The Built Environment, Climate Change, and Health
Opportunities for Co-Benefits

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Abstract: The earth's climate is changing, due largely to greenhouse gas emissions resulting from human activity. These human-generated gases derive in part from aspects of the built environment such as transportation systems and infrastructure, building construction and operation, and land-use planning. Transportation, the largest end-use consumer of energy, affects human health directly through air pollution and subsequent respiratory effects, as well as indirectly through physical activity behavior. Buildings contribute to climate change, influence transportation, and affect health through the materials utilized, decisions about sites, electricity and water usage, and landscape surroundings. Land use, forestry, and agriculture also contribute to climate change and affect health by increasing atmospheric levels of carbon dioxide, shaping the infrastructures for both transportation and buildings, and affecting access to green spaces. Vulnerable populations are disproportionately affected with regard to transportation, buildings, and land use, and are most at risk for experiencing the effects of climate change. Working across sectors to incorporate a health promotion approach in the design and development of built environment components may mitigate climate change, promote adaptation, and improve public health. (Am J Prev Med 2008;35(5):517–526) Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine.

Introduction

Evidence indicates that the global climate is changing, resulting in elevated temperatures, rising sea levels, heavier precipitation events (e.g., floods, storms, hurricanes, and cyclones), additional heatwaves, and more areas affected by drought.[1] Possible health consequences include morbidity and mortality related to heat, extreme weather events, vectorborne and waterborne infections, mental stress, food and water shortages, respiratory diseases, international conflict, and air pollution.[2,3] Greenhouse gas (GHG) emissions, composed mainly of carbon dioxide, methane, nitrous oxide, and fluorinated gases,[4] increased 70% from 1970 to 2004,[5] contributing to these changes. Carbon dioxide (CO_2) emissions, in particular, accounted for 77% of total anthropogenic GHG emissions in 2004.[5] Because these emissions are largely a result of human activity,[1] changes in policies and behaviors can help reduce GHG emissions, climate change, and adverse health consequences.

The built environment influences human choices, which in turn affect health and the global climate. Distinct from the natural environment, the built environment is comprised of manmade components of people's surroundings, from small-scale settings (e.g., offices, houses, hospitals, shopping malls, and schools) to large-scale settings (e.g., neighborhoods, communities, and cities), as well as roads, sidewalks, green spaces, and connecting transit systems. The development of the built environment involves many sectors, including urban planning, architecture, engineering, local and regional governments, transportation design, environmental psychology, and land conservation. Neighborhood design not only influences health by affecting physical activity, respiratory and cardiac health, injury risk, chronic disease risk, social connectedness, and mental health,[6] but many current community design practices also adversely contribute to global climate change.

The UN Intergovernmental Panel on Climate Change has noted the relationship between components of the built environment and climate change, reporting that global GHG emissions have grown largely as a result of the following sectors: energy supply, transportation, industry, land use and forestry, agriculture, and buildings.[5] Strategies that aim to reduce atmospheric CO_2 include decreased use of motor

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vehicles, increased energy efficiency in buildings, and reduced deforestation.[7] Based on these strategies, the current study focuses on three built environment components: transportation, buildings, and land use (including forestry and agriculture).

These aspects of the built environment may disproportionately affect vulnerable populations, such as children, the elderly, people with disabilities, racial and ethnic minorities, and people of low SES, particularly when effects on health are not incorporated into built environment decision making. These populations are also among the groups most susceptible to health effects caused by climate change.[8] The health effects experienced by vulnerable populations are highlighted in this article.

Because the built environment constitutes an important contributor to climate change and health outcomes, alternative practices offer opportunities both for improved health and reduced climate change. This article presents the current evidence and potential co-benefits of alternative practices, and illustrates built environment strategies that minimize the effects of climate change and improve health (Table 1). Opportunities for partnerships between health sectors and non–health sectors sharing similar goals are also examined. Finally, next steps and areas for further research are suggested.

