“Co-Benefits” as a Lens Through Which COVID-19 Building Upgrades Can Advance Environmental Sustainability, Climate Mitigation and Adaptation, and Social Equity

Adele Houghton


Abstract

Buildings play a critical role in disaster preparedness and response. They can protect occupants from exposure to an environmental hazard like a hurricane, a flood, or an extreme heat event. On the other hand, if systems break down or structures collapse, they also contribute to the injury and death toll. Buildings have played a similarly contradictory role during the COVID pandemic. On the one hand, they have provided safety and shelter at a time when it is safer to stay physically distant from individuals outside of one’s family unit. At the same time, mechanical ventilation systems have contributed to the spread of SARS-CoV-2, the virus that causes COVID-19. This commentary proposes deploying the public health concept of “co-benefits” as a lens through which COVID upgrades to existing buildings and design considerations for new buildings could be leveraged to advance environmental sustainability, climate mitigation and adaptation, and social equity.

Introduction

Buildings play a critical role in disaster preparedness and response. They can protect occupants from exposure to environmental hazards like hurricanes, floods, and extreme heat events. Buildings that are well insulated and equipped to stay cool when the electric grid fails can protect their occupants from exposure to dangerous outdoor temperatures (Luber & McGeehin, 2008). On the other hand, if systems break down or structures collapse, buildings also contribute to the injury and death toll (Bell et al., 2016).

The role buildings have played in both slowing down and speeding up transmission of SARS-CoV-2 (the virus that causes COVID-19) follows a similar pattern. On the one hand, the safety and shelter they have provided has made it possible for many millions of people to social distance for months on end. At the same time, mechanical ventilation systems have contributed to transmission in enclosed, public spaces like restaurants, bars, workplaces, and buildings that host congregant events (such as sports and music events) (Furuse et al., 2020; Morawska et al., 2020).

In both types of disaster, the burden of disease falls disproportionately on groups whose health is less resilient than the general population – particularly minorities, populations with low socioeconomic status (SES), individuals living with chronic disease, the elderly, and the very young. For minorities and populations with low SES, vulnerability to poor health outcomes stems from a combination of social and environmental stressors such as systemic racism, difficulty accessing medical care, and high rates of residence in housing that is poorly maintained or located in a dangerous location (such as a floodplain) (Gamble et al., 2016). Chronic disease can increase the risk of severe injury or death related to living through a disaster. For example, pre-existing medical conditions accounted for 37% of deaths in the U.S. following Hurricane Irma in 2017 (Issa et al., 2018). Vulnerability among children and the elderly often stems from a combination of physiology (i.e., their bodies are more frail and their immune systems are not as robust as healthy adults) and dependency on caregivers to keep them safe (Lowe et al., 2013). The disparities in mortality rates following Hurricane Katrina brought the combination of demographic and SES health disparities into sharp focus. Almost half of the deaths attributed to Hurricane Katrina were among people aged 75 and older; and, the mortality rate for African Americans was 1.7 times the rate among Whites (Brunkard et al., 2008).
The same racial and ethnic health disparities have been observed in the U.S. during the COVID-19 pandemic. African Americans, who represent 12.5% of the U.S. population, comprise 22% of total reported COVID-19 cases, and 23% of deaths. Sadly, we see a similar disparity among Hispanic/Latinx and Native Americans compared with Whites (Table 1).

### Table 1. Demographic Distribution of COVID-19 Cases, Hospitalizations, and Deaths through June 12, 2020

<table>
<thead>
<tr>
<th></th>
<th>% U.S. Population (U.S. Centers for Disease Control and Prevention National Center for Health Statistics, 2020)</th>
<th>% COVID Cases (U.S. Centers for Disease Control and Prevention, 2020a)</th>
<th>COVID-19 Hospitalization Rate (U.S. Centers for Disease Control and Prevention, 2020b)</th>
<th>% COVID-19 Deaths (U.S. Centers for Disease Control and Prevention National Center for Health Statistics, 2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Hispanic White</td>
<td>60.4%</td>
<td>34.9%</td>
<td>37.8 per 100,000</td>
<td>53.3%</td>
</tr>
<tr>
<td>Non-Hispanic African American</td>
<td>12.5%</td>
<td>22%</td>
<td>171.8 per 100,000</td>
<td>23%</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>18.3%</td>
<td>33.3%</td>
<td>150.3 per 100,000</td>
<td>16.5%</td>
</tr>
<tr>
<td>Native American</td>
<td>0.7%</td>
<td>1.2%</td>
<td>193.8 per 100,000</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

