Report of Multidisciplinary Task Group (MTG)

Health and Wellness in the Built Environment (HWBE)

Submitted to

Environmental Health Committee (EHC)

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Comments, criticisms, suggestions, and additional information pertaining to this report are invited. All communications regarding this report should be directed to the ASHRAE Headquarters, 180 Technology Parkway NW, Peachtree Corners, GA 30092.

MULTIDISCIPLANY TASK GROUP ROSTERS

The ASHRAE Report on Health and Wellness in the Built Environment was developed by the Society's Multidisciplinary Task Group formed on 7/14/2018, with Lan Chi Nguyen Weekes as its chair.

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Executive Summary

The formation of this multidisciplinary task group (MTG) in 2018 by President Sheila Hayter was to acknowledge the growing trend of the wellness movement and its relationship within the built environment, and to address this area of opportunity for ASHRAE members.

One of the two main objectives of the MTG on Health and Wellness in the Built Environment (HWBE) was to coordinate with various Technical Committees (TCs), task groups (TGs) and Technical Resource Groups (TRGs) within ASHRAE on the topic of enhancing health and wellness of the occupants in the built environment. The other main objective of the MTG was to help foster and expand internal and external organizational partnerships in this subject area, particularly with organizations developing building rating systems focused on various aspects of sustainability. Some of the ratings systems included occupants' health, wellness, and wellbeing (e.g., ASHRAE; LEED; WELL; Living Building Challenge; RESET, etc.). The MTG was in favor also of expanding external communications with government agencies and research institutes.

The purposes of the MTG's coordination effort are: 1) to increase ASHRAE's knowledge and expertise in this field; 2) to detect and act on potential opportunities; and 3) to become more effective in disseminating research results and practical experience in this field to ASHRAE members and others. These purposes will support the growing interest of ASHRAE members in health, wellness, and the wellbeing of the occupants in buildings.

Based on the analysis of the MTG, these recommendations are made to ASHRAE:

1. Recognize that the principal purpose of most buildings is for human occupancy and that the health and wellness of occupants must be a priority.
2. Acknowledge that energy, resource conservation and other aspects of the 'carbon footprint' of a building are legitimate concerns for ASHRAE members. However, these concerns must not override concern about the health and wellness of occupants.
3. Realize that the design, construction, operation and occupancy of buildings have tangible impacts on the health and wellness of building occupants.
4. Understand that the built environment should function beyond 'minimal' or 'normal' conditions.
5. Accept the WHO definition of heath and recommend that this definition be used in all future ASHRAE documents concerning health in the built environment.
6. Improve coordination between the various ASHRAE efforts directed towards health and wellness in the built environment and should be overseen by ASHRAE Environmental Health Committee (EHC).
7. Appreciate that, relative to IEQ, certification programs vary in rigor and inclusion. None of the certification programs, however, provide an overall holistic assessment of IEQ.
8. Recommend that ASHRAE Environmental Health Committee (EHC) initiates a Position Document (PD) summarizing the impact of the built environment on occupant health and wellness. The MTG.HWBE further recommends that the Position Document include recommendations for further action to be taken by ASHRAE to fill knowledge gaps pertaining to health and wellness in the built environment.
9. Leverage the knowledge and experience of ASHRAE membership to pursue a process for the assessment of IEQ that can be referenced by certification schemes.

1. Context

ASHRAE President Sheila Hayter spearheaded the formation of this multidisciplinary task group (MTG) in 2018 to acknowledge the growing trend of the wellness movement and its relationship within the built environment, and to address this area of opportunity for ASHRAE members.

The purposes of the MTG's coordination effort are: 1) to increase ASHRAE's knowledge and expertise in this field; 2) to detect and act on potential opportunities; and 3) to become more effective in disseminating research results and practical experience in this field to ASHRAE members and others. These purposes will support the growing interest of ASHRAE members in health, wellness, and the wellbeing of the occupants in buildings[1].

The scope of work includes:

1. Review existing definitions of health that address health and wellness as a concept. The objective is to develop or recommend a usable definition of health and wellness, and to determine their defining parameters.
2. Assemble a body of knowledge of existing ASHRAE documents and standards on the topic of indoor air quality, indoor environmental quality, health, and wellness.
3. Compare existing building certification and rating systems worldwide as they relate to indoor environmental quality (IEQ) parameters, and their known or potential impacts on health and wellness.
4. Provide a summary report and recommendations to the Environmental Health Committee (EHC). The recommendations should address how can ASHRAE help mitigate untoward impacts from the built environment on occupant health/wellness. The summary report will also promote research on topics such as the impacts of IEQ parameters and their synergies on health and wellness, as well as changes in the built environment. Recommendations shall include how to expand internal and external organizational partnerships in this subject area.

2. Background

In the 21st century, the impact of the built environment on the health and wellness of building occupants has become widely recognized. However, it is important to note that this is not new information. Ancient Romans, and perhaps Greeks and east Asians, vented exhausts from hypocaust furnaces through flues a full millennium prior to any knowledge of carbon monoxide and its harmful effects. However, energy conservation efforts, among other building trends in the late 20th century, have often resulted in adverse effect on occupant health and wellness, habitually referred to as Sick building syndrome (SBS). The hallmark of these occupant complaints is their tight temporal association with building occupancy, and their rapid resolution, within minutes to hours, when affected occupants leave implicated buildings. Sick building syndrome is distinguished from more medically serious building-related illness by its subjective nature, reversibility, and high prevalence within implicated buildings across the nonindustrial building stock in North America and Europe [2].

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[1] https://www.sciencedirect.com/science/article/pii/S0360132313002539
[2] https://www.cdc.gov/niosh/nioshtic-2/20000157.html

Occupant health and comfort are still not always included in balancing the costs and benefits inherent in the design, construction, and operation of buildings. Thus, the occupants often bore the decline in the indoor environmental quality in the buildings they occupy. Evidence documenting the occupant-related adverse health and discomfort issues continues to grow. This has resulted in the rise of indoor air quality (IAQ) as a consulting discipline and the development of an industry of IAQ specialists since the 1980s. Studies by Fisk, Mendell and others are focusing on the tangible costs of IAQ-related sickness and hospitalization while other costs such as loss of productivity and alertness at tasks are still to be quantified [3, 4].