Transportation

Transportation, a key feature of the built environment, encompasses roads, highways, airports, railroads, public transit, ports, and bicycle trails, as well as the interaction of these systems with cities and communities. Transportation accounted for 28% of total U.S. GHG emissions in 2006, of which 94% was from energy-related CO_2 emissions. Furthermore, transportation was the largest end-use sector producing energy-related CO_2 emissions in 2006, nearly all of which was caused by petroleum combustion.[9] Three aspects of the transportation sector contribute to GHG emissions: fuel efficiency of vehicles, carbon content of fuel, and vehicle miles traveled.[10] Of these, vehicle miles traveled affects GHG emissions directly through the built environment.

Transportation infrastructure and systems affect both GHG emissions and public health. Transportation patterns are related to pedestrian and motor vehicle fatalities and nonfatal injuries.[11] Motor vehicle crashes account for more than 40,000 deaths and almost 3 million injuries a year in the U.S.[12] In addition, injury rates among pedestrians and bicyclists are higher in the U.S. than in Germany or the Netherlands, although Germany and the Netherlands have substantially greater rates of walking and bicycling.[13] By reducing distances between destinations and decreasing vehicle miles traveled, transportation designs can be altered, thereby affecting injury rates among drivers, pedestrians, and bicyclists, as well as climate change.

Climate change and air quality have an interactive relationship. Climate change affects air quality by altering local weather patterns, such as temperature and wind speed, which affect the distribution of air pollution. Anthropogenic sources of air pollution (e.g., motor vehicles) promote climate change through their emission of CO_2, volatile organic compounds (VOCs), and nitrous oxide.[14] The combination of VOCs, nitrous oxide, and sunlight form ozone and smog, which are harmful to health.[15,16] Although no direct health effects are attributed to increased ambient levels of CO_2,[17] high concentrations of indoor CO_2 are associated with drowsiness, headaches, poor concentration, and increased heart rate; and extremely high concentrations of CO_2 (>5000 parts per million [ppm]) potentially lead to oxygen deprivation and serious health effects.[18] Other byproducts of fossil fuel combustion (e.g., ozone and fine particulate matter) contribute to air pollution and associated respiratory illnesses.[14,19,20]

Exposure to air pollutants is linked to chronic obstructive pulmonary disease hospitalizations,[21] respiratory and cardiovascular morbidity and mortality,[22] acute asthma care events,[23] diabetes mellitus prevalence,[24] lung cancer risk,[25] birth defects,[26] lung impairment, fatigue, headaches, respiratory infections, and eye irritation.[20] Air pollution health effects are particularly associated with SES and age. Asthmatic children living in areas with low SES were found to be more affected by air pollution than asthmatic children in high-SES regions.[27] Emergency room visits for air pollution–related asthma were highest among young children and the elderly.[28] Thus, increased exposure to air pollutants, which climate change may intensify, can exacerbate respiratory illnesses for those most vulnerable, such as children,[29] athletes, asthmatics, and people with cardiac or pulmonary conditions.[14]

Transportation infrastructure affects physical activity as well. A study of five pedestrian and bicycling trails in Nebraska found the average cost per user in 2002 was $235, but resulted in medical cost savings of $622 per person from engaging in physical activity.[30] Trails offer multiple co-benefits, by improving physical activity levels, providing alternative transportation routes, and preserving green space. Walking, bicycling, and using mass transit (which often includes walking) for commuting purposes can increase physical activity,[31,32] which in turn enhances psychological well-being and reduces risks of mortality, cardiovascular disease, stroke, colon cancer, diabetes mellitus, and depression.[33] Less time in automobiles reduces exposure to busy traffic and "road rage"[34,35] and decreases the likelihood of obesity,[36] while simultaneously reducing GHG emissions.

