Minneapolis

Climate Change Impacts & Adaptation Strategies

Prepared for: Brendon Slotterback
Gayle Prest
The City of Minneapolis
Office of Sustainability

Faculty Advisor: Carissa Schively-Slotterback

Team Members: Andrew Emanuele
Andrew Rockway
Georgia Rubenstein
Kelly Schmitt

Humphrey School of Public Affairs
University of Minnesota
May 2013

This report was created as part of a capstone project in Sustainability Planning, coordinated by the Humphrey School of Public Affairs at the University of Minnesota and the Minneapolis Sustainability Office.

Contents

Executive Summary

Minneapolis's climate is changing. Warmer weather and shifts in precipitation patterns have and will continue to be the principal drivers of climate change-induced impacts in the city. Under current emissions and climate change scenarios, by the end of the century Minneapolis will see higher average temperatures with significantly hotter summers, increases in heavy downpours, especially in the fall and spring, and extended periods of drought in the summer. These changes will likely increase public health risks, threaten the City's natural resources and ecosystems, and strain existing infrastructure.

While much of the global discussion of climate change has focused on mitigation – or reducing the greenhouse gas emissions that cause climate change – increasing attention is being paid to adaptation. Cities throughout the world are taking action to become more resilient in the face of the climatic changes they are already experiencing. City of Minneapolis staff and other stakeholders should incorporate the anticipated impacts of climate change into ongoing planning efforts. Taking these proactive steps can ensure that the City's infrastructure, ecosystems, businesses, and residents are able to adapt to, avoid the harmful consequences of, and even find opportunities in climate change.

Climate change impacts on the City of Minneapolis, and their associated adaptation strategies, can be grouped into four main categories, discussed on the next page. In addition to implementing adaptation strategies on an individual, impact-focused basis, the City of Minneapolis will likely wish to undergo a comprehensive adaptation planning process, involving a range of stakeholders including City staff, local experts, and residents. Best practices for leading this planning practice include drawing on perspectives from all relevant City departments, determining the adaptive capacity of various City systems, and working with local climate experts to create "downscaled" climate models.

Minneapolis is lucky in that the climate change impacts it faces are not as dire as those in some other cities; residents are not threatened by substantial flooding due to sea level rise or having their drinking water supply threatened by drought and poor water quality. By undergoing a thorough, thoughtful climate change adaptation planning process – working with City staff and residents to identify priorities and drawing on examples and best practices from other cities – the City of Minneapolis can act not only to protect the community from the negative impacts of climate change, but at the same time find opportunities to improve the environment, economy, and quality of life for all those who live and work in Minneapolis.

Public Health

The impacts of hotter temperatures on human health will include increased incidences of heat stress, respiratory illness, diseases spread by insects, and waterborne diseases. As temperatures rise, the need for adequate shade and air-conditioned buildings will be a key concern. These impacts will likely be disproportionately burdensome to vulnerable populations, including low-income communities, communities of color, very young and elderly populations, the disabled, and the uninsured. Accordingly, these communities will require additional attention from the City of Minneapolis.

Adaptation Measures: Manage heat, potentially including improving methods of tracking heat-related deaths, implementing cool pavements, and encouraging green roofs.

Natural Environment

As the climate hardiness zone shifts northward, native plants and animals will face habitat loss, food scarcity, and competition from invasive species. Plants and animals unable to adapt will decline and face possible extinction. As native species leave or die off, species moving in from the south will create a much different ecosystem than exists today, and the City will be required to alter the way in which it manages its parks, boulevards, and natural areas.

Adaptation Measures: Preserve the natural environment, potentially including increasing urban tree canopy, planting climate-appropriate vegetation, and managing invasive species.

Stormwater Management

As a result of changes in Minneapolis's climate, stormwater management will need to address greater runoff volumes resulting from more frequent heavy downpours and changes in the seasonal timing of precipitation. Without adaptive measures in place, larger runoff volumes will lead to more localized surface flooding, lower water quality, and greater damage to property and sewer and stormwater infrastructure.

Adaptation Measures: Manage stormwater, potentially including controlling runoff with rain gardens and bioretention, reducing impervious surfaces, and expanding surface detention capacity.

Utilities

Anticipated changes to Minneapolis's climate will have a significant impact on the operations of utilities within the City. Higher temperatures and altered precipitation patterns will affect both the operations of utilities and the demand placed on existing facilities and infrastructure. Understanding projected impacts and instituting adaptive measures is critical to ensuring a well-functioning utility system for future generations.

Adaptation Measures: Ensure a reliable water and energy supply, potentially including incentivizing microgrid projects, promoting cool roofs, and encouraging energy efficient buildings.

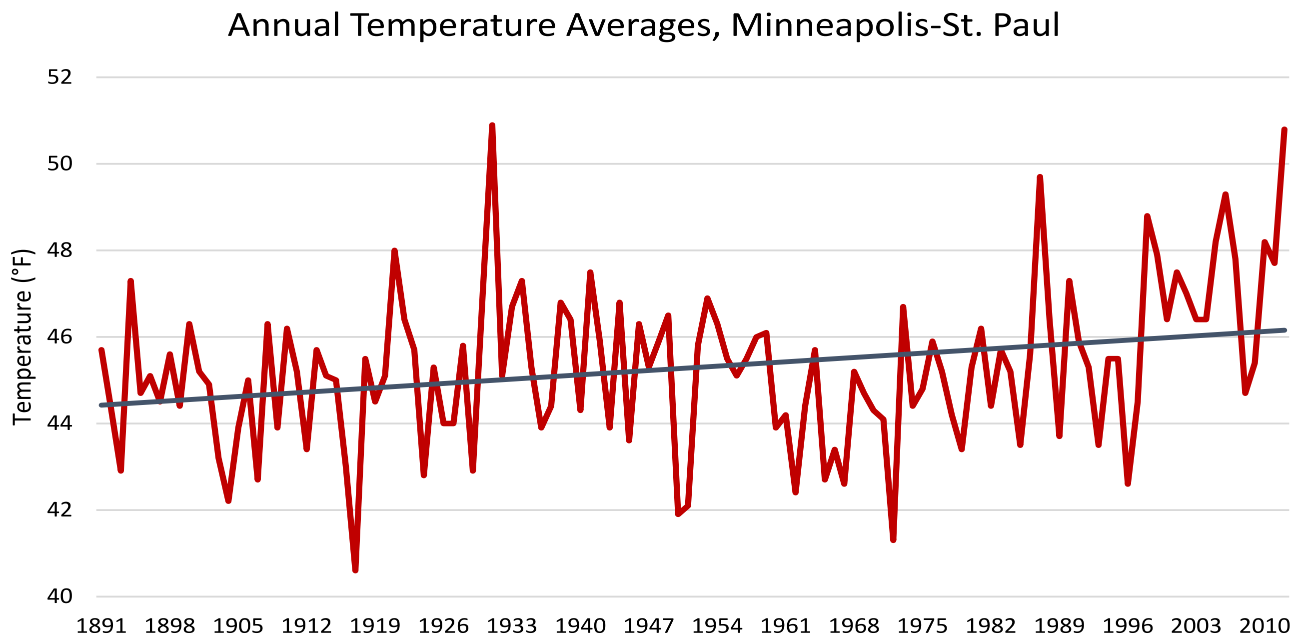
CLIMATE IMPACTS

Our Changing Climate

The science is indisputable – the world's climate is changing. The average annual temperature in Minnesota has increased by more than 2.3°F (1.3°C) over the past century, slightly above increases seen in Minneapolis.[1] The rate of warming has tripled since 1980, and that trend is only expected to accelerate as a result of climate change.[2]

The commonly used term *global warming* is misleading, as climate change will mean much more than just a warmer world. What was once a 70° day won't just become a 75° day; rather, a warming world has implications for precipitation patterns, the makeup of local ecosystems, and the ability of people and communities to maintain their daily lives.

Climate change refers to the broad shifts in the Earth's climate resulting primarily from human activity. In particular, the use of fossil fuels and the conversion of previously undeveloped land to human uses such as industry, housing, and agriculture, have substantially increased the concentration of greenhouse gases (GHGs) in the Earth's atmosphere. These gases are responsible for regulating the planet's temperature, with higher concentrations of greenhouse gases leading to warmer conditions.



Source: University of Minnesota, Climatology Working Group

The climatic changes that have been observed in Minnesota are consistent with changes elsewhere. The years between 2000 and 2010 were some of the warmest on record for the United States.[3] Further warming is expected over the next century, though the extent depends on the action we take now and in the future to reduce greenhouse gas emissions. Based on a range of potential changes in emission levels and climate scenarios, scientists expect an increase in average global temperature somewhere between 1.1°C (2°F) and 5.6°C (10°F) by 2100.[4]

DID YOU KNOW?

6 of the top 15 warmest years on record for Minneapolis-Saint Paul have occurred since 2000. Only 1 year in the last 20 (1996) has made the top 15 list for coldest years.

Climate Change in Minneapolis

Due to the unique characteristics of urban areas, cities warrant special consideration in the discussion of climate change impacts. The built environment and concentrated human activities such as transportation, heating and cooling, and industrial processes contribute to an urban heat island effect, making cities an average of 2° to 6°F (and as much as 22°F) warmer than their surrounding environs, depending on the time of day, cloud cover, and prevailing wind conditions.[5] Roads, sidewalks, and other impervious surfaces prevent infiltration and increase water runoff, while more vehicles and greater concentrations of industrial activity create higher levels of air pollution. As a result of these human influences, the consequences of higher temperatures and altered precipitation patterns expected statewide may be exacerbated in urban areas like Minneapolis.

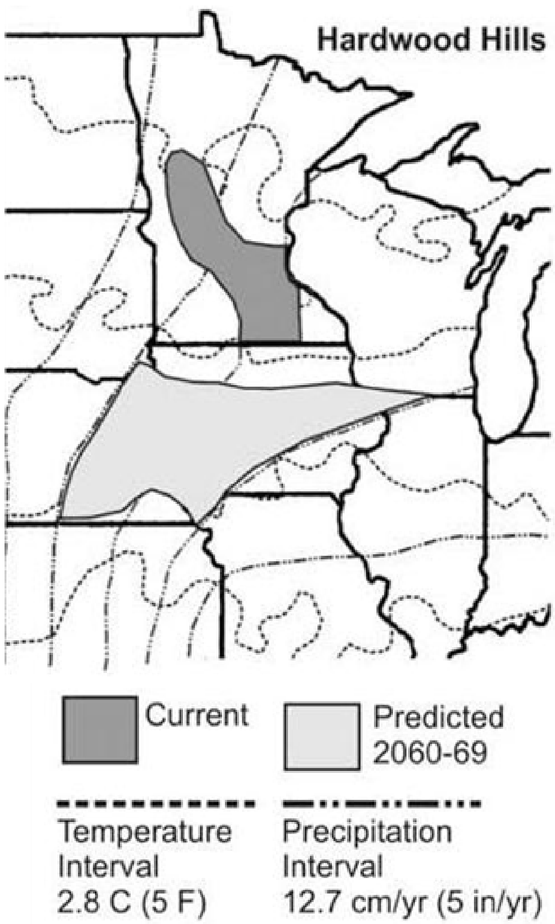
Downscaled climate modeling* designed to project climate change impacts in Minneapolis with high levels of precision has not yet been conducted, though initial studies are underway.[6] The confounding factors described above can make extrapolating general climate change impacts to localized areas, especially at the level of individual cities, difficult.[7] Nevertheless, assessments of anticipated impacts in Minneapolis based on current trends, projections from similar cities, and general predictions of climate change impacts in our region can provide a useful base of knowledge for understanding the impacts of climate change on our city.

Climate change will affect the entire city; however, vulnerable populations – especially children, the elderly, low-income individuals and families, and communities of color – will likely bear a disproportionate burden, whether due to their lack of access to adaptive measures such as air conditioning, their greater susceptibility to health problems because of age and existing health conditions, or lack of economic resources to deal with extreme weather-related events and emergencies. When prioritizing adaptation strategies, the City of Minneapolis should make a special effort to account for these disproportionate impacts and pursue adaptation efforts accordingly.

* Downscaling refers to the extrapolation from global and national climate models to the regional and local level by adding locally specific data. This technique yields more precise projections of climatic conditions at the level of cities.

Temperature

Galatowitsch, et al. have used downscaled climate models from the World Climate Research Programme to produce localized climate change projections for eight Minnesota regions. Overall, the authors predict regional climatic shifts by 2070 equivalent to current conditions of US regions located 250-300 miles to the south-southwest. Minneapolis, located in the Hardwood Hills region, is predicted to shift by the 2060s to climatic conditions similar to current central Iowa and eastern Nebraska. Average annual temperatures are expected to increase between 5.4°F and 7.2°F above the 1970 to 1999 baseline under upper mid-range* emissions projections.[8] The annual increases in temperature will not necessarily correspond to historical patterns. For example, average nighttime temperature in both summer and winter will increase more than daytime temperature. Average daily lows are expected to increase more than highs, especially in winter.[9] Overall ice cover on water bodies will be lower than historic levels, with ice out days likely to occur earlier than previous years in most instances. Across the state, numerous early ice out records have been set in the past five years, and this trend is expected to continue.[10] Higher average temperatures may also increase freeze-thaw occurrences, with water turning to ice as temperatures drop below freezing overnight and melting again during the day.[11]



Source: Galatowitsch et al.

Minneapolis summers will contain more periods of intense, sustained heat.[12] Looking forward, any future summer in Minneapolis is likely to be warmer than the hottest summer recorded during the historical baseline of 1960 to 1990.[13] If levels of GHG emissions continue at current rates, it is expected that Minneapolis will endure between 60 and 70 days per year over 90°F, with 25 to 30 of those days over 100°F.[14] The growing season is also expected to increase.

Average dew points** are also expected to increase, meaning higher humidity and "feels like" temperatures. Additional human discomfort and more heat advisories and excessive heat warnings will likely occur as a result.[15] Similarly, higher temperatures are likely to increase total evapo-transpiration,*** particularly in the summer, though projections of the magnitude of rate changes remain undetermined.[16]

DID YOU KNOW?

Higher overnight temperatures limit the body's ability to recover from extended daytime heat exposure, increasing heat stress and the risk of heat-related illness.

* Climate projections depend on predicted levels of greenhouse gases in the atmosphere. The upper mid-range (A2) estimate assumes that global GHG emissions increase along current trends and, as such, reflects a moderately pessimistic scenario..

** The human body cools itself by sweating such that when sweat evaporates, heat is drawn away from the body. Higher dew points (or dew point temperatures) mean there is relatively more moisture in the atmosphere, making it more difficult for sweat to evaporate.

*** Evapotranspiration affects surface and groundwater levels, soil moisture content, and impacts from the urban heat island effect.

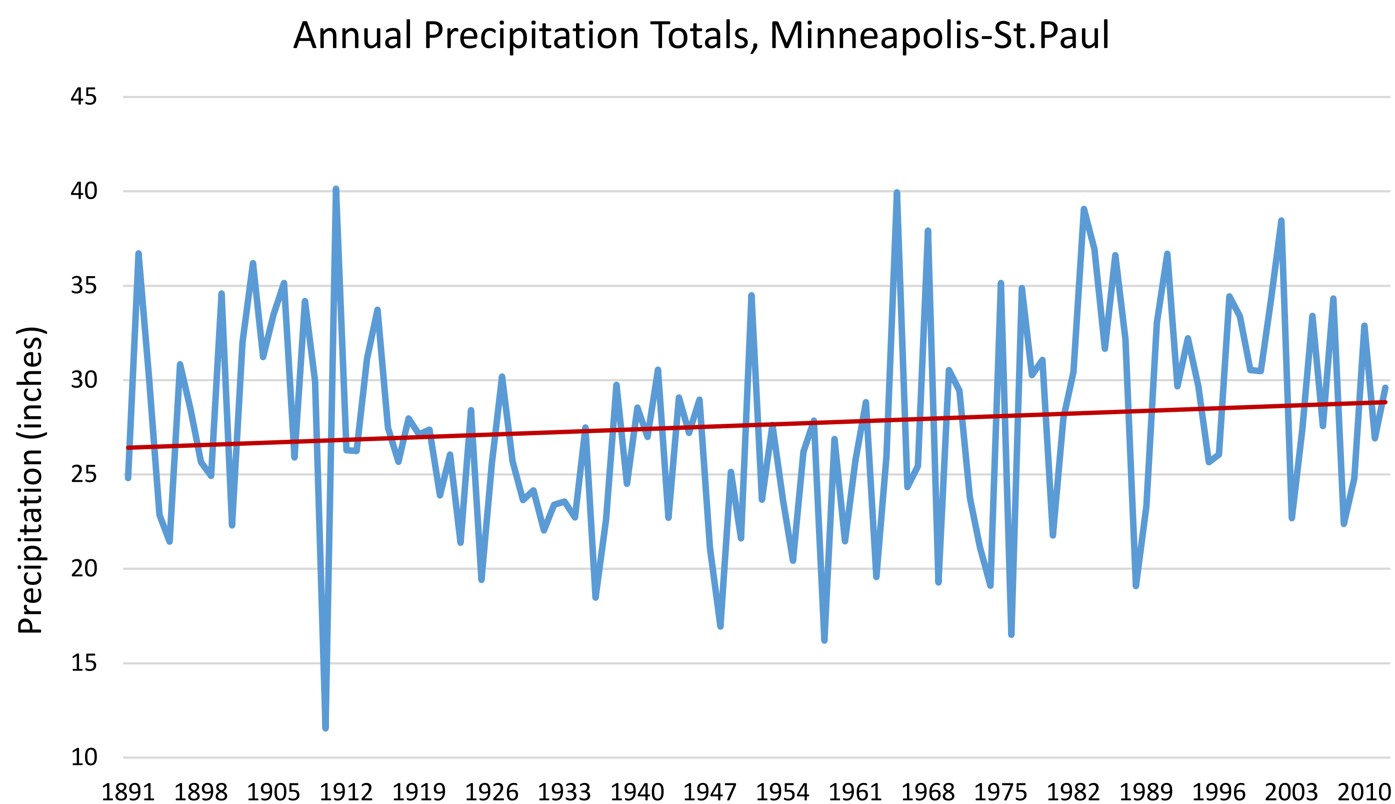
Precipitation

Normal 30-year precipitation averages in Minneapolis have increased by 20% above the 1940-1971 period.[17] Future warming is likely to increase annual average precipitation by 5% to 8% by 2070, though estimates of precipitation levels are less certain than temperature projections.[18]

As with temperature, precipitation patterns will not necessarily reflect historical patterns. For example, summers will be drier, with an approximate 5% decrease in summer precipitation by 2070.[19] The largest increase in precipitation will occur in the spring and fall; precipitation in these seasons is likely to increase by 15% over the next few decades and by 30% to 50% by the end of the century.[20]

An increased amount of winter precipitation will fall as rain rather than snow. Snow will also fall later into the winter, with an overall reduction in days with snow cover.[21]

Precipitation events in all seasons will likely be more intense, with greater amounts of rain or snow on average in each storm. Downpours in the Midwest are already twice as common as they were a century ago. The heaviest 1% of storms now account for 30% more of annual precipitation totals than 50 years ago.[22] An additional 11% increase in the magnitude of these heavy storms is expected by midcentury.[23] The frequency of storms will be reduced, however, corresponding to an increase in short-term droughts between significant precipitation events.[24]



Source: University of Minnesota, Climatology Working Group

Public Health

Many of the impacts of climate change described above will have implications for public health in Minneapolis. As temperatures rise and storm events become more intense, it is important to maintain an understanding of the effects of climate change on the City, especially its most vulnerable populations. Longer and more intense heat waves will become one of the most significant issues affecting public health in the future. Additionally, more frequent and more powerful heavy rain and snow events may result in degraded water quality and the disruption of transit systems. It is difficult to predict with precision how these changes in climate will impact all populations, but it is crucial to prepare for the likely impacts to preserve and enhance the health and well-being of all who live and work in Minneapolis.

