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How Climate Change Mitigation Can Improve Public Health

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Introduction

Reducing climate-related health risks has significant potential to improve public health. Climate change is harming public health across every region of the United States by increasing extreme heat and weather, air pollution, infectious disease, and food insecurity. Due to differences in hazard exposure, sensitivity to impacts, and adaptive capacity (link), some are more vulnerable than others to climate-related health risks. Public health practitioners can help their communities take action to reduce these health risks and negative health equity effects.

Purpose of This Resource

This resource was developed to help public health practitioners understand the health and health equity benefits of climate change mitigation strategies. This understanding can be used to support climate change mitigation planning efforts. The resource identifies key approaches to mitigate climate change across six classes of climate change mitigation strategies. These mitigation strategies are often within the control of local and state officials. It describes a selection of health pathways and health outcomes associated with each strategy. It explores the varying levels of evidence for these associations. And it presents potential health harms, when substantiated by scientific literature. Strategies that regulate energy production, such as carbon pollution standards, or vehicle fuel efficiency standards are not included because they are primarily controlled by a combination of state and federal regulations, generally cannot be implemented by local governments, and have complex political and legal restrictions limiting their potential applicability to many jurisdictions.

Related Resources

Guidance for Public Health Practitioners

- How Public Health Can Support Climate Change Mitigation - Guidance for how public health practitioners can support climate change mitigation (See the “roles” report here).
- Online trainings that explore real-life scenarios to help state and local health departments increase their understanding of how climate change impacts health (linked here).
- A practitioner framework called Building Resilience and Climate Equity (BRACE). This is a practical, flexible, and scalable approach to local public health-focused climate action. (linked here)

- A BRACE implementation guide with practical, flexible, and action-oriented worksheets, and resources for strengthening adaptation and mitigation efforts (linked here).
- Information about federal engagement with state, territorial, local, and tribal health departments (see CDC's page on the Climate Ready States and Cities Initiative (linked here) and the Climate Ready Tribes Program (linked here).
- Decision-support tools using environmental and health data to help practitioners communicate and plan in their jurisdictions. (linked here).

Guidance for Planners

- Practical strategies to incorporate the perspective of health and health equity in climate action planning (linked here).

Climate Change Mitigation Strategies, Health Pathways, and Health Outcomes

Taking action to mitigate climate change is a powerful opportunity to improve public health through interventions that shape the social and environmental determinants of health. Climate change interventions fall into two broad categories:

- **Climate change mitigation** – reducing emissions of the heat-trapping greenhouse gasses (GHGs) in the atmosphere that drive climate change; and
- **Climate change adaptation** – preparing for and responding to current and future climate change.

The various ways a climate change mitigation strategy may influence public health—either directly or indirectly—is known as a health pathway (Fig. 1). The public health benefits associated with reducing climate-related health risks are indirect. But these health pathways also have significant direct public health benefits.

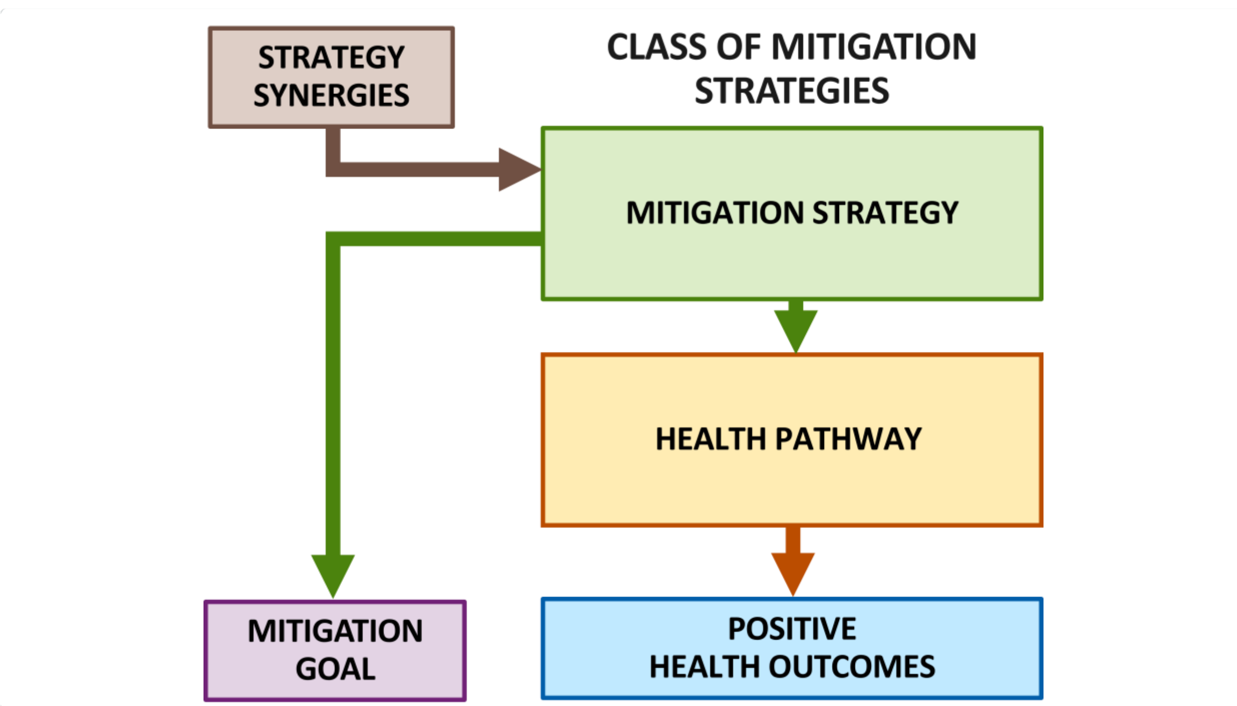


Figure 1: Diagram illustrates the way a climate change mitigation strategy may lead to positive health outcomes through a health pathway

Consider constructing bike lanes, for example. When more people bike to work instead of driving to work, it reduces greenhouse gas (GHG) emissions, improves air quality, and increases average levels of physical activity. In this example, improved air quality and increased physical activity are the specific health pathways that connect bike lane availability to positive health outcomes.[1] [2] [3] [4] Specifically, positive health outcomes from improved air quality include reduced morbidity from cancer, cardiovascular disease, respiratory disease, obesity, diabetes, and reproductive, neurological and immune system disorders.[5] [6] Positive health outcomes from increased physical activity include decreased Type 2 diabetes, cardiovascular diseases, respiratory diseases, and some cancers, as well as improved physical wellbeing and mental health.[7] [8] [9] [10] [11] [12] [13] [14] [15]

An increasing number of Americans are alarmed about climate change and believe global warming will increasingly harm health over the next 10 years.[16] For this reason, framing climate change in terms of public health may help build support for climate change mitigation and increase the likelihood that people will engage with the issue, especially when their perspective on climate change is cautious, disengaged, or dismissive.[17] Public health and allied professionals may make use of health pathways to design "win-win" interventions, policies, and programs that maximize benefits to both climate change mitigation and public health.

Transportation Mitigation Strategies

Two key transportation related mitigation strategies are active transportation and vehicle electrification. Health pathways associated with these strategies are improved air quality and increased physical activity. Examples of improved health outcomes include decreases in cancer, cardiovascular disease, respiratory disease, obesity, diabetes, and reproductive, neurological, and immune system disorders.

Active Transportation and Vehicle Electrification

Transportation is one of the largest contributors to U.S. greenhouse gas (GHG) emissions. According to the United States Environmental Protection Agency (EPA), transportation accounted for 29% of total U.S. GHG emissions in 2021.[18]

A variety of mitigation strategies can help reduce transportation-related GHG emissions. These strategies may include state and local actions that encourage less carbon-intensive modes of travel. Two mitigation strategies explored in this chapter are *active transportation* (Fig. 2) and *vehicle electrification* (Fig. 3). The health pathways associated with these strategies include improved air quality and increased physical activity.

The strategies, pathways, and outcomes identified below are based on a literature review of the health outcomes associated with specific climate change mitigation strategies.

Health Pathway Evidence Snapshots

Active Transportation

Active transportation is any kind of human-powered mobility, such as biking, walking, skateboarding, or using a mobility assistance device, like a wheelchair.[19] It also includes making use of human mobility to access public transportation. Mitigating climate change through active transportation is based on the concept of a modal shift, which is the shift from private, fossil fuel-powered vehicles to various forms of active transportation.

Encouraging active transportation may involve designing and building safer and more accessible streets, trails, and public transit systems, as well as improving active transportation infrastructure and accessibility. For example, interventions such as adding bike lanes to streets, adding curb cuts and extensions, and improving overall roadway infrastructure can help to facilitate more active transportation and physical activity.[20] [21]

Active transportation can improve health through increased physical activity.

Engaging in active transportation has been shown to increase levels of physical activity.[22] [23] [24] Several cross-sectional, longitudinal and systematic review studies have shown health benefits. Varying degrees of evidence support positive health outcomes associated with this strategy, including decreased Type 2 diabetes incidence, cardiovascular disease incidence and mortality, and some cancer incidence and mortality, as well as improved physical well-being and mental health.[25 26 27 28 29 30 31 32]

Active transportation can improve health through improved air quality.

Reducing car use and increasing modal shifts to active transportation improves air quality by reducing air pollutants generated by motor vehicles.[33] Positive health outcomes associated with improved air quality include decreases in cancer, cardiovascular disease, respiratory disease, obesity, diabetes, and reproductive, neurological, and immune system disorders.[34 35]

Exposure to air pollutants is also a long-standing environmental justice issue, because people from racial and ethnic minority groups (Black, Indigenous, and other people of color) and people with lower incomes or who experience poverty face higher exposure to air pollution and the associated negative health outcomes.[36 37 38 39 40]

Figure 2 illustrates health pathways and health outcomes associated with active transportation.