The ASHRAE Terminology document (www.ashrae.org/ashraeterms) defines indoor environmental quality (IEQ) as "a perceived indoor experience of the building indoor environment that includes aspects of design, analysis, and operation of energy efficient, healthy, and comfortable buildings. Fields of specialization that contribute to that perceived experience include architecture, heating, ventilation and air-conditioning (HVAC) design, thermal comfort, indoor air quality (IAQ), lighting, acoustics, and control systems" [5]. Based on this definition, the work of the MTG revolved around these specializations and their relationship to the perception of health and wellness. They are further explained in more detail below.

2.1 Architecture

Architecture is defined as the art and technique of designing a building, as opposed to the skills associated with the construction of a building. The practice of architecture usually fulfills both the utilitarian and aesthetic ends, although different societies have different views on their relative importance. Because every society has a spatial relationship to the natural world and to other societies, the structures they produce reveal much about their environment (including climate and weather), history, ceremonies, and artistic sensibility, as well as many aspects of daily life.

Opinions differ as to what are basic principles on which architectural design should be based on, from durability to beauty, symmetry to empty (or negative) space. However, the characteristics that seem to distinguish a work of architecture from other built structures are: (1) the suitability and the adaptability of it to a particular human activity; (2) the stability and permanence of the work's construction; and (3) the emotions and ideas expressed through its form. If the function is chiefly utilitarian, as in a factory, emotions are of less importance. If the function is chiefly expressive, as in a monumental tomb, permanence and emotions are important criteria [6].

In recent years, additional benefits and needs related to the Built Environment (BE) have been recognized and studied. Studies have shown that a perceived good BE by its occupants help to increase productivity, reduce detrimental health effects, reduce healthcare costs, reduce sick leave, and reduce employee turnover rates.

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[3] http://doas.psu.edu/fisk.pdf

[4] https://www.theguardian.com/commentisfree/2021/nov/06/student-hall-from-hell-hath-no-windows-to-distract-from-study-or-sleep

[5] *Interactions Affecting the Achievement of Acceptable Indoor Environments*, ASHRAE Guideline 10 – 2016.

[6] https://www.britannica.com/topic/architecture

When discussing public health, architecture is not generally the first thing that springs to mind. Yet, its influence on human health and emotional comfort is inescapable [7,8]. Numerous studies, especially in healthcare settings, show that a healthcare design that helps patients deal with stress can increase their recovery rate and reduce their hospital stay [9, 10]. The same positive health effect can probably be said for the architecture of most buildings [11]. The effect on the health and wellness of the occupants of a building design for human occupancy should then be paramount in any concept. For example, views of the outdoors can connect occupants with nature, and can help to reduce stress. Open and accessible stairways can encourage use of stairs rather than elevators, thereby promoting an active lifestyle. Material selection in a building can affect pollutant concentrations found in indoor air. On the other hand, unintended consequences of well-meaning measures must also be considered when evaluating a building material. Materials that are, for example, less chemically treated to lessen pollutant emission can get moldy more rapidly if not installed and maintained properly.

In natural disasters, the BE can serve as a refuge, such as from wildfire smoke, or the BE can remain functional during a region wide loss of power. Additionally, the role of the BE in either promoting or reducing the spread of infectious aerosols is now made tragically evident by the COVID-19 pandemic. Although infrequent, these aspects of the BE cannot be ignored since it can become a peril to the occupants during these events. The BE cannot be designed for only 'normal' conditions since this will serve as a multiplier of the hazard when an unexpected peril inevitably arrives. Conversely, the BE should maintain the health and wellness of the occupants during a peril.

2.2 HVAC Design and Controls

HVAC design has a substantial impact on health and wellness of building occupants. HVAC systems must provide enough clean, tempered ventilation air and acceptable thermal conditions as a minimum requirement. HVAC systems can affect the multiple aspects of IEQ in varying manners and to a varying extent. Inadequate filtration can allow introduction of outdoor particulates to the building, which could negatively impact occupants if the airborne levels become elevated. Noise and vibration that affect acoustic conditions may also be related to poor HVAC design. HVAC controls that depressurize buildings can foster dampness in interstitial spaces in hot, humid climates or pull unfiltered, unconditioned outdoor air in through leaks and cracks. This in turn can degrade IEQ and promote mold growth. The use of advanced HVAC controls can give high precision in the catering of IEQ to individual spaces based on occupancy and function. HVAC designers must consider the many ways that the HVAC system interacts with occupants and other building systems to create the overall IEQ conditions in a building.

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[7] Karl Johnson, The Guardian, 11 June 2013. https://www.theguardian.com/sustainable-business/public-health-architecture-impact-wellbeing

[8] Equipe ArchDaily Brasil. "Architecture and Health: How Spaces Can Impact Our Emotional Well-Being" [Arquitetura e saúde: como o espaço impacta no bem-estar emocional] 28 Aug 2021. ArchDaily. (Trans. Duduch, Tarsila). https://www.archdaily.com/967003/architecture-and-health-how-spaces-can-impact-our-emotional-well-being.

[9] Creasy, Timothy Michael, "The Wellness Clinic: A New Approach to Healthcare Design. " Master's Thesis, University of Tennessee, 2012. https://trace.tennessee.edu/utk_gradthes/1143

[10] Ulrich RS. Effects of interior design on wellness: theory and recent scientific research. Journal of Health Care Interior Design: Proceedings From the ... Symposium on Health Care Interior Design. Symposium on Health Care Interior Design. 1991 ;3:97-109. PMID: 10123973.

[11] Petermans, Ann & Pohlmeyer, Anna. (2014). Design for subjective well-being in interior architecture. 10.13140/2.1.1584.2241.

A well-designed and operated HVAC system can provide optimal IAQ. However, to contribute fully to health and wellness, the HVAC must also be integrated with overall building design. For example, how the HVAC systems effectively control the relative humidity will affect the performance of the building envelope. [12] Also, some natural ventilation might increase the perception of good indoor air by allowing personal control for the occupant. However, it must be noted that natural ventilation can possibly counter the effectiveness of the HVAC system.