Heat Waves and Air Quality

One of the key drivers for public health impacts in Minneapolis involves heat waves and air quality. The urban heat island effect exacerbates the public health impacts of higher temperatures by increasing general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and even heat-related mortality.[25] During more severe heat events, or heat waves, the most sensitive populations are children, older adults, individuals with existing health concerns, and those who have limited or no access to shade and air-conditioned buildings, including segments of the labor force that work outside during the day.

Heat

The most severe human health risk related to climate change is heat-related mortality. According to the Centers for Disease Control and Prevention, during the period from 1979 to 2003, excessive exposure to heat led to more than 8,000 heat-related premature deaths in the United States alone.[26] This is more than the combined total of hurricanes, lightning, tornadoes, flooding, and earthquakes. Heat stress on the body is a particular concern with elderly populations, as their bodies cannot regulate temperature as easily. This is of particular concern as the elderly proportion of the population rises.

Air Quality

In addition to heat-related impacts, poor air quality resulting from increased temperatures will negatively impact human health. Ground-level ozone forms when nitrous oxides (NOx) and volatile organic compounds (VOCs) react with sunlight and hot weather. Ozone production increases when temperatures reach 90°F.[27] An increase in ground level ozone is a concern because it is linked with decreased lung function, increased hospital and emergency room visits, and an increase in premature mortality.[28] This issue is especially relevant in cities like Minneapolis because the primary sources of NOx and VOCs – including industrial processes, motor vehicles, and chemical solvents – are more prevalent in urban areas.[29]

Particulate matter is another common pollutant that contributes to reduced air quality. Particulates come from many sources, but the largest contributors are coal-fired power plants and automobiles. While only one coal-fired plant is located in Minneapolis*, the City's air quality is still impacted by the emissions of plants in the Metro area and greater Minnesota. As demand for electricity increases alongside rising temperatures, these power plants will generate more particulate emissions.[30] Particulates from gasoline and diesel combustion vehicles on roadways are another concern. These types of particulates are more densely concentrated in urban areas, especially in

*The steam generation plant that services the University of Minnesota burns coal, though the percentage of coal in the plant's fuel mix has declined over time.

high-traffic areas.[31] Particulates can increase the severity of asthma attacks, incidence of heart attacks, and hospitalizations related to cardiovascular disease and asthma. Degraded heart and lung function resulting from exposure to particulates may also lead to early death.[32]

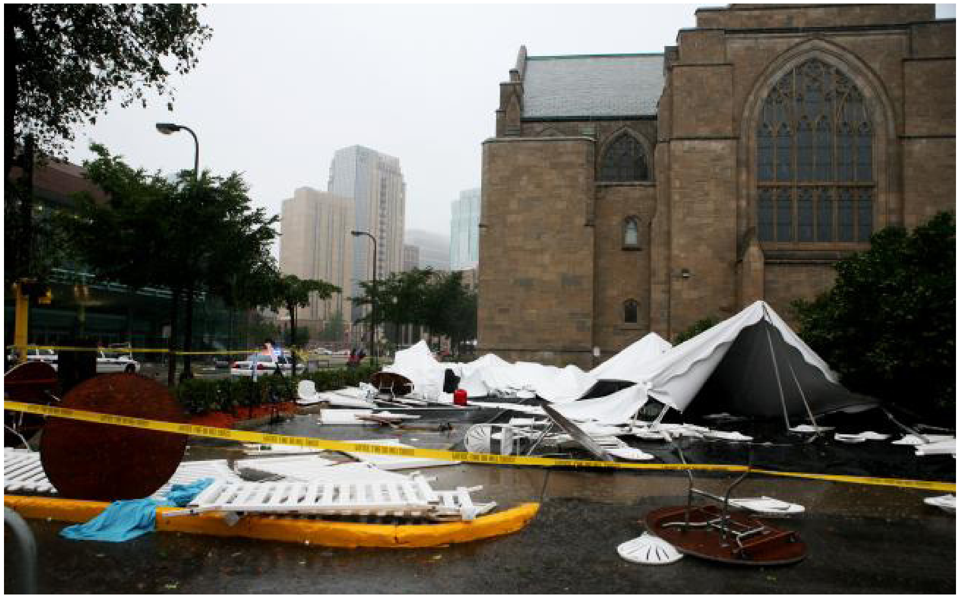
Extreme Storm Events and Water Quality

As the frequency and intensity of extreme storm events increases, severe weather may not only cause injuries during the event but can also pose risks to human health and safety over a longer time period. Flooding and stormwater runoff, for example, can reduce the availability of fresh food and water, increase exposure to disease, and interrupt operation of utilities, communication systems, and health care services. Extreme events may also impair the ability of emergency service providers to reach at-risk populations. Upstream impacts may also affect Minneapolis's drinking water supply, which comes primarily from the Mississippi River.

Disease

A benefit of Minnesota's long winters is that the cold temperatures kill off many pests and diseases during hard freezes. As winters become milder, pests like ticks and mosquitoes will be able to survive in greater numbers. As a result, this will increase the risks of acquiring diseases spread by insects, like Lyme disease and West Nile virus.[33]

Climate change can also impact water-borne diseases because of the increase in heavy rainfall events. Increased runoff during heavy downpours can contaminate water bodies, usually due to overflow from sewer systems. This type of contamination is especially harmful when receiving water bodies are used for recreation or sources of drinking water. One of the most common illnesses from water contamination is gastroenteritis, which can cause vomiting, headaches, and fever.[34] While Minneapolis has reduced the likelihood of sewage entering runoff by reducing most potential sources of sewage overflow within the City, the threat has not been entirely eliminated due to the high cost of remediating the remaining sources. Upstream runoff and attendant pollution may also affect the quality of the City's drinking water supply.



DID YOU KNOW?

Cases of Lyme disease in Minnesota have increased by over 500% since 1995. 1,050 cases were reported in 2010 according to the Minnesota Department of Health.

Natural Environment

Natural Vegetation

Trees, plants, and grasses are all part of the natural vegetation in Minneapolis and provide a variety of essential functions beyond simply aesthetic appeal. These benefits include stormwater runoff reduction, air quality improvements, energy conservation, higher property values, animal habitat, sources of food, and reductions in the urban heat island effect.[35]

Plant hardiness zones – the temperature belts at which specific floral species thrive – have been shifting northward. These shifts, exacerbated by increased periods of drought and greater competition for resources with invasive species, will have a definitive impact on Minneapolis's vegetative composition.

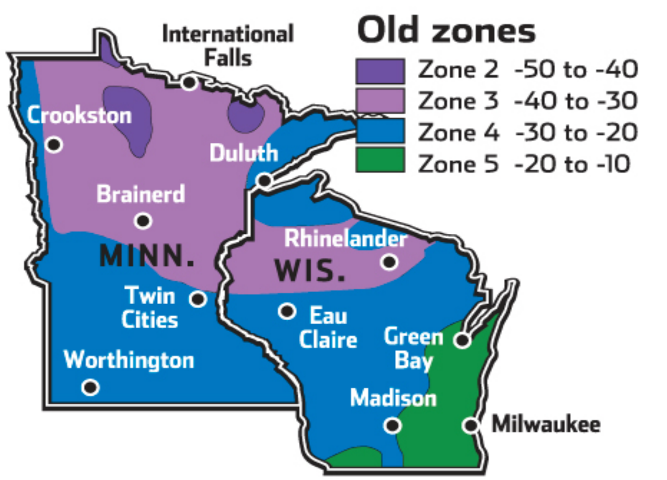
Native plants and grasses within Minneapolis have already been greatly reduced from previous levels. Trees, plants, and grasses in the city now exist in a fragmented state, with the largest remaining patches located in Theodore Wirth Park and Minnehaha Falls. This fragmentation may hinder native plants' ability to adapt to changing conditions by inhibiting migration through pollen dispersion.[36] Their conservation and restoration, however, will likely prove vital for ecosystem function, including stormwater management services and habitat for other species.

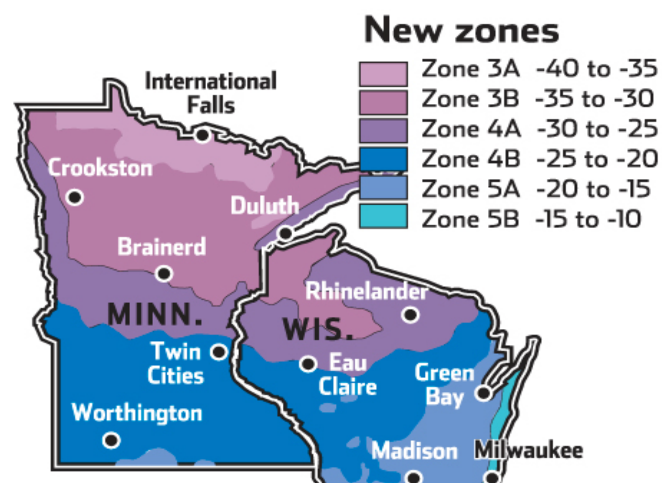
As warmer temperatures begin earlier in the season and last longer, the activity time for pests may also increase, compromising the ability of certain vegetation to remain robust. Shorter winters will also mean fewer of these pests die off, increasing their numbers during warmer periods. Invasive pests that prey directly on trees and other vegetation, such as Emerald Ash Borer and Gypsy Moth, will be of particular concern as their numbers increase.[37]

In 2009, a study placed Minneapolis's tree canopy cover at 11,469 acres, or roughly 31.5% of the city's land area.[38] Of these trees, the most populous species are green ash, sugar maple, Norway maple, and American elm – accounting for some 52% of the overall total.[39] The shift in the plant hardiness zone may cause many of these species to decline or die out, likely prompting an increase in heat-tolerant species. The same is true for native plants and grasses, as they will be facing competition from robust invasive plants such as Buckthorn and Russian Mulberry.[40]

DID YOU KNOW?

When trees die, they release much of their stored carbon back into the atmosphere. Maintaining a healthy tree canopy is important for both climate change mitigation and adaptation efforts.



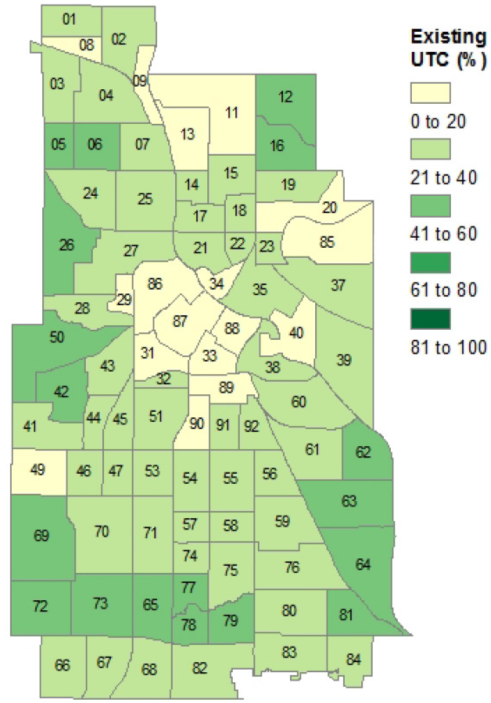


Source: Pioneer Press

Tree canopy is considered an integral part of the City, and Minneapolis has a goal of planting 6,000 trees on public land by 2015. The City has been successful in increasing the number of new trees planted in recent years, resulting in a net gain to the City's tree canopy.[41] Nevertheless, new construction, Dutch elm disease, and the invasive species mentioned above remain a challenge to maintaining a robust canopy. Current modeling estimates that the Emerald Ash Borer will deplete as much as 22% of the trees currently standing in the City; there is no existing solution to this problem.[42] Climate change impacts will likely exacerbate these issues, requiring an even more aggressive planting effort to maintain and grow the City's canopy.

While not abundant in the city, valuable wetlands and marshes such as the Quaking Bog serve to buffer impacts from extreme weather events, while absorbing and filtering water that would have entered the stormwater system. These areas are also very important to biodiversity, serving as habitats for a multitude of plants and animals that would otherwise not exist in a city.[43] The longer, hotter summers will have the most negative impact on wetlands, as increased heat will serve to dry out the normally damp vegetative areas.


An up-close look at the Emerald Ash Borer.



Existing urban tree canopy (utc) within Minneapolis.
Source: University of Minnesota,
Remote Sensing and Geospatial Analysis Lab

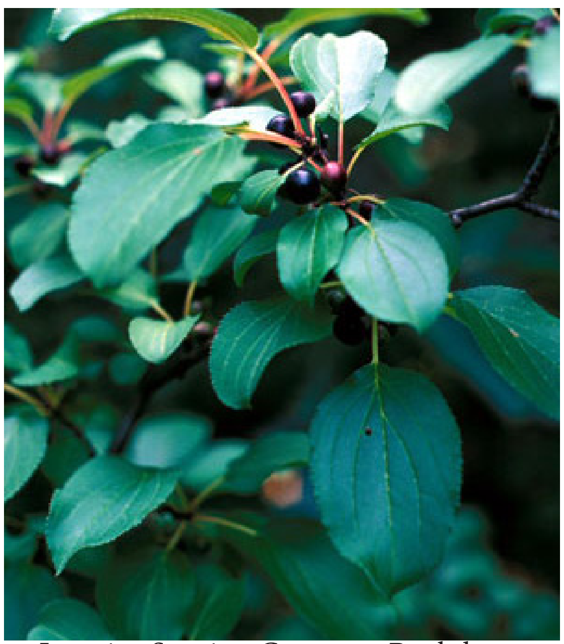
Animals

The value of diverse, indigenous animal species is important to Minneapolis on a number of levels. Having a varied native species base means bacterial, pest, and invasive species will face increased difficulty infiltrating and thriving in a given ecosystem.[44] Animals also increase enjoyment of the City's parks and open spaces.

While human development and pollution have their part in species and habitat destruction, research suggests climate change is quickly becoming one of the most important elements contributing to species extinction. According to the Intergovernmental Panel on Climate Change (IPCC), an estimated 20 - 30% of animals on the planet are at risk of extinction by end of the century if temperatures continue along current projections.[45]

Like other cities within the region, the primary driver behind Minneapolis species extinction related to climate change will be habitat loss.[46] As native trees, grasses, and wetlands disappear, so too will the animals that depend on them. Fragmented habitat patches also impede species migration – without connectivity, affected species will be unable to migrate from one habitat patch to another, resulting in isolation and possible die-off. Conversely, invasive animal species will have greater difficulty migrating into Minneapolis.[47]

In Minneapolis, it is likely all groups of animals will be affected by climate change. However, there is difficulty sorting out how the changing climate will specifically distress each species. Certainly, response and adaptation will vary widely based on each particular set of species. Hardier, more adaptive animals such as squirrel, rabbit, and opossum will fare better than animals that require a specific temperate zone or particular food type to thrive. Minneapolis cold-water fish species that require a certain water temperature, such as perch and bluegill, may decline or disappear altogether.[48] Similarly, migratory birds have begun returning north earlier than previous times in history due to warmer weather. A change in patterns like this can lead to unintended consequences relative to the timing of breeding and food availability.[49]



Invasive Species: Common Buckthorn

Invasive Species: Garlic Mustard

Environmental Recreation

Climate change will affect outdoor activities in both cold and warm weather, fundamentally shifting how Minneapolis pursues recreation. Cold-weather weather recreation such as snowshoeing, cross-country skiing, ice skating, and sledding will likely see a decline with shorter winters and reduced snowfall. Conversely, warm weather recreation such as swimming, kayaking, fishing, and biking will experience a longer activity season. However, the extreme temperatures will likely increase health risks such as heat exhaustion.