It is clear that buildings will play an important role in addressing both resilience and health disparities in their communities. The public health concept of “co-benefits” offers a lens through which COVID upgrades to existing buildings and design considerations for new buildings could be leveraged to advance the parallel objectives of environmental sustainability, climate resilience, and social equity.

The U.S. Environmental Protection Agency defines “co-benefits” as “two or more benefits that are derived together from a single measure or set of measures” (U.S. EPA Office of Atmospheric Programs, 2004, p. 8). Ürge-Vorsatz et al. describe this approach as a framework that links multiple objectives with multiple co-impact pathways with multiple co-impact endpoints (Ürge-Vorsatz et al., 2014). Within the context of architectural design and facilities operations, this concept boils down to seeking out and prioritizing strategies that meet the project’s fundamental goals in terms of program, financing, etc.; AND, reduce the risk of exposure to infectious disease, regional climatic events, and chronic disease; AND, proactively work towards dismantling the structural impediments to health and wellness that fall within the scope of architectural design and facilities operations.

Green building projects (defined as building and planning projects that seek to reduce the use of resources and create a health-promoting environment for occupants) routinely evaluate design and operations strategies based on their combined contribution to the project’s programmatic goals and environmental concerns such as reducing greenhouse gas emissions (i.e., climate change mitigation), protecting water quality, and improving indoor air quality. A co-benefit approach expands that already familiar conversation to prioritize green building strategies that also reduce the risk of COVID-19 transmission and remove structural impediments to health and wellness in the greater community. Figure 2 adapts Ürge-Vorsatz et al’s (2014) conceptual framework to the multiple pathways linking design and operations strategies with co-impact pathways and co-impact endpoints.

**Figure 2. Co-Benefit Conceptual Framework of the Interrelated Nature of Building Design and Operations Strategies with COVID-19, Climate Change, and Health Equity Outcomes**
Climate Change Mitigation

Climate change mitigation refers to actions to reduce greenhouse gas emissions. Buildings are responsible for 40% of global greenhouse gas emissions (Global Alliance for Buildings and Construction, International Energy Agency, United Nations Environment Programme, 2019). So, their actions in the realm of mitigation can contribute a great deal towards the global effort to move to a post-carbon economy. Mitigation efforts in buildings involve converting all fuels used for building operations (such as natural gas) to electricity, minimizing building electricity loads through efficiency measures, and using renewable energy to make up the difference (Edenhofer et al., 2014).

The COVID pandemic has demonstrated that the building stock in industrialized countries will need to be retooled to meet global goals for greenhouse gas reduction (Jiang et al., 2021). For example, when New York City (NYC) went into lockdown in April 2020, the city only reported a 16% reduction in average weekday electricity demand, because empty office buildings operated at 80% or higher energy use intensity and electricity demand in residential buildings increased (U.S. Energy Information Administration, 2020). Overall, the economic disruption caused by the pandemic is estimated to reduce global greenhouse emissions by only 4% - 7% in 2020 (Le Quéré et al., 2020).

The transition to working and learning from home has taken a greater economic toll on families living in poverty, who are twice as likely to live in substandard housing (8% v. 3.5%) (U.S. Census, 2017) and 4 times less likely to possess both a computer and access to broadband internet (21% v. 80%) (Ryan, 2018) than families living at ³ 200% of the federal poverty level. These families spend a higher percentage of their income on connectivity and heating/cooling their homes than families in wealthier neighborhoods.