2.3 Thermal Comfort

The thermal environment of a building affects health, performance, and comfort of its occupants. ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy, addresses the minimal requirements for the thermal environment of a building with regards to human comfort. A commonly used model for thermal comfort is predicted mean vote (PMV) and predicted percentage dissatisfied (PPD), which was established by Professor Ole Fanger in 1970 and modified in 1986[13]. This model is based on a large sample of human response as well as physical equations, including six key parameters for thermal comfort: ambient temperature, radiant temperature, relative humidity, clothing level, metabolic rate, and air velocity. ASHRAE 55 uses an adaptive thermal comfort acceptability model based on PMV-PPD.

To maximize thermal comfort in buildings, some key parameters of the model such as radiant temperature can be controlled by analyzing the placement, configuration, and type of windows and skylights. The windows and skylights can also provide appropriate shading to avoid "hot spots" caused by direct sunlight [14]. Other factors related to the thermal comfort such as clothing level and activities can vary significantly between individuals. Also, humans can adapt somewhat to a wide range of thermal conditions by development adjustment, acclimatization, cultural practices and use of technology [15].

2.4 Indoor Air Quality (IAQ)

ASHRAE 62.1 defines 'acceptable IAQ' as having no known harmful contaminants, and also when most occupants report that they are not dissatisfied. The IAQ in a building can be compromised by many different airborne pollutants of concern including volatile organic compounds (VOCs), chemicals such as carbon monoxide and ozone, mould and particulate matter [16]. Poor IAQ can have short-term and/or long-term effects to occupants, depending on the pollutant, the quantity, and the duration of exposure. Individuals can react differently to air pollutant exposure, depending on their sensitivities, such as asthma or pre-existing medical conditions, as well as their personal demographics, such as age [17].

IAQ is directly impacted by the activities inside and outside the building, including by occupants' work inside the building. Activities that are outside the building that impact IEQ include road construction or wildfires. IAQ relies on the adequacy of the building operation and maintenance,

[12] Seppänen O, Kurnitski J. Moisture control and ventilation. In: WHO Guidelines for Indoor Air Quality: Dampness and Mould. Geneva: World Health Organization; 2009. https://www.ncbi.nlm.nih.gov/books/NBK143947/
[13] https://www.sciencedirect.com/science/article/pii/S1364032113003535
[14] https://www.wbdg.org/design-objectives/productive/provide-comfortable-environments
[15] https://www2.palomar.edu/anthro/adapt/adapt_1.htm
[16] https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality
[17] https://www.cpsc.gov/Safety-Education/Safety-Guides/Home/The-Inside-Story-A-Guide-to-Indoor-Air-Quality

including maintaining a proper ventilation rate, air distribution effectiveness, and filtration. IEQ also relies on the proper operation of other building systems such as localized exhausts and water features.

It is noted that standards such ISO, CIBSE, and ASHRAE Standard 62 series contain minimum requirements for acceptable IAQ for commercial and residential buildings with set ventilation rates based on odor control. In addition, the ASHRAE Standards have made provisions for sampling indoor air for contaminants, and also for asking about occupant satisfaction in its IAQ procedure (IAQP) [18].

2.5 Lighting

Lighting can refer to daylighting or electric lighting, both of which are important factors for human visual and non-visual needs. There are multiple components to lighting including illumination for visual task performance, glare from direct light, flicker, color, duration, and contrast between interior surfaces for navigation purposes.

The absence of quality light exposure can decrease alertness, adequate sleep, and a positive mood, and it can increase the risk for mood disorders such as seasonal affective disorder, as well as the ability to set and maintain circadian rhythms or natural daily rhythm [19].

When it comes to lighting in buildings, the focus has been recently on reducing energy consumption from conventional fluorescent lighting with more energy-efficient LED lighting. Recently, new studies are being initiated to investigate its effect on health and sleep [20]. However, few standards exist that provide guidance as to how lights should be controlled to provide health benefits [21].

2.6 Acoustics

Good acoustic conditions are fundamental to the quality and enjoyment of the occupied spaces either in homes, workplaces, or other building types. Sound, either from outside of the building or from another place within the building, can affect both the human physiology and psychology. Noise, or “unwanted sound”, is associated with various mental and physical health symptoms. [22, 23] It can increase heart and respiration rate as well as increased blood pressure. Noise can also be a cause of sleep disturbance and reduced learning and performance. Conversely, pleasant sounds can help create a sense of wellbeing and relaxation.

For example, a Finnish study found that open office occupants suffered more from difficulties in concentration and tiredness. In open offices, a greater percentage of those suffering from symptoms attributed symptoms to office noise [24]. A meta-analysis published in 2015 found that

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[18] *Ventilation and Acceptable Indoor Air Quality in Residential Buildings.* ASHRAE Standard 62.2 – 2019. https://www.osti.gov/servlets/purl/1635274

[19] https://www.researchgate.net/publication/283459751_The_importance_of_light_to_health_and_well-being

[20] https://www.ledsmagazine.com/lighting-health-wellbeing/article/14209139/doe-backs-study-looking-at-lightings-effect-on-health-and-sleep

[21] Halper, M., (2017), European lighting regulations could help usher in human centric lighting. LEDs Magazine, March 2017, pp. 39-42

[22] https://www.bregroup.com/bretrust/wp-content/uploads/sites/12/2019/02/Acoustic-design-and-testing-Trust-report-online-version-1.pdf

[23] H. A. R. Jensen, B. Rasmussen and O. Ekholm, "Neighbour noise annoyance is associated with various mental and physical health symptoms: results from a nationwide study among individuals living in multi-storey housing," *BMC Public Health,* pp. 1-10, 2019.

building acoustics was the one IEQ parameter that did not consistently score better even in green buildings [25].

Acoustical comfort, including the ability to focus, collaborate, or have confidential conversations, should be addressed in a way that is both effective and aesthetically pleasing. Ultimately, the objective must shift away from specifications only (e.g., Sound Transmission Class [STC], or weighted overall sound pressure level [dBA]) towards psychoacoustic metrics (i.e., privacy, intelligibility, comfort). These metrics better evaluate the collective outcome of acoustical parameters (e.g., architectural, environmental, electronic, etc.) for the occupant in the built environment.