Invasive Species: Purple Loosestrife

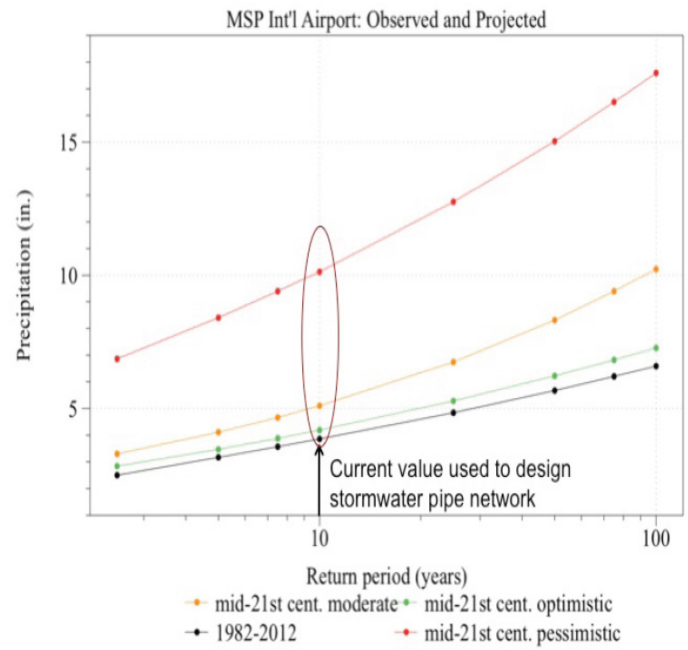
Stormwater Management

Precipitation patterns for Minneapolis are expected to shift, with more precipitation projected in the spring and fall, and less in summer. An increasing proportion of this precipitation will fall during intense downpours. Changes in the timing, intensity, and frequency of precipitation are likely to have significant consequences for stormwater management strategies within Minneapolis.

More rain or snowmelt means increases in the volume of water and a commensurate increase in flow rate of runoff during and after storm events. A recent assessment suggests that the City's stormwater conveyance infrastructure is already operating above its intended capacity in many locations.[50] In an analysis of stormwater infrastructure in the Minneapolis section of the Minnehaha Creek watershed, a storm producing 5.1 inches of rain – a "design storm" likely to occur once every ten years under projected future conditions – would overwhelm 17% of pipes in the network. A storm producing 9.2 inches of rain – a plausible storm in "pessimistic" climate scenarios which predict greater warming – would strain capacity in nearly 40% of the stormwater network.[51] Greater precipitation during heavy precipitation events would increase the volume of peak runoff, or the maximum flow of stormwater through conveyance networks. Higher runoff volumes would exacerbate stress to stormwater management infrastructure, resulting in more localized flooding, increased degradation and failure of stormwater infrastructure (both surface and subsurface infrastructure), increased erosion, more property damage, accelerated stream flows, and lower surface water quality.[52]

Additional strain on the City's sewer and stormwater system may also result in combined sewer overflow (CSO). CSO refers to the backup of water in sewer pipes, usually stemming from inflow and infiltration issues, leading to discharges of sewage into the Mississippi River and elsewhere. Inflow and infiltration refers to the flow of stormwater into wastewater pipes, most commonly from illegal surface connections to the sewer or leaky pipes. Inflow is the more familiar problem in Minneapolis, though the city has made significant improvements in reducing sources of inflow in recent years. Increasing stress to infrastructure from higher volumes of water and potential rises in groundwater levels may make infiltration issues more common.[53]

In addition to sewer overflow, inflow and infiltration problems may also increase demand for wastewater treatment services, leading to higher treatment costs and greater energy use.

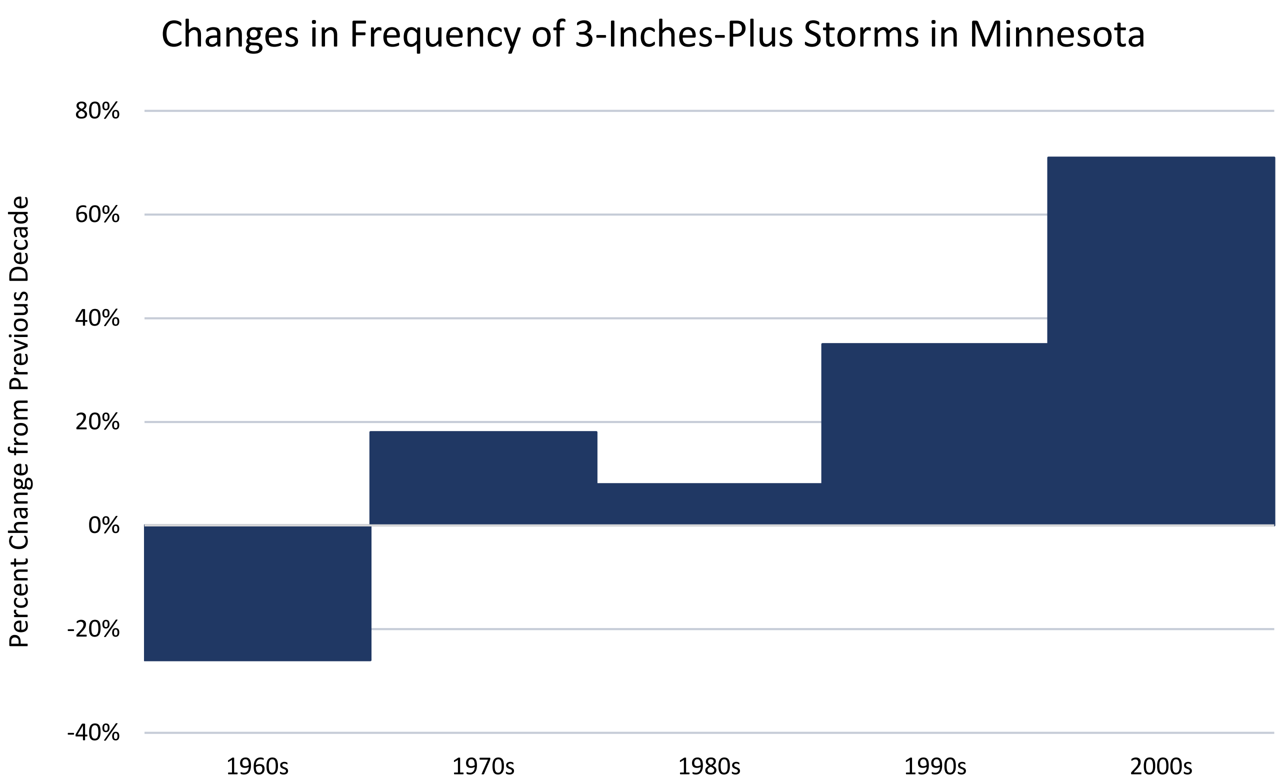


Rainfall probability distribution for Twin Cities region based on recent climate record (3.9 in, 1982-2012) and future projections based on mid-21st century optimistic (4.35 in), mid-21st century moderate (5 in), and mid-21st century pessimistic (9.8 in) emission scenarios.
Source: Minnehaha Creek Watershed District

Beyond the sewer and stormwater systems, assessing and managing water resources within and beneath the city will continue to be important. Future projections of groundwater drawdown indicate a small decline in Minneapolis, though uncertainty remains about future climatological impacts.[54] Future groundwater levels will depend on management strategies adopted in Minneapolis and elsewhere, as well as the absolute changes to local climate.[55] However, a higher groundwater table could increase the risk of flooding in some areas during heavy precipitation events or significant snowmelt. A higher groundwater table may also impact the potential effectiveness of certain stormwater management strategies, especially those related to infiltration. A lower groundwater table may increase costs associated with well installations.

Higher ambient air temperatures will likely increase the temperature of stormwater runoff.[56] Runoff that finds its way quickly to streams, lakes, and rivers may be warm enough to increase surface water temperatures. These sudden temperature changes may be lethal to some fish and, over time, could shift ecosystems in favor of species, including many invasive species, that favor warmer water.

The overall impact of future stormwater runoff depends on both natural and human factors. Natural factors, in addition to changes in precipitation patterns and temperature, include variations in groundwater recharge, soil moisture, evapotranspiration, and natural vegetative cover. Human factors include the amount of impervious surface, salt and fertilizer use in response to changing climatic conditions, selection of vegetation in residential and commercial areas, building design, and land use and zoning policies.



Source: Rocky Mountain Climate Organization

Utilities

The anticipated climate changes in the City of Minneapolis will have significant impact on the operations of local utilities. Higher temperatures and altered precipitation patterns will likely affect both the operations and the demand on the City's infrastructure at once, creating a larger challenge than either of these impacts in isolation.

Energy Demand

The demand for cooling and its associated electricity usage will increase in the summer as a result of increased temperatures, while warmer winter temperatures will decrease the demand for natural gas used for heating. Although extensive research has not yet been conducted on this topic, studies suggest that northern states, including Minnesota, will likely see a reduction in consumption of heating fuel that is greater in magnitude than the expected increase in electricity usage for cooling – translating into an overall decrease in energy consumption by end users.[57]

Although this may be seen as a positive impact of climate change, a number of complicating factors suggest that the City of Minneapolis and its energy utilities should still take proactive measures to plan for this shift.

As cooling increases and heating decreases, Minneapolis will see the balance of energy provision shift between its two primary energy suppliers – with CenterPoint Energy, the City's natural gas provider, experiencing a decrease in demand, while the City's electricity supplier, Xcel Energy, will see an increase in demand. This increase is expected to be significant: across the Midwest, it will likely exceed 10 gigawatts, or the equivalent of about ten large power plants, likely requiring over $6 billion in infrastructure investments to expand production capacity.[58] These additional costs may be reflected in higher consumer electricity bills.

Adding a further level of complexity is the fact that while electricity demand is expected to generally increase, a number of unknown factors make accurate predictions quite challenging. The impacts of climate change in other sectors may have ripple effects for utilities; as demand increases for irrigation water due to drought, for example, water utilities are likely to in turn place greater demand on energy utilities. Socioeconomic factors also play a role, from the effects on energy demand of Minneapolis's increasing population, to the uncertain rate of air conditioner adoption as summers get hotter.[59]

Energy Supply

Although energy consumption by end users may decrease, we will not necessarily see corresponding decreases in total carbon emissions from energy production or from primary energy consumption, which takes into account energy used in production and delivery of energy to the end user.[60] Climate change will contribute to energy supply challenges and may lead to even higher levels of GHG emissions.

Beyond the strain placed on the energy sector due simply to increasing demand, the extreme weather associated with climate change will create an added supply challenge. Heavy storms, floods, and droughts can lead to power disruptions and outages, which are not only costly and labor-intensive to address, but can be life-threatening for vulnerable populations without access to cooling. High temperatures can cause power lines to sag as metal expands, interfering with nearby vegetation or disrupting power delivery through the line.[61] High ambient air temperature can also increase water temperature used for power plant cooling; in some instances, power plants may have to curtail production in order to operate safely and effectively.

Despite the decrease in heating accompanying the increase in cooling, the cooling process is less energy efficient than heating. The higher temperatures associated with climate change will cause 95% of the Midwest's electricity-generating infrastructure to be susceptible to decreased efficiency.[62] Therefore, more primary energy will be required to generate electricity for cooling.[63] Furthermore, a substantial portion of Minneapolis's energy supply is generated by carbon-intensive coal-fired plants, so increased electricity production prompted by climate change may have the unfortunate consequence of further contributing to climate change as more GHGs are released.[64]

Water Supply

The Minneapolis Water Works division draws the City's water solely from the Mississippi River. The city, therefore, does not face some of the more pressing water supply concerns related to groundwater shortages that other Twin Cities area municipalities are currently facing. However, the drought conditions that we expect to see more frequently due to climate change will likely cause river levels to drop, while hotter, drier summers are associated with increased use and demand for water.[65] As with electric utilities, it is anticipated that climate change will simultaneously increase the demand for water and limit the City's capacity to meet that demand. Also important in the consideration of future impacts is the fact that Minneapolis's water supply is somewhat vulnerable; the City currently has no alternative water sources should river water be limited or unavailable, and has the storage capacity of only one to two days worth of water.[66]

Water and energy systems are closely connected, and strain on water supply will compound the challenge of increased electricity demand. Electricity generation is a highly water-intensive process because of the cooling water required to operate power plants; the production of one kilowatt-hour of electricity requires about 25 gallons of water.[67] Again, the increase in demand and limited supply go hand in hand: water shortages from droughts will limit the availability of cooling water for plants; at the same time, more cooling water will be needed to help meet increased electricity demand.

STAKEHOLDER PERSPECTIVES

> *" ... As responsible public leaders, we cannot afford the luxury of not preparing. We know now that some impacts are inevitable and we know that these impacts will affect many of the essential services and functions that our governments are expected to provide. We must prepare for the impacts underway while we work to avoid even worse future effects."*
>
> -Ron Sims, Executive, King County, WA

The City of Minneapolis has already begun to take significant action to pursue sustainability initiatives and mitigate climate change by reducing greenhouse gas emissions. The City has dedicated sustainability staff, instituted a set of 26 indicators to track progress toward sustainability goals, and has recently completed its Climate Action Plan – a roadmap to help the City meet GHG reduction targets through policies, projects, and partnerships. However, even if these steps exceed expectations and Minneapolis is able to reduce emissions to zero, the greenhouse gases already released will remain in the atmosphere long into the future, spurring changes to our climate that are likely irreversible.

Clearly, Minneapolis is facing a "new normal" in relation to weather patterns and their associated impacts on our streets and vegetation, electrical and water infrastructure, our health, and our daily lives. Cities around the world are experiencing similar changes – from hotter summers to more severe storms – and local governments are taking action to become more resilient, expanding their capacity to adapt to climate change while minimizing negative impacts and capitalizing on new opportunities.

To supplement literature-based research on the impacts of climate change on the City of Minneapolis, and to begin to understand how staff are thinking about, talking about, and acting in response to the changing weather patterns, nine interviews were conducted with City staff and other relevant stakeholders. Interviewees represented the Minneapolis Department of Public Works, Minneapolis Department of Health, Minneapolis Park and Recreation Board, Minneapolis Department of Community Planning and Economic Development, Xcel Energy, and Minnesota Department of Health.

The interviews were based on a set of questions developed in conjunction with staff in the Office of Sustainability and are provided in Appendix B. Interviews lasted approximately 45 minutes to an hour and were conducted in late March and April, 2013. A summary of each interview follows:

Lisa Cerney, Director of Surface Waters and Sewers, Minneapolis Department of Public Works

The Department of Public Works is interested in using the Minnehaha Creek Watershed District "Weather - Extreme Trends" study as a model to determine needed system-wide operational and capital changes. Public Works recognizes the need for expanded infrastructure, including the use of green infrastructure, to manage projected increases in stormwater runoff. There is a clear need for more data, especially related to climate impacts and precipitation projections. The Department's main concerns are balancing impact (in flood prevention and water quality protection) with higher costs and the need for a robust system to manage runoff despite the uncertainty of future impacts.

Heidi Hamilton, Deputy Director, Minneapolis Department of Public Works

The Department of Public Works is aware of more intense rainfall events under today's climate regime. The Department also sees the need to repair and upgrade existing infrastructure due to pressurization of storm tunnels and projected increases in runoff volumes. The Department is currently pursuing increased flexibility in its workforce models in response to greater climate variability. However, the Department is not pursuing a broad effort to incorporate climate change and climate change adaptation into its work. More data and greater certainty is needed to justify multi-million dollar investments in stormwater infrastructure**.**

Jennifer B. Ringold, Director of Strategic Planning, Minneapolis Park and Recreation Board

While the MPRB has no stand-alone plans related to climate change, adaptation measures and policy are being woven into the Department's latest Master Plan, currently under development. MPRB believes the Forestry Division is taking progressive steps to adapt the City's tree canopy to the changing climate. Areas for improvement include increasing strategic collaboration with residents in order to obtain more hard data and incentivize tree planting on private property, as well as work more closely with the City on climate change adaptation (the MPRB is a separate, semi-autonomous entity). In the future, they would also like to start an "ecological system plan" to look at all biological systems in the City, then assess vulnerability and future interaction according to modeled climate change scenarios.

Ralph Sievert, Director of Forestry, Minneapolis Park and Recreation Board

In response to Emerald Ash Borer, Dutch Elm disease, and increased heat patterns the Forestry Division is experimenting with more heat- and disease-tolerant tree species. These include include bald cyprus, London plane trees, American beech, prairie torch buckeye, and flowering cherry trees. Alder trees are also being considered. However, some experimental trees are receiving pushback from residents on aesthetic grounds, including Japanese tree lilacs and river birch.

Pam Blixt, Public Health Preparedness Manager, Minneapolis Department of Health

In response to observed increases in extreme heat events and an expectation of more in the future, the Department of Health has designed a heat response plan for Minneapolis. As part of this plan, the Department's first steps are to conduct surveillance with EMS providers and engage the community through education and outreach programs related to extreme heat. The next level of action includes providing shelter, air-conditioned transportation, and door-to-door outreach to groups in need. The Department has indicated a need for an improved method of coding deaths to determine the patterns of heat-related mortality in Minneapolis. This would enable the City to better understand how extreme heat events related to mortality.

Kristin Raab, Climate Change Coordinator, Minnesota Department of Health

The Minnesota Department of Health is doing a great deal of work confronting public health issues related to extreme heat. For example, they have mapped an increase in hospitalization events in the state and found a strong correlation between average increases in temperature and increases in emergency room visits, but they do note that this does not necessarily imply causation. To more completely address the issue of climate change, the Department needs more data and more general information. They have identified that a Syndromic Surveillance System, which provides real-time data about hospital visitors with a heat-related condition, is one key way to help identify how public health is affected by extreme heat. This type of system would also assist in alerting the public when heat-related hospital visits spike.

Jason Wittenberg, Planning Director,
Minneapolis Department of Community Planning and Economic Development

Minneapolis's climate change mitigation efforts have led to a greater focus on sustainability in policy and regulatory frameworks. CPED has already updated or amended codes – including those related to density along transit corridors, pedestrian-oriented development, landscaping requirements, and on-site renewable energy generation for new development – to address sustainability goals. CPED would like more information on expected impacts as well as what zoning and building code updates are needed to encourage adaptive development in the face of a changing climate. CPED would also like information related to the economic and population impacts of climate change, particularly with respect to population growth due to "climate refugees" moving to Minneapolis from areas with more severe impacts.