A co-benefit approach to maximizing climate change mitigation through building design and operations would emphasize insulation (i.e., weatherization); installing operable windows and window screens; either using on-site or purchasing off-site renewable power; encouraging low carbon modes of transportation to and from the building; and, in more complicated buildings like office towers, using engineering practices like commissioning and building automation/management systems to control how the building controls systems in response to occupant fluctuation (Table 2).
Extreme heat has been the leading cause of death from natural disasters in the U.S. for many decades (National Weather Service Office of Climate, Water, and Weather Services, n.d.). Its health risk factors are similar to COVID-19 in that the elderly (particularly nursing home residents) are at high risk of hospitalization and death (Balbus & Malina, 2009; U.S. Centers for Disease Control and Prevention National Center for Health Statistics, 2020) and many of the working-age adults who succumb to heat-related illness are exposed at their workplace (Arbury et al., 2014; Dyal et al., 2020). The pre-existing conditions that increase the risk of heat-related injury and death also overlap with COVID-19 – namely cardiovascular disease, diabetes, and chronic respiratory disease (Garg et al., 2020; Sarofim et al., 2016, p. 46). Additionally, public health officials are concerned that fear of COVID may lead some vulnerable groups to remain in overheated homes, which could dramatically increase their risk of heat-related injury or death (Kovats & Hajat, 2008), rather than risk exposure by visiting cooling centers (Flavelle, 2020).

A co-benefit approach to minimizing building occupant exposure to extreme heat would likely start with some of the climate change mitigation strategies mentioned above – particularly weatherization and operable windows with screens. Outside the building, targeted plantings, including on the roof, can reduce heat exposure by lowering ambient air temperatures on-site. Installing an on-site solar (photovoltaic) array with a battery pack can make it possible for occupants to stay cool at home during heat-related power outages without increasing regional air pollution or greenhouse gas emissions (Table 2).

Air Quality, Drought, Wildfire

Climate change compromises air quality both through the burning of fossil fuels (which is the primary cause of climate change) and through climatic events such as droughts and wildfires (Fann et al., 2016). Traffic-related air pollution (TRAP) in particular can increase the risk of death from both climatic events and COVID-19. For example, TRAP has been found to increase death rates for heat-related illness (Scortichini et al., 2018), particularly in marginalized communities – whose residents are also more likely to live in substandard housing with poor indoor air quality (Fann et al., 2016) and to suffer from chronic respiratory and cardiovascular disease (Sacks et al., 2011). In terms of COVID-19, a recent Harvard study found that an incremental increase in fine particulate matter pollution was associated with an 8% increase in COVID-19 death rates (Wu et al., 2020). And, a preliminary study in Italy found traces of the virus that causes COVID-19 (SARS-CoV-2) on polluted air particles, indicating that particulate matter may contribute to the spread of infection (Setti et al., 2020).

A co-benefit approach to reducing occupant exposure to poor air quality would look at opportunities to influence community planning to reduce the sources of air pollution (such as freeways, congested roads, and industrial installations). It would also assess the sources of air pollution most relevant to the site as part of the site assessment process. And, it would design the air conditioning and ventilation system to support the use of HEPA filters, plant landscaping that can remove particulate matter from the air, orient the building away from sources of air pollution, and maximize air movement on site (Table 2).

Hurricanes and Flooding

A number of regions in the U.S. have been forced to contend with the compound threat of extreme weather and the COVID-19 outbreak. These events can dramatically increase the risk of COVID-19 transmission for a number of reasons. Evacuations place people fleeing from the storm within close proximity to others in emergency shelters, increasing the risk of a major outbreak in those locations (Sellers & Freedman, 2020). If hospitals with COVID patients lose power, are flooded, or need to be evacuated, COVID patients will be placed at increased risk of health complications and death during the transfer to a new facility (Eastburn, 2020). Transfers could be disrupted if essential equipment, such as ventilators, stop working or cannot be transferred alongside the patients. Also, if power, water, and other necessities are not available for days or weeks, it could increase the spread of COVID in the community; because, personal hygiene will suffer (Favas, 2020).