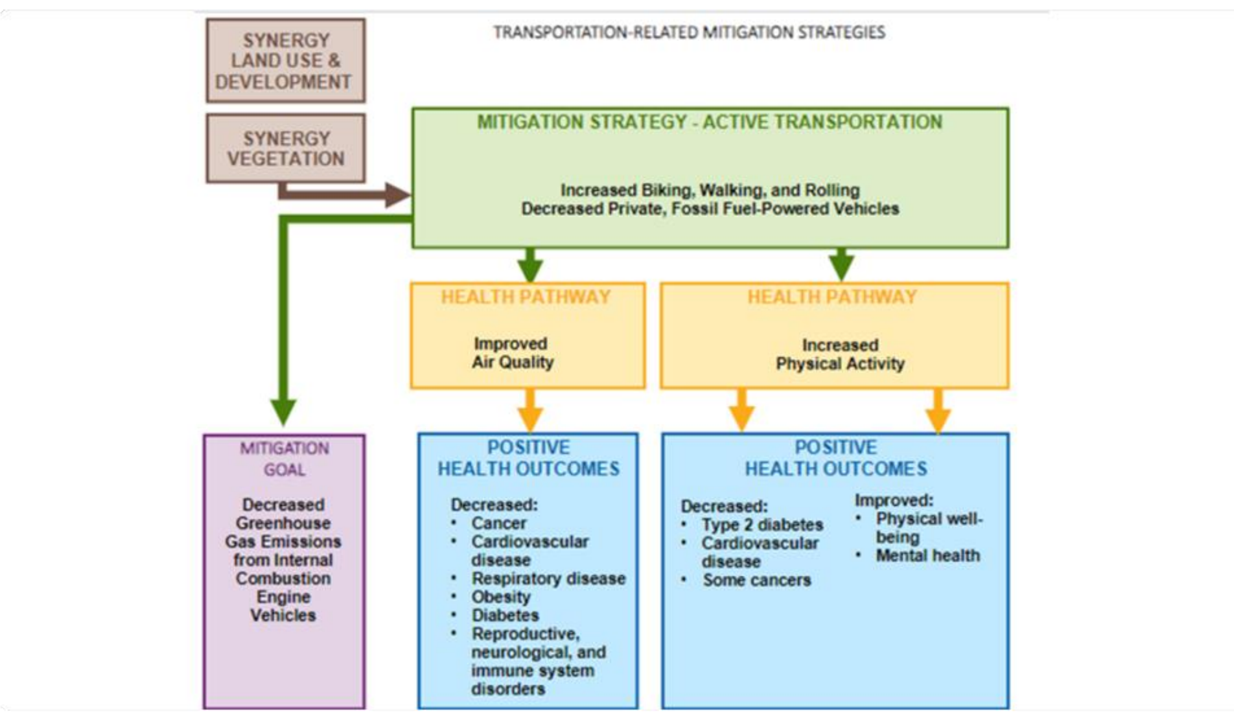


Figure 2. Diagram illustrating health pathways and health outcomes associated with active transportation

Vehicle Electrification

Vehicle electrification is the process of phasing out the use of vehicles that burn fossil fuels for power and phasing in the use of vehicles that are powered by electricity. Although there are potential benefits to vehicle electrification, this strategy may not entirely eliminate health risks because tire and brake wear will contribute to fine particulate matter (PM_2.5) due to the heavier weight of these vehicles compared to combustion engine vehicles.[41]

Vehicle electrification can improve health through improved air quality.

Electrifying vehicles reduces air pollutants generated by internal combustion engines.[23,24]Positive health outcomes associated with improved air quality and vehicle electrification include decreased mortality and decreased prevalence of chronic disease, such as asthma and cardiovascular disease.[42 43 44 45] Though not explicitly documented in research focused on vehicle electrification, positive health outcomes associated with improved air quality more broadly also included decreased respiratory disease, cancer, diabetes, and reproductive, neurological, and immune system disorders.[16] Exposure to air pollutants is an environmental justice issue, because people with lower-incomes and people from racial and ethnic minority groups face higher exposure to air pollution and the associated negative health outcomes. [46 47 48 49 50 51]

Figure 3 illustrates health pathways and health outcomes associated with vehicle electrification.

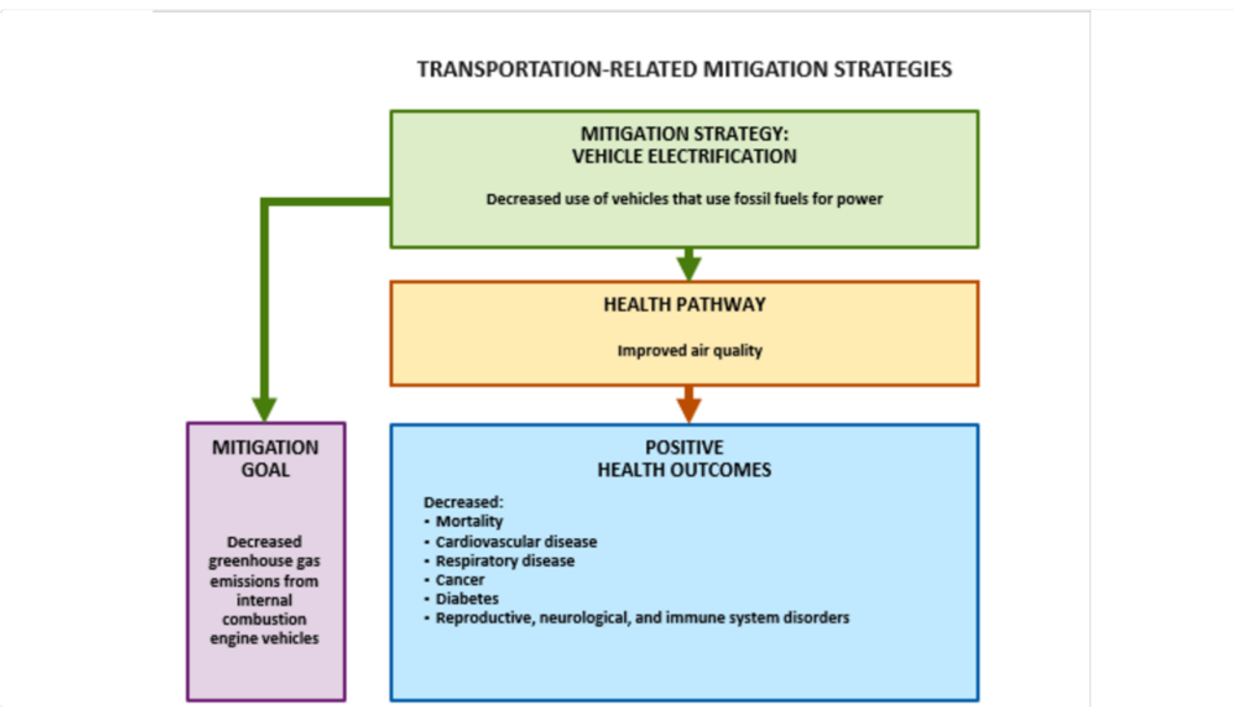


Figure 3. Diagram illustrating health pathways and health outcomes associated with vehicle electrification

Synergies with other Classes of Mitigation Strategies

Active transportation and vehicle electrification are closely associated with mitigation strategies related to land use and development and vegetation. At the local level, land use policies influence transportation connectivity, population density, and urban design, all of which may affect the shift from private motorized transportation to public and active transportation.[52] The presence and design of bicycle and pedestrian infrastructure, such as designated bike lanes and sidewalks, also influences active transportation. In planning and designing built environments, combining vegetation-related strategies with transportation mitigation strategies can simultaneously improve greenhouse gas (GHG) emissions, climate resilience, and public health.[53]

Conclusion

Transportation mitigation strategies show promise for reducing the impacts of climate change and improving public health. Increasing the use of active and public transportation and vehicle electrification are likely to produce positive health outcomes. Some benefits might result from combining these transportation mitigation strategies.

Vegetation Mitigation Strategies

Interventions that increase vegetation include expanding green infrastructure, green space, and tree canopy. Health pathways associated with these strategies include reduced heat exposure, improved air quality, and improved community resilience against extreme precipitation and flooding. Examples of improved health outcomes include decreased respiratory disease, cardiovascular disease, heat stress, and cancer.

Expanding Green Infrastructure, Green Space, and Tree Canopy

Vegetation-related climate change mitigation strategies include state and local actions that increase vegetation as a measure to absorb greenhouse gas emissions and reduce energy use. Typical interventions that increase vegetation include *expanding green infrastructure and green space* and *increasing tree canopy* (Fig. 4). The health pathways associated with these strategies include reduced heat exposure, improved air quality, and improved community resilience against extreme precipitation and other flood hazards.

The strategies, pathways, and outcomes identified below are based on a literature review of the health outcomes associated with specific climate change mitigation strategies. A supplemental review of published literature identified additional evidence on the outcomes associated with health pathways indicated for each mitigation strategy.

Health Pathway Evidence Snapshots

Green Infrastructure, Green Space, and Tree Canopy

Vegetation-related climate change mitigation strategies include actions to expand green infrastructure and green space, and to increase tree canopy. Green space is land partly or completely covered with grass, trees, shrubs, or other vegetation. It includes parks, community gardens, and cemeteries.[54] [55] Green infrastructure refers to an interconnected network of green space that conserves the value and functions of a natural ecosystem.[56]

Tree canopy is the percentage of land surface that is covered by treetops.[57] Tree planting can be used as a stand-alone mitigation strategy, or can be integrated into green spaces, green infrastructure, and green streets projects in urban areas.

Green infrastructure, green space, and tree canopy can improve health by reducing heat exposure.

Urban heat islands (UHI) contribute to heat-related deaths and heat-related illnesses.[58] Green infrastructure, green space, and tree canopy in urban areas can reduce ambient and surface temperatures by shading building surfaces, deflecting radiation from the sun, and releasing moisture into the atmosphere.[59] [60] [61] Increased tree canopy is associated with reductions in extreme air and land surface temperatures and decreased heat stress, decreased heat-related emergency calls, and improved thermal comfort.[62]

The effects of UHI are not experienced equitably, and there is a legacy of racist policies that limit many BIPOC communities' access to green space. For example, communities that were formerly **redlined** have less access to green space[63] and are surrounded by more nonpermeable surfaces, which are, on average, 2.6° C (36.7° F) hotter than communities that were not redlined.[64]

Green infrastructure, green space, and tree canopy can improve health through improved air quality.