2.7 Controls Systems and Personal Control

Control systems play an important role in the operation of a building, and these controls can determine whether many of the design aspects included in the original plan function as intended. Control systems for heating, ventilating, air-conditioning (HVAC) and related systems are at the core of building performance. The control systems can assist in conserving resources through the scheduling, staging, and modulation of equipment to meet the needs of the occupants, as well as the systems that they are designed to serve**.** When the systems work well, the indoor environment promotes productivity with the light, comfort, and ventilation that occupants need to carry out their tasks [26].

There are interactions among the individual IEQ categories that influence overall IEQ and complicate the ability of engineers and practitioners to design controls systems that operate buildings for human health. There is a significant interaction between thermal comfort and IAQ. For example, higher temperature can increase the emission of Volatile Organic Compounds (VOCs) from materials, but lower temperature create discomfort for some occupants. Low relative humidity levels can worsen the health effects of particulate matter and virus transmission, and increase discomfort while higher humidity can support mould growth in some cases. High air velocity creates a cooler thermal environment, and it can also reduce or redistribute local air pollutant concentrations.

Another important factor as shown by a study in 2019 is that occupants with a higher level of personal control were reported to be more productive within their working environment [27]. Moreover, occupants who maintained high degrees of personal control over their indoor environment reported higher levels of IEQ satisfaction. However, it is noted that allowing more personal control by the occupants can also complicate the operation of the building by the control systems.

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[24] Haapakangas, Annu & Helenius, Riikka & Keskinen, Esko & Hongisto, Valtteri. (2008). Perceived acoustic environment, work performance and well-being–survey results from Finnish offices.

[25] G. J. Allen, P. MacNaughton, J. G. Cendeno Laurent, S. S. Flanigan, E. S. Eitland and J. D. Spengler, "Green buildings and health," *Global Environmental Health and Sustainability,* vol. 2, pp. 250-258, 2015.

[26] https://www.sciencedirect.com/book/9781933742076/the-ashrae-greenguide

[27] Sakellaris I, Saraga D, Mandin C, de Kluizenaar Y, Fossati S, Spinazzè A, Cattaneo A, Szigeti T, Mihucz V, de Oliveira Fernandes E, Kalimeri K, Carrer P, Bartzis J. Personal Control of the Indoor Environment in Offices: Relations with Building Characteristics, Influence on Occupant Perception and Reported Symptoms Related to the Building—The Officair Project. *Applied Sciences*. 2019; 9(16):3227. https://doi.org/10.3390/app9163227.

3. Definition of Health and Wellness

One of the objectives of the MTG.HWBE is to develop or recommend a usable definition of health and wellness and its defining parameters.

The criteria defined by the MTG.HWBE to develop or recommend a definition for health and wellness were to:

- Provide a broad/high level and inclusive definition of health.
- Use an existing definition so not to add unwanted 'noise' to the field and to the definition of health.
- Show that health is a spectrum that goes beyond 'acceptable' or critical conditions. and that health can be improved, not just maintained.
- Include people in the definition, not just buildings.
- Include both perceived health (comfort), mental health, physiological and psychological health.
- Avoid ambiguous and redundant terminology (e.g., wellness, well-being) and focus on the word 'health' as an umbrella term.
- Keep it simple.

The relationship between the physical characteristics of the built environment and the health of its occupants is not completely understood. However, there is ongoing research connecting the productivity, cognitive capabilities, satisfaction, and physiological health of occupants to various building design elements and attributes. Among the topics of interest, each with varying degrees of known causality, are clean air and surfaces, humidity, properly controlled temperature, access to daylight, light intensity and distribution, sound and vibrations, opportunities for social interactions, access to adequate nutrition, water quality, opportunities for exercise, connection to the outdoors, and exposure to nature. Moreover, as noted before, the interactions or synergies of these parameters are not well understood either.

According to the World Health Organization (WHO): "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." [28]

Beyond the WHO definition, the task group reviewed various papers and definitions by the Center for Disease Control and Prevention (CDC), as well by the National Institute for Occupational Safety and Health (NIOSH). Some of these definitions are listed below:

- "Health is more than the absence of disease; it is a resource that allows people to realize their aspirations, satisfy their needs and to cope with the environment in order to live a long, productive, and fruitful life."[29]

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[28] World Health Organization. (N.d.). "Constitution." https://www.who.int/about/who-we-are/constitution.

[29] Centers for Disease Control and Prevention. (Updated October 2018). "Well-being Concepts." https://www.cdc.gov/hrqol/wellbeing.htm#:~:text=There%20is%20no%20consensus%20around,with%20life%2C%20fulfillment%20and%20positive.

- "Employee health affects an organization in various ways, as direct costs such as healthcare costs or as indirect costs such as productivity and engagement. When it comes to workplace health, there are seven key performance indicators (KPI's) to consider. These include physical fitness, physical comfort, physical nourishment, cognitive well-being, social well-being, emotional well-being, and environmental well-being. Various environmental attributes of these seven KPIs in the workplace affect not only health but also performance and engagement of employees via their physical, mental, and social interactions within the environment. For instance, ergonomics, acoustics, lighting, thermal comfort, and olfactory comfort address the overall physical comfort while biophilic components contribute to employee cognitive functions as well as their capacity to cope with mental stress and fatigue. These seven KPIs of workplace health ultimately contribute to five positive organizational outcomes, including healthy organizational culture, higher productivity, improved individual health and safety, financial savings, and enhanced reputation of the organization." [30]
- "Well-being is a positive and unifying concept that captures multiple factors that contribute to workers' health and quality of life. This work lays the foundation for larger well-being measurement efforts and will provide tools for NIOSH partners to help workers flourish". [31]
- "The *Total Worker Health* (TWH) approach prioritizes a hazard-free work environment for all workers. It also brings together all aspects of work in integrated interventions that collectively address worker safety, health, and well-being. Traditional occupational safety and health protection programs have primarily concentrated on ensuring that work is safe and that workers are protected from the harms that arise from work itself. TWH builds on this approach through the recognition that work is a social determinant of health. Job-related factors such as wages, work hours, workload, interactions with coworkers and supervisors, and access to paid leave impact the well-being of workers, their families, and their communities. The long-term vision of the TWH program is to protect the safety and health of workers and advance their well-being by creating safer and healthier work". [32]

While there is a lot of similarity among the definitions reviewed and discussed, the WHO definition is the most succinct and inclusive. Hence, the recommendation from the MTG was to accept the WHO definition of health.

