

Energy Efficient Housing as a Healthcare Intervention

in Communities Facing Environmental Injustice in USA Climate Zone 4



Brooke Troxmondo, Emily Huhman, Jacqueline Lewy, and Natalie DeLiso

Organizational Partner: Molly Berg, Senior Specialist, Building Science Habitat for Humanity International

Faculty Advisor: Dr. Andrew Ibrahim, Maud T. Lane Research Professor of Surgery, Architecture, and Urban Planning; Co-Director, Center for Healthcare Outcomes and Policy

Dow Sustainability Fellows Final Report 2023

Executive Summary

Greenhouse gas (GHG) emissions are a large contributing factor to the climate crisis. Buildings account for 39% of global GHG emissions, highlighting the large impact man-made structures have on the environment (World Green Council, 2019). As one of the world's largest residential builders, Habitat for Humanity International (HFHI) understands its role in mitigating the effect of residential buildings on the environment. However, considering the higher costs associated with sustainable building design and construction, affordable housing developers often have difficulty integrating these designs into their homes without negatively impacting its affordability. HFHI approached the Dow Sustainability Fellowship Program to collaborate with students to create materials that their affiliates can reference in each stage of the building process, from conceptualization to obtaining funding to construction, that provides accessible recommendations relating to GHG emissions reduction in their own builds.

To address the barriers to sustainable construction in the affordable housing sector, our team developed a ArcGIS Pro web map and a Healthy Housing Building Strategies Booklet, which work in tandem to assist Habitat affiliates in making informed decisions on building design that can address the specific climate, health, and social conditions affiliates see in their communities. Our project aims to address GHG emissions from an equity lens by identifying areas through our mapping that experience higher temperature changes, air pollution, negative health impacts, and other measures. Additionally, the Booklet aims to provide feasible design solutions that take costs into account, such as eave extensions on roofs to reduce the impact of sunlight on home temperatures. By focusing on basic improvements that have a large potential impact on the long-term sustainability of a residential building, our team considers the funding challenges affordable housing developers often experience in sustainable design.

Our team hopes that HFHI will use the map and the Booklet to determine locations that experience higher vulnerability based on our chosen indicators where affiliates can focus their building activities. Additionally, our goal is to improve HFHI's success in obtaining grant applications because it relates building design strategies directly to improved health, climate, and social outcomes. In short, HFHI's status as one of the largest affordable housing builders can set a precedent for sustainable construction to reduce the level of GHG emissions in the residential buildings sector. Through the web map and the Healthy Housing Building Strategies Booklet, we aim to increase the accessibility of sustainable building construction for Habitat affiliates.



A Habitat for Humanity sign in front of a future Habitat home.

Introduction & Background

Habitat for Humanity International (HFHI) is a U.S.-based nonprofit organization aimed at partnering with communities to provide decent, affordable housing. Habitat affiliates operate in all fifty states and over 70 countries. In addition to building new homes, HFHI also renovates existing homes, helps people repair and improve their own neighborhoods, and advocates for homeownership at a community and government level (Habitat for Humanity, 2023).

In 2022, HFHI and a Dow Fellowship team produced case studies featuring innovative work affiliates were utilizing for home electrification, alternative building models, community impact, inclusion of solar energy, and data collection on Habitat homeowners experiences. This year, as a continuation of that work HFHI asked our team to develop materials that could help their affiliates make building design and construction decisions to reduce associated GHG emissions.

In addition to the effects the building sector has on climate change, housing also has major impacts on human health, both directly from housing quality (e.g., toxin exposure, water access/quality, air quality, walkability, etc.) as well as indirectly due to climate change (World Health Organization, 2023). As many prominent health organizations have stated, climate change itself is “the greatest global health threat facing the world in the 21st century” (Elsevier, 2023). Buildings not only contribute to climate change by way of GHG emissions, they also serve as many people’s primary protection against the severe storms, flooding, poor air quality, and extreme temperatures driven by climate change (Moore & Doyon, 2023). In these ways, housing, sustainability, and health are inextricably intertwined.

Although our team would have enthusiastically tackled this enormous topic, in order to pare down the scope to a manageable one year project, we focused on sustainable, healthy housing opportunities in Climate Zone 4. This region encompasses parts of the East, Southeast, and Midwest in the United States. It includes portions of Kansas, Missouri, Arkansas, Illinois, Indiana, Kentucky, Tennessee, Georgia, North Carolina, Virginia, West Virginia, Ohio, Maryland, Pennsylvania, and New York. Climate Zone 4 is characterized by a “mixed-humid” climate, defined as “a region that receives more than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or fewer, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months” (U.S. Energy, 2023). As GHG emissions continue to fuel climate change, precipitation and temperature extremes will be among the most serious health threats, potentially impacting numerous communities already experiencing these phenomena in Climate Zone 4. However, there is currently a dearth of publicly available sustainable building recommendations specific to the conditions of this area. For these reasons, our team aimed to find solutions for Climate Zone 4 that would increase climate, health, and building resilience.

Methods

1. Data Collection

1.1 Data Sources

The data collection phase of this project included identifying indicators related to health, housing stock, social capital, environmental injustices, and energy burden in order to assist HFHI in determining where investments in energy efficient and healthy housing could be most impactful.

Below are the sources from which we downloaded data and the indicators we selected to include in the mapping portion of the project.

Spatial Data

1. U.S. Energy Information Administration, Climate Zones - DOE Building America Program
 - » Information Used: U.S. Climate Zone 4
2. U.S. Census Bureau
 - » Information Used: TIGER/Line Shapefiles for 2018 Census Tracts
3. Habitat for Humanity U.S. Affiliates
 - » Information Used: Addresses of Habitat for Humanity U.S. Affiliates
4. NOAA/NCEI U.S. Climate Division Data
 - » Information Used: U.S. Climate Divisions

Indicators

1. EPA Climate Change Indicators in the U.S.
 - Data Source Description:** The EPA's Climate Change Indicators collects data on over 50 indicators that outline the causes and effects of climate change, including temperature levels, global GHG emissions, and extreme weather events.
 - Why It's Important:** Understanding the causes and impacts of human-caused climate change can provide insight on its effects on the ecosystem and human quality of life.
 - » Geography: Climate Divisions
 - » Climate Indicators Utilized:
 - ◇ Rate of Temperature Change in the United States 1901-2021
2. CDC/ATSDR Environmental Justice Index (EJI)
 - Data Source Description:** This Index collects information from the U.S. Census Bureau, the U.S. EPA, the U.S. Mine Safety and Health Administration, and the U.S. CDC to rank 36 different environmental, social, and health factors by Census tract.
 - Why It's Important:** Disadvantaged communities, such as minority or low-income populations, often face the brunt of the effects of pollution and climate change. By ranking a number of factors by Census tract, inequalities in these environmental, social, and health factors can be visualized.
 - » Geography: Census Tract
 - » Environmental Indicators Utilized:

- ◇ Percentile rank of domain consisting of ozone, PM2.5, air toxics cancer risk, and diesel particulate matter
 - » Health Indicators Utilized:
 - ◇ Percentile rank of percentage of individuals with raw high blood pressures values
 - ◇ Percentile rank of percentage of individuals with asthma
 - ◇ Percentile rank of percentage of persons with cancer
 - ◇ Percentile rank of percentage of individuals reporting not good mental health
 - ◇ Percentile rank of percentage of individuals with diabetes
 - » Social Indicators Utilized:
 - ◇ Percentile rank of percentage of persons aged 65 and older estimate
3. U.S. DOE Low-Income Energy Affordability Data (LEAD) Tool
- Data Source Description:** The U.S. DOE's LEAD Tool collects data on low- to medium-income housing in the U.S., including energy burden, building age, and heating fuel type.
- Why It's Important:** Low-income and medium-income households are often overburdened with utility costs. Collecting data on the characteristics of low- and medium-income housing can reveal some of the barriers to equity in housing.
- » Geography: Census Tract
 - » Housing Indicators Utilized:
 - ◇ Energy Burden (% income)
4. Replication Data for: Social Capital's Impact on COVID-19 Outcomes at Local Levels
- Data Source Description:** Social capital describes "the social ties that enable trust, reciprocity, and collective action" that people can reach to during times of crisis (Fraser, Page-Tan, & Aldrich, 2022). Types of social capital include bonding, where one builds connections with those of similar demographics, bridging, where one builds connections with those of different demographics, and linking, where one builds connections with those in different formalized power structures (Institute for Social Capital, n.d.).
- Why It's Important:** Social capital is key to strong participation in one's community. Making planning and building design decisions that encourage building bonds with neighbors and community members can improve quality of life for low-income households.
- » Geography: Census Tract
 - » Social Indicators Utilized:
 - ◇ Social Capital Index
5. American Community Survey 5-Year Estimates of Physical Housing Characteristics for Occupied Housing Units
- Data Source Description:** In addition to population counts, the U.S. Census Bureau's American Community Survey collects data related to physical and financial housing characteristics, employment, and educational attainment, among other metrics on an annual and every-five-year basis.
- Why It's Important:** The physical and financial characteristics of housing, including the year the building was built and the fuel type used, has impacts on the long-term sustainability and affordability of a building.
- » Geography: Census Tract
 - » Housing Indicators Utilized:

- ◇ Year Structure Built
- ◇ House Heating Fuel

1.2 Data Processing

U.S. Climate Zone 4 includes all or part of the following states: Arkansas, Delaware, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Missouri, North Carolina, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. Data for Indicators #1, #2, and #4 were downloaded for the entire U.S. Data for Indicators #3 and #5 were downloaded by each of the states listed above. Specific information about how the Indicator data were processed is below:

Indicators

1. EPA Climate Change Indicators in the U.S.
 - » Heading was simplified.
2. CDC/ATSDR Environmental Justice Index (EJI)
 - » No processing was necessary because the downloaded data included spatial data.
3. U.S. DOE Low-Income Energy Affordability Data (LEAD) Tool
 - » Information from all relevant states was combined into one .csv file.
4. Replication Data for: Social Capital's Impact on COVID-19 Outcomes at Local Levels
 - » No processing was necessary because the downloaded data were in a format and contained all relevant information to be joined with spatial data in GIS.
5. American Community Survey 5-Year Estimates of Physical Housing Characteristics for Occupied Housing Units
 - » AFFGEOID and all relevant indicators from each state were copied and pasted into a new .csv file containing only the desired data for all relevant states.
 - » The number of structures built before 1980 were summed into one column.
 - » All housing heating fuel types excluding electric were summed into one column.

2. GIS Mapping

The GIS mapping was conducted using ArcGIS Pro from ESRI.

2.1 Spatial Data Specification

Per HFHI's request, we concentrated our mapping and analysis to U.S. Climate Zone 4. We utilized the "Select by Attributes" feature to isolate the polygon of Climate Zone 4 from Spatial Dataset #1. Then, we utilized ArcGIS Pro's embedded geolocator to geolocate the addresses from Spatial Data #3. Finally, we used the Climate Zone 4 polygon to clip Spatial Data #2, #3, and #4.

2.2 Joining Indicators with Spatial Data

Each indicator source was initially visualized on a separate map. The indicator was joined with the clipped version of either Spatial Data #2 or #4 depending on the indicator geography and then combined once all joins had been completed. The clipped version of Spatial Data #3 was overlaid on the top of each map.

Indicators

1. EPA Climate Change Indicators in the U.S.
 - » Joined with: Spatial Data #4
 - » Join based on: Climate Division number
2. CDC/ATSDR Environmental Justice Index (EJI)
 - » No join was necessary because the downloaded data included spatial data.
3. U.S. DOE Low-Income Energy Affordability Data (LEAD) Tool
 - » Joined with: Spatial Data #2
 - » Join based on: AFFGEOID
4. Replication Data for: Social Capital's Impact on COVID-19 Outcomes at Local Levels
 - » Joined with: Spatial Data #2
 - » Join based on: AFFGEOID
5. American Community Survey 5-Year Estimates of Physical Housing Characteristics for Occupied Housing Units
 - » Joined with: Spatial Data #2
 - » Join based on: AFFGEOID

2.3 Data Visualization

To visualize each of the indicators, we used a graduated color symbology with 5 classes split into equal intervals.

2.4 Creation of a Web Map Application

The feature layers for the affiliate locations (Spatial Data #3) and each of the indicators were shared as a web layer to our ArcGIS Online account. ArcGIS Web AppBuilder was used to compile all of the feature layers.

The following widgets were added to help the user experience:

- Bookmark: Users can add spatial bookmarks for faster navigation.
- Distance and Direction: Users can draw circles to visualize map information around a point of interest.
- Near Me: Users can find information within a 5 mile radius of their current location or an inputted address.
- Print: Users can print the current map.
- Share: Users can share the map to their social media account(s) or send an email with the link to the map.

Deliverables

Healthy Housing Building Strategies Booklet

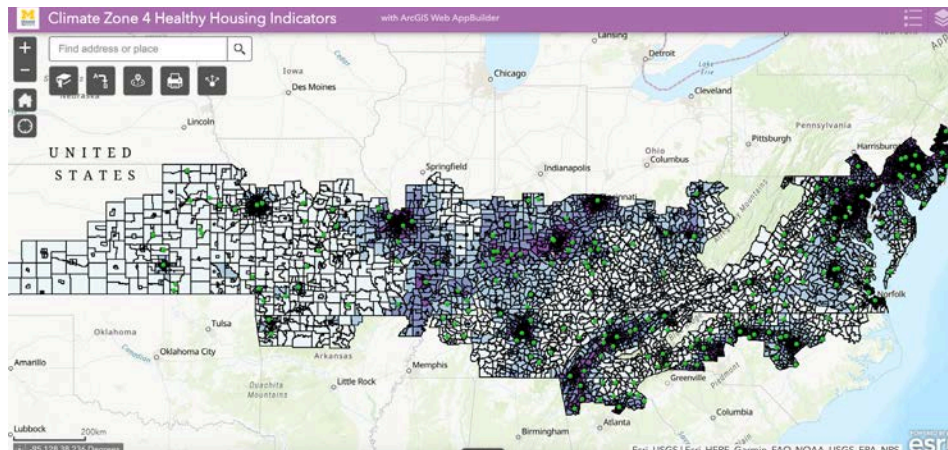
To address HFHI's desire to make GHG emissions reduction strategies more attainable to its affiliates while focusing on broader social- and health-related impacts, our team developed the Healthy Housing Building Strategies Booklet that connects concrete building design and construction recommendations to some of the health and social indicators outlined in the Methods section. While the main audience is Habitat affiliates, this Booklet can be beneficial for anyone looking to build or retrofit their home in a more sustainable way, should HFHI choose to make the Booklet externally available. Each page of this Booklet highlights a specific indicator, like Energy Burden or High Prevalence of Asthma, and outlines why the indicator impacts social well-being, how it can contribute to GHG emissions, and what building recommendations could make a positive impact on this indicator. Habitat affiliates can use this Booklet to make informed decisions on building strategies that reduce overall GHG emissions and address the specific social and health issues affiliates see in their communities. The full Healthy Housing Building Strategies Booklet is included in this report as Appendix 1.



"High Prevalence of Asthma" in the Healthy Housing Recommendations Booklet

GIS Files and Web Map

In addition to our Healthy Housing Building Strategies Booklet, HFHI's GIS team will be given our ArcGIS Pro file to expand and improve on to continue to learn more about other areas of the United States and the world where HFHI should potentially focus their activities. These maps can also be used to learn more about how our selected indicators present themselves in other places around the globe, and could provide this information to other departments to provide tailored building and health recommendations to address these indicators. Our team also created a web map that is available online to a broader audience. Those interested in learning more about the intersections of social, climate, and health factors in Climate Zone 4 can look at the web map to explore this information.



"Exposure to Air Pollution" Layer of the Climate Zone 4 Healthy Housing Indicators Web Map

Recommendations

Through our research, our group came to a number of recommendations on additional areas of future research and the process for developing maps and building recommendations. Importantly, there are a number of health and environmental factors in Climate Zone 4 that can be addressed with additional research. Humidity, for example, is an issue that affects all of Climate Zone 4 whose impacts can be remediated through sustainable building design. High humidity levels in homes can lead to mold issues, which negatively impacts lung health. Conducting additional research on humidity and its effect on housing quality and health in Climate Zone 4 can illuminate a common issue faced throughout the climate zone, providing backing for Habitat affiliates in the area to apply for funding and partnership opportunities.