Table 1. Relationships among the built environment, climate change, and health

Built environment category	Link to greenhouse gas emissions and climate change	Built environment strategies	Impacts	Health co-benefits
Transportation	• Fuel consumption associated with personal and commercial vehicle use • Number of vehicle miles traveled per capita • Long distances between homes, jobs, schools, and other destinations • Long distances from farm and factory to market	• Increase proportion of people and goods transported on rails rather than roads • Promote telecommuting • Decrease air travel • Decrease distances between destinations (denser and mixed-use development) • Increase facilities and opportunities for transit use, walking, and bicycling • Promote safe routes to school programs • Promote use of food and goods from local suppliers • Develop infrastructure for alternative fuel generation and distribution	• Improved air quality from reduced motor vehicle emissions • Increased physical activity from walking and bicycling • Enhanced social capital	• Reduced motor vehicle injuries and fatalities from reduced motor vehicle travel • Reduced levels of respiratory illnesses (e.g., asthma) due to improved air quality • Reduced likelihood of cardiovascular diseases, some cancers, and osteoporosis, due to increased physical activity • Improved mental health and decreased depression and anxiety, due to enhanced social capital
Buildings	• Energy use in producing and transporting construction materials ("embedded energy") • Energy use in construction practices • Energy use in heating and cooling • Energy use in building operations, such as lighting and elevators • Building site choices that promote automobile dependency and sprawl	• Increase use of sustainable, local, and/or recycled construction materials and reuse of older buildings • Increase heating and cooling efficiency through site orientation, insulated windows, green roofs, and natural ventilation • Decrease electricity use by occupants by providing convenient stairs, compact florescent bulbs, day-lighting, and motion sensor light switches • Adopt LEED guidelines for energy-efficient buildings • Use less square footage when designing and building houses • Reduce drive-through services that typically involve idling automobiles	• Improved air quality from reduced coal-generated electricity • Increased physical activity from stair use • Decreased heat island effects	• Reduced levels of respiratory illnesses (e.g., asthma) due to improved air quality • Reduced likelihood of cardiovascular diseases, some cancers, and osteoporosis, due to increased physical activity • Improved mental health and productivity from use of day-lighting • Reduced susceptibility to heat-related illnesses due to decrease in heat island effects
Land use, forestry, and agriculture	• Deforestation associated with logging, agriculture, and sprawling development • Separation of land uses, which increases travel • Buildings constructed in vulnerable areas, such as coastal regions and flood plains	• Develop mixed-use communities following smart growth and LEED-ND principles • Preserve and expand parks, trails, and green space • Encourage community gardens and farmers' markets • Reduce construction in coastal locations, flood plains, and other vulnerable areas • Provide incentives to protect, manage, and sustain forests • Coordinate regional planning • Support sustainable logging and agriculture • Reduce demand for meat consumption	• Increased physical activity from walking and bicycling in mixed-use communities • Improved social capital from use of parks and trails and contact with nature • Improved nutrition and social capital from locally grown food • Increased multi-use forests for recreation and commercial use	• Reduced likelihood of cardiovascular diseases, some cancers, and osteoporosis, due to increased physical activity • Improved mental health and decreased depression and anxiety, due to improved social capital • Reduced fatal and nonfatal injuries from severe weather events

LEED, U.S. Green Building Council's Leadership in Energy and Environmental Design rating systems; LEED-ND, for neighborhood development

Communities highly dependent on automobiles pose mobility barriers for children, the elderly, those without vehicles, and people with mobility impairments. Accessible, walkable, and safe neighborhoods with mixed-land use, good connectivity, public transit options, and recreational facilities encourage people with limited mobility or special needs to stay physically active, independent, and involved in community activities.[37,38] Among the elderly, exercise is associated with lower rates of functional decline[39] and dementia,[40] and may

enable seniors to remain independent longer.[38] Aspects of the built environment that facilitate physical activity for all populations offer the co-benefit of reducing motor vehicle associated pollution, thereby diminishing both health hazards and the GHG emissions contributing to climate change.

Transportation in the U.S. has been influenced by policies encouraging highway expansion,[41] decreasing fuel efficiency standards,[42] and providing purchasers of trucks and sport utility vehicles with considerable tax deductions.[43] Although strategies to reduce the contribution of transportation to climate change have focused on technologic improvements (e.g., alternative fuels or more efficient vehicles), personal transportation choices and the policies that influence those choices must also be considered. Policies that influence personal transportation choices include those that facilitate increased use of mass transit options, land-use planning that results in decreased travel distances between destinations, and workplace options that reduce travel (e.g., telecommuting). "Complete streets" can be designed to accommodate all users, including pedestrian, bicycle, and vehicular traffic.[44] Communities can be planned and redeveloped with "smart growth" principles to account for various modes of travel.[45] A decaying shopping mall in Denver, for instance, has been transformed into a mixed-use community with access to the city's light-rail system, thus providing convenient travel alternatives that promote health and reduce climate change.[46] Personal choices such as walking, bicycling, reducing vehicle miles traveled, combining trips, and living in transit-oriented mixed-use developments not only reduce CO_2 emissions, but also increase levels of physical activity.