Beth Chacon, Environmental Policy Relations Manager, & Kathryn Valdez, Environmental Policy Manager,
Xcel Energy

Xcel Energy has taken significant steps to reduce greenhouse gas emissions and environmental impacts. The efforts Xcel has taken in response to climate change are primarily driven by local, state, and federal policy, as well as demand from the public, but not by a perceived need to adapt the company's operations to anticipated climatic changes. Anticipated increases in extreme storm events and heat associated with climate change are not brand new phenomena, but issues that the company feels it is adequately equipped to deal with. Future climate scenarios are not driving new policies or action steps. Coal plant retirement has begun near Minneapolis, which will reduce emissions over time. In addition, Xcel is on track to meet Minnesota's renewable energy standards[*], also contributing to reduced emissions. There is less concern in Minneapolis with transmission disruption related to extreme weather, since the City's power comes from a diverse, widespread network, and has high levels of redundancy built in.

Barret W.S. Lane, J.D,WW Director,
Office of Emergency Management

Climate change adaptation is something the Minneapolis Office of Emergency Management is aware of, but adaptation measures are on the back-burner behind more immediate risk-related issues. They are aware that more weather-related emergency events will likely occur, but view their relationship with climate change as "second-order" – meaning that they serve as more of a reactionary entity after the emergency occurs, rather than taking the responsibility to avoid it. Additionally, the Office currently lacks the staff capacity to set aside research hours necessary to investigate documented climate and weather-related emergency trends. They tend to view climate change as a "piece of the puzzle" in relation to risk, though limits on staff capacity have prevented updates to risk and hazard patterns that account for the changing climate.

---

* Xcel Energy is required by law to generate 30% of its energy from renewable sources by 2020.

Interviews revealed that Minneapolis staff and other stakeholders are planning for climate change impacts in various ways, and many are taking steps to adapt their processes and policies, improving their resiliency in the face of changing weather patterns. The table below highlights a number of these actions.

What types of climate change adaptation efforts are they taking?
Community Planning and Economic Development • Zoning code amendments such as high density along transit corridors, pedestrian-oriented development, increased requirements for bike parking • Incentivizing developers to have buildings LEED-certified, install green roofs and living walls, on-site energy
Minneapolis Department of Health • Implementing more surveillance and monitoring when severe storm is predicted • Education and outreach on climate change impacts • Partner with other organizations to assist during extreme heat response plan, including EMS providers, home-visiting community organizations like visiting nurses and Meals on Wheels
Minneapolis Department of Public Works • Monitoring results of Minnehaha Creek Watershed study on weather trends and impacts on stormwater management • Staffing models and internal processes are being made more flexible in response to weather uncertainty and volatility
Minneapolis Park and Recreation Board • Testing interactions between Zone 5 and Zone 6 plants in response to changing hardiness zones • Increasing diversity in plant species on City land
Xcel Energy • Improving operations and reducing emissions, primarily in response to public demand and legislation • Retiring coal plants

However, most of these action steps are not labeled explicitly as *climate change adaptation*. City staff commonly see them as one piece of a larger puzzle – one way in which they are effectively doing their job – but climate change adaptation does not seem to be of primary concern. As a result, these under-the-radar actions to guard against climate change impacts are not necessarily being coordinated among departments or communicated to staff in the City's Sustainability Office as a larger effort to plan ahead and adapt to the potentially significant changes that will be experienced in Minneapolis.

Minneapolis, unlike some other cities around the world, does not face urgent challenges related to climate change that are in need of immediate action, such as floods that threaten to wipe out entire neighborhoods in New Orleans or along the New Jersey coast, or dire droughts that threaten the quality and supply of drinking water as in some cities in the Southwest.

Rather, due to the City's geographic position as a landlocked, northern city, the climate change impacts Minneapolis will face will be more gradual. Hot summer days and extreme rainstorms are not new – residents and City staff have dealt with these events before, and will not likely see dramatic spikes in these events from one year to the next. Taking action to protect residents from extreme heat, or ensure that its stormwater infrastructure can manage heavy downpours, are things that City staff already do.

On one hand, this lack of urgency has created a barrier to effective climate change adaptation in Minneapolis. As several interviewees reported, especially in a tight economic climate and with diminishing staff capacity, it simply does not make sense to change course or implement a new program or policy to plan ahead for a phenomenon that is slow and vaguely understood (and the existence of which is still debated in popular news media). However, it is the unpredictability of climate change that makes this a risky approach, and may encourage over-complacency. While summer weather might seem normal for several years, a single extreme weather event that the City is under-prepared for could wreak havoc – just as occurred in Duluth in the summer of 2012, or like the 2010 heat wave in Europe that contributed to thousands of deaths.

At the same time, though, the long-term nature of climate change impacts in Minneapolis is also a benefit. By acting now to take on adaptation efforts, Minneapolis can continue to be a leader among US cities, and particularly those in the Midwest, where few have planned and implemented comprehensive climate change adaptation programs. The City of Minneapolis can intentionally build its adaptive capacity, adjusting behavior, policies, resource allocation, and use of technology to enhance the ability of its residents, staff, and infrastructure to successfully withstand changes to our climate. By taking proactive measures, rather than reacting to urgent situations, Minneapolis can seek "no regrets" strategies to adapt to climate change. These strategies will not only ease adaptation to future climate changes, but bring benefits and opportunity regardless of what the future climate looks like, making the City more livable, improving quality of life, and bringing new economic opportunities.

"Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies. [It] also enables sectors and institutions to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism."

-Intergovernmental Panel on Climate Change

CLIMATE ADAPTATION: BEST PRACTICES

With the recent completion of Minneapolis's Climate Action Plan, the City's Sustainability staff wish to begin the process of planning adaptation action, seeking not only to mitigate climate change but to plan ahead for anticipated impacts and ensure that City staff, departments, and others are equipped to manage and adapt to projected changes.

Based on interviews with stakeholders and a literature review of both academic research and climate change adaptation plans and policies in other cities, this report outlines a set of adaptation strategies and tools to inform the City's work as they begin their efforts. A range of best practices and case studies have been identified, and are listed under the following five general categories for climate change adaptation:

GOAL 1: MANAGE HEAT

Take steps to reduce the urban heat island effect and work to ensure that all who live and work in Minneapolis maintain comfort and safety during hotter summers.

GOAL 2: PRESERVE THE NATURAL ENVIRONMENT

Maintain a healthy, robust, and resilient natural infrastructure and ensure that Minneapolis residents continue to be able to enjoy our city's natural resources.

GOAL 3: MANAGE STORMWATER

Improve the capacity of the stormwater system to handle heavier storm events, reduce flooding, and improve water quality.

GOAL 4: ENSURE A RELIABLE WATER AND ENERGY SUPPLY

Take steps to both reduce demand for water and energy and improve the reliability of supply.

GOAL 5: PLAN FOR THE FUTURE

Maximize the efficacy of adaptation efforts by intentionally creating a citywide plan involving a range of stakeholders.

Some of the best practices and case studies outlined below are commonplace in cities where climate change is a more visible, pressing issue – but, if implemented in Minneapolis, could ensure that the City is well-equipped to deal with long-term climate impacts. Emphasis was placed on selecting adaptation strategies that offered innovative, "no regrets" solutions to problems that exist now and are likely to be exacerbated by future climatic changes.

The strategies and practices listed here are not intended to serve as a "to-do" list, or set of recommendations. Rather, the goal of this report is to offer City staff and others a selection of adaptation strategies and best management practices that have been successful in other cities, to serve as a guide and offer a set of options for future adaptation planning efforts. Included with each description is an evaluation of how the given practice and case study might apply to Minneapolis, based on ongoing efforts in the City and information gained from the stakeholder interviews. Ultimately, though, Minneapolis's approach to climate adaptation will depend on the resources allocated, the expertise and capacity of staff, the engagement of residents and businesses, and what, collectively, Minneapolis deems to be the most pressing impacts and the most effective, economical, and equitable approaches to adapting to climate change.

DID YOU KNOW?

A 2012 survey by the International Council for Local Environmental Initiatives (ICLEI) found that of 298 US cities surveyed, 74% have observed changes in their climate and 59% are pursuing climate adaptation planning. The top three ranked impacts were increased stormwater runoff, changes in electricity demand, and loss of natural systems.

The first four of these general adaptation strategies focus on managing heat, stormwater, the natural environment, and water and energy, and relate directly to the climate change impacts described previously in this report. The fifth strategy section provides a selection of action steps that have been instrumental in other cities' efforts to develop and engage stakeholders in the process of developing their adaptation plan. The City of Minneapolis is already in the early stages of pursuing some of these best practices, but might be interested in reviewing and learning from examples in other cities.

Although the best practices are categorized under specific adaptation strategies, many have co-benefits that extend beyond this single strategy. The impacts of climate change are highly interconnected, influence one another, and can sometimes serve to exacerbate climate change even further – higher temperatures, for example, threaten public health, cause an increased demand for cooling and related energy generation, and, where non-renewable sources are used, lead to even more greenhouse gas emissions. Similarly, strategies like green roofs can serve to cool buildings and reduce energy demand, while simultaneously reducing the urban heat island effect and making residents more comfortable and healthier. The table below lists each of the best practices that are included in this report, and marks their primary benefit – or the adaptation strategy under which they've been categorized – as well as any co-benefits that might also help the City adapt to another climate change impact.

Citations and additional resources for further reading on each best practice and case study are included in Appendix A.

	Manage Heat	Natural	Stormwater	Energy/Water
1.1 Improve methods of tracking heat-related illness and death to ensure ability to accommodate more patients and appropriately target extreme heat responses	✔			
1.2 Expand access to pools, misting stations, and other cooling opportunities for those particularly at risk of suffering from heat-related illness	✔			
1.3 Implement cool pavements to reduce urban heat island effect	✔			✔
1.4 Increase green roofs to reduce urban heat island effect	✔	✔	✔	✔
2.1 Adapt recreation opportunities to the changing climate		✔		
2.2 Increase urban tree canopy	✔	✔	✔	✔
2.3 Conduct vulnerability study of natural ecosystems		✔		
2.4 Conserve urban plant and animal habitat		✔		
2.5 Manage invasive and native species		✔		
2.6 Initiate Programs to Engage the Private Sector				
3.1 Control runoff with rain gardens and bioretention		✔	✔	
3.2 Harvest rainwater to control runoff and decrease water		✔	✔	✔
3.3 Expand surface detention capacity to reduce runoff volumes			✔	
3.4 Reduce impervious surface coverage with permeable	✔	✔	✔	
3.5 Maintain and expand traditional infrastructure to control			✔	
4.1 Understand the energy use patterns and needs of homeowners in order to implement comprehensive smart grid technology on a localized scale				✔
4.2 Incentivize microgrid projects				✔
4.3 Incentivize cool roofs on new/existing buildings	✔			✔
4.4 Pursue an "urban cap-and-trade" policy to encourage energy	✔			✔
4.5 Encourage energy efficiency and conservation in both new and existing buildings through the identification of a geographic district	✔			✔
4.6 Mandate 100% renewable energy use	✔			✔
4.7 Encourage residential water conservation			✔	✔
4.8 Diversify water supply and plan for potential supply				✔

The climate adaptation practices included in this report are listed in the table above. Each is marked by both its primary benefit – or which type of climate adaptation it contributes to the most – as well as any co-benefits.

GOAL 1: MANAGE HEAT

Best Practices

1) Improve methods of tracking heat-related illness and death to ensure ability to accommodate more patients and appropriately target extreme heat responses

2) Expand access to pools, misting stations, and other cooling opportunities for those particularly at risk of suffering from heat-related illness

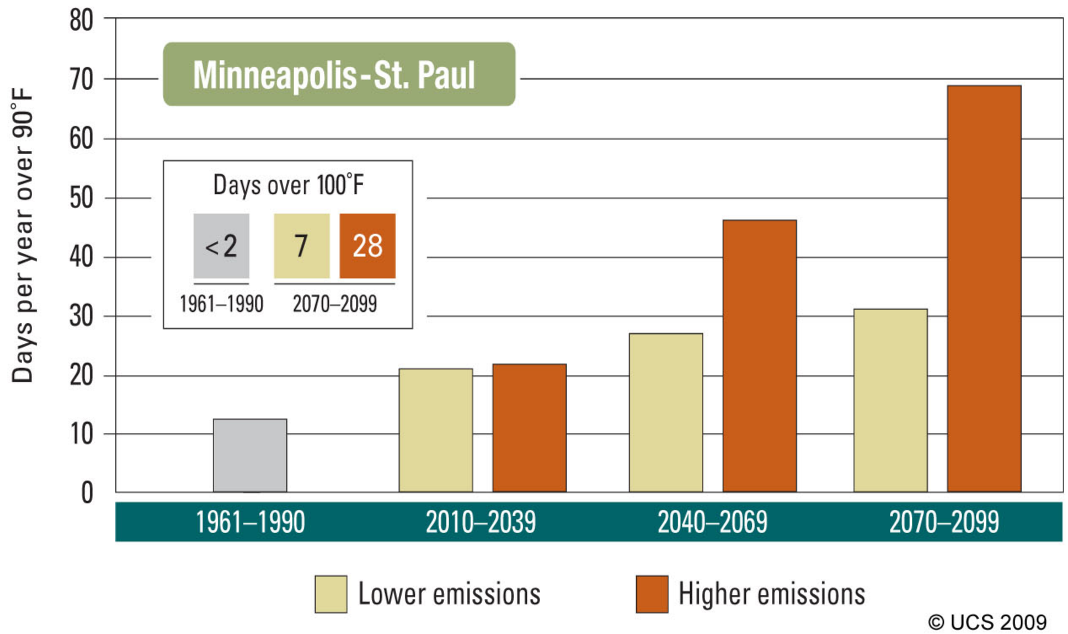
3) Implement cool pavements to reduce urban heat island effect

4) Increase green roofs to reduce urban heat island effect

1) Improve methods of tracking heat-related illness and death to ensure ability to accommodate more patients and appropriately target extreme heat responses

Background

Deaths related to extreme heat or prolonged heat waves are the number one cause of weather-related deaths in the United States. Heat can also cause a number of illnesses including heat stroke, heat exhaustion, cramps, or rash, and can cause damage to the brain and other organs. In response to the hotter summers and more prolonged heat events due to climate change, heat-related illnesses and death will likely become more common. Accurately tracking illness and mortality related to heat will allow health officials to ensure they have the capacity to handle additional patients, enact heat response activities as needed, and understand how heat is impacting residents and how heat response efforts should be targeted.



Minneapolis is expected to experience increasing numbers of days over 100°F in the coming years, even under lower greenhouse gas emissions scenarios, increasing the threat of heat-related illness. Innovative methods of tracking heat-related deaths and illnesses can make heat response efforts more effective and efficient.

However, it can be difficult for cities to get a complete and accurate picture of heat-related deaths and illnesses. Deaths are most often recorded only by their primary cause, while heat is more often a secondary cause, exacerbating another health problem. In addition, detailed information about the spatial distribution of heat-related illness around the city is not always known. Without the ability to closely track heat-related deaths and illnesses, it is more difficult for health officials to identify and react quickly when intervention is needed. It also makes retroactive evaluation of heat responses and preventative measures against heat-related illness more difficult, as patterns in hospital visits and deaths are more difficult to identify.

Case Study: Southeastern Ontario

In Southeastern Ontario, eleven hospitals took part in a pilot project using an existing syndromic surveillance system to track both environmental heat and heat-related illnesses in real-time. Using this data, health workers hope to be able to respond to heat events more effectively and efficiently and better identify vulnerable populations. The program was initiated in response to an anticipated increase in regional average

1) Improve methods of tracking heat-related illness and death to ensure ability to accommodate more patients and appropriately target extreme heat responses

annual temperature of about 2.8°C (5°F) and an increase in the Heat Wave Duration Index (HDI), which measures the number of consecutive days that are 5°C (9°F) above normal temperatures – both climate change impacts that suggested an increased challenge of managing heat-related public health concerns.

The pilot project utilized a syndromic surveillance system that was already in place at area hospitals. The system, generally used to track and provide early detection of infectious disease outbreaks, provides real-time monitoring of initial information gathered from patients upon first being seen by medical workers – including their main complaint, symptoms, and non-protected information about the patient and the circumstances under which they've arrived at the hospital. This data is then mapped, allowing the identification of geographic trends in symptoms and areas of vulnerable populations, as well as the evaluation of the effectiveness of intervention strategies.

To adapt this system for use in specific relation to heat, it was redesigned to focus only on symptoms of heat-related illnesses, including sunburn, heat stroke, sun stroke, and exhaustion. This patient data was complemented by the collection of data from heat sensors placed throughout the area that measured real-time temperature, humidity level, wind speed, and solar load (or temperature increase directly attributed to the sun's rays). This data set allows health officials to observe both geographic trends in heat-related illnesses and the relationship between the heat environment and other public health indicators (such as the number of hospital visits), ideally informing an optimal heat response during extreme heat events. Before the system can be adopted more widely, the data must be validated. Currently participating hospitals are evaluating whether the system provided accurate information about geographic trends and vulnerable populations.

Applicability

Interviewees from the Minneapolis Department of Health noted that their heat response plans would greatly benefit from a surveillance system that tracks hospital visits and heat-related deaths more reliably and in real-time. Challenges to implementing a system similar to Ontario's, however, include the fact that they can be costly to maintain and operate, and do have some data limitations. Although the system provides accurate, more complete information about illness incidence and location directly triggered by heat, it still does not necessarily include deaths or illnesses that are exacerbated, but not directly caused, by heat, such as heart attacks. Additionally, health care agencies and workers would need to be dedicated to utilizing this new technology consistently in order for it to be effective and accurate. Both the City of Minneapolis and the State of Minnesota do already have robust plans in place for responding to extreme heat, but these efforts could perhaps be bolstered by adopting a syndromic surveillance system.