One of the largest barriers to utilizing healthy and sustainable building design is obtaining funding to support these efforts. Climate Zone 4 is one of many geographies where healthy housing is understudied. More research is needed to directly connect healthy building design to improved health outcomes. Being able to make these connections is necessary for many of the grant opportunities available to support innovative building design and construction. To further investigate the financial barriers and feasibility of sustainable construction decisions, a cost analysis should be conducted to determine at what point implementing sustainable design choices will bring long-term costs savings to affiliates. Conducting this type of analysis could bolster grant applications relating to sustainable housing or construction, increasing the feasibility of implementing these recommendations into affordable housing.

An additional project that could be considered by HFHI and future Dow Sustainability Fellows could be to expand the mapping geography and building strategies for other regions in the US. For the scope of this project, we isolated specific information from sources like the CDC's Environmental Justice Index and the U.S. Census' American Community Survey. These sources have a rich array of data, so the map could easily be expanded to include more demographic, health, social, and environmental indicators to help affiliates identify community needs and apply for additional funding.

Impact

We expect our Healthy Housing Building Strategies Booklet to have multiple impacts for Habitat staff and affiliates. First, the Booklet provides information on how to mitigate multiple health and social impacts through building design choices in one simple, easy-to-read source. This assists Habitat affiliates in making design choices for their buildings that reflect the conditions they are seeing in their communities. Next, the Booklet can strengthen Habitat affiliates' ability to apply for local, state, and federal funding opportunities. For example, Inflation Reduction Act funding opportunities, such as the Environmental Justice Thriving Communities Grantmaking Program, requires applicants to include a work plan that furthers the federal government's goal of environmental justice and improving health and environmental outcomes for vulnerable communities (U.S. Environmental Protection Agency, 2023). By providing evidence-based design recommendations that relate directly to measures of environmental justice and physical and social health, the Healthy Housing Building Strategies Booklet can be used to support federal funding applications that will be key in funding innovative building strategies in affordable housing.

In addition to the impacts the project deliverables can have for HFHI, there are broader impacts on residential construction that could materialize as the result of this project. As mentioned previously, HFHI is one of the largest residential builders in the world. By leading the charge of sustainability in residential construction as a non-profit affordable housing provider, HFHI can show that other builders, from private, for-profit developers to Public Housing Authorities, can implement GHG emission reduction and healthy housing strategies.

Finally, our project impacts multiple of the United Nations Sustainable Development Goals (United Nations, 2015). Namely, our work directly relates to the goals of Good Health and Well-Being; Industry, Innovation, and Infrastructure; Sustainable Cities and Communities; and Climate Action. The Healthy Housing Building Strategies Booklet relates to Good Health and Well-Being and Climate Action because it directly connects health and environmental concerns to building design interventions that can prevent or mitigate symptoms of poor health and climate. The mapping process our team developed connects with the goal of Sustainable Cities and Communities because it can assist housing providers in narrowing down targeted areas where these sustainable building recommendations would be the most impactful. Lastly, our project supports Industry, Innovation, and Infrastructure goals by making creative sustainable building design recommendations more accessible to affordable housing developers.

Conclusion

Sustainability in building design and construction is frequently complex and difficult to implement for affordable housing developers. Oftentimes, sustainability in design is limited to higher-income developments that can afford the additional costs that come with sustainable construction. However, given the impact buildings have on the climate crisis, it is necessary for all housing developers to deeply incorporate sustainability in their builds. Habitat affiliates are

leading the way in centering equitable GHG emissions reduction and sustainability strategies into their builds. Our goal is that the materials developed through this project will assist Habitat affiliates in determining the building design strategies that address the climate, health, and social factors they see in their regions. Additionally, we hope the web map and the Booklet can be used to support funding applications dedicated to addressing the financial barriers to implementing sustainable construction. This is one of many steps that need to be taken to alleviate the impacts of climate change around the globe.

Acknowledgements

We would like to acknowledge the many people who were instrumental in thoughtfully advising and mentoring us throughout the year.

Thank you to Molly Berg, who helped shape our indicators and building strategies to best benefit HFHI. She was essential to guiding us towards a project that would utilize our passions and interests, be useful for HFHI, and connect us with other experts at HFHI who helped improve our project.

Thank you to Dr. Andrew Ibrahim, who enthusiastically shared his vast knowledge of medicine and architecture to help us define our project scope, collect indicator data, and realize our healthy housing strategies.

Additional gratitude to:

- Lars Junghans for sharing energy-efficient building technical expertise
- Derek and Jenna Ross from Catawba Valley Habitat for Humanity for their hospitality during our visit and for sharing their knowledge of sustainable construction with us
- Dow Team: Bridget Gruber (Program Manager), Jen Maigret (Director), Megan McLaughlin and Lauren Furey (Program Coordinators)
- Dow Foundation Corporation



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Appendix 1

Healthy Housing Building Strategies Booklet



Building Strategies Booklet
Dow Sustainability Fellowship 2023

Overview

Introduction:

This booklet serves as a vital bridge connecting extensive research on environmental justice and the social determinants of health to the realm of the built environment. It is a comprehensive resource designed to shed light on the undeniable associations that exist between the physical world and the well-being of individuals and communities. Our aim is to empower and educate, providing insights for those keen to understand the profound impact that the built environment has on health and quality of life.

Intended Audience:

Whether you are a community advocate, a homeowner looking to make informed choices, or simply someone curious about the important interplay of design and health, this booklet is for you. The contents of this resource is tailored to a diverse audience that includes affiliates of Habitat for Humanity, homeowners, and all interested parties seeking a deeper comprehension of how our constructed environments are intricately entwined with health and wellness. Its broad scope ensures that it can serve as a valuable resource for a wide range of readers, from the novice to the expert, offering an accessible entry point into this crucial subject.

How to Use:

Consider this booklet as your initial point of contact with a complex and multifaceted topic. Our intention is to encourage further exploration and research. Use it as a stepping stone, a primer that sparks curiosity and inquiry. As you delve into the pages that follow, we invite you to continue your journey, engage in additional research, and develop a deeper understanding of how we can enhance environmental justice and health through thoughtful design and urban planning.

Together, let's embark on a journey that connects the dots between our built environment, health, and the pursuit of a more just and equitable society.

Meet the team

We are a multi-disciplinary team at University of Michigan with expertise in environmental science, urban planning, medicine, and architecture. This work is supported through the Dow Sustainability Fellowship, Graham Sustainability Institute, and Habitat for Humanity International. Special thank you to our incredible advisors who helped guide on this journey, Molly Berg with HFHI and Dr. Andrew Ibrahim with Michigan Medicine and Taubman College.

We have collected and aggregated data from established sources including CDC, EPA, WELL, WHO, academic journals, among many more. We categorized the control indicator into one four categories, researched potential health hazards, and responded with actionable design solutions.



Brooke Troxmondo (she/her) is currently a dual degree Master's student studying Urban and Regional Planning and Environmental Justice at the University of Michigan. She has a Bachelor's of Science in Biology with Neuroscience and Women and Gender Studies minors. She is interested in reparative planning and working to empower communities around issues of climate resiliency, adaptation, sustainability, and equity.



Emily Huhman (she/her) is a Master's of Urban and Regional Planning student at Taubman College at the University of Michigan. She has a Bachelor's of Political Science and Sociology with a minor in Urban Studies from the University of Michigan. Her interests include planning inclusive of the needs of unhoused populations, creative housing models, and community-conscious economic development.









Jacqueline Lewy (she/her) is a 4th year medical student. She is honored to have contributed to these healthy housing recommendations and fortunate to have been able to learn from her interdisciplinary colleagues this year.



Natalie DeLiso (she/her) is currently a Master's of Architecture student with a concentration in Design and Health at the University of Michigan's Taubman College. She holds a Bachelor of Science in Architecture with minors in sociology, real estate, and urban studies. She is interested in improving health equity, underscored by a firm conviction in the transformative potential of design to positively impact human well-being.