Green infrastructure, green space, and tree canopy can improve air quality by catching particle pollutants on vegetation surfaces, reducing downwind exposure to air pollutants, and absorbing gaseous pollutants.[65] [66] [67] The effectiveness of this strategy is influenced by plant species, site characteristics, and climatic and environmental conditions. For example, pollution exposure can be reduced by strategically locating green infrastructure between pollution sources, such as traffic emissions, and receptors, such as pedestrian and cyclist pathways.[68] While the health outcomes of improved air quality through green infrastructure and green space remain to be adequately quantified, these strategies may result in decreased respiratory disease, cardiovascular disease, and cancer.[69] [70] [71] Trees may act as a trigger for allergies and asthma in some circumstances,[72] however the prudent selection of non-allergenic trees can help address this risk.[73]

Figure 4 illustrates health pathways and health outcomes associated with green infrastructure, green space, and tree canopy.

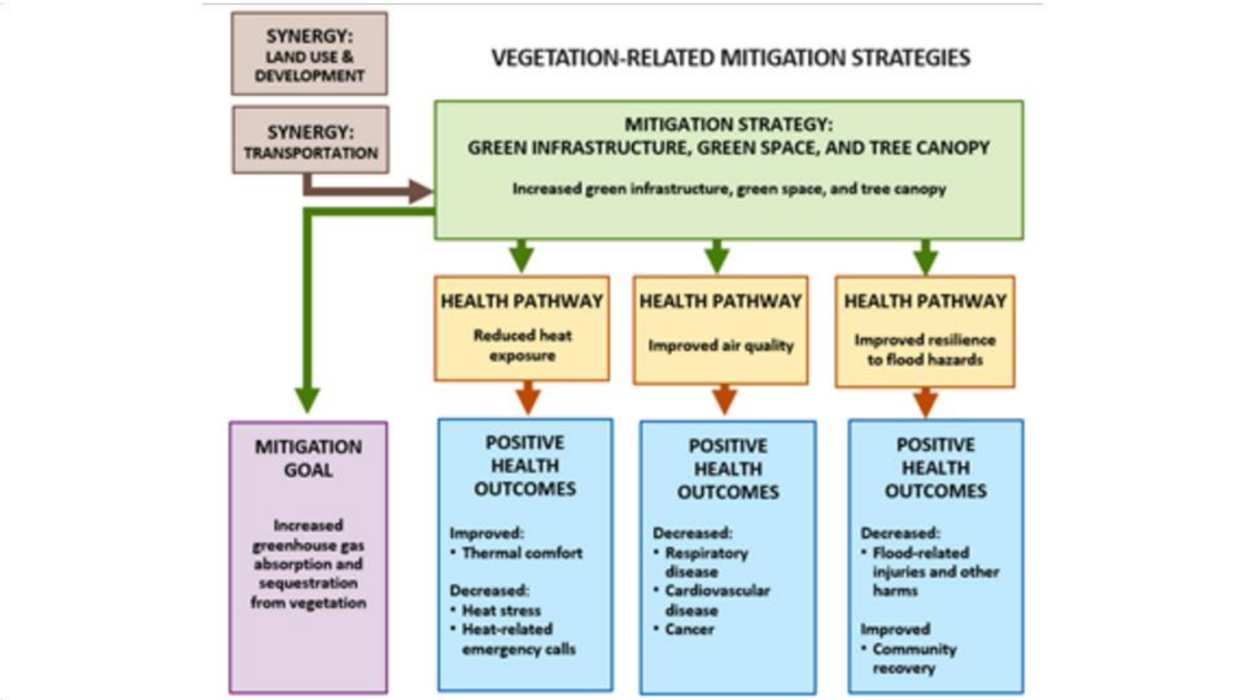


Figure 4. Diagram illustrating health pathways and health outcomes associated with green infrastructure, green space, and tree canopy

Synergies with Other Classes of Mitigation Strategies

Strategies that expand green infrastructure and green space, and which increase tree canopy, are closely associated with mitigation strategies related to land use and development and transportation. Land use policy can determine the location or amount of land in a particular neighborhood or jurisdiction that is usable for green infrastructure or green space. Approaches to transportation infrastructure such as green streets or complete streets combine designs for active transportation with the inclusion of trees and green infrastructure.

Conclusion

While vegetation-related mitigation strategies may have a range of potential positive health outcomes, more research is needed on how factors such as individual characteristics, the type of green space or green infrastructure, and the context of surrounding geography may mediate these outcomes. Still, vegetation-related mitigation strategies show promise for both mitigating climate change and supporting population health.

Building Systems and Performance-Related Mitigation Strategies

Building systems and performance-related mitigation strategies include green building, building weatherization, and phasing out fossil fuel-based indoor appliances. Associated health pathways include improved indoor and outdoor air quality, temperature regulation, lighting, and reduced energy burden. Examples of health outcomes include decreased respiratory symptoms and improved general physical and mental health.

Green Building, Building Weatherization, and Phasing Out Fossil Fuel-Based Indoor Appliances

The production of electricity used in commercial and residential buildings for heating, cooling, refrigeration, ventilation, lighting, and appliances is responsible for 36% of U.S. greenhouse gas emissions.[74]

Green building (Fig. 5)*, building weatherization* (Fig. 6), and *phasing out fossil fuel-based indoor appliances* (Fig. 7) are three building systems and performance-related mitigation strategies that may be applied at the state or local level. The health pathways associated with these strategies include improved indoor air quality, outdoor air quality, temperature regulation, and lighting, as well as reduced energy burden.

The strategies, pathways, and outcomes identified below are based on a literature review of the health outcomes associated with specific climate change mitigation strategies. A supplemental review of published literature identified additional evidence on the outcomes associated with health pathways indicated for each mitigation strategy.

Health Pathway Evidence Snapshots

Green Building

The Environmental Protection Agency (EPA) defines green building as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction."[75] Green buildings aim to improve occupant health through ventilation, materials selection, temperature control, and indoor lighting conditions.[76] The evidence identified for this mitigation strategy focuses heavily on buildings that are certified by the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system, which is a widely used system for evaluating green building.[77] However, the LEED rating system has faced some criticism due to its development by industry stakeholders rather than indoor- environment and public health research communities.[78] There are also other more recent rating systems focused on healthy buildings, or buildings that address a broad range of health behaviors and risks, such as Fitwel and Well. These rating systems have overlap and consistency with green building rating systems on relevant issues such as indoor air quality and lighting.[79]

Green building can improve health through improved indoor air quality and lighting.

Green building practices can improve indoor air quality and lighting through window design, temperature and ventilation systems, and the selection of building materials.[80] These building features may also impact health outcomes. For example, one study found that in comparison to conventional housing, living in green homes reduced the number of symptoms adults experienced from sick building syndrome. It also found that children with asthma living in green buildings were at lower risk of asthma-related health concerns, including symptoms, attacks, hospital visits, and school absences.[81] Green buildings may also improve productivity and cognitive test performance—outcomes associated with improvements in ventilation and reduced exposure to volatile organic compounds and carbon dioxide.[82]

Green building can improve health through improved outdoor air quality.

Green buildings can improve outdoor air quality through reduced emissions from electricity generation and on-site fuel use. By reducing harmful air pollutants, energy efficient buildings in the United States were estimated to have averted between 172 and 405 premature deaths, 171 hospital admissions, 11,000 asthma exacerbations, 54,000 respiratory symptoms, 21,000 lost days of work, and 16,000 lost days of school from 2000 to 2016.[83]

Figure 5 illustrates health pathways and health outcomes associated with green building.

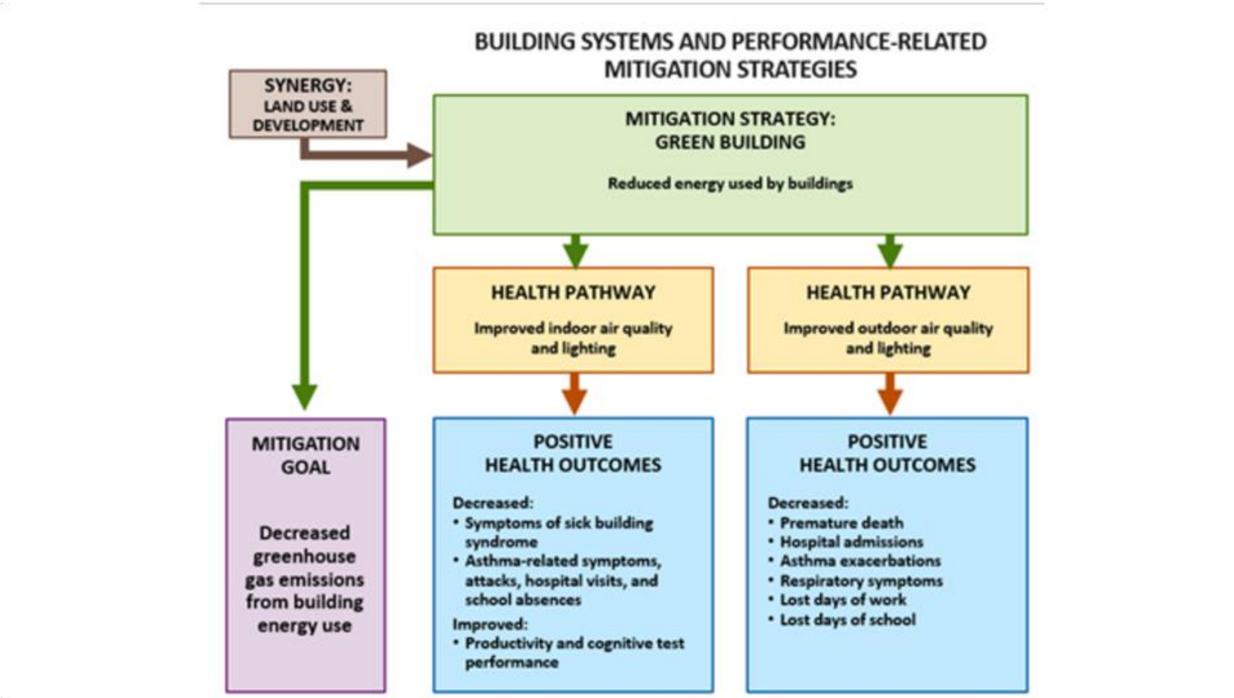


Figure 5. Diagram illustrating health pathways and health outcomes associated with green building

Building Weatherization

Weatherization refers to strategies that increase a building's energy efficiency by upgrading the building envelope, heating, cooling, and electrical systems.[84] [85] In one systematic review and meta-analysis, interventions to increase household energy efficiency, such as heating, insulation, sealing measures, and glazing, were associated with small but significant positive improvements on the health and well-being of residents.[86]

Building weatherization can improve health through improved indoor air quality and temperature regulation.