The task group decided to use an existing definition of health instead of 'reinventing the wheel'. The task group focused on the connection to the built environment as a contributing factor to health and well-being. The WHO definition recognizes that health extends beyond 'acceptable' conditions or critical health issues. The WHO definition is a broad, umbrella definition that covers physical, mental, and social aspects of health. This definition thus reflects the complexity of the subject.

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[30] Lee, Young. (2019). "Workplace health and its impact on human capital: seven key performance indicators of workplace health. *Indoor Environment and Health.* DOI: 10.5772/intechopen.85936.
[31] Chari R, Chang CC, Sauter SL, et al. Expanding the Paradigm of Occupational Safety and Health: A New Framework for Worker Well-Being. *J Occup Environ Med*. 2018;60(7):589-593. doi:10.1097/JOM.0000000000001330
[32] https://www.cdc.gov/niosh/twh/totalhealth.html

The term health is often used synonymously or in conjunction with terms like comfort, well-being, and wellness. The task group did not find a consensus that makes a clear distinction between these terms. For example, CDC states: "There is no consensus around a single definition of well-being, but there is general agreement that, at a minimum, well-being includes the presence of positive emotions and moods (e.g., contentment, happiness), the absence of negative emotions (e.g., depression, anxiety), satisfaction with life, fulfillment and positive functioning" [33]. Since the task group did not see a significant difference between this definition of well-being and the WHO and CDC definitions of health, it was agreed that it is not productive to distinguish between these terms.

It is noteworthy that, in September 1988, an inter-ministerial committee of the Ontario Canada government reached a similar conclusion [34]. Beginning in 1976, various provincial ministries collectively had investigated over 2,000 indoor air complaints. In response to the then emerging concerns about 'sick building syndrome' or 'tight building syndrome', this committee was formed and charged with developing a coordinated response to indoor air quality issues. These responses included identifying associated hazards, developing protocols, and recommending acceptable criteria. Since the impetus for the committee concerned health effects of IAQ, an early goal was to adopt a definition of health. The WHO definition, which includes both health and comfort, was adopted. Due to the prevalence of IAQ complaints that related to comfort rather than clinically significant diseases, including comfort in the definition was key to the committee's preference of the WHO definition.

4. Review of Resources related to Health and Wellness

At the same time as the review of various health and wellness definitions, a compilation of relevant literature within ASHRAE, and of rating systems from other organizations was performed to provide a basis for review and comparison. The focus was on organizations developing building rating systems focused on various aspects of sustainability, some including health, wellness and wellbeing (e.g., ASHRAE; LEED; WELL; Living Building Challenge; RESET, etc.).

Criteria for comparison of different certification systems and standards were also compiled. These criteria are primarily based on a recent review paper from Wei et. al. (2020) [35] and are generally included in best practice rating systems on the topic of health and wellness in the built environment. This list includes most aspects of IEQ within the scope of ASHRAE as discussed earlier such as architecture, HVAC design, thermal comfort, indoor air quality (IAQ), lighting, acoustics, and control systems. It was important to adopt a set of criteria to provide a basis for comparison between different documents and different rating systems. However, it is expected that there will be some subjectivity depending to the specific topic of their interest.

The review process undertaken by the MTG.HWBE is certainly not all encompassing. It is quite possible that existing documents might have been updated recently, that some relevant documents

[33] Centers for Disease Control and Prevention. (Updated October 2018). "Well-being Concepts." https://www.cdc.gov/hrqol/wellbeing.htm#:~:text=There%20is%20no%20consensus%20around,with%20life%2C%20fulfillment%20and%20positive.

[34] https://www.aivc.org/sites/default/files/airbase_4009.pdf

[35] Wei, W., Wargocki, P., Zirngibl, J., Bendžalová, J. and Mandin, C. (2020) 'Review of parameters used to assess the quality of the indoor environment in Green Building certification schemes for offices and hotels', *Energy and Buildings*. Elsevier B.V., 209, p. 109683. doi: 10.1016/j.enbuild.2019.109683.

might have not been identified nor reviewed, or that new documents and rating systems have emerged since the beginning of the process and were not included.

4.1 Review of Resources within ASHRAE Related to Health and Wellness

A list of ASHRAE documents was compiled based on a search for the terms “indoor air quality” and “indoor environmental quality” in ASHRAE’s Guidelines, Standards and Position Documents. For Guidelines and Standards, terms such as IAQ, IEQ, air quality, contaminants, health-related impacts of indoor air and odor were used (see Table 1).

From this list, relevant documents that were reviewed are also indicated (see Table 1). Test methods were not included nor were standards only tangentially related to IEQ. For example, ASHRAE 90.1 which only notes that provisions of the standard should not be used in ways that contravene occupational health and safety.

In Appendix A, Table A-1 compares the standards and the best practices found in ASHRAE documents that also address health and wellness against the predetermined set of criteria. Not surprisingly, ASHRAE’s focus on indoor air is at the core of many of its best practice rating systems There were clear gaps in areas that are considered more broadly to be a part of the subject of indoor environmental quality: thermal comfort, acoustics, visual quality, and other wellness amenities. Whether these gaps represent essential topic areas for ASHRAE, and whether the core focus should not be diluted by a broadening of the mission, is still to be decided.