Contents

	Indicator	Page
	Web Map Utilization Getting to know your census tract	5
	Housing Energy Burden <i>More than 9% of monthly income</i> Building Age <i>High (>0.40) concentration</i> Heat Energy Source <i>High (>0.40) concentration</i>	6 7 8
	Social Age 65+ <i>High (>0.40) Concentration</i> Social Capital Index <i>Low (>0.44) ranking</i>	9 10
	Environmental Increasing Local Temperatures <i>[High (>1.57) change rate</i> Air Pollution: PM2.5 <i>High (>0.40) exposure</i>	11 12
	Health Prevalence of Asthma <i>High (>0.40) percentile rank</i> Prevalence of Cancer <i>High (>0.40) percentile rank</i> Prevalence of High Blood Pressure <i>High (>0.40) percentile rank</i> Prevalence of Diabetes <i>High (>0.40) percentile rank</i> Prevalence of Poor Mental Health <i>High (>0.40) percentile rank</i>	13 14 15 16 17
	Case Study Catawba Valley	18



Web Map Utilization

Getting to know your census tract



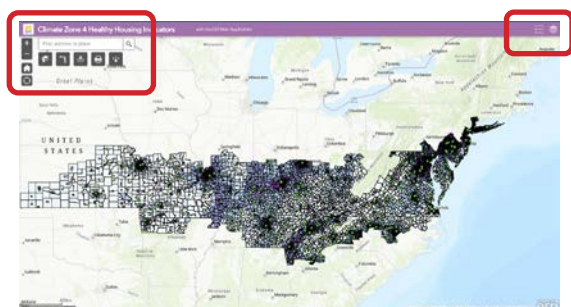
How to use the Climate Zone 4 Healthy Housing Indicators Web Map to determine relevant building strategies in your community

Scan here:



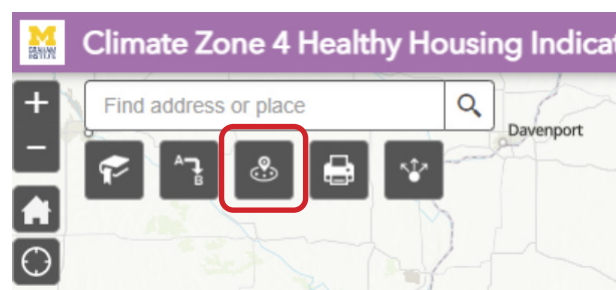
Step 1:

Visit our web map at:
<https://umich.maps.arcgis.com/apps/webappviewer/index>.



Step 2:

You can use the "Near Me" widget in the top left corner of the webpage to orient the map to your current location or type in an address.



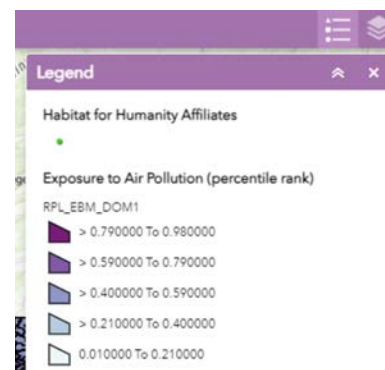
Step 3:

Use the "Layers" icon in the top right corner of the webpage to switch between different indicators to see which challenges your community might be facing.



Step 4:

Utilize the "Legend" icon in the top right corner of the webpage to understand the color-coding for specific indicators.



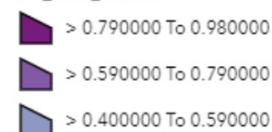
Step 5:

Interpreting the Indicators:

Example: If your community has a high (>0.40) exposure to air pollution, check out our building recommendations for Air Pollution.

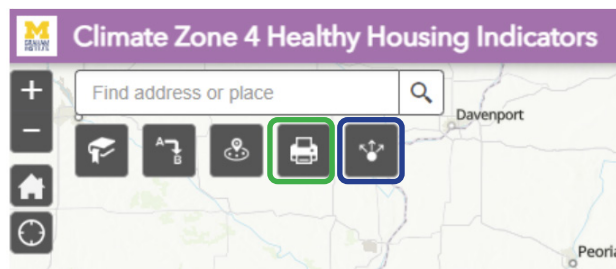
Exposure to Air Pollution (percentile rank)

RPL_EBM_DOM1



Step 6:

Use the "Print" (outlined in green) widget in the top left corner of the webpage to print the map or the "Share" (outlined in blue) widget to share the map via social media or email.





Energy Burden

Reducing financial strain of energy costs



Reducing the energy needs of a home can in turn reduce the potential mental distress associated with financial strain.

Overview

Energy Burden is understood as the average annual housing energy costs relative to annual household income. When the ratio of energy costs to household income is high, it can lead to increased risk of severe mental distress⁴⁹. This financial strain may lead to sacrifices in other areas of household spending such as food, medical needs, or inability to heat or cool the home. High energy burden is more likely in neighborhoods with households headed by women of color, illustrating how this financial burden is part of a larger systemic issue⁴⁷. The solutions outlined here are meant to stress the potentially hazardous impacts of high energy burden, and some actionable solutions to mitigate these effects.

Health-Related Concern:

High Energy Burden disproportionately affects minority populations and can lead to mental distress and financial strain.

Design Strategies:

Investing in energy-efficient products, or implementing more conscious energy-saving solutions within a household can reduce energy consumption. Upgrading from an electric furnace/AC to a high-efficiency heat pump, and upgrading to an Energystar refrigerator has high potential for energy savings⁵. Other initiatives such as reducing infiltration, installing LED lighting, drill-and-fill wall cavity insulation, high-efficiency ductless heat pumps, smart thermostats, reducing air leaks and increasing R values around ductwork, attic spaces, and walls can aid in energy use reduction^{5, 11}. Other active behaviors such as adjusting window treatments to reduce solar gain, or turning down the thermostat when gone for the day can contribute to energy savings.

Behavior

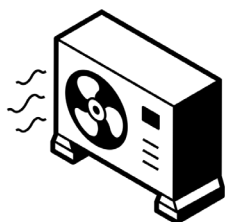


Blind control



Temperature adjustment

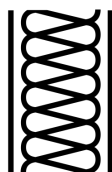
Upgrade



Heat pump



Energy Star refrigerator



Increase insulation



Smart Thermostat



LED Lights



Reduce leaks

Measurable Outcome:

Mitigating potential causes of high energy may allow residents to invest their finances elsewhere, reducing the need to make potentially difficult sacrifices and improve the individual mental health and collective stability.



Building Age

Mitigating risk in older housing stock



Poor maintenance in older buildings may lead to potentially serious health concerns. Knowing where to look for these risks is essential for a healthy home.

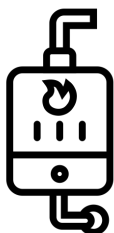
Overview

Older homes, especially those built before 1978, correlate to an increased probability of lead-paint exposure. If an older structure has experienced lack of proper maintenance over the years, it is possible that dampened space has created opportunities for mold growth. Furthermore, there may also be an increased likelihood of carbon-monoxide poisoning due to older appliances. While faults in construction and appliances are possible in any building, new or old, it is important to take special precautions when renovating or inhabiting older structures. Radon, especially in structures that experience cracks or other holes in the foundation may also pose other serious health risks.⁸⁸ Awareness, proper surveillance, and attentive maintenance within the home can prevent future health risks, some of which may not be readily obvious.