Weatherization strategies that ensure adequate ventilation can improve indoor air quality by reducing levels of radon, mold, bacteria, house dust mites, volatile organic compounds, formaldehyde, carbon dioxide, carbon monoxide, and black carbon.[87] These strategies can also help maintain comfortable indoor temperatures.[88] [89] [90] [91] [92] Positive health outcomes related to building weatherization include thermal comfort improvements, decreased respiratory and asthma symptoms, and improvements in general physical and mental health.[93] [94] [95] [96] [97]

Weatherization strategies must ensure adequate ventilation to prevent the presence of indoor air pollutants from mold, pollen, dust, smoke, animal droppings, viruses, or bacteria from exacerbating illnesses.[98] A 2022 systematic review found that airtight construction and insulation without mechanical ventilation may have adverse health effects, including increased indoor radon levels. Mechanical ventilation can alleviate these issues but may increase exposure to outdoor pollutants when ambient air quality is poor.[99]

Building weatherization can improve health through reduced energy burden.

Energy burden is the percentage of household income spent on energy costs.[100] Households with high energy burden are unable to meet basic household energy needs, such as heating and cooling, in their home.[101] High energy burden among people with lower incomes may exacerbate a variety of health conditions, including reduced general health, mental health, and respiratory health; building weatherization may reduce indoor sources of asthma triggers.[102 103] Weatherization can reduce energy burden by increasing a building's energy efficiency and reducing the amount of money spent on heating and cooling.[104]

Figure 6 illustrates health pathways and health outcomes associated with building weatherization.

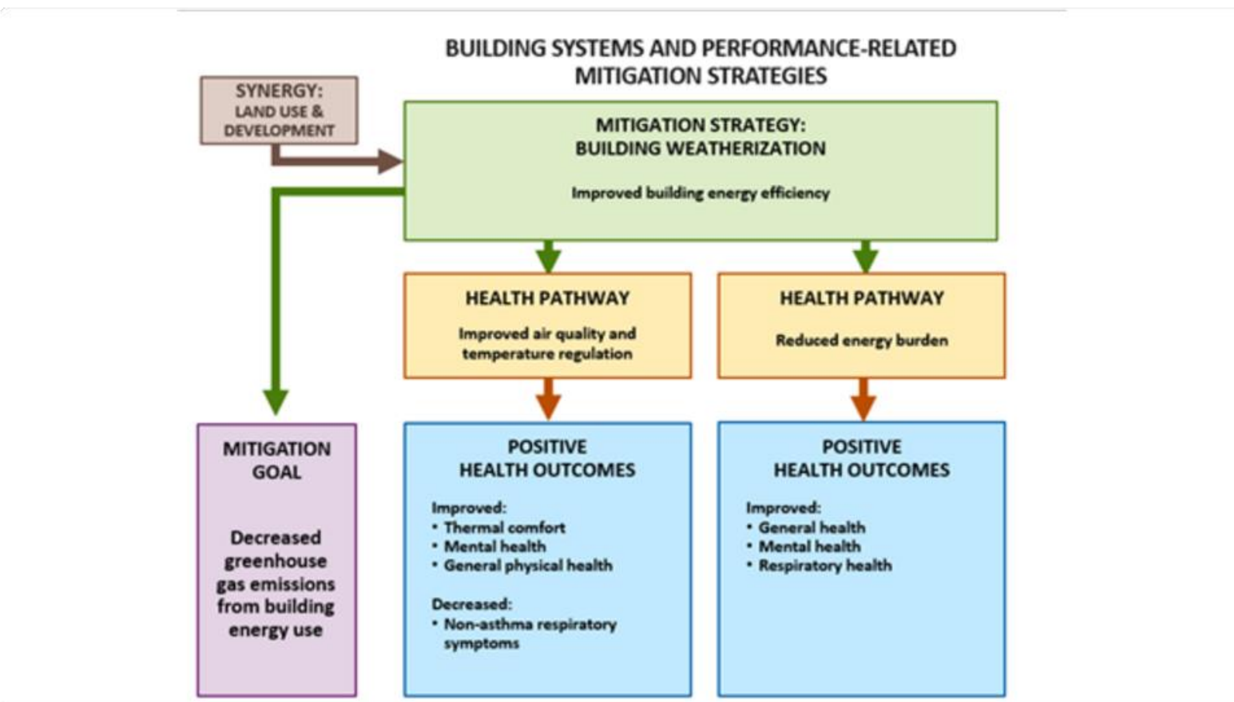


Figure 6. Diagram illustrating health pathways and health outcomes associated with building weatherization

Phasing Out Fossil Fuels for Indoor Appliances

Fossil fuels that are used to heat indoor spaces and to operate appliances such as ovens, stoves, and dryers can be reduced or eliminated.

Phasing out fossil fuel-using indoor appliances can improve health through improved indoor air quality.

Gas stoves can be a source of indoor air pollutants. Use of gas for cooking may be associated with some negative respiratory health outcomes when compared to electric stoves, including increased risk of pneumonia and chronic obstructive pulmonary disease.[105] [106] However, there is variability across studies. The relationship between gas stoves and negative respiratory outcomes differs by study context, study population, and the specific outcome examined.[107]

Burning fossil fuels, such as oil, natural gas or propane, to heat homes emits particulate matter.[108] A modeling study in New York City estimated that the phase-out of high-sulfur heating fuels could potentially prevent 290 decreased respiratory and asthma symptoms, and improvements in general physical and mental health, and 550 emergency department visits for asthma every year.[109]

Figure 7 illustrates health pathways and health outcomes associated with phasing out fossil fuel-indoor appliances.

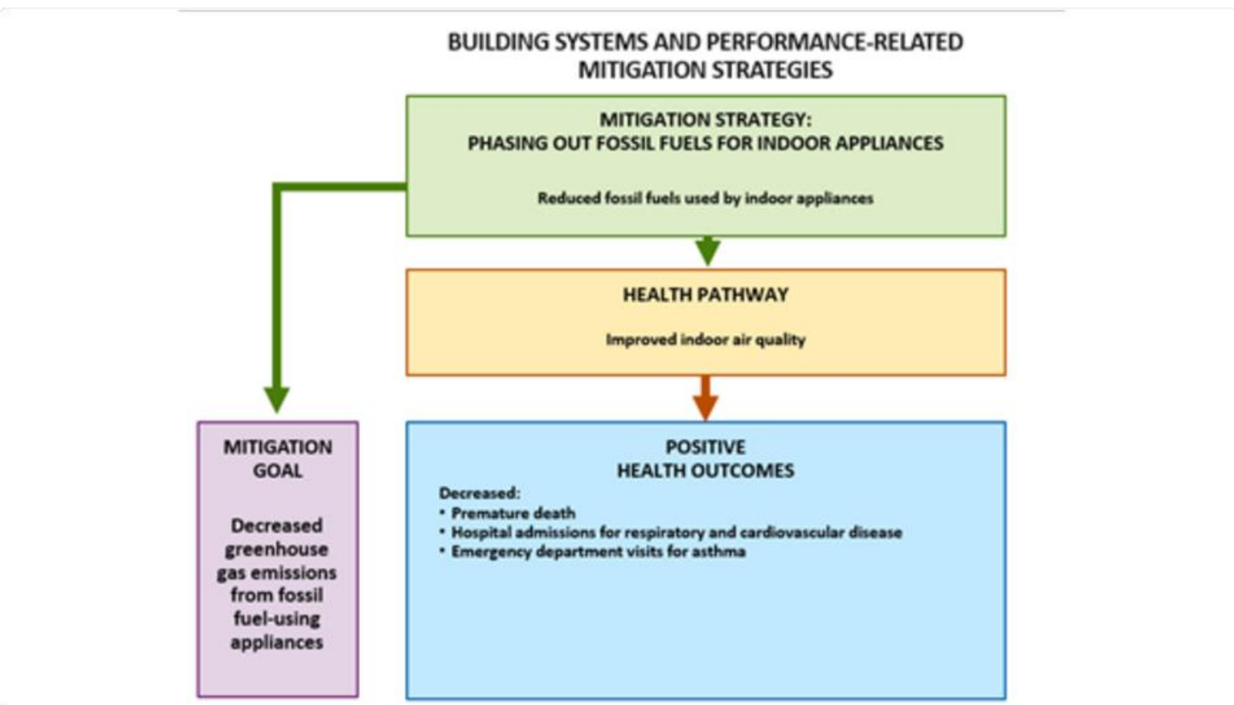


Figure 7. Diagram illustrating health pathways and health outcomes associated with phasing out fossil fuel-using indoor appliances

Synergies with Other Classes of Mitigation Strategies

Building systems and performance-related mitigation strategies are closely connected with land use and development. Zoning and land use regulations influence building design and permitted uses, and therefore are significant policy levers for affecting health outcomes associated with building-scale climate change mitigation measures. Additionally, policy goals articulated in planning documents are significant levers to potentially advance sustainable building construction practices and systems.