2) Expand access to pools, misting stations, and other cooling opportunities for those particularly at risk of suffering from heat-related illness

Background

Increasing access to cooling opportunities for residents that are at risk of heat-related illnesses will be an increasingly important strategy as summer temperatures increase. Individuals that lack sufficient means of cooling, such as air conditioning and adequate shade, are particularly vulnerable to suffering from heat-related illness such as heat stroke, heat exhaustion, and heat rash. Even if an air conditioning system is installed in a home, some may lack the ability to pay for the electricity to run it. These at-risk groups tend to be those living below the poverty line and those who do not speak fluent English. The elderly and individuals with high blood pressure are also at higher risk, and more prone to suffer from heat stroke or exhaustion.

Another group that is less obviously at risk for suffering from lack of cooling is 15-34 year old males. As the Minnesota Department of Health points out, the high incidence of heat-related illness in these individuals may be due to their higher likelihood of having jobs that require outdoor work or playing outdoor sports, without sufficient water intake or cooling.

These at-risk groups, particularly the elderly and low-income populations, will be especially in need of accessible, affordable methods of cooling in the face of hotter summer days. Increasing access to public amenities such as misting stations, pools, cooling centers, or increased shade can help alleviate heat stress and reduce potential hospital visits. These types of cooling strategies are an essential part of reducing the risks of heat-related illness.

Case Study: Detroit, MI

The City of Detroit has developed a document that assesses heat vulnerabilities and access to cooling centers in the city. The study was undertaken after the city observed that the incidence of heat-related illness was increasing along with increasing summer temperatures. In response, Detroit created a vulnerability index to identify where the need for cooling centers was highest. It was found that almost 80% of the city's most at-risk groups were within a 15-minute bicycle ride from an existing cooling area, but only 30% were within a 15-minute walk. This information suggested that cooling centers should be more strategically located throughout the city to better serve vulnerable groups and reduce heat-related illness. The assessment also concluded that the City needed to strengthen its emergency response measures during extreme summer heat events. Based on these conclusions as well as available resources and cost constraints, they developed a ranking system to prioritize locations where additional cooling stations would benefit the greatest number of vulnerable residents.

Applicability

Much of the older housing stock in Minneapolis was built to keep in heat during cold Minnesota winters. These design standards inhibit cool down during intense summer heat. Minneapolis residents living in these homes therefore often depend on publicly available means of cooling, whether at a library or recreation center, or misting station in a City park. The Minneapolis Department of Health, in concert with the Minnesota Department of Health, has already taken the first step in a targeted cooling method such as Detroit's by identifying the concentration of at-risk groups (those in poverty and the elderly) by census tract in Minneapolis. This valuable data can help the city geographically-target their heat relief resources to the groups that need them most.

3) Implement cool pavements to reduce urban heat island effect

Background

Conventional pavements are dark in color, with low reflectivity and high heat retention. These pavement types can reach peak temperatures between 120° and 150°F. This excess heat is transferred to the ambient air and to stormwater that runs across the pavement surface. Pavement continues to release its trapped heat throughout the night, contributing to higher nighttime temperatures in urban areas. Elevated overnight temperatures have a negative impact on public health, as people are better able to recover from heat stress when given the opportunity to cool down for an extended period of time.

Cool pavements can reduce both surface and air temperatures and, in turn, reduce the urban heat island effect. Of the variety of cool pavement types, the two most common are porous and light-colored pavement. Porous pavement allows water and air to permeate the pavement surface; the air and water flow helps to reduce surface and air temperatures. Light-colored pavement helps to reduce the heat island effect by reflecting, rather than absorbing, much of the sun's solar radiation. Traditional pavements have an albedo (reflectivity) of less than 0.1, meaning only 10% of incident radiation is reflected back into the atmosphere. Most reflective pavements have an albedo above 0.35. An increase in albedo of 0.1 translates to a drop in surface temperature of 7°F. Implementing cool pavements alone could reduce surface temperatures by at least 20°F.

A test road at the Lawrence Berkeley National Lab is shown with partial light-colored pavement and partial dark or "normal" pavement. The image on the left shows that the lighter pavement is about 17°C (30°F) cooler than the darker pavement.

Case Study: California

Governor Jerry Brown signed Assembly Bill 296 in October, 2012, directing the California Department of Transportation to develop a standard for use of reflective pavement on roads. This policy strengthens the voluntary cool pavement efforts that are currently part of California's Green Building Code. The bill directs the Department of Transportation to develop a Cool Pavement Handbook and take on pilot studies to determine the best standard approach to implementing cool pavement in the future.

The legislation was informed by research from the Lawerence Berkeley National Lab testing various types of cool pavements and their effects on the urban heat island, smog, and energy consumption. The group's research has advised that cool pavements will cool urban areas and contribute to improved air quality by reducing smog formation.

3) Implement cool pavements to reduce urban heat island effect

Applicability

Close to 50% of land cover in Minneapolis is impervious. These mostly dark, non-porous surfaces consist of rooftops, sidewalks, streets, and parking lots and, by absorbing the sun's heat, contribute to the urban heat island effect. As summer temperatures rise, this will have impacts on the comfort and health of Minneapolis residents, especially those who live and work in parts of the city with high levels of impervious surfaces.

The adoption of cool pavements in Minneapolis could serve to reduce the urban heat island effect and positively benefit public health. The effectiveness of cool pavements is still being researched, and selecting a type of cool pavement for Minneapolis will hinge on its suitability for the City's climatic conditions. Recent research from the University of California, San Diego has suggested that because light-colored pavements have such a high rate of reflectivity, they may have the unintended effect of increasing cooling needs for surrounding buildings. Light-colored pavement also does not have the benefit of stormwater infiltration offered by porous pavement. However, of the two main cool pavement types, light-colored may be better suited than porous for Minneapolis's climate. Porous pavement may not hold up as well in cold, snowy winters unless additional care is taken during installation, and past pilot tests in the City have had limited success. However, recent developments in porous technology may improve this success rate. Both cool pavement types can have a secondary benefit of improving water quality by preventing the increase in temperature of stormwater runoff.

4) Increase green roofs to reduce urban heat island effect

Background

Green roofs can provide a variety of benefits to a city related to reductions in heat and stormwater runoff and improvements in air quality and public health. First, the vegetation of the roof can absorb rainwater and help reduce runoff. The vegetation also pulls heat from the air through evapotranspiration, which cools both the roof and the surrounding air. Reducing a building rooftop temperature can help to reduce energy costs for the building which reduces the generation of greenhouse gas emissions. A reduction in temperatures in the air surrounding the green roof can help to reduce the urban heat island effect which contributes to public health by reducing risks of heat stress and illness. Finally, vegetation on green roofs helps remove air pollutants and carbon emissions through sequestration.

A green roof in London.

There are two general types of green roofs: extensive and intensive. Extensive green roofs are much thinner and require less maintenance over time. These types of green roofs are less costly and can support various types of flowering plants and herbs. Intensive green roofs require much deeper growing beds and can support a much more diverse set of plants including full grown trees. These types of green roofs work best on large commercial buildings and parking garages that have the structural integrity necessary to support them. Both types of green roofs require roof slopes of less than thirty degrees in order to support the vegetation and reduce stormwater runoff.

Case Study: London, England

A wedge shaped building at the corner of Poultry and Queen Victoria Street in London is home to a rather unique green roof. This intensive green roof was completed in 1998 and has both hard landscaping and plantings in its inner and outer gardens. This green roof is about 450 m^2 in size, which is 18% of the total roof area. Access to this green roof is restricted to the restaurant which is located on the top floor of the building. What is most unique about this green roof is that one portion of it is specifically designated for culinary use for the restaurant. They have planted various things like herbs, grapes, and crab apples which help increase biodiversity by attracting pollinating bees, moths, butterflies, and birds. This green roof also helps insulate the building and has deep enough planting beds to infiltrate stormwater. The characteristics of this roof garden make the restaurant unique and distinguish it from any other restaurant in London.

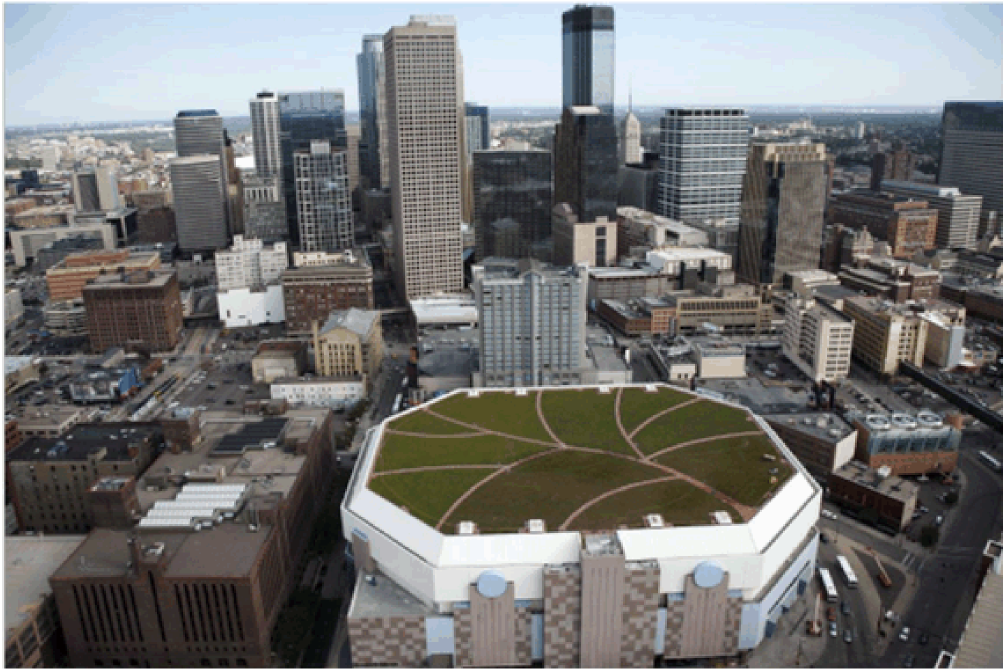
4) Increase green roofs to reduce urban heat island effect

Case Study: Toronto, Canada

The City of Toronto has created a strong foundation to promote green roofs. In 2009, they became the first city to enact a green roof bylaw, which gives the City Council the power to govern the construction of green roofs. In addition, the City also offers a green roof incentive program. Toronto's new bylaw applies to all new commercial, industrial, and many of their residential developments. The green roof bylaw has a graduated coverage requirement that depends on the size of the building. For example, a 21,500 ft^2 building requires a 20% coverage of available roof area, a 75,350 ft^2 building requires a 30% coverage, and a 215,300 ft^2 or larger building requires a 60% coverage. There are some exemptions to this requirement, but all exemptions are subject to City Council approval and are usually accompanied by a fee paid to the City.

Applicability

The City of Minneapolis is already home to several green roofs; two well-known examples include the extensive green roof installations on the Target Center and the Minneapolis Central Library. The City has also identified green roofs as a great way to help reduce stormwater runoff and create healthier communities and more efficient buildings as part of a green initiatives program. Moving forward, the City may want to think about potential methods to increase the installation of green roofs throughout the city. Rather that implementing a mandate such as Toronto's bylaw, an incentive program may be better-suited for Minneapolis. One possible incentive is a tax credit for green roof installation, similar to those offered in cities such as Portland and Chicago. Minneapolis could also offer a density bonus for developers who utilize green roofs.



The green roof on Minneapolis's Target Center.

GOAL 2: PRESERVE THE NATURAL ENVIRONMENT

Best Practices

1) Adapt recreation opportunities to the changing climate

2) Increase urban tree canopy

3) Conduct vulnerability study of natural ecosystems

4) Engage residents in environmental stewardship of their property

5) Manage invasive and native species

1) Adapt recreation opportunities to the changing climate

Background

Instituting a best practice that outlines adaptation for recreation in face of the changing climate is important on two levels. First, many cities will see cold-weather activities such as ice fishing, sledding, and snowshoeing decrease. In turn, warm-weather activities such as running, swimming, and biking stand to increase. However, as noted in the impacts section, the sharp rise in temperatures will increase the amount and severity of heat waves alongside degradation of air quality and an increase in harmful pests such as ticks and mosquitos. The excessive heat and degraded air quality will be a threat to public health during recreation for reasons discussed in the impacts section. The second important measure of recreation adaptation is fiscal. Cities that rely disproportionately on one source of recreation income, such as skiing or water-sports, may find related budgets negatively impacted if recreation adaptation is not considered to manage the changes in recreation patterns.

Case Study: Vermont

In 2011, the State of Vermont undertook a multi-level study to assess the potential impacts of climate change on recreation. A recreational and financial assessment of the state's natural beauty, fishing, beaches, skiing, hiking, camping, and sledding opportunities was conducted, with a corresponding analysis of potential impacts from climate change. In particular, they looked at the potential loss of snow days in the future, given that winter recreation in the state generates over $1 billion annually. The study's adaptation recommendations included expanding campgrounds, trails, and promoting various summer activities to make up for lost revenue from changing recreation patterns as the winter season is shortened.

Applicability

While this particular study was conducted on a state level, a similar endeavour could be downscaled for Minneapolis (or possibly undertaken in conjunction with the state) to assess potential recreation impacts. While exact estimates of changing recreation patterns in Minneapolis will remain uncertain depending on the severity of climate change, a few areas may be identified at this time. According to interviews with the Minneapolis Park and Recreation Board, most recreation centers were not originally designed to be air-conditioned. Accordingly, when they reach a temperature threshold the entire building must be shut down. These will be need to be adapted for air conditioning in some manner as the heat index continues to increase – otherwise they will be unsuitable for public use without posing a health risk. The City will also need to look at implementing more areas of shade and providing adequate drinking water access along popular recreation corridors, such as the City's bike paths. If a preference for winter activities persists despite the changing climate, the use of artificial snow may have to be increased (it is occasionally used as a cross country ski loop).

2) Increase urban tree canopy

Background

A large and resilient tree canopy is an important component of climate change adaptation. As noted in the impacts section, increased temperatures and the urban heat island effect will have a detrimental effect on human health, air pollution, and the robustness of vegetation. Therefore, achieving a diverse, expansive tree canopy is considered a best practice measure for climate change adaptation. Proper implementation will mitigate health risks, decrease high temperatures, add habitat, and filter air pollution.

There are other benefits to increasing tree canopy cover as well. Studies have shown mature urban trees are worth roughly $30-$90 per tree per year. Additionally, having at least a 20% canopy over a home provides an 8%-18% annual savings on cooling, plus a 2%-8% cost saving on heating. The practice is also integral for carbon sequestration. It has been estimated that total carbon storage in US urban trees was roughly 700 million tons, with a sequestration rate of roughly 24 million tons a year (the equivalent of 88.5 million tons of CO^2).

Case Study: Chicago, IL

The Chicago Tree Initiative is a comprehensive, large-scale project designed to increase, care for, and adapt the City's tree canopy. The public-private effort is comprised of many stakeholders, including community-based groups, non-profits, developers, green industry, property owners, and city, state, and federal agencies (a complete list of partners is available online). The initiative was created in response to several factors Minneapolis also faces, including loss of trees due to severe weather events, changes in the hardiness zone, pests such as the Emerald Ash Borer, and an ongoing battle with Dutch Elm Disease.

Chicago Mayor Rahm Emanuel planting trees as part of Chicago's efforts to expand its tree canopy.

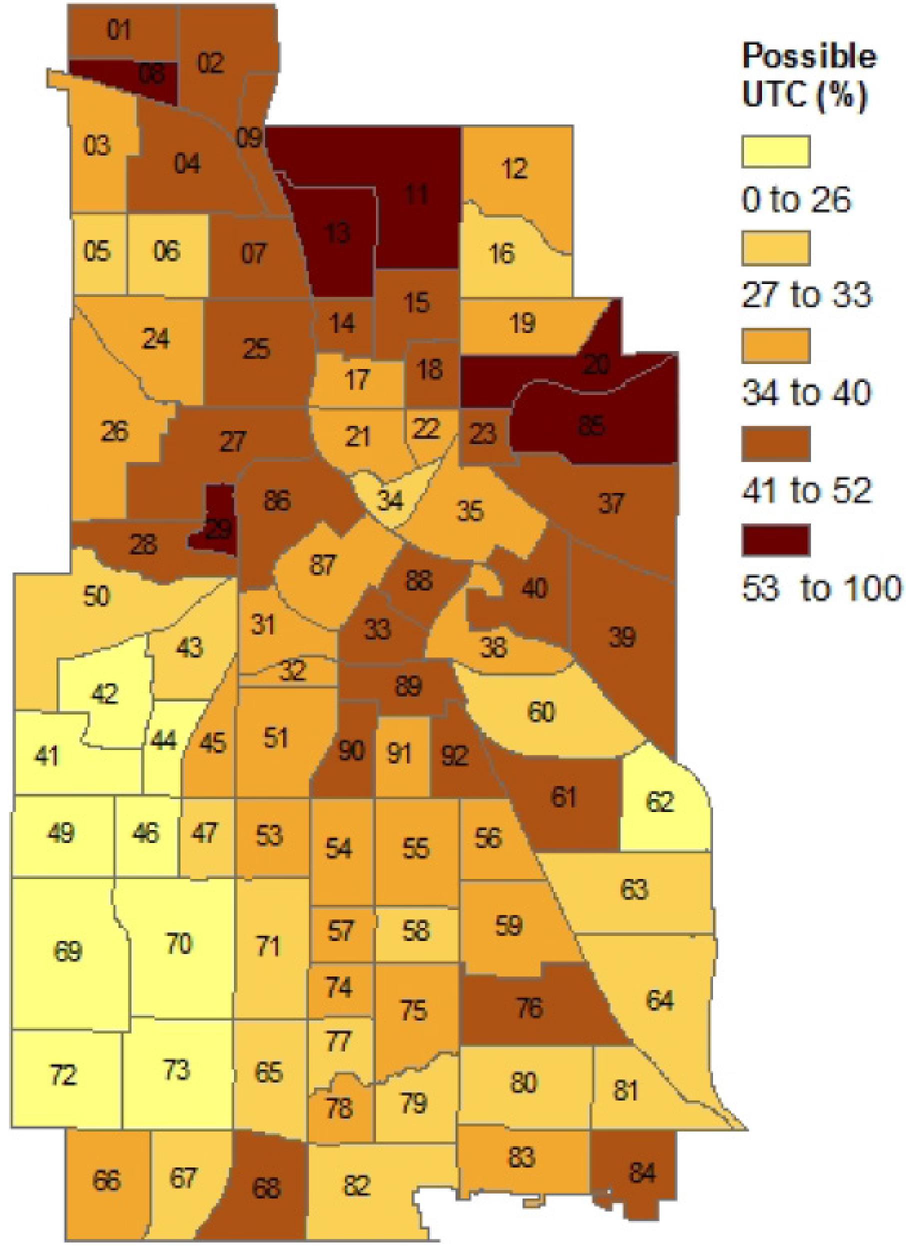
Chicago has been able to plant several thousand new trees each year, as well as integrating more heat-tolerant tree species into the canopy. Thanks to initiatives such as this one, the value of Chicago's urban forestry is now cited at $2.3 billion, with a carbon sequestration rate of 25,200 tons/year valued at almost $15 million dollars.