Buildings

Global CO_2 emissions from energy use in buildings grew approximately 3% per year between 1999 and 2004.[47] Residential, commercial, and industrial buildings account for 43% of U.S. CO_2 emissions, with most (71%) of these emissions caused by electricity consumption in residential and commercial buildings.[48,49] Coal, the predominant energy source consumed by the electric power sector, produced 83% of U.S. CO_2 emissions in 2006 and contributed to methane emissions as well.[9] Buildings affect GHG emissions through various aspects of their design, location, orientation, and use, such as their relationship to each other and the neighboring landscape, the material composition and design elements of their interiors and exteriors, and the energy and water resources used by their occupants. A building's energy use is also affected by features of its surrounding environment (e.g., sunlight, wind, trees, and water), which in turn affects its GHG emissions.

Various building aspects influence the health of users. For example, design characteristics of hospitals, such as better lighting, layout, and ventilation, have resulted in reduced stress and fatigue in patients and staff, as well as improvement in overall health.[50] Similarly, building placement relative to residential and commercial areas influences whether occupants must depend on automobiles or are able to walk, bicycle, and use public transit to other destinations,[51–53] and has been shown to have a considerable impact on BMI.[54]

The conditions of a building affect the health of its occupants. Mold, pests, lack of safe drinking water, and inadequate heating or cooling, waste disposal, and ventilation systems result in adverse health effects, including respiratory illnesses, asthma, infectious diseases, injuries, and mental health disorders. These conditions, which are characteristic of substandard housing, predominantly affect vulnerable populations, specifically people of low SES and racial minorities.[55] Moreover, susceptibility of poor and minority populations to hazards may be increased due to underlying health conditions,[56] such as asthma[57] and cardiovascular disease.[58] Therefore, maintaining the conditions of a building improves the health of its occupants.

Decisions to use sustainable building materials and operation practices can promote health and protect the environment by mitigating the *urban heat island effect* (higher temperatures in metropolitan areas than in surrounding areas),[59] conserving resources, and allowing safe disposal of contaminated or hazardous waste products.[60] Environmentally friendly supplies (e.g., recycled materials) can be substituted for products that use nonrenewable resources. Buildings constructed with locally produced materials support local economies and reduce transportation-related air pollution.[61] In addition, building and landscape designs can encourage routine physical activity by providing accessible, attractive stairwells with clear signage[62,63] and outdoor walking paths.

Carbon dioxide emissions from buildings are primarily caused by the use of electricity to provide heating, cooling, lighting, water, information management, and entertainment systems.[48] Because of their long life expectancies, buildings affect the environment and public health for many years. Commercial buildings last an estimated median of 70–75 years. One fourth of existing commercial floor space was constructed prior to 1960. Similarly, approximately one fourth of existing residential housing in 2003 had been built before 1949.[49] Both older building renovation and new construction offer opportunities to promote energy efficiency and support healthier working and living for future decades.

Energy-efficient materials may cost more initially, but offer long-term savings.[48] Although strained budgets can limit opportunities to use environmentally friendly, sustainable ("green") technologies and building mate-

rials, forward-thinking clients, architects, and developers are working together to design and build energy-efficient buildings. For instance, as part of its Office of Sustainability Initiatives,[64] Emory University is renovating existing university buildings for energy efficiency and constructing new buildings according to green building standards.[65] The Yang and Yamazaki Environment and Energy (Y2E2) building at Stanford University is another example of energy efficiency and innovation in an academic setting.[66,67]