Conclusion

Building systems and performance-related climate change mitigation strategies show the potential for a range of positive physical and mental health outcomes. Increased understanding of how isolated specific, isolated building strategies (as opposed to clustered strategies that are captured by LEED- or other types of certifications for green building) and features may mediate health outcomes could inform future public health action. However, building systems and performance-related mitigation strategies show promise for both mitigating climate change and supporting population health.

Waste Management Mitigation Strategies

Waste management climate change mitigation strategies include reducing solid waste incineration and reducing waste generation. Health pathways associated with these strategies include improved air quality and reduced exposure to toxicants, respectively. Evidence about improved health outcomes associated with these strategies is emerging.

Reducing Solid Waste Incineration and Waste Generation

An important aspect of the built environment is waste management—processes that follow waste from inception to its collection, treatment, and final disposal—as well as the transportation required at each stage. Landfills are the largest waste management-related source of GHG emissions, and account for approximately 17.1% of total U.S. methane emissions.[110]

Waste management-related climate change mitigation strategies include reducing solid waste incineration (Fig. 8) and reducing waste generation (Fig. 9). The health pathways associated with these strategies include improved air quality and reduced exposure to toxicants, respectively.

The strategies, pathways, and outcomes identified below are based on a literature review of the health outcomes associated with specific climate change mitigation strategies. A supplemental review of published literature identified additional evidence on the outcomes associated with health pathways indicated for each mitigation strategy.

Health Pathway Evidence Snapshots

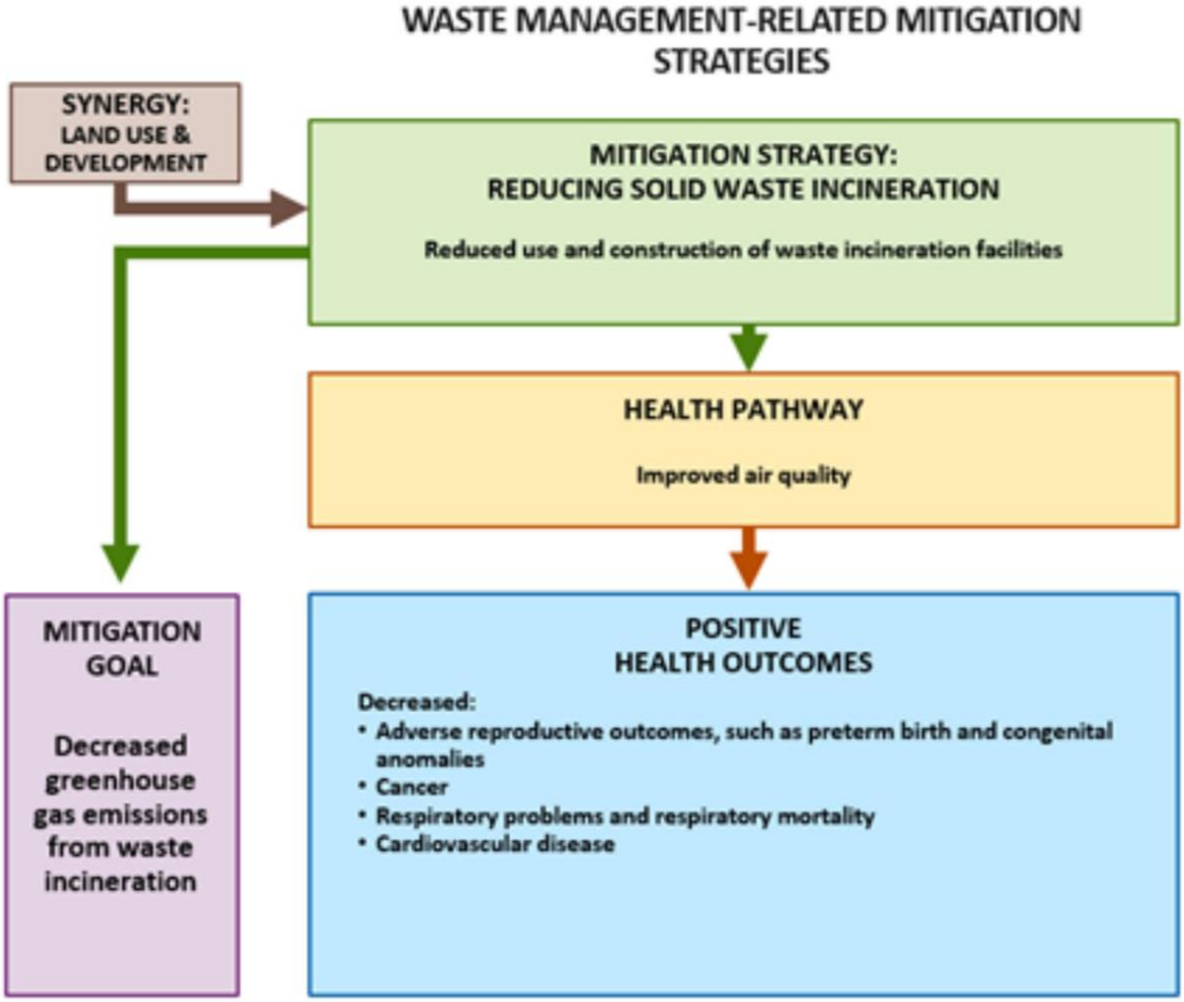
Reducing Solid Waste Incineration

One climate change mitigation strategy related to waste management involves reducing solid waste incineration by closing existing incineration facilities and banning the construction of new ones. Waste management efforts can redirect waste from incineration facilities toward more sustainable technologies such as recycling or composting and can encourage improved product design to support reuse.

Reducing solid waste incineration can improve health through improved air quality.

Waste incineration is associated with the release or creation of harmful pollutants such as particulate matter, lead, dioxins, and mercury.[111] These pollutants are known to have adverse effects on health.[112] Living near landfills or waste incinerators has been significantly associated with increased risk of adverse reproductive outcomes, including preterm birth and congenital anomalies.[113] [114] [115] [116] Exposure to pollutants from waste incineration may also be associated with cancer,[117] [118] [119] [120] respiratory problems that include respiratory mortality,[121 122 123] and cardiovascular disease.[124 125 126] However, studies exploring the health effects of incinerators have been inconsistent due to poor research methodologies or lack of reported information on specific incinerator technologies.[127]

Figure 8 illustrates health pathways and health outcomes associated with reduced use and construction of waste incineration facilities.



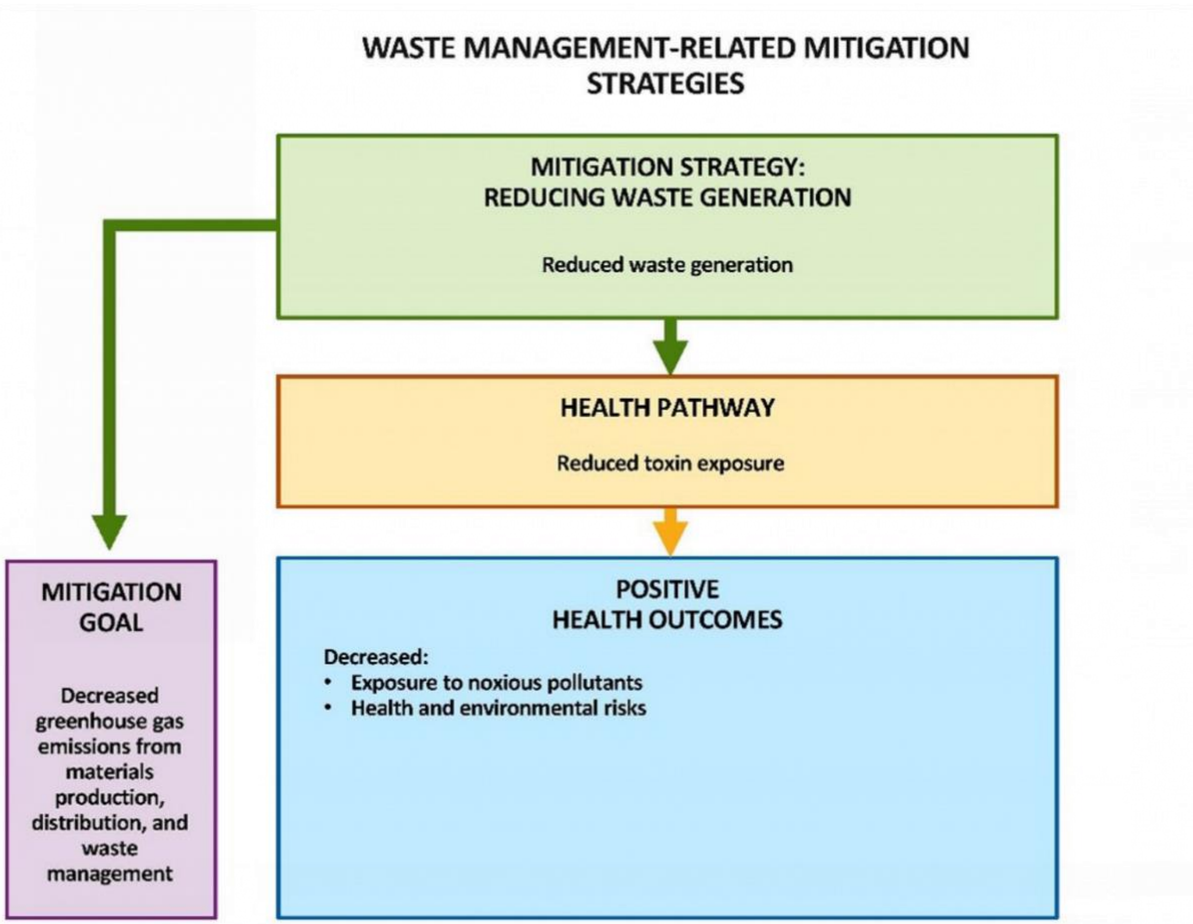
Reducing Waste Generation

This strategy can include putting measures in place that promote or require zero waste practices, such as passing waste reduction legislation.[128] It may also involve fostering a culture of reduced waste generation through community and commercial outreach,[129 130 131] and shifting cultural norms to align with zero waste practices and strategies.[132]

Reducing waste generation can improve health through reduced exposure to toxins.