Caution:



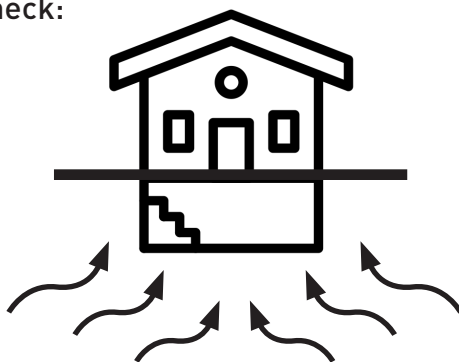
Lead-safe



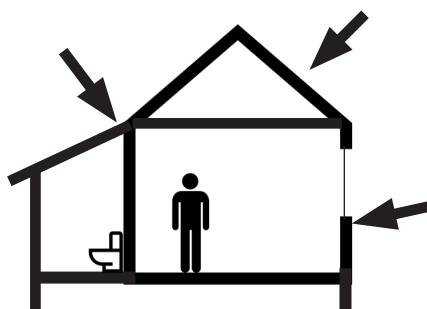
Monitor closely



Check:



Radon exposure mitigation



Check damp-prone

Health-Related Concern:

Mold exposure can cause an increase in respiratory symptoms, infections, allergic rhinitis, asthma, and allergic reactions such as sneezing, a runny nose, red eyes and skin rashes.⁸⁰ Lead paint exposure is also linked to serious health problems including kidney, nerve, and brain damage, and even infertility.⁸⁰

Building Strategies:

If renovating a home built before 1978, be sure to hire a contractor that is lead-safe certified, as it is possible that lead paint may even exist under multiple layers of paint. Per EPA recommendation, test your home for radon exposure, especially at the lowest level. This is especially true if you plan to remodel or finish your basement.³² If you do find radon in the basement, this can typically be fixed using underground ventilation systems, or by increasing the rate of air changes in the building.⁶¹ Check the home for any damp-prone areas, that could be more prone for mold exposure, such as attic spaces, exterior walls, or adjacent to plumbing. Appliances should be monitored regularly, especially older boilers or other carbon-burning appliances to avoid any carbon monoxide leakage.⁸⁰

Measurable Outcome:

Serious health problems may be prevented with proper maintenance and understanding of home hazards, especially in older homes.



Heat Energy Source

Making heat healthier



Potential serious health hazards can be prevented with proper ventilation, energy need reduction, and cleaner heat energy sources.

Overview

Heating and cooling accounts for a huge portion of the energy consumed globally. Where this energy comes from is not always understood to homeowners, but taking steps towards cleaner energy is possible even at the scale of the home. The first step is reducing heating load by increasing efficiency in the home. Passive strategies include air tightness, increased insulation, and greater thermal capacity of building materials. Efficient electric appliances, as opposed to oil or gas, are better for both human health and planet health. Harmful exposures to unventilated gas heaters may cause methemoglobinemia, which symptomatically could present with headaches, tiredness, brain fog and altered mental status, and bluish lips, fingers, or skin.

Health-Related Concern:

NO₂, a major indoor air pollutant, primarily emanates from unventilated gas heaters and cookers. Prolonged exposure can lead to methemoglobinemia, a condition that impairs the body's oxygen-carrying capacity.

Building Strategies:

Passive approaches, such as optimizing window orientation, using extended eaves, and adjusting behaviors like closing blinds, can reduce solar gain, resulting in reduced energy demand. Transitioning to electric cooking alternatives, such as replacing gas stoves with electric ones or utilizing induction hotplates, can minimize harmful exposure in inadequately ventilated spaces. Enhancing insulation, installing energy-efficient windows and doors, and utilizing heat pumps for heating and cooling can further decrease energy consumption. Additionally, incorporating solar panels or participating in community wind or solar programs can provide cleaner and more sustainable energy for homes.

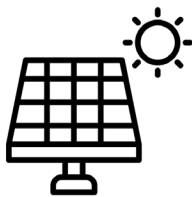
Measurable Outcome:

By mitigating potentially harmful indoor air pollutants, we not only improve the overall health of our planet but also reduce health concerns related to NO₂ exposure.

Invest



Wind energy



Solar energy

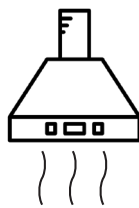
Consider



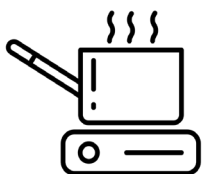
Window blinds



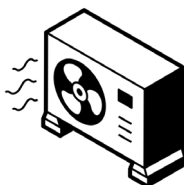
Eave extension



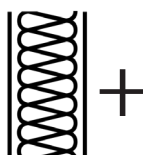
Hood vent



Electric cooking



Heat pump



Improve insulation



Age 65+

Homes to support Aging in Place



Understanding the needs and actionable solutions to aging in place can prevent potential hazards, support independence, and improve well-being in older adults.

Overview

The majority of older adults, 88%, reported remaining in their homes was important.⁷³ Adapting to the changing needs of aging individuals can maintain independence and reduce potential hazards of the home that may be associated with injury or even death. These considerations can happen well in advance of aging; in the planning stages of a new home it is important to consider adequate clearances, well-laid out rooms, and potential for adaptability if the mobility household members begin to change. These adaptations can range from significant home renovations, to small adjustments of furnishings. Benefits of aging in place may include reduced feelings of loneliness, maintaining one's identity, and better utilization of local neighborhood services.⁷⁶ The emotional and sentimental value of the home may be significant for mental health and well-being.

Health-Related Concern:

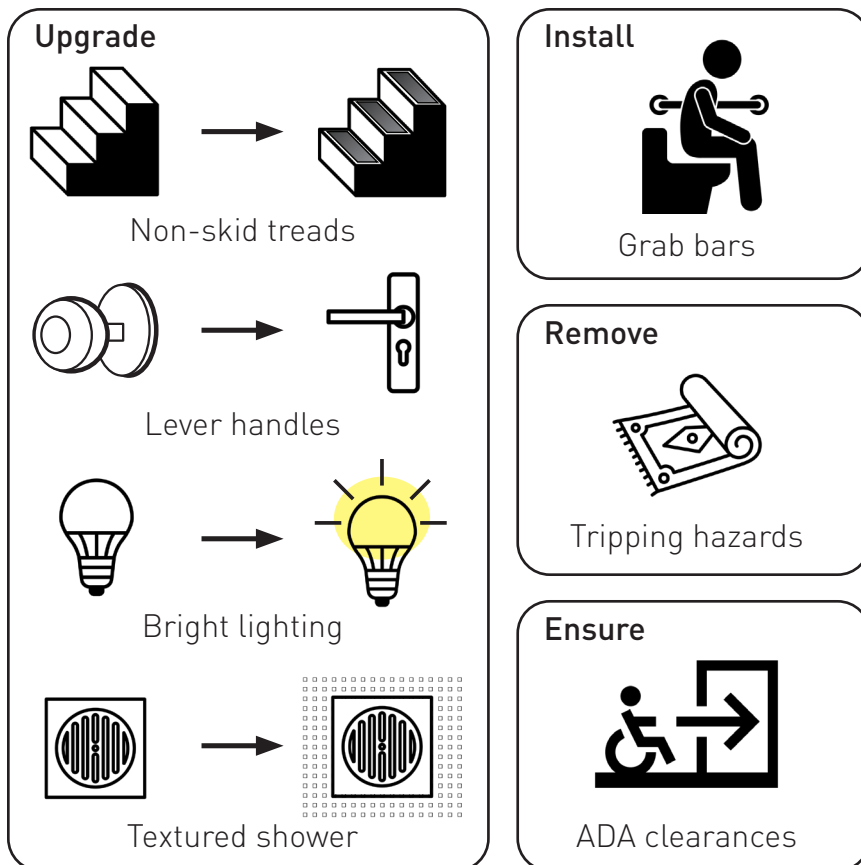
More than one out of four older people fall each year, with one out of five falls leading to a serious injury such as broken bones or a head injury.⁷⁰

Building Strategies:

Reducing home hazards can lead to a reduction in personal injury or even death. To create a less hazardous home environment and improve accessibility, modifications include installing nonskid treads on steps, removing throw rugs, replacing doorknobs to lever handles, and improving light brightness. Bathroom spaces are especially hazardous, which can be made safer by adding a waterproof seat in the shower, having textured showering surfaces, installing grab bars per ADA standards, and having zero-threshold entryways, using rubber-backed bathmats, or upgrading the toilet with a raised or high-profile toilet. It is also important to consider proper clearances and guidelines outlined in the ADA standards for increased mobility.

Measurable Outcome:

By modifying the home environment, aging individuals can have an improved sense of independence, and reduced likelihood of injury due to unintentional falls.