In the last several years, there have been efforts to green the healthcare industry and promote sustainability and health. Health Care Without Harm, an international coalition of hospitals and healthcare organizations, supports green building practices and ecologically sustainable policies.[68] Environmental conferences, such as CleanMed, bring together healthcare leaders to discuss ways to green health care.[69] In addition, the Green Guide for Health Care, a toolkit for healthcare institutions, was developed to aid in the design and construction of sustainable buildings that promote the health of staff, patients, and visitors, as well as the environment.[70] Creation of a green hospital at the University of Pittsburgh includes constructing innovative buildings and retrofitting existing buildings using green practices, altering procedures in waste management and housekeeping, supporting strategies that improve air quality, and promoting water and energy conservation.[71] Sustainable hospitals can recover incremental costs after 1 year and accrue financial benefits during subsequent years.[60] These activities illustrate the involvement of the healthcare sector in the green movement, thereby mitigating climate change and promoting human health.

Mitigation strategies, such as reducing overall meat consumption and supporting local farmers' markets and community gardens, ease the burden of food production an GHG emissions by decreasing the distance goods are transported and the demand for deforestation. LEED rating systems consider the development of sustainable sites, water savings, energy efficiency, material choice, and quality of indoor environments.[72] LEED-ND for neighborhood development considers location and connectivity, pattern and design, and construction on a community scale.[73] Through tax rebates, LEED incentives, energy-efficient appliances, and reuse of existing materials, clients and developers are beginning to realize economic benefits from promoting sustainability and health through building decisions.[74]

Compared to a standard building, a LEED-certified building uses 32% less electricity and reduces annual average CO_2 emissions by 350 metric tons (385 tons).[75] Through specific energy-saving strategies, such as building sites, building form, material selection, window location, day-lighting, and energy-efficient systems for heating, cooling, and ventilation,[76] the impact of climate change can be lessened. Sustainable and healthy building design principles are cost effective,[77] promote health, conserve energy, protect the environment, and mitigate the GHG emissions that contribute to climate change.[78]

Land Use, Forestry, and Agriculture

Land use, land-use change, and forestry accounted for 12% of U.S. GHG emissions in 2005 and were responsible for 16% growth in net carbon accumulation between 1990 and 2005.[9] Carbon accumulation is important because forests "sequester" CO_2 by absorbing it from the atmosphere, therefore reducing the amount contributing to the overall levels of GHG emissions. In 2005, 85% of net U.S. CO_2 sequestrations were from forests.[9] Deforestation increases the levels of atmospheric CO_2 and promotes climate change.[79] Thus, reducing deforestation offers the greatest and most immediate impact for decreasing carbon emissions.[80]

Agriculture and land-use development have led to increasing rates of deforestation in recent decades.[79] Agriculture accounted for an estimated 10%–12% of total anthropogenic GHG emissions worldwide in 2005,[81] and specifically for 30% of U.S. methane emissions in 2006.[9] Emissions from the agricultural sector come primarily from livestock production (80%), which includes land used for grazing, energy for growing grains for feed, transportation of grain and meat for processing and sale,[82] and methane produced by livestock digestive processes.[83] Livestock production contributes significantly to deforestation, as seen in Latin America, where 70% of once-forested land in the Amazon is now used as pastures and feed crops.[84] Mitigation strategies, such as supporting local farmers' markets and community gardens, ease the burden of livestock production on GHG emissions by reducing the distance goods are transported and the demand for deforestation.

In a traditional urban setting, residential and commercial land uses are mixed, allowing for proximity of home, work, school, and other destinations. Workplace proximity is a major influence on the commuting decision to walk, particularly for women.[85] Similarly, situating schools near residential areas encourages students to walk or bike to school, thereby yielding the co-benefits of physical activity and reduced GHG emissions.[86–88] Parents who walk their children to school accrue the health benefits of physical activity, as well as the advantages of interacting with other parents and strengthening community ties.[89] In general, walkable communities are associated with higher physical activity levels, lower obesity prevalence, lower car dependency,[90] and higher levels of social capital.[91]

The location of community resources is particularly relevant for vulnerable populations. A disparity often exists because poor people and ethnic minorities live

far from high-quality schools, supermarkets, and employment opportunities,[92] resulting in a cycle of poverty that is difficult to escape.[93] Situating community facilities, such as libraries, parks, health centers, and fire and police departments, near residential and commercial areas can have a positive effect on the health of all residents.