There is evidence for a potential relationship between the volume of waste stored in landfills and negative health impacts, as well as the contamination of bodies of water, soil, and vegetation.[133] People who live and work near waste sites may be exposed to noxious pollutants, and thus may have higher health and environmental risks compared to those residing a greater distance away from landfills.[134]

Figure 9 illustrates health pathways and health outcomes associated with reduced waste generation.



Synergies with Other Classes of Mitigation Strategies

Waste management-related mitigation strategies intersect with food systems (e.g. food packaging and waste) and land use (e.g. where waste management sites or facilities are located).

Conclusion

Literature on waste management does not focus on the potential for positive health outcomes resulting from mitigation strategies, but instead focuses on hazards resulting from exposure pathways. Additional research on this promising set of strategies could be helpful for understanding the positive health outcomes of waste management practices that also mitigate climate change.

Food Systems Mitigation Strategies

Food systems mitigation strategies include sustainable agriculture, local food production and distribution, and promoting dietary changes. Health pathways associated with these strategies include improved air quality, food system resilience to global crises, and nutrition.

Examples of improved health outcomes include decreased morbidity from cancer, cardiovascular disease, respiratory disease, and diabetes.

Sustainable Agriculture, Local Food Production and Distribution, and Promoting Dietary Changes

Agricultural sources of emissions, such as livestock, agricultural soils, and rice production, accounted for 10.6% of U.S. greenhouse gas emissions in 2021.[135] Actions may be taken on a state and local level to mitigate climate change through all stages of the food system, including pre- production, production, post-production, consumption, loss, waste, and disposal.[136] Food systems-related mitigation strategies include sustainable agriculture (Fig. 10), local food production and distribution (Fig. 11), and promoting dietary changes (Fig. 12). The potential health pathways associated with food system mitigation strategies include improved air quality, food system resilience to global crises, and nutrition.

The strategies, pathways, and outcomes identified below are based on a literature review of the health outcomes associated with specific climate change mitigation strategies. A supplemental review of published literature identified additional evidence on the outcomes associated with health pathways indicated for each mitigation strategy.

Health Pathway Evidence Snapshots

Sustainable Agriculture

Sustainable agriculture strategies involve shifting pre-production and production practices to reduce the use of manufactured agricultural inputs (such as synthetic fertilizers and biocides) and increase sustainable agriculture practices (such as using animal feed with reduced nitrogen and practices that use less resources to produce more food).[137]

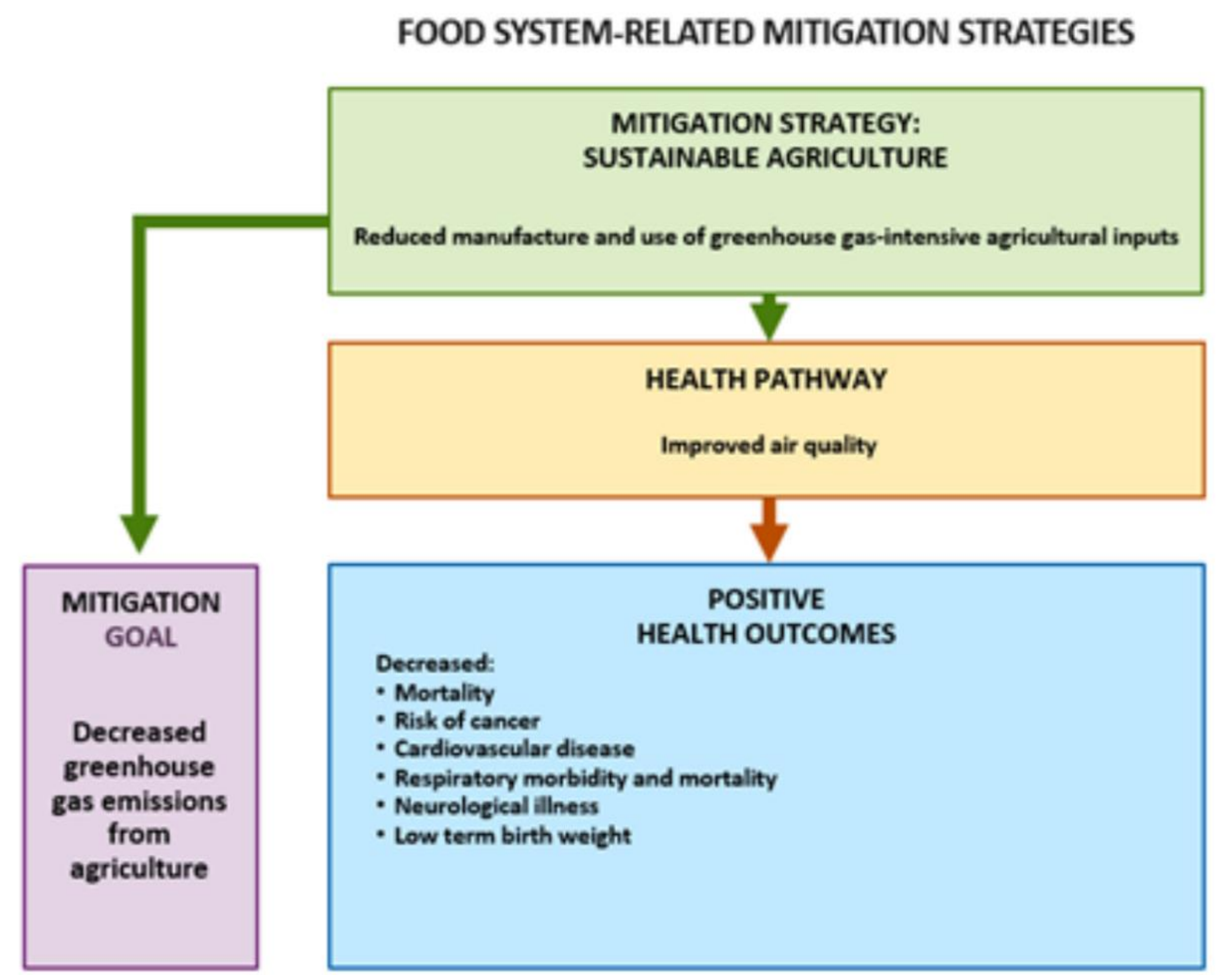
Sustainable agriculture can improve health through improved air quality.

Agriculture is responsible for about half of the total fine particulate matter (PM2.5) air pollution in the United States.[138] These pollutants mostly come from manure processing and decomposition and (to a lesser extent) fertilizer use[139 140] and they are both the largest relative contributor to PM2.5) air pollution and the leading cause of mortality attributable to PM2.5 air pollution in the United States.[141] Positive health outcomes associated with more sustainable agricultural practices include decreased mortality and additional health benefits associated with reduced PM2.5, largely in connection with reduced ammonia emissions.[142] [143] Negative health outcomes associated with exposure to various agriculture- related air pollutants include increased risk of cancer,[144] cardiovascular illness[145] [146] respiratory morbidity and mortality,[147] [148] neurological illness,[149] and low-term birth weight.[150]

Emerging Evidence in Detail: Sustainable agriculture and air quality

Using low-nitrogen animal feed and other agricultural practices that reduce emissions from agriculture can reduce adverse health impacts such as mortality associated with ammonia and high PM 2.5 concentrations.

Figure 10 illustrates health pathways and health outcomes associated with sustainable agriculture.



Local Food Production and Distribution

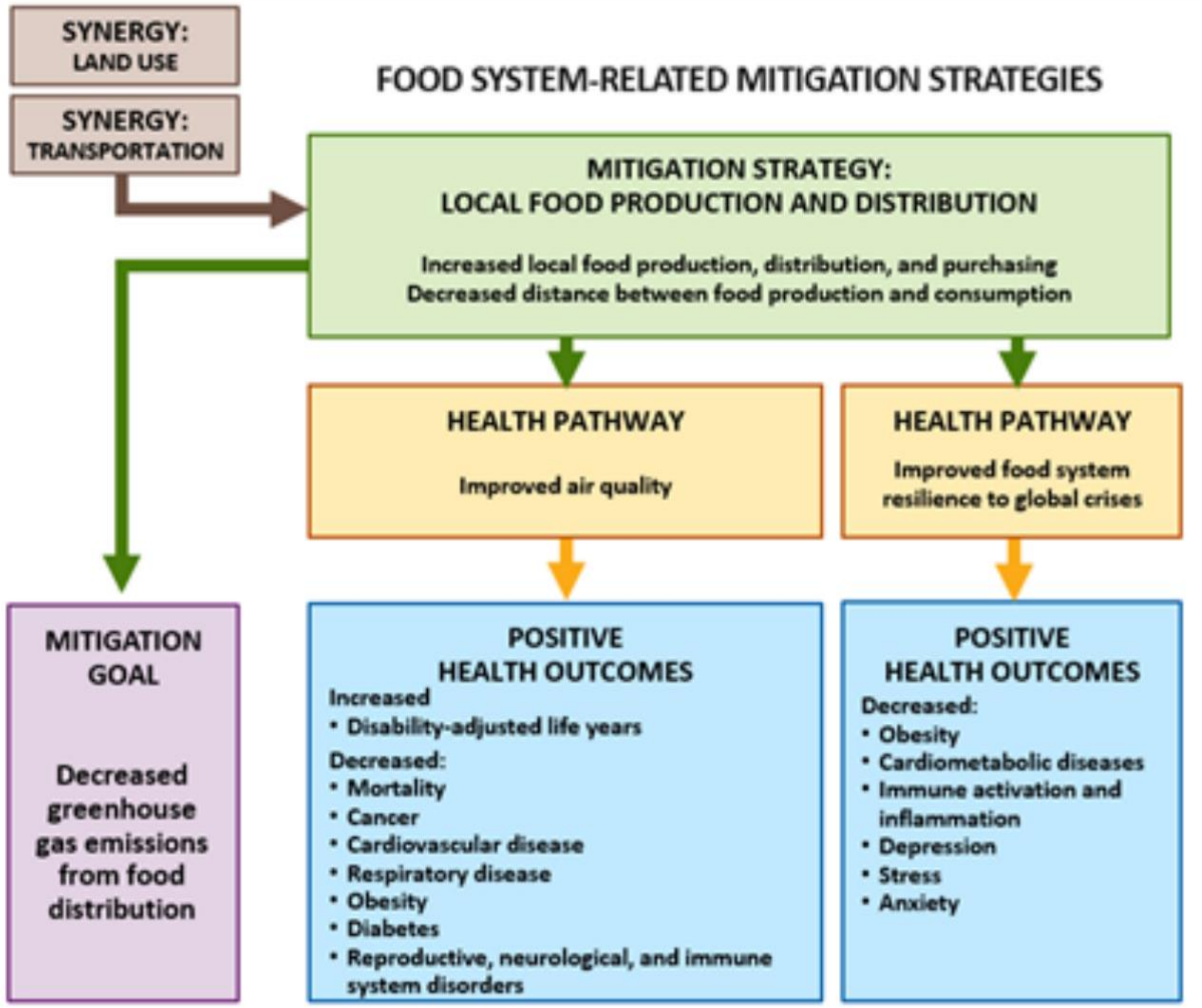
This set of strategies includes efforts to connect consumers with locally and regionally produced food through farmers' markets, community supported agriculture, institutional food purchasing strategies (also known as procurement), and other policies and practices. This can also involve using strategies related to land use to produce and/or sell more food near homes and job centers