Table 1 - ASHRAE Documents Identified and ASHRAE Documents Reviewed by the MTG.HWBE

ASHRAE Documents Identified	ASHRAE Documents Reviewed
Guideline 1.2 – 2019 - Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies	
Guideline 10 – 2016- Interactions Affecting the Achievement of Acceptable Indoor Environments	
Guideline 23 – 2016- Guideline for the Design and Application of Heating, Ventilation, and Air-Conditioning Equipment for Rail Passenger Vehicles	
Guideline 27 – 2019- Measurement Procedures for Gaseous Contaminants in Commercial Buildings	
Guideline 28-2016 Air Quality within Commercial Aircraft	X
Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	X
Guideline 32 – 2018 -Management for Sustainable High-Performance Operations and Maintenance	
Guideline 33 – 2013 (RA 2016) - Guideline for Documenting Indoor Airflow and Contaminant Transport Modeling	
Standard 34 -2019 – Designation and Safety Classification of Refrigerants	
Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	X
Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	X
Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	X
Standard 129 - Standard Method of Measuring Air Change Effectiveness	

Table 1 - ASHRAE Documents Identified and ASHRAE Documents Reviewed by the MTG.HWBE

ASHRAE Documents Identified	ASHRAE Documents Reviewed
Standard 161- 2018 Air Quality within Commercial Aircraft	X
Standard 170 - 2017 Ventilation of Health Care Facilities	X
Standard 180 – 2018 – Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	X
Standard 189.1 – 2020 – Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings	
Standard 189.3	
Position Document: Infectious Aerosols	
Position Document: Resiliency in the Built Environment	
Position Document: Limiting Indoor Mold and Dampness in Buildings	
Position Document: Combustion of Solid Fuels and Indoor Air Quality in Primarily Developing Countries	
Position Document: Environmental Tobacco Smoke	
Position Document: Filtration and Air Cleaning	
Position Document: Indoor Air Quality - updated July 2020	X
International Green Construction Code, 2018 - Third Printing, January 2021	X
Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009	X

4.2 Review of Building Certification Programs related to Health and Wellness

The first step was to compile all relevant literature and previous comparisons of green building rating systems. The next step was to evaluate how organizations, particularly those involved in the high-performance building rating systems, compare, define and measure health and wellness in the built environment.

There are currently over 600 green building rating systems in use globally [36]. Therefore, the MTG.HWBE decided to focus on those with most relevance to ASHRAE in terms of geographical regions, types of buildings, rating criteria and coverage (i.e. number of buildings / areas covered). Finally, a list of 17 rating systems was chosen for inclusion in this comparison. These systems cover USA, Europe (UK, Germany, France), Australia, Asia (Japan, China, Singapore) and Middle East (UAE). A full list of the rating systems reviewed, including country of origin, year of origin and version, is provided below in Table 2. The work was organised on Google Drive and Basecamp, with links provided here: Google Drive Link | Basecamp Link.

Table 2 - Green Building Certifications and Rating Systems included in MTG.HWBE Review

CERTIFICATION	Origin	Year of Origin	Version
LEED	USA	2020	v4.1
WELL	USA	2014	v2 (2020)
Living Building Challenge	USA	2009	v4.0 (2019)
BREEAM	UK	1990	
DGNB	Germany	2007	v2018
Three Star	China	2012	
CASBEE	Japan	2004	v2014
Pearl	Abu Dhabi	2009	
HQE	France	1995	
Green Star	Australia	2007	2020
Green mark	Singapore	2005	5th ed (2015)
RESET	China		
Green Globes	USA	2019	NC
Passivhaus	USA	2019	2.1
Fitwel	USA	2011	2.1
Enterprise Green Communities	USA	2004	2020
UL Verified Healthy Building	USA	2020	2020

The findings of the analysis are available in Appendix B - Table B.1, with additional notes in Appendix B - Table B.2.

[36] *Guide to Sustainable Building Certifications*. Danish Building Research Institute – SBI (2018).

5. Communication of MTG.HWBE Findings

The initial dissemination of information from the MTG.HWBE was an “IEQ Applications” column in the April 2020 issue of the ASHRAE Journal. In this column, MTG Chair Lan Chi Nguyen Weekes outlined the discussion of health and wellness criteria that must occur within ASHRAE, and how the MTG.HWBE was acting to foster this discussion.

The MTG.HWBE prepared this report for submittal to the ASHRAE Environmental Health Committee (EHC) to summarize the MTG.HWBE findings. Upon review and acceptance of this report by the EHC, the MTG.HWBE anticipates that the report will be forwarded through appropriate channels within ASHRAE for review, and then dissemination through publications and presentations to different audiences.

The MTG.HWBE recommends that EHC include the recommendations of this report into its strategic plan for implementation over a longer term. For a start, the MTG.HWBE suggest that an ASHRAE Position Document (PD) be prepared on the impact of the built environment on health and wellness of occupants. The MTG.HWBE anticipates that such a PD would be prepared at the direction of the ASHRAE Environmental Health Committee, and that it could incorporate content from this report.

6. Observations / Conclusions

The purposes of the MTG’s work were: 1) to increase ASHRAE's knowledge and expertise in this field; 2) to detect and act on potential opportunities; and 3) to become more effective in disseminating research results and practical experience in this field to ASHRAE members and others. These purposes will support the growing interest of ASHRAE members in health, wellness, and the wellbeing of the occupants in buildings.

The work included:

1. The review of existing definitions of health, and the recommendation of a usable definition of health and wellness.
2. The selection and review of relevant ASHRAE documents and standards on the topic of indoor air quality, indoor environmental quality, health, and wellness.
3. The selection and comparison of existing building certification and rating systems worldwide as they relate to indoor environmental quality (IEQ) parameters, and their known or potential impacts on health and wellness.
4. The creation of a summary report with recommendations for future actions under the guidance of the Environmental Health Committee (EHC), a General Standing Committee of ASHRAE Society. The recommendations address how ASHRAE can help mitigate untoward impacts from the built environment on occupant health/wellness, while promoting research on such topics as the impacts of IEQ parameters and their synergies on health and wellness, as well as changes in the built environment.

It should be noted that this was a high-level overview of various documents and certifications with an emphasis on IEQ by members of the MTG.HWBE.