2) Increase urban tree canopy

Applicability

In an effort to boost and diversify the canopy, Minneapolis offers different species of low-cost trees (at a price of twenty-five dollasrs) to residents in partnership with Tree Trust, a local nonprofit. This effort, in conjunction with a geospatial map prepared by the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory, targets areas for canopy improvement and preservation. The Chicago Tree Initiative offers a framework for Minneapolis to take these accomplishments and improve upon them by engaging a multi-stakeholder, citywide initiative that brings in community groups, developers, green industry, and other governmental agencies.

As noted earlier, Minneapolis currently has a relatively ample tree canopy at 31.5% (compared with 17.2% for Chicago). However, according to interviews with the Minneapolis Park and Recreation Board, the City's tree canopy is not diverse or resilient enough to combat climate change impacts related to pests, invasive species, and rising temperatures. While impacts to existing species such as Dutch elm, ash, and maple trees are fairly well understood, adaptation with more tolerant species such as American beech, bald cyprus, and London plane is still in the experimental stages. Barriers to this adaptation measure include the usual caveat of funding, but time is also a significant factor. Assessing the ability of better-suited species will be an iterative process; trees take a long time to grow, and as they grow the climate will be simultaneously changing (at a pace dependent on future emissions and other factors).



Potential urban tree canopy coverage for Minneapolis.
Source: University of Minnesota, Remote Sensing and Geospatial Analysis Laboratory

3) Conduct vulnerability study of natural ecosystems

Background

As noted earlier in the document, wetlands, parks, and other ecosystems within the urban environment serve a broad range of functions including species habitat, flood control, pollution mitigation, and recreation. However, while data informs us of the broader effects of climate change, ecosystem-specific vulnerability on a city scale is often unknown. Accordingly, a vulnerability assessment of the city's natural ecosystem to withstand climate change should be conducted to isolate where policy, funding, and other resources should be focused.

A vulnerability assessment is defined as "the process of identifying, quantifying, and prioritizing the vulnerabilities in a system." Once this assessment is made in the context of a city's ecosystem, the most vulnerable areas (such as tree species, wetlands, or endangered animals) can be highlighted and earmarked for adaptation resources. Prioritization can be based on the city's own criteria, but low-cost, high-return adaptation measures should be conducted first. As economic and environmental benefits are incurred, the increased funds can be reinvested in longer-term adaptation goals.

		Probability / Likelihood of Occurrence			
		Low	Moderate	High	Very High
Magnitude of Consequence	Low			Heat Wave	
	Moderate	Shoreline Inundation		Coastal Cliff Erosion	
	High	Wildfires	Downtown Flooding	Water Table Rise Downtown	Water Shortages

Risk = Probability x Consequence

Figure 30a. Short to Intermediate Term Risk Ranking 2010 – 2050

Case Study: Santa Cruz, CA

In 2011, the City of Santa Cruz conducted a vulnerability study to analyze potential climate change "risks and hazards" to the ecosystem. This information was then used to prioritize adaptation measures. Research was conducted using GIS to map coastal erosion due to increased storm activity, identify likely flood-prone areas in the watershed due to sea level rise, and assess natural and artificial stormwater management to deal with these changes. Data was drawn from several sources, including NOAA, USGS, the National Academy of Sciences, and the State of California. Based on a "Risk = Probability x Consequence" formula, Santa Cruz created a matrix ranking the magnitude of vulnerability associated with each climate change impact. When the data analysis was complete, water shortages for the general population and a rise in the water table downtown were prioritized as the most important action items, which in turn influenced future policy.

3) Conduct vulnerability study of natural ecosystems

Applicability

Minneapolis has completed modeling of flood-prone areas, tree canopy, habitat, soil quality, storm frequency, and other possible climate-related impacts detailed previously in this document. However, a comprehensive ecosystem vulnerability study has not been undertaken to rank mitigation and adaptation measures in terms of priority. Several interviews suggested that, while analysis is being conducted throughout the City on a variety of levels, a consistent methodology was needed to rank and display recommendations to decision makers. A vulnerability assessment similar to Santa Cruz's would prioritize adaptation measures for Minneapolis in an easy-to-understand matrix, easing the process of adaptation planning.

4) Engage residents in environmental stewardship of their property

Background

Environmental stewardship of private property is an adaptation measure being experimented with in a variety of cities and a variety of ways. Opportunities for engagement include recycling, composting, porous pavers, green roofs, stormwater management, or solar panels, to name a few. Implementation techniques range from tax credits to rebates and discounts to simple advice and informational resources. In most cases, the availability of these programs is welcomed by residents as a way to improve their property, reduce household expenses, and promote environmental stewardship.

Case Study: Chicago, IL

In an effort to engage residents, the City of Chicago recently implemented the "Sustainable Backyards" program, designed to promote sustainability involving "water, waste, energy, and habitat loss" issues "one backyard at a time." The program is funded by the Chicago Department of Transportation (CDOT) and is being implemented by the Center for Neighborhood Technology (CNT), a Chicago think-tank that "combines rigorous research with effective solutions" across a number of issues, including transportation and community development, energy, water, and climate change. Easy to understand and accompanied by a user-friendly website, the program offers a 50% rebate from the City of Chicago geared toward the purchase of trees, shrubs, rain barrels, compost bins, and native plants. Each item has a maximum rebate amount to prevent bulk purchasing from larger entities. Because the program was launched quite recently, early evaluations of its effectiveness are not yet available.

Residents can contribute to maintaining Minneapolis's ecosystem through easy and sustainable actions.

4) Engage residents in environmental stewardship of their property

Applicability

Minneapolis currently engages residents in a number of programs designed to promote climate change adaptation through environmental stewardship. This includes single-stream recycling, an informative website, frequent informational classes, low-cost trees, solar panel rebates (from the state), and grants for planting rain gardens. With Minneapolis already engaged in a number of programs designed to promote sustainability, the greatest applicability from the Sustainable Backyards program is in terms of outreach. The Chicago program has a colorful, comprehensive, user-friendly website serving as the primary source of information for the program. The website highlights frequently asked questions (FAQ), retailer maps, information on different tree and shrub species, a workshop calendar, and an informative blog featuring tips on how residents may practice environmental stewardship on their property with the newly purchased materials.

Chicago's Sutsainable Backyards Program offers rebates for residential environmental stewardship. The program's user-friendly outreach efforts seem particularly effective.

5) Manage invasive and native species

Background

Invasive species associated with climate change are already infiltrating ecosystems and, as noted in the previous section on impacts, this problem will likely become worse in the future. Exact species dynamics (the interaction among species and their relationship with a changing ecosystem) will depend on actual climate shifts and other local factors, and may produce conditions that favor a particular invasive species, alter the dynamic among current species, or possibly even tip the scales in favor of a current native species. Regardless of where the eventual relationship between species lies, management response needs to focus on species that become damaging to the ecosystem. If the intrusion of invasive species can be prevented, this is usually the best course of action. If this is not possible, a specific management strategy based on local factors (such as species type in that area) should be adopted. Failure to adopt such a plan may cause a city to incur unnecessary costs and biodiversity loss.

Applicability

Invasive species management in Minneapolis is led by the Minneapolis Park and Recreation Board, following guidelines set forth by the Minnesota Department of Agriculture and Minnesota Department of Natural Resources. According to interviews with staff, invasive species are being managed to the best of their ability, focusing on prevention, early detection, and control. The MPRB has identified areas of priority, focusing on areas that are considered to have ecological importance and some or all of their native species community intact. Invasive plants of particular concern include Buckthorn, Russian mulberry, and Tartarian honeysuckle. Reducing damage from Emerald Ash Borer, an insect that is highly destructive to ash trees, is also considered a priority. As noted in the impacts section, the Emerald Ash Borer has the potential to wipe out the entire ash tree population in Minneapolis. A document similar to Portland's, adopted by the City Council and with specific mandates and goals, would align invasive species commitments across the City and formalize actions already underway.

Case Study: Portland, OR

The City of Portland recently found itself battling a number of invasive plants and animals. As an example, invasive animals included English Starlings, which compete with indigenous Western Bluebirds and Tree Swallows for nests, while plants included Japanese knotweed, a weed that dominates the riverbank and prevents new trees from taking root. In 2005, Portland's City Council adopted an order that required a three-year work plan with ten-year goals related to invasive plant management. The order established the "Invasive Plant Strategy" plan, which contains cross-departmental plant species management instructions alongside a list of invasive plants earmarked for total eradication. An invasive animal assessment is also currently underway with 10-year goals. A current list of invasive animal species, along with those slated for eradication, is available online. An annual report for the plant strategy is currently available, citing areas of progress alongside room for improvement. A similar report will occur for the animal assessment once the final strategy is adopted by the city council.

GOAL 3: MANAGE STORMWATER

Best Practices

1) Control runoff with rain gardens and bioretention

2) Harvest rainwater to control runoff and decrease water demand

3) Expand surface detention capacity to reduce runoff volumes

4) Reduce impervious surface coverage with permeable pavements

5) Maintain and expand traditional infrastructure to control runoff from heaviest storms

6) Incorporate "Better Site Design" principles to reduce impervious surface coverage and control runoff

1) Control runoff with rain gardens and bioretention

Background

A rain garden is an alternative landscaping option designed to infiltrate stormwater into the soil. Rain gardens are installed below-grade, usually at no more than a 5% slope and a depth of 6-12 inches, to encourage runoff to flow toward the garden. Rain gardens help filter pollutants and divert or slow runoff that would normally enter the storm sewer system, reducing the rate, volume, and timing of stormwater runoff entering local water bodies. Well-designed rain gardens contribute to groundwater recharge, reduce long-term landscaping maintenance for the owner, and expand habitat for native species.

Other bioretention strategies include vegetated swales, filter strips, and landscaping design that encourages infiltration and short-term retention to reduce peak runoff from impervious surfaces after precipitation events or snowmelt. Bioretention is a good strategy for retrofitting existing development, especially in residential areas. Bioretention techniques are typically sized to cover 5-10% of the area drained; for example, a lot of 5,000 square feet would require a rain garden and other bioretention systems to cover at least 250 square feet, though site-specific considerations will alter the necessary bioretention capacity.

Case Study: Seattle, WA

The City of Seattle's Natural Drainage Systems program is a comprehensive effort to implement low-impact or "green infrastructure" development to manage urban stormwater runoff. One goal of this program is to "disconnect" impervious surface cover from storm sewers by encouraging on-site drainage and infiltration. In its "Street Edge Alternatives" pilot project, Seattle reduced impervious surface coverage by 11% by decreasing the size of the street and incorporating bioretention techniques into landscaping. Seattle was able to reduce runoff by 99% below pre-project levels and mitigate all runoff from storms producing less than .75 inches of rainfall in a 24-hour period. This and other projects have achieved stormwater management goals below the cost of traditional stormwater technologies. Accordingly, Seattle has updated its Stormwater Code to require adoption of bioretention techniques and other green infrastructure to the "maximum extent feasible."

Chicago, Philadelphia, and Milwaukee, among many other cities, are pursuing bioretention and green infrastructure to manage stormwater in a way that more closely resembles pre-development hydrology.

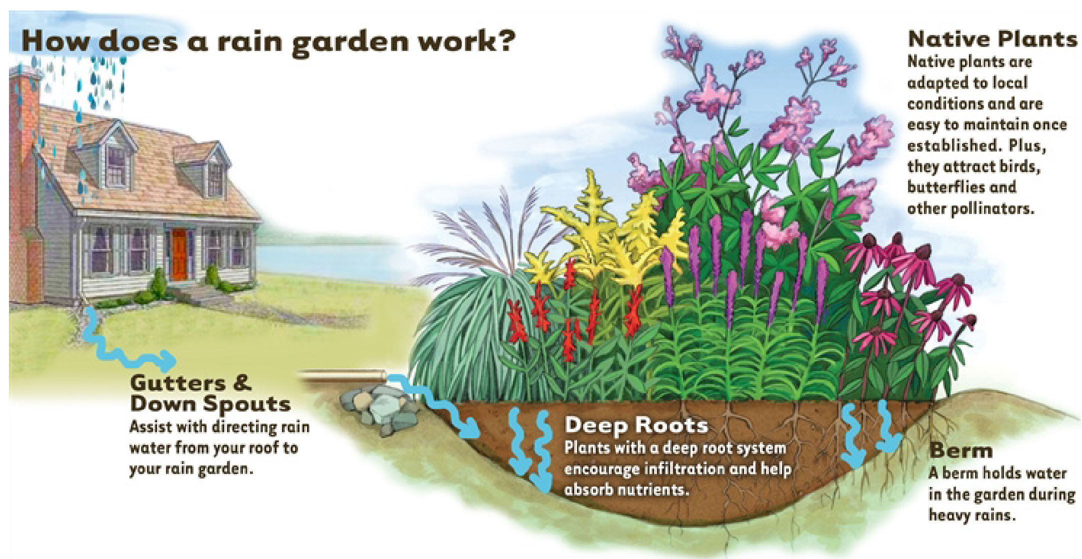
1) Control runoff with rain gardens and bioretention

Applicability

The increased incidence of heavy rainfall events projected for Minneapolis necessitates a comprehensive approach to attenuating stormwater runoff flows. Bioretention techniques, including rain gardens, are commonly designed to reduce runoff flows from 2-in, 24-hr precipitation events; larger storms will likely exceed this retention capacity. In conjunction with other strategies, including traditional stormwater infrastructure, bioretention can positively alter the rate, volume, and timing of runoff, improving water quality and reducing the likelihood of localized flooding. Interviews with staff in Public Works suggest the need to incorporate bioretention and green infrastructure into the City's overall approach to managing stormwater. However, green infrastructure alone will likely not meet the City's goals with respect to flood prevention during the heaviest storms.

Minneapolis already offers credits to homeowners and developers to install bioretention as a best management practice for reducing stormwater runoff. The City also has a target to double the number of installed rain gardens by 2015. Increasing rain garden installations can be accomplished by offering direct subsidies to homeowners, developers, and businesses, or by increasing the stormwater utility fee to encourage higher uptake rates of bioretention techniques.

A rain garden at 7 Sigma in Minneapolis.



2) Harvest rainwater to control runoff and decrease water demand

Background

Rainwater harvesting involves the use of rain barrels, cisterns, and similar storage devices to capture precipitation, especially runoff from roofs. Water captured by rainwater harvesting systems reduces the volume of runoff commensurate to the storage capacity of the system. Rainwater harvesting can be used in conjunction with other technologies, including bioretention systems, to limit runoff to local water bodies during precipitation events by altering the timing of runoff and encouraging greater infiltration.

Harvested rainwater is appropriate for watering plants and other outdoor uses. The use of harvested rainwater can help decrease strain on municipal water supplies during summer months. Rainwater harvesting is appropriate for all building types, including residential and commercial development. Harvesting systems can be designed to meet the water usage and capture needs of a variety of users.

Case Study: San Diego, CA

The City of San Diego has tested a variety of rainwater harvesting systems to meet water quality standards by reducing runoff from impervious surfaces. The systems were designed to capture 100% of runoff from a 0.6-in, 24-hr design storm. Harvesting systems, especially gravity-flow devices, were effective at mitigating runoff in conjunction with infiltration and bioretention practices. San Diego has since initiated a pilot rebate program for residential rainwater harvesting systems.

Two 60-gallon rain barrels installed in-series in Longfellow.

Applicability

The increased incidence of heavy precipitation events projected for Minneapolis necessitates a comprehensive approach to managing stormwater runoff. While typical 55-gallon rain barrels offer limited reductions in runoff, especially during the heaviest storms, rainwater harvesting systems can be designed to capture larger volumes of water. 55-gallon rain barrels can be installed in-series to increase the storage capacity of the system, which may be suitable for most residential sites. Commercial sites can install larger systems on roofs or underground depending on space availability and desired capacity. Harvested water can also be used to decrease the severity of impacts from projected increases in drought between precipitation events. Ensuring that rain barrels are emptied during dry conditions, in anticipation of wet weather, would maximize the runoff reduction benefits of rainwater harvesting.

2) Harvest rainwater to control runoff and decrease water demand

The City of Minneapolis already offers credits to reduce the stormwater utility fee for homeowners. Providing direct subsidies to purchase harvesting systems or increasing the stormwater utility fee would make adopting rainwater harvesting systems more attractive if the harvesting system, in conjunction with other practices, met reduction requirements. City ordinances can also be amended to classify rainwater harvesting as a best management practice for stormwater runoff reductions for new development and existing commercial and industrial sites.

GOOD

PLANTER – BARREL

Cost: $$$

FLOW

Planter-barrel systems detain/filter runoff through an engineered soil media. They are used to retrofit impervious areas and will discharge to MS4, unless in-series to LID BMPs.