Local food production and distribution can improve health through improved air quality.

The farther food is grown from where it is consumed, the more it must travel. Compact development reduces vehicle travel and vehicle-related emissions such as CO2, NOx, and PM2.5.14 Reducing these emissions can increase disability-adjusted life years (DALYs), and decrease mortality.[151] Positive health outcomes associated with improved air quality include decreased morbidity from cancer, cardiovascular disease, respiratory disease, obesity, diabetes, and reproductive, neurological, and immune system disorders.[152 153]

Note that only 11% of total food system-related GHG emissions in the United States are from the distribution of food and agricultural input.[154]

Figure 11 illustrates health pathways and health outcomes associated with local food production and distribution.



Shifting from Animal-Based to Plant-Based Food Production

Producing animal protein generates more GHG emissions than producing plant protein.[155] This strategy includes actions to reduce GHG emissions from agriculture by promoting dietary patterns that include less meat and more plant-based foods.

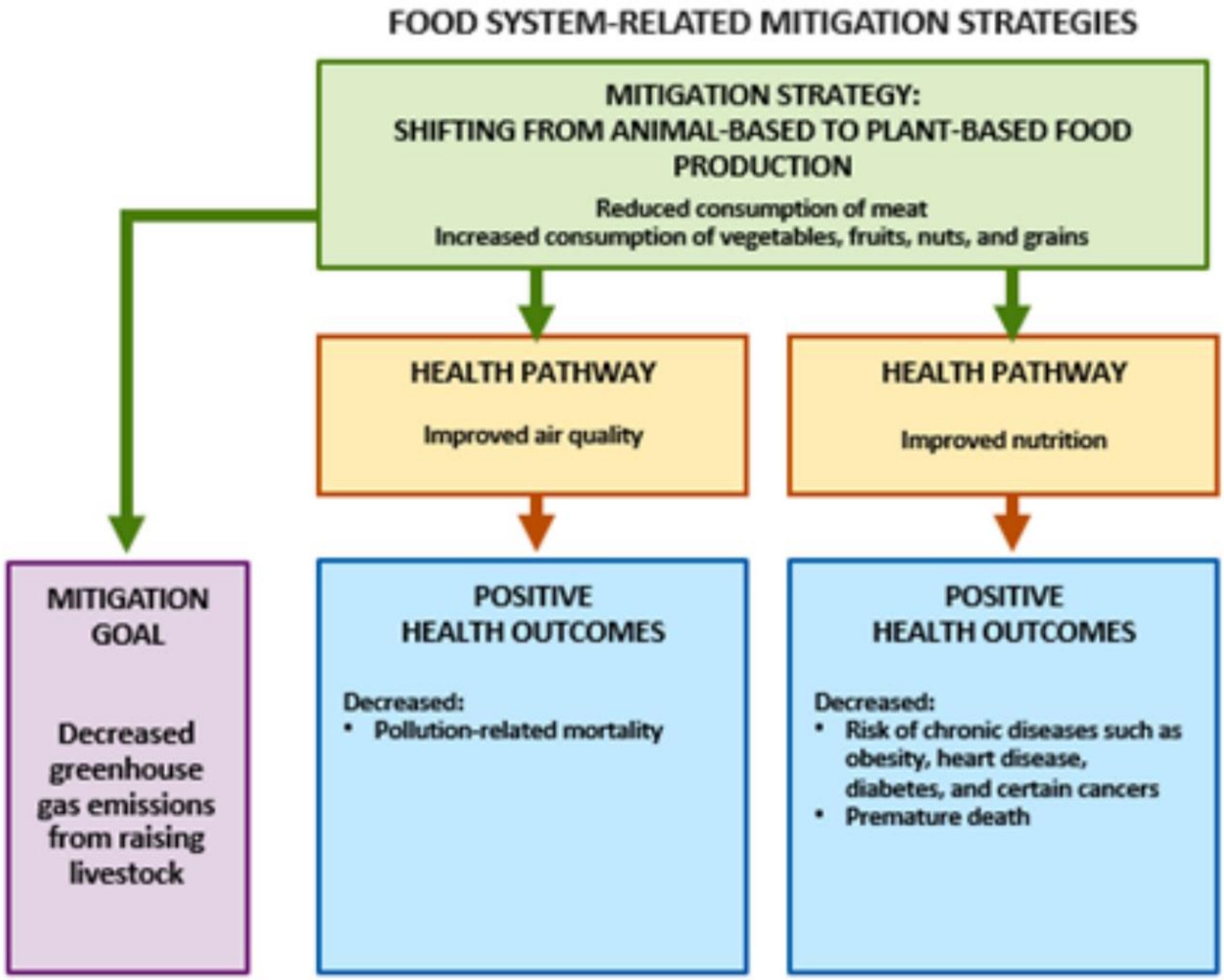
Shifting from animal-based to plant-based food production can improve health by supporting dietary patterns that include more plant-based components.

Many studies discuss the health benefits of vegetarian and semi-vegetarian diets. Dietary patterns associated with positive health outcomes include higher intake of plant-based food such as vegetables, fruits, legumes, and nuts and low consumption of red and processed meats.[156] Health benefits associated with vegetarian and semi-vegetarian diets in particular include increased life expectancy and lower risk of chronic diseases such as obesity, heart disease, diabetes, and certain cancers.[157] [158] [159] [160] [161] An analysis of the Adventist Health 2 Study found that the mortality rate for nonvegetarians is 20% higher than for vegetarians.[162] A global systematic analysis conducted across 21 regions from 1990 to 2010 concluded that "increased consumption of whole grains, vegetables, nuts and seeds, and fruit could prevent 1.7 million, 1.8 million, 2.5 million, and 4.9 million premature deaths per year, respectively, via the beneficial effects on chronic disease risk factors."[163]

Shifting from animal-based to plant-based food production can improve health through improved air quality.

The air-quality impacts of agriculture in the U.S. are largely driven by PM2.5 pollution in connection with animal-based food production.[164] One study estimated that 17,900 deaths per year can be attributed to U.S. agriculture due to reduced air quality, mainly from livestock waste, fertilizer, and PM2.5 pollution.[165]

Figure 12 illustrates health pathways and health outcomes associated with shifting from animal-based to plant-based food production.



Synergies with Other Classes of Mitigation Strategies

Food systems-related mitigation strategies intersect with transportation (how food is transported and how it must travel), and land use (where food production, distribution, and food waste processing are sited in communities and across regions).

Conclusion

Food systems-related mitigation strategies show promise for both mitigating climate change and supporting population health. More research is needed to better understand the specific, positive health outcomes associated with these strategies.

Land Use and Development Mitigation Strategies

Compact and connected development involves planning and designing dense, mixed-use neighborhoods that support other mitigation strategies. Health pathways associated with land use and development include improved air quality and increased physical activity. Examples of improved health outcomes include reduced cardiovascular disease, respiratory disease, and diabetes.

Compact and Connected Development

Land use and development-related climate change mitigation strategies include updating regulations at the state and local level, such as zoning, subdivision codes, and form-based codes. These strategies may also include updating planning documents, such as comprehensive plans and master plans. These regulations and planning documents establish goals, policies, actions, standards, and guidelines that shape development patterns, infrastructure, transportation networks, open space, and many other aspects of the built environment. The primary land use and development-related mitigation strategy is compact and connected development (Fig. 13), which involves planning and designing dense, mixed- use neighborhoods with buildings, streets, and open spaces that are coordinated to support other mitigation strategies such as active transportation and expanding green infrastructure, green space, and tree canopy. See the "Synergies With Other Classes of Mitigation Strategies" section in this chapter for more detail about the relationships between these different strategies.

The health pathways associated with land use and development include improved air quality and increased physical activity.

The strategies, pathways, and outcomes identified below are based on a literature review of the health outcomes associated with specific climate change mitigation strategies. A supplemental review of published literature identified additional evidence on the outcomes associated with health pathways indicated for each mitigation strategy.

Health Pathway Evidence Snapshots

Compact and Connected Development

Building compact and connected development involves planning and regulating characteristics of the built environment (e.g. the design of buildings and open spaces and the distribution and intensity of land uses) in ways that align with the design of transportation infrastructure to support active transportation.