Designing a hurricane- and flood-resilient building using a co-benefit lens would likely prioritize strategies that enhance the occupants’ ability to shelter in place during and after a storm rather than relocating to a shelter. It would also lead to designing public buildings and parking structures to accommodate pop-up emergency shelters, neighborhood microgrids, and community gardens, so that neighborhoods are not cut off from basic necessities during and immediately following hurricanes and flooding events (Table 2).

Vector-Borne Disease

Vector-borne diseases are diseases that are transmitted from animal reservoirs (like mosquitoes and ticks) to humans (Beard et al., 2016). While its origins are still unclear (Haider et al., 2020), the virus that causes COVID-19 (SARS-CoV-2) may be classified at a late date as a zoonotic disease — i.e., a pathogen that jumps from an animal to humans and then subsequently from human to human (Jones et al.,
Warming temperatures, changes to precipitation patterns, and the stresses they are causing to ecosystems are increasing the risk of vector-borne, zoonotic, and emerging infectious diseases of probable animal origin (like COVID-19) in three ways (O’Callaghan-Gordo & Antó, 2020; Williams, 2020).

Animals that can transmit new diseases to humans are suffering from damaged immune systems, which increases their risk of falling ill and then infecting nearby humans.

- Humans are coming into closer contact with wildlife that have migrated away from changing or collapsing ecosystems and into the areas surrounding human settlements.
- Warmer weather is allowing pathogens to survive in locations closer and closer to the poles, where they are encountering human populations with little or no immunity to them.

The climatic changes that made it possible for SARS-CoV-2 to jump to humans are also increasing the risk of larger outbreaks of vector-borne diseases throughout the world (Córdoba-Aguilar et al., 2021).

A co-benefit approach to minimizing occupant exposure to vectors like mosquitoes and ticks would likely prioritize planting and maintaining landscaping that encourages a healthy, diverse ecosystem, avoids fragmenting habitat, and eliminates standing water. It would also recommend installing screens on windows, sliding doors, and outdoor air intakes. And, it would emphasize the use of integrated pest management in building maintenance (Table 2).

### Conclusion

Over the past year, the COVID-19 pandemic has placed great strain on both the global healthcare system and the economy. The “co-benefits” approach responds to calls by global leaders such as the World Health Organization, the United Nations, the World Economic Forum, and the private sector to rebuild the post-COVID world according to a vision of equity and carbon neutrality (Mendiluce & Siri, 2020; United Nations, 2020; World Health Organization, 2020). Architects and built environment professionals can do their part by expanding design conversations to consider and synthesize the wide array of environmental, health, and societal challenges facing us during these turbulent times into a set of design solutions that maximize co-benefits and minimize co-harms.

### Table 2. Potential Co-Benefits of Green Building Strategies to Reducing COVID-19 Transmission, Addressing Climate Change, and Advancing Health Equity

<table>
<thead>
<tr>
<th>Strategy</th>
<th>COVID-19</th>
<th>Climate Change</th>
<th>Health Equity</th>
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<tbody>
<tr>
<td><strong>Climate Change Mitigation</strong></td>
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<tr>
<td>In moderate climates and regions with low levels of air pollution, shade the building, install window screens, open windows, and use ceiling fans (or plug-in fans, if ceiling fans are not available).</td>
<td>Increase outdoor air volume and ventilation rates.</td>
<td>Reduce demand for fossil fuels.</td>
<td>Reduce electricity bills.</td>
</tr>
<tr>
<td>Weatherize the building to maximize energy efficiency. Weatherization includes installing insulation in the roof and walls, sealing cracks and leaks, and sealing the building against moisture intrusion.</td>
<td>Reduce asthma triggers, which could exacerbate chronic respiratory disease, a risk factor for poor COVID-19 outcomes (Rabbani et al., 2021).</td>
<td>Reduce demand for fossil fuels.</td>
<td>Reduce electricity bills.</td>
</tr>
<tr>
<td>Take the opportunity to perform integrated pest management at the same time, so that the weatherization process helps reduce asthma triggers rather than sealing them inside.</td>
<td>Reduce demand for fossil fuels.</td>
<td>Maintain healthy indoor air temperatures during blackouts.</td>
<td>Repair substandard building stock.</td>
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</table>

- In commercial buildings, install a building automation/management system (BAS) or tune the existing BAS to reduce electricity use when the building is unoccupied or low occupancy. Assess plug loads in the building to minimize phantom electricity use when the building is unoccupied.
- In residential buildings, install programmable thermostats and program them to minimize conditioning demand when it is not needed.