Unlike traditional neighborhoods, sprawling developments outside of city centers feature low-density land use, extensive road systems, a lack of centralized community centers, and a greater distance between destinations such as home and work. These factors contribute to increased automobile dependence and decreased ability to walk, bike, or use mass transit,[94] as well as loss of farmland and forests.[95] Highways, which link suburbs to downtown areas, are often routed through low-income neighborhoods, thereby creating a physical barrier that interferes with community cohesion.[92] Poor people and people of color are disproportionately affected because they often live near highways, which are major sources of air pollution.[96] Urban sprawl affects air and water quality, physical activity level, mental health, and social capital, resulting in elevated risk of respiratory, cardiovascular, and chronic diseases, cancer, psychological and emotional disorders, and injuries. In addition, the increased driving time typical of urban sprawl contributes to climate change.[56,97]

Increasing density in urban areas is only part of the solution to urban sprawl. Although most urban environments offer sidewalks, mixed-land use, public transportation options, and connectivity, these aspects may be undermined by factors that pose health threats, such as crime,[98,99] waste or industrial sites,[100] and inadequate infrastructure maintenance.[92] Neighborhood indicators characteristic of underprivileged communities (e.g., the lack of nearby walkable destinations, or sidewalks in disrepair) are significantly associated with obesity.[101] Living in disadvantaged neighborhoods is linked to higher rates of cardiovascular and stroke mortality.[102] When these areas are redeveloped, gentrification often occurs, causing property values to rise and forcing lower-income residents to move out.[93] Involvement by health professionals and adequate representation of vulnerable populations in zoning and planning decisions represent important opportunities to benefit public health and climate change.

Improved urban green space planning and management can help mitigate climate change while offering considerable co-benefits for human health. Urban green spaces reduce atmospheric CO_2 levels through direct sequestration and accumulation of carbon by trees and shrubs. In addition, urban green spaces decrease building heating and cooling needs, thus reducing fossil fuel consumption.[103] Lack of contact with nature can influence the mental, physical, and emotional health of the public, particularly children.[104] Urban green spaces such as parks and trails provide access to nature and encourage physical activity, thereby helping combat obesity and its co-morbidities, such as hypertension, osteoarthritis, sleep apnea, and stroke.[105] Access to green space decreases aggression and violence, improves mental fatigue,[106] and increases social capital and community building.[107] Finally, exposure to nature reduces pain in patients undergoing bronchoscopy,[108] improves attention among children with attention deficit disorder (ADD),[109] and increases the life span of the elderly.[110]

Improved land-use planning can be a cost-effective way to mitigate climate change and promote public health. Specific approaches for reducing GHG emissions include creating new green spaces (e.g., on roofs and along streets and railroad lines),[111] maintaining existing green spaces, conserving natural lands through controlled development, and planting trees with high growth rates for additional green cover.[103] Land-use planning is particularly relevant for cities. Dark, impervious surfaces on buildings and roads and the lack of shade and vegetation cause urban areas to have higher average temperatures than rural areas, resulting in the urban heat island effect. This effect decreases the relief available from nighttime cooling and amplifies the susceptibility of urban residents to heat-related illnesses, including those anticipated to occur more frequently under climate change scenarios.[59]

Reuse of previously developed land such as *greyfields* and *brownfields* is also an important method for mitigating climate change and its health implications. Greyfield sites, such as underutilized shopping centers, can be redeveloped into valuable real estate assets because they are usually located along well-traveled areas with good infrastructure.[112] Similarly, brownfield sites, which are properties contaminated with hazardous substances,[113] can be decontaminated and redeveloped into healthy communities that feature mixed-land use and connectivity. In addition to economic benefits, such projects help preserve existing agricultural and forest lands.