In addition to the design of transportation infrastructure, the following characteristics of the built environment can influence travel behavior in ways that support active transportation:

Mixed-use development locates a variety of origins and destinations in close proximity to each other:

- Dense or clustered development reduces the distance between origins and destinations, or clusters a greater number of destinations close to each other;
- Street networks with smaller blocks and more connections create more direct routes between origins and destinations;
- Transit-oriented development improves access to transit and reduces the distance between transit stops and origins or destinations; Distribution and location of public open spaces increase access by active transportation;
- Buildings that are located close to, connected to, and oriented to sidewalks increase access to buildings by walking or rolling; and Building design that improves the pedestrian-scale experience can encourage active transportation.

Because these characteristics of the built environment are highly interrelated, health pathways associated with these characteristics are complex. The amount and type of evidence that supports each step in health pathways associated with compact and connected development varies. And this evidence is distributed across multiple disciplines including climate change mitigation, land use planning, transportation planning, and public health.

Compact and connected development can improve health through increased active transportation related physical activity.

Higher levels of active transportation-related physical activity have been found in built environments that combine compact and connected development with active transportation infrastructure.[166] Several cross-sectional, longitudinal and systematic review studies have shown health benefits of active transportation-related physical activity. Varying degrees of evidence indicate positive health outcomes, including decreased Type 2 diabetes incidence, cardiovascular disease incidence and mortality, and some cancer incidence and mortality, as well as improved physical well-being and mental health.[167] [168] [169] [170] [171] [172] [173] [174]

Other research has examined the relationship between compact and connected development and health outcomes without explicit measurement of physical activity. Compact and connected street networks (characterized by the density of the street network, the level of connectivity between destinations, and the overall configuration) have been associated with reduced rates of obesity, diabetes, high blood pressure, and heart disease.[175] A land use health impact assessment indicated that a compact city scenario (characterized primarily by land use density, land use diversity, and public transit accessibility) was associated with health gains in cardiovascular disease, respiratory disease, and diabetes.[176] Evidence also associates compact and connected built environments with healthy weight.[177] Other evidence draws connections between suburban sprawl and obesity.[178] [179] [180]

See the “Transportation” sub-section in “Synergies with Other Classes of Mitigation Strategies” section of this chapter for more information about health outcomes associated with physical activity related to modal shift.

Increased active transportation-related physical activity due to compact and connected development may also improve health through a secondary pathway of social cohesion. Land use diversity or mixed-use development may have positive impacts on social cohesion.[181] One study documented a higher sense of community among those who live in places with locally serving retail within a walkable distance, compared to those living in areas that require vehicular transportation with nonlocally serving shops and services.[182] A systematic review of reviews found positive correlations between social cohesion and physical activity and healthy weight, and between social capital and healthy weight and between social interaction and mental health outcomes.[183]

Compact and connected development can improve health through improved air quality.

Compact and connected development can improve air quality by shaping built environments in ways that encourage modal shift from private vehicular transportation to active transportation, including walking, cycling, public transportation, and multimodal combinations.[184] Compact and connected development can also improve air quality by influencing patterns of development in ways that enable increased green infrastructure, green space, and tree canopy.

Positive health outcomes associated with improved air quality include decreased morbidity from cancer, cardiovascular disease, respiratory disease, obesity, diabetes, and reproductive, neurological, and immune system disorders.[185] [186]

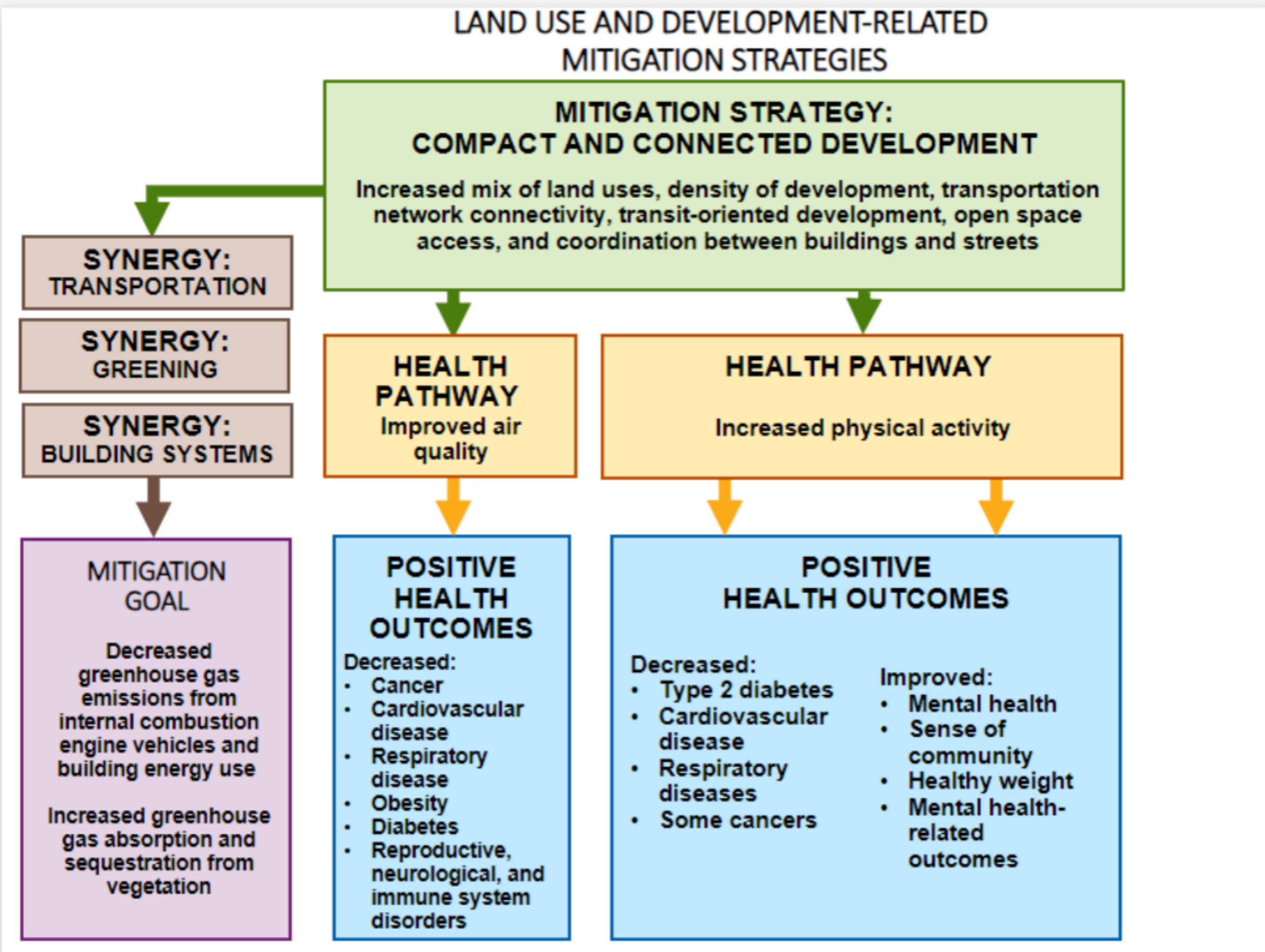
See transportation-related mitigation strategies for more information about health outcomes associated with improved air quality from active transportation.

See vegetation-related mitigation strategies for more information about health outcomes associated with improved air quality from expanding green infrastructure and green space.

Potential negative health outcomes of compact and connected development

The relationship between urban density and health is complex. In some dense, urban contexts, increased density is associated with increased exposure to stressors such as heat, light, air, and noise pollution. These factors can have negative impacts on health.[187] Dense environments that encourage walkability and transit access may also increase exposure to environmental pollution and injury risk, which can have compounding impacts on health over time.[188] Physical density, social density, and transit connectedness may have negative impacts on social cohesion.[189]

Figure 13 illustrates health pathways and health outcomes associated with compact and connected development.



Synergies with Other Classes of Mitigation Strategies

Land use and development regulations significantly influence patterns of development (i.e., the location, density, diversity, and design of buildings and infrastructure). Different patterns of development can shape the availability of, and access to, social determinants of health such as housing, jobs, transportation, open space, and food. There is a particularly strong synergy between land use and development-related mitigation strategies and those related to transportation, building systems and performance, and vegetation.

Transportation

Land use and development strategies shape the intensity, mix, distribution, and design of buildings. These characteristics of the built environment influence travel behaviors and can either support or create barriers to increasing active transportation and reducing use of private motor vehicles (also known as modal shift).[190]

See the “Active Transportation” section of the “Transportation Mitigation Strategies” chapter for more information about the health outcomes of active transportation.

Vegetation

Taking actions to create dense and clustered development in urban areas can potentially reduce the total area of land covered by buildings and pavement. If more attention is paid to land management and preservation, this may free up more area for green infrastructure, green space and tree canopy.[191] Dense, mixed-use development is also correlated with active transportation,[192] which may reduce demand for parking infrastructure, freeing up space to increase vegetation through green infrastructure, green space, and trees. Land use regulations, such as zoning, can determine how much built or paved surface is required to park vehicles in each development. These regulations can also establish how much and what kind of green space and tree canopy is required as part of development. Finally, they can establish where different types of green spaces are permitted and can preserve or designate land to be used as green space.

See vegetation-related mitigation strategies for more detail on the health outcomes associated with increasing vegetation.

Building Systems and Performance

Land use regulations govern many characteristics of building design, site design, and construction that can be used to mitigate climate change, such as permitted density, open space requirements, parking regulations, permitted uses, glazing requirements, building orientation, and architectural design. Zoning requirements can either require, facilitate, and encourage green building and weatherization practices, or they can make them challenging to incorporate.

See building systems and performance-related mitigation strategies for more detail on health outcomes associated with green building and weatherization.

Conclusion

Land use and development-related climate change mitigation strategies show the potential for a range of positive physical and mental health outcomes. There is a growing understanding of how layered strategies, such as mixed-use development and densification, can support a range of positive health outcomes through increased physical activity and improved air quality, along with ancillary benefits such as social cohesion and a greater sense of community. Compact and connected development shows promise for both mitigating climate change and supporting population health.

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