Review energy use schedules.

- Tune building systems to maximize ventilation for periods of time when it will most benefit occupants.
- Link the BAS to on-site solar and battery system, so that it can be used both on a daily basis and during blackouts.
- Use the thermostat installation as an opportunity to provide other upgraded services to low-income families (such as a replacement air conditioner).
Perform building commissioning or retro-commissioning to assess building systems in detail. Commissioning actions may include recalibrating air handling units, fans, and occupancy sensors.
- Operations procedures may also need to be updated to ensure that energy efficiency protocols are followed, such as turning off lights and lowering ventilation rates after nightly cleaning.
- Perform this work in conjunction with assessments related to COVID, such as assessing the ventilation system to improve filtration media to HEPA (MERV 13) filters, rearranging seating to promote social distancing, increasing the frequency of cleaning and sanitization, etc.

Tune the ventilation system to maximize outdoor air introduced into the building and maintain clean filters and ductwork.

Reduce demand for fossil fuels.

Reduce electricity bills.

Use this program as an opportunity to install MERV 13 filters in low-income housing (via portable fans if the home does not have a central air conditioning system).

Assess the ways in which the building could help reduce ambient air emissions permanently:
- Install on-site renewable power, such as solar panels.
- Purchase renewable power.
- Promote the use of active transportation and public transit to and from the building.
- Install recharging stations in the parking garage to encourage electric cars.
- Build out telecommuting infrastructure so that staff can continue to work from home at least a few days a week after the pandemic winds down.

Active transportation is one way to maintain social distancing while traveling.

Telecommuting is a way to maintain social distancing while working.

Reduce demand for fossil fuels.

Use this program as an opportunity to expand access to rooftop solar, charging stations, and broadband in low-income and minority neighborhoods.

Active transportation and public transit are often less expensive than owning and maintaining a private car.

**Extreme Heat**

**Overlap with Mitigation Strategies:** Weatherization practices and retrofitting buildings with operable windows, screens, and fans can lower the indoor temperatures in addition to reducing power use.

Increase outdoor air volume and ventilation rates.

Reduce demand for fossil fuels.

Some weatherization programs also donate air conditioning units to low-income residents. This is a particularly effective approach during the COVID-19 outbreak, because it makes it safer for residents to shelter in place during the heat event.

Planting and maintaining vegetation around buildings, on their roofs, and as shading devices can also reduce indoor temperatures during heat waves.

Increase outdoor air volume and ventilation rates by increasing the amount of time it feels comfortable to open the window.

Reduce demand for fossil fuels.

Increase access to nature, which can benefit mental health, particularly in low-income and minority neighborhoods which often have lower vegetation density than high income neighborhoods.

Installing on-site photovoltaic arrays with a battery pack.

Provide backup power during brownouts and blackouts can help reduce the risk of unsafe indoor temperatures during heat waves without contaminating the air adjacent to the building with products of combustion and without increasing regional air pollution or GHG emissions.

Use this program as an opportunity to expand access to rooftop solar in low-income and minority neighborhoods.

**Air Quality, Droughts, and Wildfire**
Individual real estate development projects should support and contribute to the success of local community plans to increase the viability of multi-modal transportation and reduce the number of vehicles on the road. Design strategies include:
- Work with the authorities having jurisdiction to construct complete streets adjacent to the site.
- Minimize on-site parking.
- Design flexible office spaces that allow for part-time telecommuters.