Social Capital Index

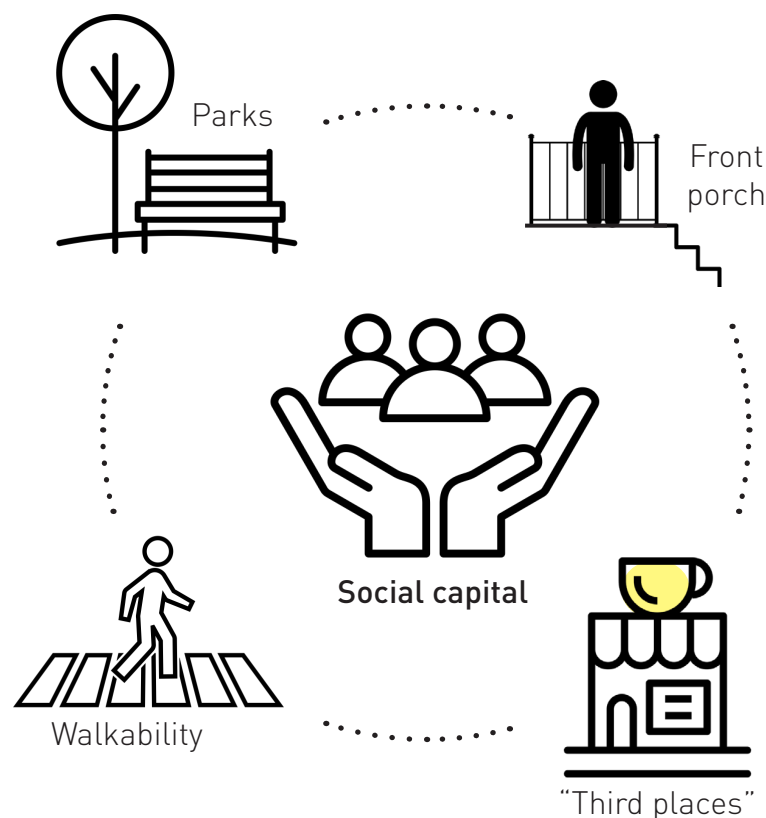
Improving community connections



Prioritize walkable neighborhoods, green space, and homes that encourage interaction for elevated social connection and positive health outcomes.

Overview

Being connected to those around you has huge implications on health and longevity. Multiple studies have shown that people who are socially disconnected are between 2 and 5 times more likely to die from all causes, compared with matched individuals close social ties.⁵⁶ These social ties are influenced by the places we live, both in the quality of connections, number of connections, and frequency of social engagement. While neighborhood walkability seems to be the strongest correlation to high social capital, it is still possible to implement measures at the scale of the home. Having opportunities for social space close to the public realm can encourage spontaneous interaction and support increased communal ties.



Health-Related Concern:

Lower social integration is related to increase risks of colds, heart attacks, strokes, cancer, depression, and premature death.

Building Strategies:

Emphasizing neighborhood walkability is pivotal in cultivating robust social capital. Features like well-maintained sidewalks, crosswalks, well-lit pathways, and traffic-calmed streets beckon residents to choose walking as their mode of transportation. It's equally important to ensure that these walkable areas lead to enticing destinations, including parks, recreational centers, or coffee shops, encouraging social interactions. In addition to infrastructural elements, the design of homes plays a significant role. Incorporating front porches and positioning communal spaces like living, dining, and kitchen areas closer to the front of the house fosters community engagement and interaction among neighbors. These thoughtful urban and architectural design choices contribute to the development of strong, connected neighborhoods and vibrant communities.

Measurable Outcome:

Enhancing social capital through thoughtful urban and architectural design can significantly reduce health risks.



Increasing Local Temperatures

Reducing demand in a changing world



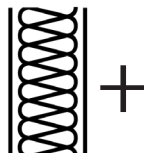
Implementing strategies for reduced heating and cooling loads can address the concerns of our changing planet, and prevent associated health-related concerns.

Overview

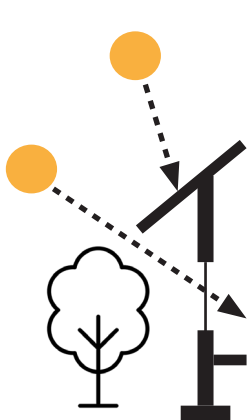
Within our changing climate, we are seeing a greater need to heat and cool our homes. However, this is not impacting everyone equally, as those who are living in hotter regions or of lower socioeconomic status are at higher risk for health-related concerns. To address the burden many households face with the rise in heating and cooling-degree days, efficiency is key. For both for new construction and existing homes, this can be addressed in a multitude of ways with varying degrees of financial investment. Proper orientation of windows, vegetation around the home, upgraded insulation, extended eaves, and even behavior changes of shutting blinds during the hottest hours of the day can all contribute to mitigating heat-related health risks, and reduction of energy bills.



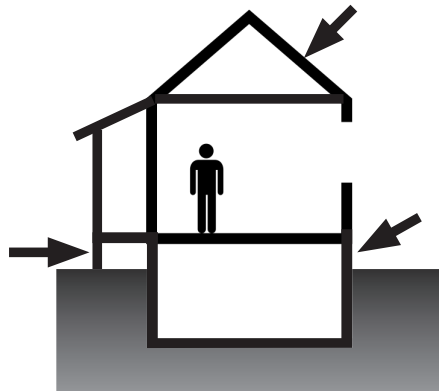
Pollutant proximity



Improve insulation



Orientation and eave design



Check air tightness in vulnerable areas

Health-Related Concern:

Hotter regions or regions with a lower socioeconomic status are at a higher risk of heat-related mortality.⁵⁷

Building Strategies:

Air leakage excess can increase heating and cooling bills by up to 30%, creating large inefficiencies in the way we heat and cool our homes.⁹ These vulnerable areas are most commonly found in spaces such as the attic, crawl spaces, and the basement.⁹ Special attention should be paid to these areas to test for inefficient homes, and, if needed, increase insulation and reduce air leakage. Avoiding direct sun exposure in the hottest times of the day should be a central design consideration. Passive strategies to reduce solar gain, such as window orientation and extended eaves, should be considered during the design phase. For existing homes, using vegetation to block direct exposure, introducing curtains, and installing awnings can all aid in solar gain reduction. Depending on window orientation, solar reduction from an awning could be as much as 65% on south facing facades, or up to 77% on west-facing windows.⁶⁵

Measurable Outcome:

Reducing the need for heating and cooling can prevent potential temperature-related illness, and reduce stress related to energy burden.



Air Pollution:PM2.5

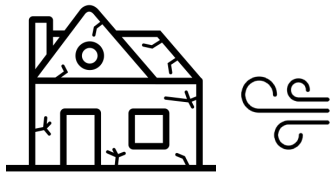
Improving indoor air quality



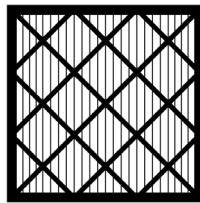
Improving indoor air quality, energy-efficiency, and personal health with improved construction, ventilation, and air filtration.

Overview

Air pollution from PM2.5 poses significant health concerns, contributing to respiratory disorders, cardiovascular issues, lung cancer, and it can even jeopardize brain and mental health. Sources of this air pollutant can be attributed to combustion of oil, gas, wood, cigarette smoke, and natural sources such as forest fires and dust storms.^{28,29,90} Urban areas and others characterized by population congestion, urban sprawl, and heavy industry are the most vulnerable.²⁹ To address this, a comprehensive approach to improving indoor air quality is recommended. This includes well-insulated homes, mechanical ventilation to ensure a constant supply of fresh outdoor air, and pollutant source control to minimize exposure. Additionally, air filtration using upgraded HVAC filters or portable air cleaners can provide an added layer of protection against indoor air pollution.



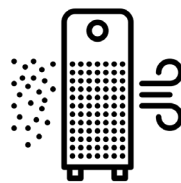
Seal leaks, cracks, joints



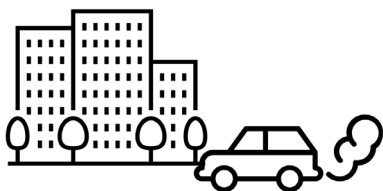
MERV 13 filters



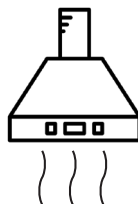
Ensure filtration and circulation of outdoor air



Portable air purifier



Caution vulnerable areas



Proper kitchen ventilation

Health-Related Concern:

Air pollution can lead to health problems, including respiratory disorders, cardiovascular issues, lung cancer, and even increased risk for psychiatric issues, lower cognitive performance, and increase rates of depression and suicidal ideation.^{29,90}

Building Strategies:

Opt for well-insulated homes that reduce air leaks, yet ensure enough fresh air to circulate. Better control of the air circulating will reduce energy costs, and improve indoor air quality through proper management of moisture, humidity, and air pollutants.³² Ensuring filters are properly installed and changed often, can ensure continued protection from indoor air pollution. When replacing filters, it is recommended that they hold a MERV 13 rating or above, as are most effective in eliminating potentially harmful small air particles.⁸⁶ Portable air purifiers which are designed to reduce pollutants locally, can provide an extra layer of protection against indoor air pollution.⁸⁶ When cooking, it is essential to have proper ventilation systems filter air directly to the outdoors.