LOAD

Load reduction improvement is anticipated once vegetation becomes established.

O&M

Plants may be vandalized and require regular watering. Consider enhanced iron/zeolite soils with decorative rock instead of plants to reduce O&M costs while improving treatment.

BETTER

AUTOMATED / CAPTURE

Cost: $$

FLOW

Automated or manual capture systems hold 100% roof runoff up to the capacity of the barrel/cistern.

LOAD

100% load reduction for runoff is captured in barrel.

O&M

Automated systems have the most moving parts and greatest motivation for theft. Manual timers powered by 12-volt DC photovoltaics are recommended rather than 120-volt AC ground fault circuit interrupt (GFCI) systems. Algae and adverse odors were present in translucent tan barrels.

BEST

GRAVITY-FLOW

Cost: $

FLOW

Gravity-flow systems act like miniature detention basins. Roof runoff is attenuated and a volume, up to six times the capacity of the original barrel, is infiltrated to existing landscaping eliminating discharges to the storm water conveyance system.

LOAD

100% load reduction for runoff is attenuated and infiltrated.

O&M

Allows for the easiest, fastest, and cheapest repairs. This configuration was vandalized the least. Use opaque barrels to eliminate potential algae growth.

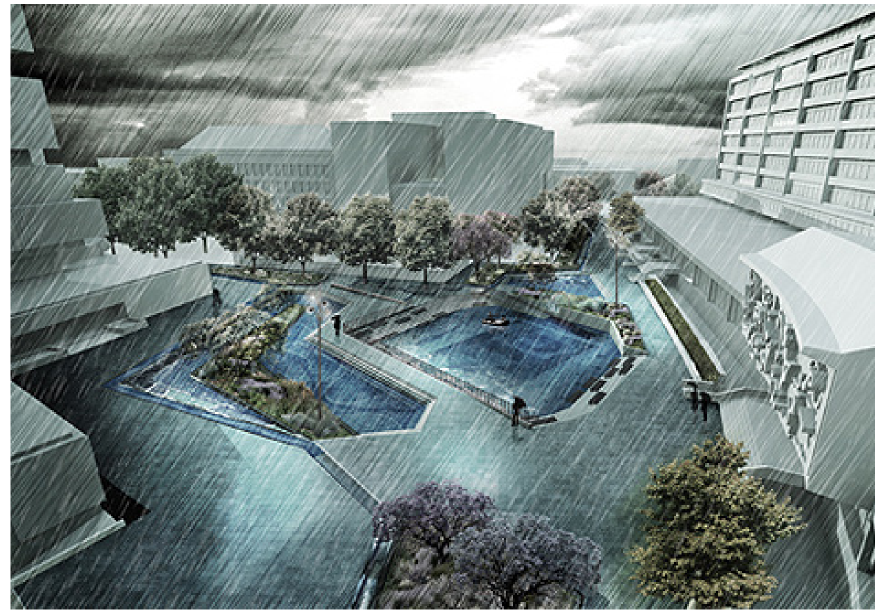
3) Expand surface detention capacity to reduce runoff volumes

Background

Detention basins or detention ponds are large-scale basins designed to temporarily store stormwater runoff, usually for less than 24 hours. Detention basins offer protection against localized flooding by capturing relatively large volumes of water. These basins also enhance water quality by allowing pollutants in stormwater to settle before the water is discharged to storm sewers or local water bodies.

Detention basins typically require a minimum of 10 acres to effectively protect water quality and limit channel erosion. However, smaller sites are feasible, particularly in dense urban areas, if water quality is less of a concern than flood control or if other treatment technologies are used to filter pollutants from stormwater.

Lakes, ponds, and wetlands also offer detention capacity during heavy storms. Protecting and expanding natural habitat can be used to detain water and enhance water quality.



A sketch of the Water Plaza in Benthemplein.

Case Study: Rotterdam, the Netherlands

Rotterdam is a low-lying port city (much of the city is below sea level) in the Netherlands. Heavy precipitation events overwhelm the capacity of the city's system of sewers and canals, leading to localized flooding of streets and basements. Rotterdam is pursuing dual-use stormwater detention basins to reduce runoff volumes in its dense urban core. The "Water Plaza" in Benthemplein is a below-grade basin that incorporates athletic courts and open public space into its design. During heavy storms, gutters draw rainwater toward the basin, where it is stored until a shutoff valve is opened, releasing the water to nearby storm sewers.

The design of the plaza is intended to alter the timing of runoff in dense, highly impervious urban areas where peak runoff during the heaviest precipitation events is likely to overwhelm storm sewer capacity and produce localized flooding.

3) Expand surface detention capacity to reduce runoff volumes

Case Study: New York City, New York

The Staten Island "Bluebelt" in New York City offers an example of a detention system at the watershed level. The Bluebelt is a series of constructed detention ponds and wetlands connected by streams. Stormwater enters storm drains along streets and is diverted to the Bluebelt system, where runoff is slowed and pollutants are filtered out of the water. The Staten Island Bluebelt is designed to manage runoff from storms producing 1.75 inches of precipitation in a 1 hour period. New York City estimates the Bluebelt was 50% less expensive than a comparable storm sewer system. New York City is currently pursuing similar "bluebelt" projects in other areas of the City.

The master plan for a Bluebelt project on Staten Island.

Applicability

Projected runoff flows during heavy precipitation events will likely overwhelm the capacity of storm sewers in many areas of Minneapolis, leading to flooding in streets and other areas. Increasing the capacity of storm sewers to handle larger runoff volumes may be prohibitively expensive. Increasing surface detention capacity is an attractive and likely cost-effective alternative.

In dense, highly-impervious areas like downtown Minneapolis (particularly in East Downtown, where new development seems likely), detention plazas like those under construction in Rotterdam will ease the strain on storm sewers.

In areas where land availability is less of a concern, natural detention basins provide useful storage capacity to reduce runoff volume. Incorporating multiple detention basins, wetlands, and conveyance channels into a Bluebelt-like system offers a comprehensive strategy for preventing flooding and enhancing water quality. This approach represents an aesthetically-pleasing solution to stormwater runoff that preserves habitat. Minneapolis could coordinate action between the four watersheds within the City to develop a Bluebelt-like system.

4) Reduce impervious surface coverage with permeable pavements

Background

Permeable pavements are designed to infiltrate precipitation and snowmelt into soil beneath paved surfaces. The most common permeable pavement types are pervious concrete, porous asphalt, and paving stones installed with gaps to allow water to percolate beneath the pavement. Permeable pavements help limit stormwater runoff by encouraging infiltration on-site, reducing the need for traditional conveyance mechanisms. Newly-installed permeable pavements may have infiltration rates above 1,500 inches per hour. Permeable pavements are also highly-effective in filtering pollutants from stormwater.

Permeable pavements work best in areas with soils that have suitable infiltration capacity and low potential for sediment loading (as pervious and porous pavements can become clogged). Underdrains and other design considerations may increase infiltration in areas with clay or compacted soil. Clogged pavement can be treated with vacuuming, though even highly-clogged pavement infiltrates water at rates exceeding 1 inch per hour. Some permeable pavements may have less strength than their impermeable counterparts; accordingly, permeable pavement may not be appropriate in areas with high traffic volumes or extreme loads.

Initial installation costs are usually higher than traditional pavement types. Permeable pavements can range from $0.50 to $7 per square foot. Life cycle costs may be lower for permeable pavements in comparison to traditional pavement, as properly-installed permeable pavements can last up to 40 years.

There has been some concern that the freeze-thaw cycle will limit the effectiveness of permeable pavements in cold climates. Research at the University of New Hampshire Stormwater Center shows that properly-installed and well-maintained permeable pavements function well in cold climates, often preventing road ice and reducing the need for salt applications.

Applicability

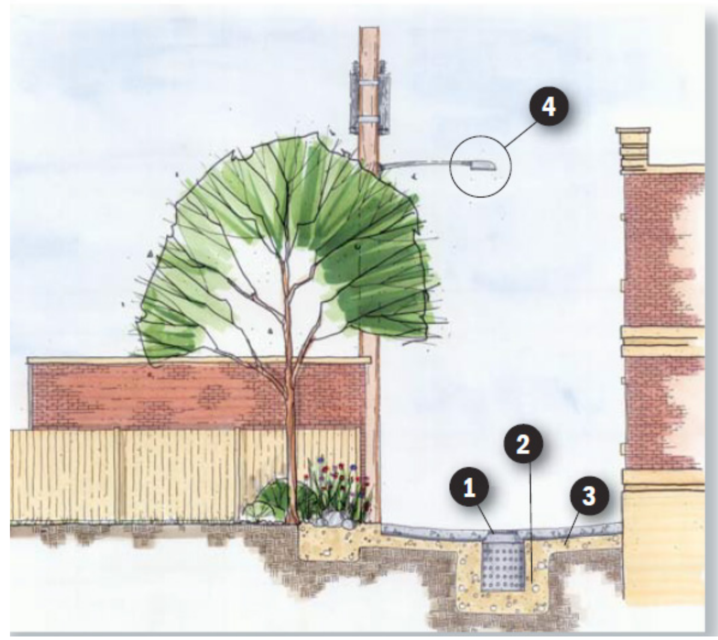
Projected increases in peak runoff volumes will likely necessitate reductions in impervious surface cover in Minneapolis. Permeable pavement, in contrast to conventional pavement, reduces impervious coverage by allowing water to infiltrate into subsoils. Permeable pavements thus present an attractive option for stormwater management.

Permeable pavements have been successfully implemented in cold climates and, in certain cases, have proven more robust than conventional pavements in the face of freeze-thaw cycles. However, permeable pavement represents a small percentage of paved surface. Contractor inexperience with permeable pavement may lead to high initial failure rates, limiting the effectiveness of new pavers as a stormwater management technique. Other cities have overcome this problem by conducting small-scale demonstration projects to assess the performance of different pavement types and build engineering capacity. Minneapolis should work with the Minnesota Department of Transportation and other municipalities to determine which pavement types and mixtures work best in Minnesota's climate.

4) Reduce impervious surface coverage with permeable pavements

Case Study: Chicago, IL

Chicago began its "Green Alleys" program in 2006 to limit flooding, reduce pollutants from stormwater runoff, and increase albedo (reflectivity) on its more than 13,000 alleys. Conventional solutions, including connecting alleys to the city's storm sewer system, were deemed too expensive. The initial pilot project demonstrated permeable and high-albedo pavements in 5 locations, at a total cost of $900,000. In the first year of the program, prices for pervious concrete dropped from $145 to $45 per cubic yard. As of 2010, the City had renovated nearly 200 alleys with permeable and/or high albedo pavements. Public response has been overwhelmingly positive, with many neighborhood groups encouraging the Chicago Department of Transportation (CDOT) to install green alleys in their neighborhood. Though initial results have been positive, CDOT is continuing to monitor performance and assess long-term maintenance needs as Chicago expands its program to more alleys and other paved surfaces throughout the City.



Sample green alley design for the City of Chicago.

Left: Pervious concrete.
Right: Porous asphalt compared to traditional asphalt.

A green alley in Chicago.

5) Maintain and expand traditional infrastructure to control runoff from heaviest storms

Background

Traditional stormwater management infrastructure should continue to play an important role in managing heavy runoff, especially in highly-dense urban areas where green infrastructure and detention basins cannot be implemented at the scale necessary to handle peak runoff. Assessing the capacity of existing infrastructure to handle larger runoff volumes from future storms is a critical first step in adapting a city's stormwater management system. In areas where the existing infrastructure is inadequate and green infrastructure practices prove implausible, cities should retrofit storm sewers to handle larger flows. Storm sewers can also be adapted to more effectively store runoff, rather than discharging it to local surface water bodies as quickly as possible.

Applicability

Increases in the 10- and 100-year design storms will likely strain and, in many places, overwhelm the capacity of Minneapolis's existing storm sewer infrastructure to prevent localized flooding and protect water quality. Retrofitting the system to handle higher projected runoff volumes is an important best management practice for the City. The Minnehaha Creek Watershed is conducting relevant modeling assessments (see sidebar for more). Minneapolis should expand the MCWD efforts throughout the City and begin upgrading infrastructure as needed. The City of Minneapolis should also encourage developers to incorporate expanded stormwater infrastructure in new projects.

Case Study: Philadelphia, PA

The City of Philadelphia is completing a comprehensive assessment of its traditional stormwater infrastructure to increase the efficiency of flow conveyance, storage, and treatment and extend the life of the storm sewer system. In 2005, Philadelphia created GIS coverage of its entire storm sewer system, and is beginning to inspect the system through the use of closed-circuit television. Philadelphia is relining existing storm sewer pipes to increase the effectiveness and longevity of the system when dealing with higher runoff volumes and attendant pressure issues. Subsurface infiltration tanks and other underground detention facilities that exceed the City's code requirements are being incorporated into new development projects to significantly reduce runoff volumes. Philadelphia is also conducting extensive data collection, monitoring, and modeling programs to assess existing performance and inform future planning efforts. For more, please see the "Green City, Clean Waters: Comprehensive Monitoring Plan" included in the appendix.

6) Incorporate "Better Site Design" principles to reduce impervious surface coverage and control runoff

Background

The Better Site Design (BSD) approach involves preserving natural areas and striving to mimic pre-development conditions in order to minimize the impact of development on regional ecosystems and watersheds. BSD incorporates many of the green infrastructure practices identified above. BSD also encourages:

- introducing soil amendments to improve infiltration and drainage
- limiting clearing and grading to maintain undisturbed natural drainage systems
- increasing density or reducing lot sizes to create more green space
- reducing impervious surface coverage (from roofs, sidewalks, streets, parking lots, and driveways) to alter runoff volume and flow rate, and
- "daylighting" streams where possible when replacing culverts to increase storage, reduce peak flows, and provide aesthetic and property value benefits

BSD standards, along with conservation design and low-impact development practices, can and should be tailored to local conditions and local needs. These principles are intended to encourage new and redevelopment projects to consider design that attenuates runoff and related pollutant loadings in a cost-effective and ecologically-sensitive manner. Evaluating and revising building codes, zoning ordinances, street standards, and related policies to better reflect new research and practices is an important step in managing stormwater effectively and efficiently.

Applicability

The use of BSD principles and practices is an innovative way for Minneapolis to reduce runoff and pollutant loading from projected increases in precipitation. By mimicking pre-development hydrologic conditions, BSD helps reduce localized flooding and other issues from excessive runoff. BSD also fits well with Minneapolis's commitment to make communities more walkable and more sustainable, and does so in a cost-effective manner.

However, existing building codes and zoning ordinances may limit the extent to which developers can apply BSD principles to manage stormwater. BSD principles may be less successful in highly-dense areas (such as Downtown Minneapolis) where land values limit flexibility in design. Still, taller buildings and narrower roads may be possible in some sections of Downtown, and increasing green space within the Downtown area coincides with a greater demand for natural amenities. Other areas of Minneapolis have greater flexibility in adopting many BSD principles in order to preserve green space and natural ecosystem features, reduce impervious surface coverage, and increase surface water storage in order to reduce flow volumes and slow runoff.

6) Incorporate "Better Site Design" principles to reduce impervious surface coverage and control runoff

Case Study: Santa Clara, CA

In 2001, the City of Santa Clara reviewed its existing ordinances and policies and revised many to allow developers to pursue alternative ways of meeting runoff and water quality requirements. Since then, development and redevelopment projects across the Santa Clara Valley have incorporated many of the practices outlined above. The City has also offered awards each year for projects that achieve or exceed stormwater requirements outlined in the City's NPDES permit. For information on specific projects, please see the Santa Clara Site Design Manual in the appendix.

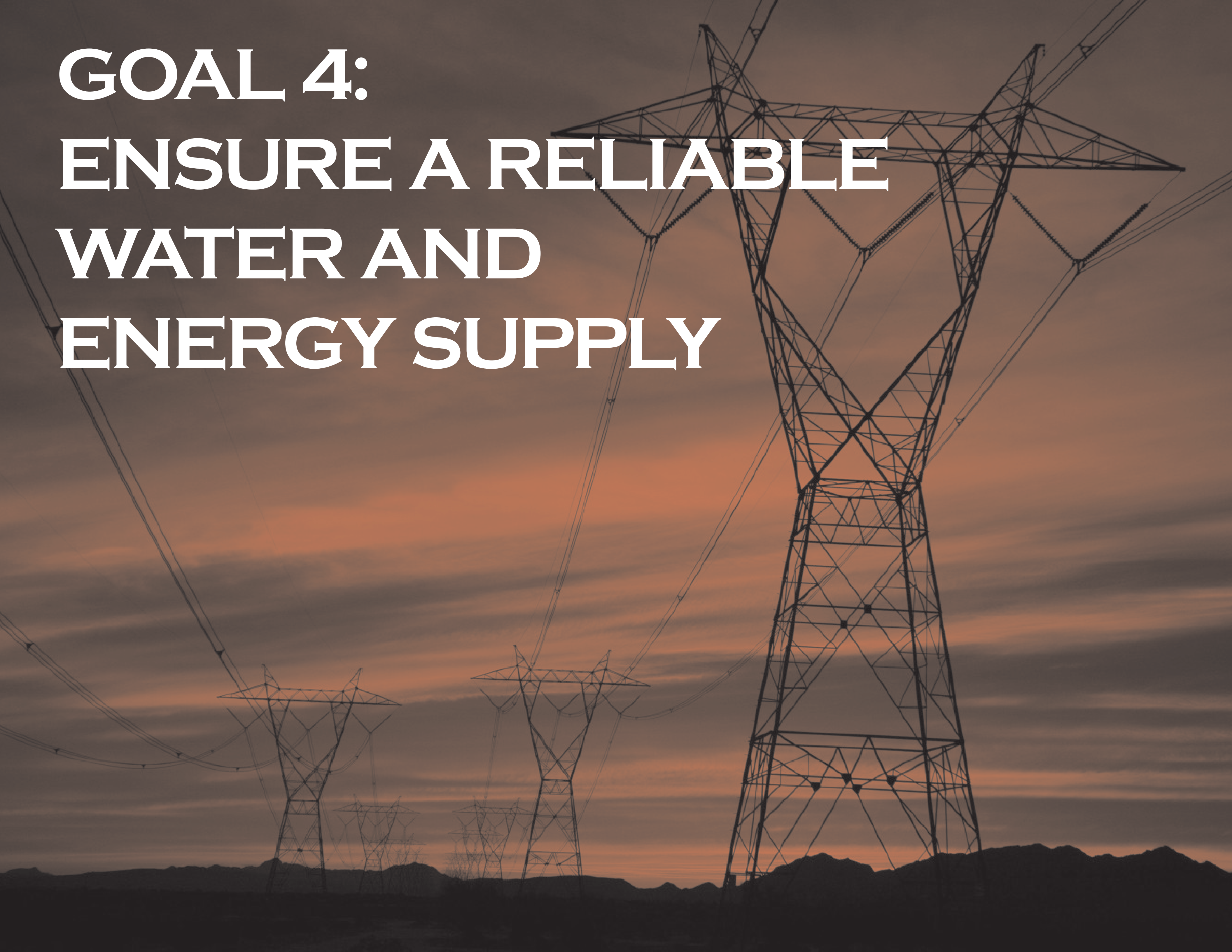
Case Study: Milwaukee, WI

The City of Milwaukee has implemented BSD principles in the redevelopment of the Josey Hills neighborhood. The project is expected to reduce stormwater runoff by over 80% compared to development without the use of BSD practices.