Discussion

The built environment offers opportunities to improve health and livability while reducing the GHG emissions that underlie climate change. This article contributes to a growing dialogue addressing the impacts of climate change on human health, by highlighting built environment strategies that minimize the effects of climate change and concurrently improve health. Research on these relationships, although needed, is difficult because built environment data are infrequently collected and usually local in nature. By contrast, climate change indicators such as temperature, weather, wind, and precipitation trends are often measured on a macro-

scale level.[114] Although work is underway to identify key indicators for the built environment[115,116] and climate change,[117,118] using these divergent data to describe and understand the relationships among the built environment, climate change, and human health is a complex challenge for researchers.

Adaptation strategies, although not the focus here, merit attention because they can help prepare the built environment to better withstand the effects of climate change. An example of an adaptation strategy is a policy that limits situating buildings in flood plains or low-lying coastal regions because of the increased risk of flooding from heavy precipitation and rising sea levels.[119] Some adaptation strategies may have a negative impact on climate change. For example, although air conditioning in buildings is an important adaptation strategy to reduce heat-related illnesses caused by higher temperatures,[120] the energy used to cool a building contributes to GHG emissions and climate change.[121] Although some literature discusses adaptation strategies for various built environment components to address climate change effects,[122–124] more research on this interplay is needed, especially in relation to health impacts.

Future research could include cost–benefit analyses of the impact of built environment interventions on GHG emissions and public health. For instance, a light-rail transit line in Charlotte NC with 15 stations covering 9.6 miles averaged 14,000 daily riders in its first year (2007), exceeding projections by 55%.[125] Estimates suggest this transit line will save $12.6 million dollars in total healthcare costs over 9 years.[126] Possible research projects from this transit system include climate change–impact assessments by measuring transit users' vehicle miles traveled, the health outcomes for residents and transit riders, and social cohesion and economic impacts on the city. Similar monitoring and evaluation research may be conducted for GHG emissions associated with larger projects such as new buildings, transportation systems, land-use patterns, and major infrastructure changes, as well as for smaller projects such as new sidewalks, bicycle lanes, and parks. Research that examines how built environment interventions both affect the health of vulnerable populations and reduce climate change is encouraged.

Because health systems will need to address the effects of climate change on public health, it is important for healthcare providers to become leaders in the built environment discussion. Co-benefits from promoting these changes will directly improve health. CDC scientists have described how ten public health functions can help alleviate and respond to the health effects of climate change.[8] As part of this response, individual physicians can be models for behaviors that promote sustainability. It has been shown that physicians with healthier personal habits are more likely to encourage patients to adopt similar habits.[127] This effect may hold true for behaviors related to sustainability through transportation choices, energy use, and involvement in local policies affecting land use and community design. Healthcare providers can collectively and individually influence the built environment and climate change through their actions and leadership.

Decisions about the built environment are routinely made by city planners, architects, political leaders, financiers, and public service officials. Because the built environment affects health, public health professionals should be included in land use and transportation decision-making processes. Health Impact Assessment is a tool that can be used by public health practitioners to assist planners and developers in understanding the health impacts of the decisions they make about land use and transportation planning.[128] Fostering such multidisciplinary collaboration can help maximize the positive health impacts of infrastructure changes and reduce their negative effects.

Potential for collaboration exists among scientists, politicians, urban and transportation planners, healthcare providers, and concerned individuals across numerous agencies and organizations. These partnerships can promote the concept that built environment interventions will yield the co-benefits of mitigating climate change and promoting public health. Although some of the impacts of climate change cannot be predicted or fully understood today, the precautionary principle suggests there is enough evidence to justify proceeding with known mitigation strategies to counter the effects of climate change. Through careful planning of transportation systems, buildings, and land uses, built environment programs can support climate change mitigation and enhance human health.

Conclusion

The built environment, climate change, and public health are closely connected. Built environment strategies that promote climate change mitigation through transportation infrastructure, building construction, and land-use planning provide opportunities both to improve health and reduce climate change. By combining various built environment strategies through complimentary policies and programs, multiple co-benefits emerge. Encouraging leadership and collaboration among various professions within the built environment, climate change, and public health fields is an important step toward reducing GHG emissions, thereby mitigating climate change effects and promoting healthier living.

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