Measurable Outcome:

These strategies collectively foster a more comfortable, economical, and healthier indoor environment while addressing air pollution-related health concerns.



High Prevalence of Cancer

Reducing exposure in the built environment



Cancer risk factors are multi-factorial, but thoughtful design elements and radon testing may reduce overall risk.

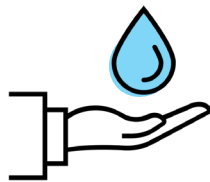
Overview

Cancer poses a significant threat to many Americans, often influenced by environmental factors. One prominent risk factor for non-smokers developing lung cancer is radon, a colorless, odorless radioactive gas that can be present in homes at ground level. Unfortunately, radon exposure, combined with other environmental and lifestyle factors, can increase the risk of cancer. To mitigate this risk, it is crucial to take proactive steps, such as improving ventilation, and conducting regular radon testing in homes. Addressing other environmental factors, like reducing exposure to harmful chemicals and pollutants, also plays a role in minimizing cancer risks. By recognizing these influences and taking preventive actions, we can reduce the chances of cancer impacting ourselves and our loved ones.

Environmental Factors



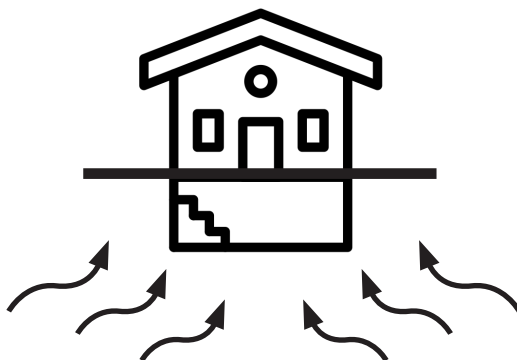
Pollutant proximity



Water quality



Air quality



Radon testing

Health-Related Concern:

Nearly 2 million Americans will be diagnosed with cancer each year, and over 600,000 will die from it annually. For lung cancer specifically, radon exposure is a major risk factor for non-smokers.

Building Strategies:

Radon testing for your home is crucial, especially on the lowest level (ground or basement), and it's wise to repeat the test periodically. It's more cost-effective to assess radon levels before starting remodeling or renovation projects. Additionally, consider other environmental factors like air quality, proximity to industrial sites using toxic chemicals, and water quality. Prioritizing a healthy lifestyle through a balanced diet, regular physical activity, and other wellness practices is equally important in reducing health risks. Testing for radon and maintaining overall environmental and personal well-being can significantly contribute to a healthier and safer living environment.

Measurable Outcome:

While there are many environmental and lifestyle risk factors that affect cancer risk, radon is one of the most important and actionable to reduce the chances of developing lung cancer. Keeping in mind other environmental and lifestyle factors can play a role in risk reduction as well.



Prevalence of High Blood Pressure

Promoting healthy lifestyle through design



Physical activity, healthy eating, and other lifestyle changes may reduce the prevalence and risk of high blood pressure.

Overview

High blood pressure, or hypertension, affects nearly 1 in 4 Americans and is a significant risk factor for cardiovascular disease and strokes. To mitigate this risk, embracing physical activity and adopting a healthy diet are vital. These lifestyle choices can effectively lower blood pressure and reduce the likelihood of developing hypertension. Furthermore, creating green spaces and walkable neighborhoods in close proximity to nutritious food sources can foster less sedentary lifestyles, encouraging individuals to engage in regular physical activity and make healthier dietary choices. By prioritizing these factors, we can collectively work towards reducing the prevalence of high blood pressure and its associated health risks in the United States. This multifaceted approach not only promotes better cardiovascular health but also enhances overall well-being within communities.

Health-Related Concern:

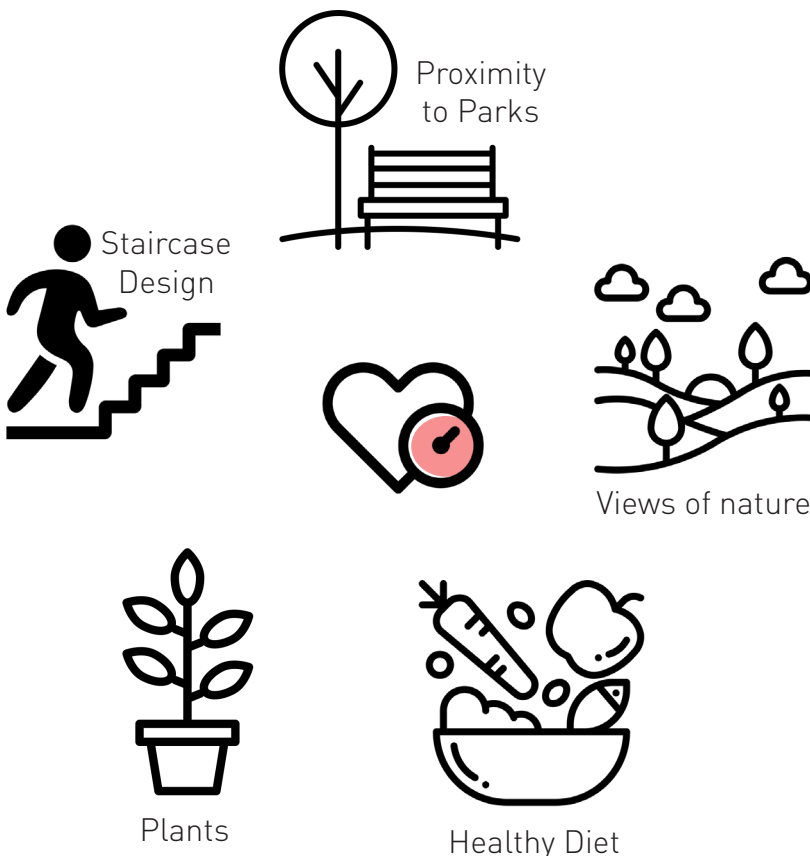
Hypertension is sometimes known as the “silent killer” because it is often asymptomatic but is a dangerous risk factor for cardiovascular disease and stroke. It affects nearly 1 in 4 Americans (about 120 million people in the US).

Building Strategies:

Highly walkable neighborhoods in close proximity to nutritious food resources support the lifestyle modifications essential to reducing the risks of high blood pressure. Green spaces in particular, as well as plants, vistas, and other aesthetic design elements, contribute to environments that encourage people to get out of their chairs and out of their homes. Staircase design is another opportunity to encourage aesthetic but safe in-home activity. These concepts can also be applied to neighborhoods as a whole, by mindfully thinking about access to safe, interesting walkable locations that also promote activity.

Measurable Outcome:

Indoor and outdoor spaces that encourage movement in a safe, aesthetic manner are important to promoting non-sedentary lifestyles. In combination with access to healthy nutrition, these design elements may reduce the risk for hypertension, a common but potentially deadly disease affecting millions of Americans.





High Prevalence of Asthma

Reducing triggers in the built environment



Mitigating asthmatic triggers is possible with proper selection of heat energy sourcing, ventilation, and management of external vegetation.

Overview

Nearly 25 million Americans suffer from Asthma⁶³, a condition that affects the ability to move air in and out of your lungs⁶². Due to the nature of this incurable disease, management is essential. The built environment plays a critical role in influencing asthmatic symptoms, prevention of triggers, and mitigating potential asthma attacks. Utilization and selection of vegetation, mechanical ventilation, and heat energy sources should be carefully considered in areas where high prevalence of asthma exists. It should be noted that external environmental factors based on geographic location can have significant influence on asthmatic occurrence. Extra care for proper mechanical ventilation is essential when clean, external fresh air is jeopardized.