Based on the analysis of the MTG, these recommendations are made to ASHRAE:

1. Recognize that the principal purpose of most buildings is for human occupancy and that the health and wellness of occupants must be a priority.
2. Acknowledge that energy, resource conservation and other aspects of the 'carbon footprint' of a building are legitimate concerns for ASHRAE members. However, these concerns must not override concern about the health and wellness of occupants.
3. Realize that the design, construction, and operation of buildings have tangible impacts on the health and wellness of building occupants.
4. Understand that the built environment should function beyond 'minimal' or 'normal' conditions.
5. Accept the WHO definition of heath and recommend that this definition be used in all future ASHRAE documents concerning health in the built environment.
6. Improve coordination between the various ASHRAE efforts directed towards health and wellness in the built environment and should be overseen by ASHRAE Environmental Health Committee (EHC).
7. Appreciate that, relative to IEQ, certification programs vary in rigor and inclusion. None of the certification programs, however, provide an overall holistic assessment of IEQ.
8. Recommend that ASHRAE Environmental Health Committee (EHC) initiates a Position Document (PD) summarizing the impact of the built environment on occupant health and wellness. The MTG.HWBE further recommends that the Position Document include recommendations for further action to be taken by ASHRAE to fill knowledge gaps pertaining to health and wellness in the built environment.
9. Leverage the knowledge and experience of ASHRAE membership to pursue a process for the assessment of IEQ that can be referenced by certification schemes.

At this point, the MTG.HWBE is not able to recommend specific action items with regards to collaboration within ASHRAE or with other organizations. However, it recognized that formal partnerships should be considered in the area of health and wellness particularly with organizations developing building rating systems focused on various aspects of sustainability, some including health (e.g., ASHRAE; LEED; WELL; Living Building Challenge; RESET, etc.). The MTG was in favor also of expanding external communications with government agencies and research institutes.

Appendix A

Table A1 - ASHRAE documents related to H&W in the built environment

Parameter \ ASHRAE Document	Guideline 28-2016 Air Quality within Commercial Aircraft	Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	Standard 161- 2018 Air Quality within Commercial Aircraft	Standard 170 - 2017 Ventilation of Health Care Facilities	Standard 180 - 2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	Position Document: Indoor Air Quality - updated July 2020	International Green Construction Code, 2018 (Third Printing, January 2021)	Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009
Thermal Comfort											
In-operation testing / reporting?											X
Ambient Temperature (Air / Operative)	X	X	X			X					X
Air Velocity / Draughts	X		X	X	X	X	X				X
Relative Humidity (RH %)	X	X	X	X	X	X	X				X
Predicted Mean Vote (PMV / PPD)			X								X
Adaptive Comfort			X								X
Radiant Temperature / Asymmetry	X		X			X					X
Vertical air temperature difference	X		X			X					X
Surface Temperatures (Floor / Wall)			X								
Occupant satisfaction with thermal comfort	X	X	X			X					
IAQ - Pollutant limit											
Reference Standard (if applicable)											
Pollutant monitoring and verification (continuous or one-off)											
TVOC	X					X					X
Formaldehyde	X			X		X			X		X

ASHRAE Document Parameter	Guideline 28-2016 Air Quality within Commercial Aircraft	Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	Standard 161- 2018 Air Quality within Commercial Aircraft	Standard 170 - 2017 Ventilation of Health Care Facilities	Standard 180 - 2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	Position Document: Indoor Air Quality - updated July 2020	International Green Construction Code, 2018 (Third Printing, January 2021)	Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009
CO2	X					X			X		X
CO	X			X	X	X			X		X
PM10	X			X		X			X	X	X
PM2.5	X			X	X	X			X	X	X
Ozone	X			X		X			X	X	X
Visible mold	X	X		X		X	X	X	X		X
Other											
IAQ other											
Reference Standard (if applicable)											
Ventilation	X			X	X	X	X	X	X	X	X
Air filtration / cleaning	X	X		X	X	X	X	X	X	X	X
Moisture control	X	X		X	X	X	X	X	X	X	X
Low-emitting materials & products	X			X		X			X	X	X
Smoking control	X					X		X	X	X	
Outdoor air quality consideration	X	X		X	X	X	X	X	X	X	X
Source emission control	X	X		X	X	X	X	X	X	X	X
IAQ Management Plan	X	X		X		X			X		X
Occupant satisfaction with IAQ	X			X	X	X	X		X		X
Acoustical comfort											
Reference Standard (if applicable)											
In-operation testing / reporting?										X	
Ambient noise level										X	

ASHRAE Document Parameter	Guideline 28-2016 Air Quality within Commercial Aircraft	Guideline 29 - 2019 Guideline for the Risk Management of Public Health and Safety In Buildings	Standard 55 - 2020 Thermal Environmental Conditions for Human Occupancy	Standard 62.1 - 2019 Ventilation for Acceptable Indoor Air Quality	Standard 62.2 - 2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings	Standard 161- 2018 Air Quality within Commercial Aircraft	Standard 170 - 2017 Ventilation of Health Care Facilities	Standard 180 - 2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems	Position Document: Indoor Air Quality - updated July 2020	International Green Construction Code, 2018 (Third Printing, January 2021)	Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning, 2009
Material Quality/Acoustic Performance										X	
Sound reducing barriers/technology										X	
Noise abatement plan/assessment										X	
Occupant satisfaction with acoustical comfort											X
Visual comfort											
Reference Standard (if applicable)											
In-operation testing / reporting?											
Exposure to artificial light											
Exposure to daylight										X	X
Lighting quality - circadian response											
Lighting quality - flickering											
Glare from direct sun										X	
Contrast (e.g., illuminance ratio between surfaces)											
Occupant satisfaction with visual comfort											X
Other Wellness Amenities											
Fitness / Exercise											
Occupant amenities											
Nutrition											
Controllability										X	X
Biophilia											
COVID-19 and Airborne Infection Control						X [1]					X

[1]Section on control of bacteria and viruses based on design (HEPA filters, airflow patterns, balancing), maintenance

Appendix B

Table B1 - Comparison of the H&W related elements of building rating systems (X indicates the parameter is addressed in the rating system, SN indicates the percentage or points related to this topic in the rating system and are related notes in the colored sections of the specific topics in Table B2)

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Thermal comfort	SN				SN								SN		SN		
In-operation testing / reporting?		X									X	X					
Ambient Temperature (Air / Operative)	X				X		X	X	X		X	X		X			X
Air Velocity / Draughts	X				X		X	X	X								
Relative Humidity (RH %)	X	X			X		X	X			X	X		X	X	X	X
Predicted Mean Vote (PMV / PPD)	X	X		X				X			X						
Adaptive Comfort	X																
Radiant Temperature / Asymmetry	X	X			X												