Prioritize sidewalks, cycling infrastructure, and safe routes to transit stops.

<table>
<thead>
<tr>
<th>If the concern is regional air pollution alone, the best options may be to support local AQ plans (as discussed above), design the HVAC system to support the use of HEPA filters, plant landscaping that has been shown through studies to be effective at removing the ambient air toxins that are most prevalent in the region, and orient the project to enhance air movement across the site.</th>
<th>Active transportation is one way to maintain social distancing while traveling.</th>
<th>Increase outdoor air volume and ventilation rates. Avoid introducing contaminants into the building.</th>
<th>Reduce the risk of an increase in respiratory and cardiovascular visits to the hospital during combined ozone action and heat advisory days.</th>
<th>Low-income and minority neighborhoods are disproportionately located near sources of air pollution.</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the project is located near or adjacent to a source of air pollution such as a freeway or an industrial plant, the project team should move the building as far from the source(s) of pollution as possible, turn the building’s “back” on the source(s) of pollution, strategically place the outdoor air intakes to minimize exposure, plant a wall of vegetation and possibly build a solid wall on the property line(s) facing the source(s) of exposure to keep at least the larger particles off site, and design the building entrance(s) to minimize the introduction of air pollution into the building.</td>
<td>Increase outdoor air volume and ventilation rates. Avoid introducing contaminants into the building.</td>
<td>Reduce the risk of an increase in respiratory and cardiovascular visits to the hospital during combined ozone action and heat advisory days.</td>
<td>Low-income and minority neighborhoods are disproportionately located near sources of air pollution.</td>
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<tr>
<td>If a source of air pollution is connected with building operations — such as the carpool line at a school or the ambulance bay at a hospital — the entrance next to the source(s) of pollution should be designed as a vestibule with dedicated exhaust. Operable windows may not be advisable for buildings located in areas with elevated air pollution. But, natural ventilation may still be possible if it is brought in through a central outdoor air intake and filtered prior to being introduced to the indoor spaces.</td>
<td>Increase outdoor air volume and ventilation rates. Avoid introducing contaminants into the building.</td>
<td>Reduce the risk of an increase in respiratory and cardiovascular visits to the hospital during combined ozone action and heat advisory days.</td>
<td>Low-income and minority neighborhoods are disproportionately located near sources of air pollution.</td>
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**Storms and Flooding**

<table>
<thead>
<tr>
<th>Build outside of the floodplain or at a high enough elevation to avoid 500-year or 1,000-year floods.</th>
<th>Make it possible for families to shelter in place during a disaster rather than risk being exposed to COVID at an emergency shelter.</th>
<th>Reduce the risk of flood-related injuries or death.</th>
<th>Low-income and minority neighborhoods are more likely to be located in floodplains. Building outside of the floodplain would reduce the risk of flooding, mold, pest infestations, and injury/death while traveling.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make use of low impact development (LID) strategies that maximize capturing, cleaning, and absorbing rainwater onsite. For example, include a high percentage of vegetation on site, rain gardens, constructed wetlands, and site grading strategies that minimize erosion and standing water, etc.</td>
<td>Make it possible for families to shelter in place during a disaster rather than risk being exposed to COVID at an emergency shelter.</td>
<td>Reduce the risk of flood-related injuries or death.</td>
<td>Low-income and minority neighborhoods are more likely to be located in floodplains. Constructing LID projects would reduce the risk of flooding in those neighborhoods.</td>
</tr>
<tr>
<td>Install pervious pavement in roadways, parking areas, and pathways.</td>
<td>Make it possible for families to shelter in place during a disaster rather than risk being exposed to COVID at an emergency shelter.</td>
<td>Reduce the risk of flood-related injuries or death.</td>
<td>Low-income and minority neighborhoods are more likely to be located in floodplains. Installing pervious pavement would reduce the risk of flooding in those neighborhoods.</td>
</tr>
</tbody>
</table>
Design public buildings that are already located throughout communities — such as schools and hospitals — to accommodate pop-up emergency shelters that balance social distancing, increased ventilation/enhanced filtration, and distributed power/water/food systems.