Seal leaks, cracks, joints



Ensure filtration and circulation of fresh outdoor air



Choose low-pollen plants



Caution

Oil



Gas



Coal



Kerosene



Wood



Health-Related Concern:

Asthma is a common and incurable disease of the lungs, affecting 1 in 13 people in the US⁶². Many triggers are a result of environmental circumstances which can be avoided with proper prevention methods in place.

Building Strategies:

Reducing the amount of indoor air pollutants, unintentional “leaky” home environments, moisture, pollen, and extreme temperature and humidity conditions can aid in reducing the prevalence of asthmatic symptoms. Avoiding oil, gas, kerosene, coal, and even wood heating elements can reduce indoor air pollution³². Strategies to increase air tightness by sealing cracks, penetrations, and joints can provide more control over air quality, and aid in tight, energy efficient homes³². These should be coupled with proper active systems that ensure enough fresh outdoor air is being circulated. Attention should be paid to adjacent plantings and vegetation; when possible choose plants with low pollen levels.

Measurable Outcome:

By reducing asthmatic triggers, it is possible to increase quality of life by avoid potentially dangerous circumstances for individuals living with asthma.



Prevalence of Diabetes

Promoting physical activity and healthy nutrition



Accessible physical activity and healthy foods are essential to diabetes risk reduction and management.

Overview

Diabetes is an alarmingly prevalent and severe chronic condition, afflicting over 38 million individuals in the US, which amounts to about 11% of the population.² Managing this disease entails more than just medications; lifestyle choices are pivotal. Physical activity and a balanced diet play a critical role in diabetes management. Creating considerate built environments can enhance access to exercise resources, promote in-home food preparation, and encourage the adoption of healthy nutrition practices. By optimizing living spaces to facilitate physical activity and nutritious eating, we can empower individuals to better manage their diabetes and improve their overall health, thereby mitigating the impact of this widespread chronic ailment.

Health-Related Concern:

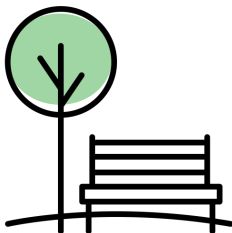
Diabetes is a serious and deadly chronic disease affecting approximately 38.4 million Americans and is becoming increasingly common among younger people.

Building Strategies:

To combat the rising prevalence of diabetes, neighborhoods can implement several strategies in their built environments. These include providing accessible parks, playgrounds, workout stations, trails, or bodies of water within 0.5 miles of residences.³⁸ Some residential complexes may offer complimentary access to gyms, playing fields, or swimming pools. Proximity to nutritional food resources and creating environments that promote in-home food preparation resources, as opposed to reliance on meals prepared outside the home, such as fast food, can significantly impact the risk of developing diabetes and enhance the quality of life for those already living with the disease.

Measurable Outcome:

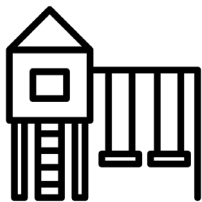
Promoting physical activity and healthy nutrition in the built environment may be conducive to improving lifestyle factors that are important for people managing this condition and reducing the risk of others developing it in the future.



Parks



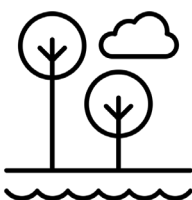
Healthy Eating



Playground



Close to playing fields



Connection to water



Gym access



Prevalence of Poor Mental Health

Mitigating impacts for improved lifestyle



Designing our homes to support our mental well-being can lead improved mood, stress reduction, and a healthier lifestyle.

Overview

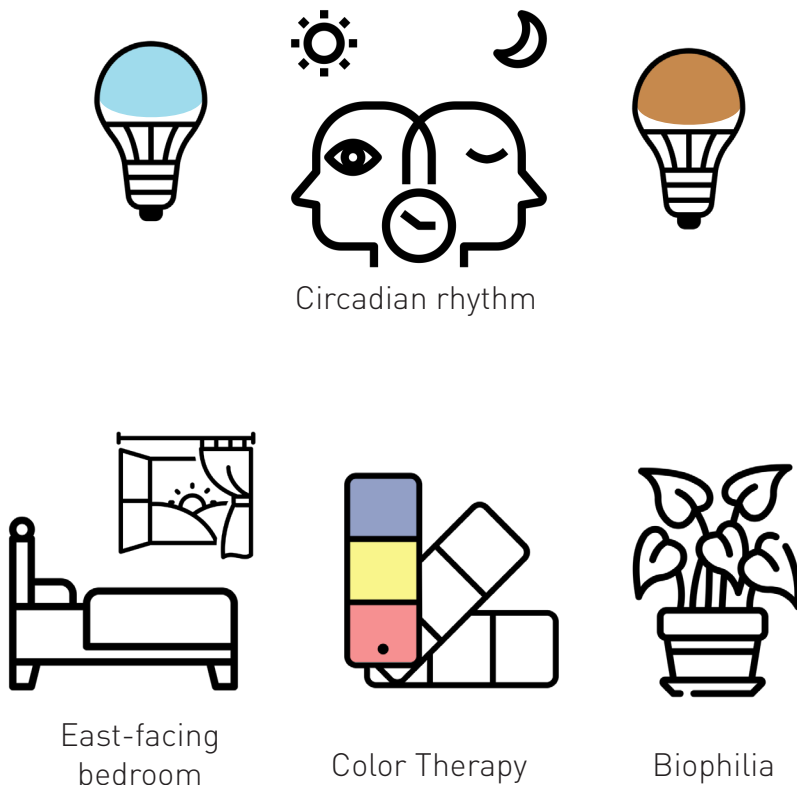
Poor-quality housing has been linked to increased psychological distress, which can cause or potentially worsen existing mental illness.⁴⁵ With concerns around rising prevalence of mental illness, and the disproportionate amount of time spent indoors, it is important to understand the effects of our environments on our health. Some strategies to improve mental health in the home include proper lighting to support regular circadian rhythms, increasing connection to nature, improved organization of the home, and consideration of color. Management of our mental health can also be attributed to behavioral change, so making our environments places that encourage healthy choices is an essential part of holistic care.

Health-Related Concern:

Mental illness affects 1 in 5 U.S. adults each year, and has been linked to increased risk of developing cardiovascular and metabolic diseases.⁷⁷

Building Strategies:

Changing our home environment can lead to improvement and encourage healthier behaviors to prevent onset of symptoms. Ensuring proper daylighting, increased lighting control, east-facing bedrooms, and adjusted color temperature have shown to support regular circadian rhythms cycles.^{37,38} Using brighter white colored bulbs in the morning, and warmer orange-hues in the evening can assist in natural circadian cycles.³⁷ Increased connection to nature, even by having house plants, can perform an important biophilic function, leading to improved mood and reduced stress.¹⁸ Consider location of color throughout the home, as some colors, such as yellow, have energizing effects, where cooler colors may provide a more calming environment.⁷⁹ Reducing clutter can help provide sense of control and reduce stress.



Circadian rhythm

East-facing
bedroom

Color Therapy

Biophilia

Measurable Outcome:

Improved conditions to support our mental health can increase healthy behaviors and improve quality of life.



Case Study: Catawba Valley

Sustainability is Affordability



Energy efficiency is a key part of the long-term affordability and health of a home. Affordable, sustainable, and healthy homes are the best way to set new homeowners up for success.

Overview

The Catawba Valley Habitat for Humanity is working to ensure that their partner homeowners have affordable and healthy housing for the entire time they live in their homes. They do this by utilizing the latest energy-efficiency standards to guarantee electric bills under \$40/month.

Local Programs & Partners:

System Vision

- Certification that provides an affordability guarantee
- HERO Program* through Duke Energy
- Provides incentives to builders for energy efficient homes

Southern Energy Management

- Does energy efficiency inspections and offers grants

TightLines Design

- Created the socially-conscious and community-driven floor plan

Health-Related Concerns:

- Low VOC materials (because of tight insulation)
- Air filters & dehumidifiers in the crawl space (reduce risk/triggering of asthma)

Building Strategies:

Sustainability:

- 2x6 frame (allows for more insulation)
- Stringent air sealing (important for tight insulation)
- Measure HVAC specific to each home (ensures maximum efficiency)
- Fully electric/Solar ready



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