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Vertical air temperature difference							X										
Surface Temperatures (Floor / Wall)							X	X						X			
Occupant satisfaction with thermal comfort		X	X					X							X		X
Additional Comments / Info	X												X				
IAQ - Pollutant limit	SN				SN										SN		
Pollutant monitoring and verification (continuous or one-off)	SN	SN	SN					SN			X	X			X		
TVOC		A	X	X	X		X		X		X	X	X		X	X	X
Formaldehyde	X	X	X	X	X		X		X		X				X	X	X
CO2	X	X	X		X			X			X	X			X		X
CO	X	X	X					X	X			X	X		X	X	X
PM10	X	X	X					X	X				X				X
PM2.5	X	X	X						X			X	X		X		X
Ozone	X	X	X						X						X		X

Certification / Parameter	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Visible mold														X	X		X
Other	X	X	SN					SN	SN		X			X		X	X
Additional Comments / Info				SN											X		
IAQ other															SN		
Ventilation	X	X	X	X	X		X	X	X		X	X		X	X	X	
Air filtration / cleaning	X	X									X			X	X	X	X
Moisture control	X													X	X	X	X
Low-emitting materials & products	X	X	X	X			X	X						X	X	X	
Smoking control	X	X	X				X	X					X		X	X	X
Outdoor air quality consideration	X	X	X								X	X					X
Source emission control	X	X	X												X	X	
IAQ Management Plan	X		X	X			X	X							X		X
Occupant satisfaction with IAQ			X														

Certification / Parameter	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Additional Comments / Info												X	X		X		
Acoustical comfort	SN				SN								SN		SN		
In-operation testing / reporting?								SN			SN						
Ambient noise level	X	X		X	X		X	X	X		X		X			X	X
Material Quality/Acoustic Performance	X	X		X	X		X		X		X			X		X	
Sound reducing barriers/technology		X					X						X	X		X	
Noise abatement plan/assessment		X			X		X						X			X	X
Occupant satisfaction with acoustical comfort																	
Additional Comments / Info													X		X		
Visual comfort	SN				SN								SN		SN		
In-operation testing / reporting?		X						SN									
Exposure to artificial light	X	X		X	X		X	X	X		X		X	X		X	X
Exposure to daylight	X	X	X	X	X		X	X	X		X		X	X	X	X	X

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
Lighting quality - circadian response		X											X	X			
Lighting quality - flickering		X			X						X		X	X			X
Glare from direct sun	X	X		X	X		X	X			X		X		X		
Contrast (e.g., illuminance ratio between surfaces)		X					X	X					X				
Occupant satisfaction with visual comfort			X					X					X				
Additional Comments / Info													X				
Other Wellness Amenities					SN										SN		
Fitness / Exercise		X			X										X	X	
Occupant amenities		X		X			X	X							X	X	
Nutrition		X			X										X	X	
Controllability	X	X	X	X	X		X	X									
Biophilia		X	X								X					X	

Parameter \ Certification	LEED	WELL	Living Building Challenge	BREEAM	DGNB	Three Star	CASBEE	Pearl	HQE	Green Star	Green mark	RESET	Green Globes	Passivhaus	Fitwel	Enterprise Green Communities	UL Verified Healthy Building
Version Reviewed	v4.1	v2 (2020)	v4.0 (2019)		v2018		v2014			2020	V5 (2015)		NC	2.1	2.1	2020	
COVID-19 and Airborne Infection Control	X	X													X		
Additional Comments / Info								X							X		X

Appendix B

Table B2 - Notes for Table B1

Parameters	Notes
Thermal comfort	0.90% LEED 4.5% DGNB 23 points Green Globes 0.5 Fitwell
Occupant satisfaction with thermal comfort	Qualitative survey / feedback system/occupant control etc.
IAQ - Pollutant limit	7.27% LEED 5.10% DGNB 6.4 Fitwel
Pollutant monitoring and verification (continuous or one-off)	LEED - Continuous monitoring of CO_2 WELL - One-off Living Building Challenge C – Either method Pearl - Continuous Monitoring CO_2, CO, PM_{10}, NO_2
TVOC	WELL – As per ASHRAE 62 or international equivalent
Other	Living Building Challenge: NO2, 4-PCH Pearl: NO2 HQE: Benzene Radon NO2, SO2
Additional Comments / Info	BREEAM: avoidance of asbestos

Parameters	Notes
IAQ other	11.8 Fitwell
Ventilation	Outdoor and/or treated air rates Distribution Controls
Air filtration / cleaning	Minimum filter rating Gaseous air cleaning Air cleaner requirements, etc.
Moisture control	Intention to reduce mold, condensation
Low-emitting materials & products	Furniture Paints Cleaning Products
Outdoor air quality consideration	Ozone Pollen Particulate Matter from Wildfires, etc.
Source emission control	Pressurisation Combustion venting Garage direct exhaust, etc.
IAQ Management Plan	Construction, Operation, Maintenance, etc.

Parameters	Notes
Acoustical comfort	0.90% Leed 2.90% DGNB 35 points Green Globes 0.5 Fitwel
In-operation testing / reporting?	Pearl A - Field Tests/ Green Mark B - SS 553:2016 or GM NRB: 2015 Technical Guide and Requirements
Material Quality/Acoustic Performance	Sound insulation Transmission rating
Sound reducing barriers/technology	Screens Sealant Window films, etc.
Noise abatement plan/assessment	24 CFR 51B

Parameters	Notes
Visual comfort	5.45% LEED 3.40% DGNB 32 points Green Globes 2.5 Fitwel
In-operation testing / reporting?	Pearl - Occupancy sensors / photographs
Exposure to artificial light	Horizontal illuminance level Task lighting Color rendering index
Exposure to daylight	Window proximity Spatial daylight autonomy Daylight factor, etc.)
Lighting quality - circadian response	Circadien stimulus Equivalent melanopic lux Vertical illuminance, etc.
Glare from direct sun	Shades, blinds Desk layout
Occupant satisfaction with visual comfort	Visual connection to the outdoors
Other Wellness Amenities	5.4% DGNB 47.3 Fitwel
Fitness / Exercise	Gym, sauna Navigation system / information
Occupant amenities	Roof garden Balconies, etc.

Controllability	Ventilation Shading Temperature Light