented and can be visited

5.3.2 Core problems identified

The main issues the stakeholders are dealing with are summarised in Table 17. In summary, the results show that knowledge and awareness gaps, policies, standards, regulations, implementation and effectiveness approach, and societal and behavioural challenges are the main issues the different stakeholders are dealing with.

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Table 20. The core challenges identified during the workshop analysis

Category	Description
Knowledge and awareness gaps	Appeared as: - *Scientific and technical knowledge gaps* - *Knowledge, awareness, and information gaps* - *Awareness and stakeholder engagement*
Policy, standards, and regulations	Appeared as: - *Standards, regulations, and professional guidelines* - *Domain-specific challenges: attention of policymakers and the government's financial support* - *'Virus-safety' verification frameworks (need a certification/pilot project)*
Implementation and effectiveness approach	Appeared as: - *Scientific validation vs. Practical implementation* - *Measurement and effectiveness approach (mentioned twice)* - *Technology and application challenges* - *Cost-benefit trade-offs and business case development* - *Client-centric design approach*
Societal and behavioural challenges	Appeared as: - *Societal resistance and acceptance (motivation/communication)*

5.3.3 Future required actions

The workshop outcomes have been translated into some recommendations in the form of an infographic [6], to address the challenges (Figure 20). Some required actions were discussed during the workshops with stakeholders and suggested by the participants.

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Concrete advice on

How to introduce mitigating strategies in an effective way

Guidelines & standards (policy, regulation, industry best practices)

Develop evidence-based guidelines/standards/KPI's (what, where, when)

Develop design principles

Testing protocols & certification (manufacturers, regulatory bodies, quality control)

Develop testing protocols for e.g. air cleaners

Initiate a 'virus-safety' certification scheme

Scientific evidence & research (researchers, engineers, industry experts)

Develop evidence-based specifications like ASHRAE

Develop scientific evidence and research on the transmission risk of airborne infections

Government & policy (policymakers, Regulators, Funding Bodies)

Direct the attention of policymakers towards indoor air quality and health performance of buildings, , in addition to the energy performance

Convince the government to provide financial support for schools and nursing homes so they can purchase mobile air cleaners

Develop related codes for older buildings and renovation

Awareness & communication (public, end users, educational institutions, media)

Increase awareness towards ventilation and air-cleaning systems and improving communication of mixed groups, e.g. specialists, politicians, GGD, employees, and popular scientists

Develop Awareness video/actions

Reduce fear and empowering citizens, and create trust between general public and the government

User-centered approaches (end users, stakeholders, market needs)

Develop user-centred approaches

Apply the V-model to verify that the design meets client expectations

Engage clients early to capture users' perspectives, demands, and requirements

Figure 20. Infographic of introducing mitigating strategies

www.mist-project.nl

5.4 Preferred dissemination formats

Based on the analysis of the final activity across all workshops, the preferred dissemination formats vary by stakeholder group. Manufacturers indicated a preference for interactive websites, technicians favoured webinars, and end users preferred infographics and interactive websites (Figure 21). However, it was frequently noted during discussions that dissemination preferences are highly personal and may differ significantly between individuals. Additional suggestions included the use of media outlets, podcasts, practical guideline books, educational packages, and Programmes of