<table>
<thead>
<tr>
<th>Reduce the risk of COVID-19 transmission at emergency shelters.</th>
<th>Enhance preparedness for climate-related disasters.</th>
<th>Converting existing public buildings into emergency shelters could increase access to the surrounding neighborhood, which is critical in low-income neighborhoods where residents may not have access to a car.</th>
</tr>
</thead>
</table>

Seek federal and state hazard mitigation funding to support designing new and retrofitting existing community schools and healthcare facilities as neighborhood hubs for combined heat and power or microgrid installations from renewable sources, on-site stormwater and (where allowed) wastewater collection and treatment, and urban farms/community gardens.

<table>
<thead>
<tr>
<th>Make it possible for families to shelter in place during a disaster rather than risk being exposed to COVID at an emergency shelter.</th>
<th>Enhance preparedness for climate-related disasters.</th>
<th>This approach is particularly important in low-income and minority neighborhoods with a history of food and utility insecurity and in neighborhoods that have been cut off from the rest of the community during previous flooding events.</th>
</tr>
</thead>
</table>

Design parking lots, parking structures, and communal spaces (like gymnasiums) to be easily converted into emergency shelters following National Mass Care Strategy space allowance and ventilation guidelines for COVID-19 general and medical shelters (National Mass Care Strategy, 2020).

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<th>Converting existing public buildings into emergency shelters could increase access to the surrounding neighborhood, which is critical in low-income neighborhoods where residents may not have access to a car.</th>
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### Vector-borne Disease

Plant and maintain a healthy, diverse ecosystem in the landscaping surrounding a building to protect human occupants from vectors like mosquitoes, cockroaches, and mice. Biodiversity in plants attracts a variety of animals, including predators of these pests.

<table>
<thead>
<tr>
<th>Some vector-borne diseases have similar symptoms as COVID-19 (Wilder-Smith et al., 2020). So, it is important to minimize risk of misdiagnosis by reducing exposure to vectors.</th>
<th>Deter vector populations, which are migrating to new regions as a result of climatic shifts.</th>
<th>Increase access to nature, which can benefit mental health, particularly in low-income and minority neighborhoods which often have lower vegetation density than high income neighborhoods.</th>
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Design landscaping to remove sources of standing water, which could breed mosquitoes.

<table>
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<tr>
<th>Some vector-borne diseases have similar symptoms as COVID-19 (Wilder-Smith et al., 2020). So, it is important to minimize risk of misdiagnosis by reducing exposure to vectors.</th>
<th>Deter vector populations.</th>
<th>Standing water is a particular problem in many low-income neighborhoods.</th>
</tr>
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</table>

Implement integrated pest management strategies through building maintenance. Seal penetrations in the envelope that could admit pests. Fix leaks and replace deteriorating building materials that could provide water, food, and shelter for pests.

<table>
<thead>
<tr>
<th>Reduce asthma triggers, which could exacerbate chronic respiratory disease, a risk factor for poor COVID-19 outcomes (Rabbani et al., 2021).</th>
<th>Helps with weatherization efforts, which reduce energy use.</th>
<th>Repair substandard building stock.</th>
</tr>
</thead>
</table>

Green buildings that use natural ventilation to reduce electricity consumption should pay particular attention to installing mosquito screens on windows and other outdoor air intakes to keep mosquitoes out of the building.

|---|---|---|---|

Developments in regions with Lyme disease should keep bushes away from the building, avoid fragmenting habitat, and clear space next to walking, hiking, and cycling trails so that users do not brush up against vegetation.

<table>
<thead>
<tr>
<th>Some patients have been delayed in being diagnosed with Lyme disease because of the pandemic, leading to unnecessary complications (Wormser et al., 2021).</th>
<th>Deter vector populations, which are migrating to new regions as a result of climatic shifts.</th>
<th>Increase access to nature, which can benefit mental health, particularly in low-income and minority neighborhoods which often have lower vegetation density than high-income neighborhoods.</th>
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