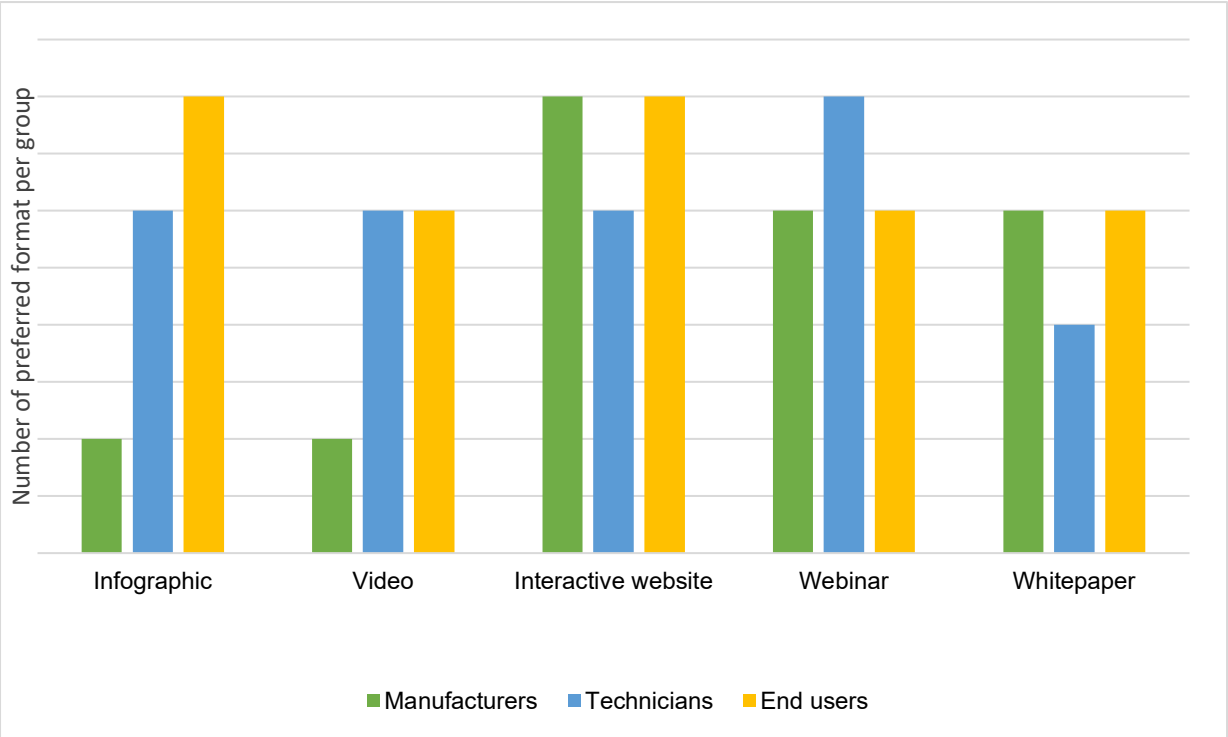

Figure 21. The preferred format of dissemination of the results per group

Requirements (PvEs) as effective communication tools.

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5.5 Summary of actions needed

The alignment of the workshop's objectives with the outcomes and the required actions is shown in Table 18.

Table 21. Summary of actions needed

Workshops' objectives	Outcomes	Required action
Inventory of the wants and needs of stakeholders	- Knowledge and awareness gaps, - Policies, standards, regulations, implementation and effectiveness approach, - Societal and behavioural challenges	- Develop guidelines and standards (policy, regulation, industry best practices) - Develop testing protocols for e.g., air cleaners and initiate a 'virus-safety' certification scheme (manufacturers, regulatory bodies, quality control) - Develop scientific evidence and research (researchers, engineers, industry experts) - Bringing the attention of the government and policy (policymakers, regulators, funding bodies) - Increasing awareness and improving communication (public, end users, educational institutions, media) - Develop user-centred approaches (end users, stakeholders, market needs)
2. Determine preferred dissemination format	1. Interactive website 2. Webinar	It can be different according to the target group and the type of information

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6. Conclusions and recommendations

In this report, the demands of each type of stakeholder concerning mechanical ventilation systems or air cleaning technologies to mitigate airborne infection were recognised, and the challenges each stakeholder was dealing with were discussed. In summary, integrated practical and scientific evidence-based guidelines/standards/regulations/approaches/design principles are needed, depending on the type of stakeholders. They also need to refer to a pilot project, a concrete business case, or certification. Additionally, the lack of awareness and knowledge of stakeholders (such as end users/installers/policymakers/architects/designers and engineers) on infection risks, the role of ventilation, and the possibilities of air cleaning techniques is a challenge.

Most existing studies mainly focus on the evaluation of mechanical ventilation systems on airborne infection control [7-11], but not specifically on the challenges of using mechanical ventilation systems for airborne infection control, nor on the associated difficulties faced by stakeholders. Therefore, our research goes beyond consideration of the role of mechanical ventilation systems and air cleaning technologies in controlling airborne infections and considers the implementation of the air cleaning system in practice. However, this study is limited to the Dutch context and the demands of different stakeholders in the Netherlands. Further research is recommended in other contexts, both within and outside European countries.

In terms of improvements, depending on the target group the following action is recommended: effective communication and collaboration, increasing knowledge of end users/installers/ policymakers/ architects/ engineers/ designers; providing information on protection factors/ scientific evidence-based tools and guidelines, data for different types of spaces; developing preparation guides, regulations/standards/building decree/design principles; improving energy-efficient and proven technologies, and design of the systems; introducing appropriate indicators.

Regarding the preferred format for dissemination, it is difficult to conclude a specific format because of the different needs and types of target groups. Also, preference of individuals differs. However, the most highlighted format for manufacturers is an interactive website; for technicians, it is a webinar; and for end users, it is infographics and interactive websites.

The recommended steps to achieve airborne-infectious safe spaces, depending on the target group, are:

1. Increasing awareness of target groups through effective communication among different stakeholders.

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2. Developing guidelines/standards/regulations/certificates/design principles.

In conclusion, participants indicated that **increasing awareness among target groups** is a fundamental step. This requires effective communication between researchers, industry, policymakers, and end users to address existing knowledge and awareness gaps. Participants emphasised that communication should not only disseminate information, but also support understanding of policies, standards, regulations, and the effectiveness of implemented measures. Improving awareness was seen as essential for addressing societal and behavioural challenges and for enabling informed decision-making across different stakeholder groups.

In addition, participants stressed the importance of **developing clear and consistent guidelines, standards, regulations, certificates, and design principles**. As reflected in Table 18, this includes developing evidence-based guidelines and standards for policy and industry practice, establishing testing protocols for technologies such as air cleaners, and initiating certification schemes related to virus safety. Participants also highlighted the need to strengthen the scientific evidence base through targeted research and to actively draw the attention of government and policymakers to support regulation, funding, and implementation. Finally, they underlined that dissemination formats, such as interactive websites and webinars, should be tailored to the target group and type of information, ensuring that guidance and tools are accessible, understandable, and usable for end users, professionals, and decision-makers.

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