Case Studies: Maryland and Virginia

Maryland and Virginia have passed laws mandating the implementation of BSD practices to the maximum extent feasible or practicable for most development and redevelopment projects to limit runoff from urban areas. Initial reviews of projects that have implemented BSD and similar practices have seen significant reductions in impervious cover, significant increases in open and green space, and lower overall project costs.

GOAL 4: ENSURE A RELIABLE WATER AND ENERGY SUPPLY



Best Practices

1) Understand the energy use patterns and needs of homeowners in order to implement comprehensive smart gird technology on a local scale

2) Incentivize microgrid projects

3) Incentivize cool roofs on new and existing buildings

4) Pursue an "urban cap-and-trade" policy to encourage energy conservation and energy efficiency retrofits in buildings

6) Mandate 100% renewable energy use

7) Encourage residential water conservation

8) Diversify water supply and plan for potential supply disruptions

1) Understand the energy use patterns and needs of homeowners in order to implement comprehensive smart gird technology on a local scale

Background

The "smart grid" involves increasing the technological sophistication of the electrical grid to provide real-time monitoring of energy usage and potential disruptions to the electric power system, deliver direct price signals to encourage users to shift or reduce their demand, increase the capacity of the power grid to integrate distributed electricity generation, and enhance the overall efficiency and resiliency of the grid. The smart grid is not an end in itself. Rather, it is a process of upgrading our current electrical grid to manage the challenges presented by a changing world.

The Pecan Street Project homes.

To more effectively pursue smart grid strategies, a better understanding is needed of how energy is used in homes and what consumers need to better manage their energy use. Therefore, working toward a smarter grid will depend on the engagement of residents, businesses, and utilities, and ongoing experimentation and pilot projects. As this understanding increases, pursuing technologies and policies related to the smart grid will help reduce energy load and increase the overall resilience of the grid – actions that are necessary now as the country's electrical infrastructure ages, and may become even more necessary in the event that more extreme weather threatens the resiliency of energy transmission systems.

Case Study: Austin, TX

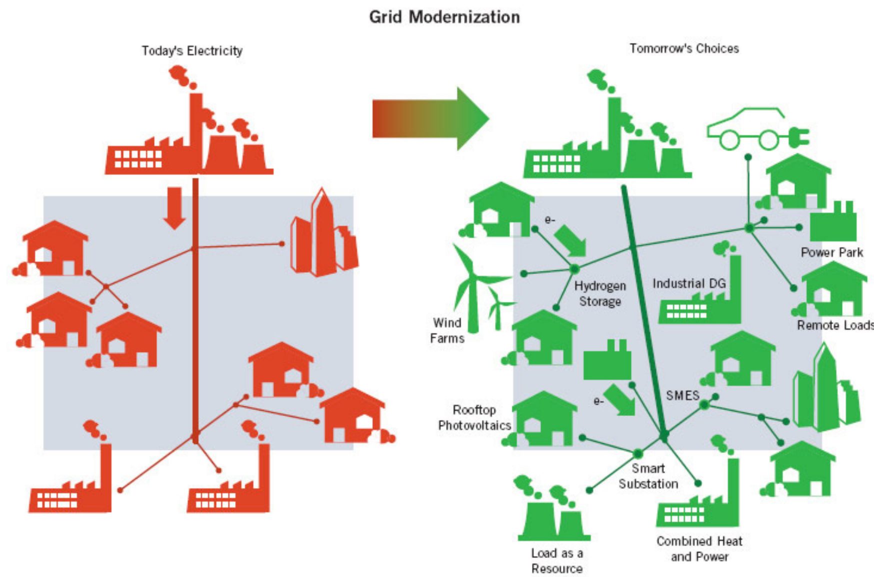
The Pecan Street Project, launched in February 2011, is a University of Texas-led initiative to pilot test a range of options for home energy management systems, electric vehicles, rooftop solar energy systems, and other cutting edge energy technology. The project focuses on the needs and responses of consumers, ensuring that any smart grid policies that are pursued in the future are grounded in reality. In partnership with utilities and a number of companies that produce energy technology, the project provides participating homeowners access to an individualized web page that allows them to track their energy use and costs and receive personalized tips to use less and lower their bills. Easy-to-use "self-programming thermostats" are being tested in 200 homes, as is a system that links electric car charging with energy produced by rooftop PV panels. The project has completed one of the most comprehensive, in-depth research studies in the country on consumer energy use habits, and the data will be instrumental as governments, utilities, and individuals plan for the future of energy infrastructure.

1) Understand the energy use patterns and needs of homeowners in order to implement comprehensive smart gird technology on a local scale

Applicability

Increasing awareness of the smart grid and related technologies, understanding their mechanisms, and encouraging input from ratepayers is a crucial first step in designing a modern power grid that will meet the needs and goals of all Minneapolis residents and businesses, especially in the face of increasing demand for cooling and potential disruptions due to extreme weather. Drawing on research conducted elsewhere would be valuable to the City, but determining the behavior and needs of Minneapolis residents to ensure that future energy solutions are appropriate is a priority.

Xcel Energy, Minneapolis's electrical energy utility, recently led a smart grid project in Boulder with mixed results; unexpected difficulties increased project costs significantly over original estimates. This does not necessarily suggest that Minneapolis should not pursue similar efforts or work with Xcel to explore options for smart grid implementation and pilot projects. Rather, it highlights the need for effective communication between consumers, the City, and utility partners, and a reminder that understanding of smart grid technology is still developing.



A smart grid utilizes real-time information from both energy suppliers and consumers to keep the grid running effiiciently, effectively, and sustainably.

2) Incentivize microgrid projects

Background

Microgrids, or localized power grids, are increasingly being lauded as an important component of a "smarter grid" and an opportunity to significantly increase the resilience of energy systems. They allow a community, institution, or neighborhood to produce power locally, reducing their reliance on the broader electrical infrastructure network. Localized power generation could be instrumental to helping maintain consistent access to electrical energy should transmission disruptions become more frequent due to more extreme weather and higher temperatures, or electricity supply be limited due to demand increases during peak hours.

The United States Department of Defense, research universities, and technology companies have been working to explore the potential for microgrids. While the necessary technology does exist – including solar cells, wind turbines, fuel cells that convert chemical energy into electricity, and energy storage systems – cost can be a significant barrier, particularly for microgrids that can operate independently of the larger power grid.

Applicability

The City of Minneapolis has a number of renewable energy projects, such as solar panels on several City buildings and several hydroelectric projects, so the development of a microgrid project or EID like Stamford's would not be a significant leap. Furthermore, microgrids would work not only toward climate change adaptation, but would also address the renewable energy goals laid out in the City's sustainability indicators and the Climate Action Plan. However, the impacts of increased extreme weather will likely not be as dire in Minneapolis as in Stamford, a coastal northeastern city and as our interviewees commented, Xcel Energy's Minnesota crews are well prepared for the effects extreme weather events might have on transmission. The decision to implement microgrid technology would have to take into account both the significant costs and the perceived necessity of a given community or neighborhood being independent from the grid.

Case Study: Stamford, CT

In November 2007, Stamford passed a municipal ordinance to create an Energy Improvement District (EID) in the City's downtown, facilitating the sharing of costs and benefits of community energy infrastructure among businesses and property owners in a localized geographic area. Drivers for this decision included increasingly unreliable, aging electrical infrastructure that has led to extended power outages during recent storms as well as high electricity costs under the existing system. In response to some skepticism among business owners and doubts about pricing, the city has opted to use its Government Center as an EID and microgrid demonstration site. Using fuel cell technology they hope to make the building independent from the power grid. Although the project has faced a number of political and cost barriers, as of spring 2013 the Government Center was one of 27 finalist projects in a bid to receive state financing to support microgrid projects.

3) Incentivize cool roofs on new and existing buildings

Background

Dark roofs store heat from the sun, increasing demand for cooling in the summer and contributing to the urban heat island effect. "Cool," or light-colored roofs, reflect the sun's heat and can help conventional roofs absorb less heat and keep them up to 50°-60°F cooler during hot summer weather. Cool roofs are created by rolling or spraying a highly-reflective white membrane onto rooftops, including both low-slope roofs typical of commercial or industrial buildings and steeper-sloped roofs on residential or retail buildings. This covering can reflect between 70 and 90% of the sun's heat and is suitable for a range of roof types including granule, smooth asphalt, and smooth aluminum.

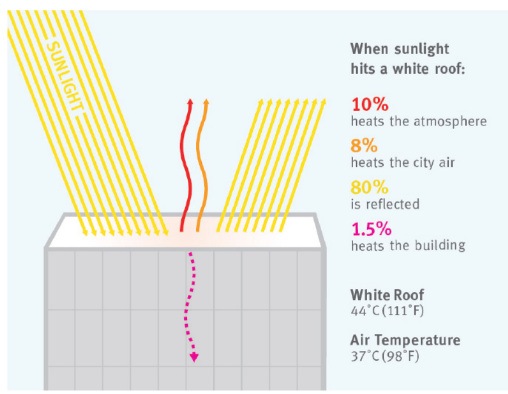
Individually, cool roofs have a number of benefits. By lowering a building's temperature, they reduce the need for air conditioning and associated electricity demand, as well as keeping building occupants more comfortable and less susceptible to heat-induced health issues. Indirectly, they contribute to reduced air pollution and GHG emissions by decreasing energy use. By reducing the stress of dramatic variations in temperature, cool roofs can also extend a rooftop's lifetime, saving the building owner maintenance or replacement costs. Furthermore, when many cool roofs are concentrated in an area, they can mitigate the urban heat island effect and reduce ambient air temperatures.

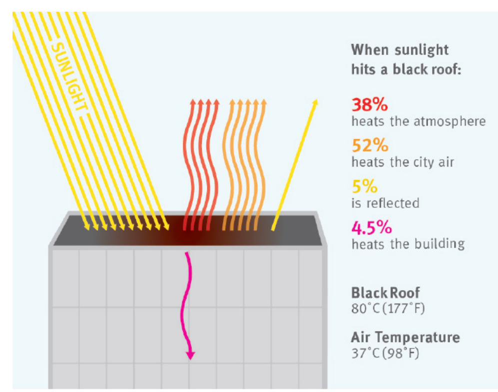
Case Study: Chicago, IL

Chicago's 2009 Energy Conservation Code mandates that new residential and commercial buildings meet specific sets of reflectivity requirements based on their slope. Low-slope roofs are subject to the most stringent requirements, while steeply-sloped roofs are exempt. The code requires that all cool roof coverings must be rated either by ENERGY STAR or the Cool Roof Rating Council (CRRC). Other types of roofs that limit solar absorption, such as green or ballasted roofs – those that are covered by a loose covering and held in place by rock or other heavy material, are exempt from the requirement. To complement this mandate, Chicago instituted a Cool Roof grant program that awarded $6,000 grants to residents and small business owners seeking to update their roofs to meet or exceed cool roof standards.

Applicability

Cool roofs have been used successfully in a number of cities but there is some uncertainty about their net benefits in northern climate cities like Minneapolis. Some studies have suggested that the increased heating demand in the winter resulting from cool roofs might outweigh summer savings, although a 2009 study concluded that even in northern cities like Chicago summer benefits of reduced energy costs outweigh winter increases. The efficacy of reflective roofs can also depend upon building design, roof slope, and other factors. The relevance of this strategy in Minneapolis is unclear, but might be kept in mind as more is understood about the extent to which summer cooling demands will increase relative to winter heating.





4) Pursue an "urban cap-and-trade" policy to encourage energy conservation and energy efficiency retrofits in buildings

Background

Energy efficiency and conservation efforts are generally considered to be primary strategies for climate change mitigation because of their role in reducing greenhouse gas emissions associated with energy production. However, these strategies can serve also as important adaptation strategies as demand for cooling in the summer increases – particularly during critical-peak hours – and more extreme weather events potentially threaten the reliability of energy supply. Energy efficiency and conservation measures can reduce the need for additional power generation to meet this increased peak demand, lessen the strain on the electrical infrastructure that provides Minneapolis its energy, and protect City residents and businesses from potentially higher energy costs associated with infrastructure upgrades and increased demand. Indirectly, energy efficiency can also contribute to a more reliable water supply; since less energy is produced than what would have been absent energy efficiency measures, the energy production process uses less water.

Energy efficiency is also a valuable climate change adaptation strategy because of its relatively low cost. Reducing energy use is often the least expensive way to address increased demand. Utilities, for example pay about $.025/kilowatt-hour (kWh) for savings that result from energy efficiency programs – equivalent to about one-fifth the cost per kWh of new nuclear electricity or a quarter of the cost of new coal-fired electricity generation.

Case Study: Tokyo, Japan

Many are familiar with the carbon cap-and-trade legislation that has been debated on a federal level in the United States. In 2010, Tokyo – supported by the Tokyo Metropolitan Environmental Security Ordinance – enacted a policy mandating a cap-and-trade-like program among the city's largest commercial and industrial buildings. Building owners are responsible for reducing their properties' emissions between six and eight percent from baseline levels by 2014. Participants were issued a set number of emissions credits upon the start of the program, and are able to buy and sell the credits as they work to reach their goal.

Building owners are required to provide the Tokyo city government with an emissions report in November each year. In the second year of the emissions trading program, participating facilities saw a 23% reduction in emissions and a 93% reduction below the law's requirements.

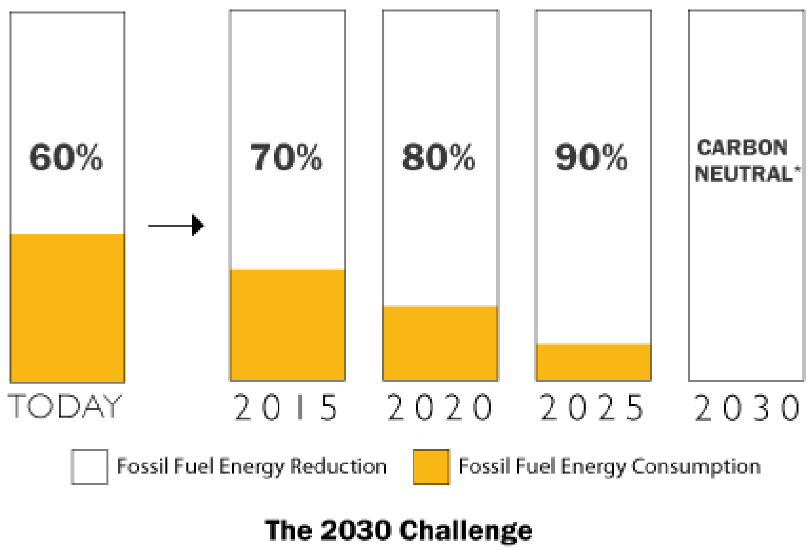
Applicability

With the passage of its Commercial Building Rating and Disclosure Ordinance in 2013, the City of Minneapolis already is on the frontlines of building emissions reporting. It was the first city in the Midwest to institute such a policy. With the new mandate in place, Minneapolis has already taken the first step toward a policy like Tokyo's. The City could take a step further by using this baseline information to designate a realistic "cap" on emissions and a corresponding reduction goal, evaluating progress and ensuring the cap is not surpassed through its annual data collection. In addition, the recent Climate Action Plan has identified energy efficiency as a priority for climate change mitigation, so pursuing energy efficiency policies such as this work toward mutually reinforcing goals.

5) Encourage energy efficiency and conservation in both new and existing buildings through the identification of a geographic district

Background

Buildings – both commercial and residential – consume over 50% of the country's energy. Therefore, as in the Tokyo case study described above, they should be a priority in the effort to reduce energy consumption and improve efficiency. Prescribing a specific set of goals or mandates through a special district (such as the EID in Stamford, CT described previously), zoning regulation, or building code, allows cities to ensure in a comprehensive manner that new and existing buildings consume less energy.



The 2030 Challenge has aggressive emissions reduction goals.

The 2030 Challenge is an initiative of the global architecture and building community to adopt a set of targets related to GHG emissions, energy consumption, and energy efficiency for new and existing buildings. Several cities have applied the challenge to specific geographic areas, creating "2030 Districts."

Case Study: Pittsburgh, PA

Pittsburgh's 2030 District was formed downtown in August 2012 by the non-profit organization Green Building Alliance. Since then, more than half of the buildings in the district have voluntarily signed on to meet the goal of reducing energy consumption, water usage, and transportation by 50% by 2030. One of the District's primary goals is to demonstrate that highly efficient, environmentally friendly buildings and companies can still be highly productive and profitable; they seek to identify and promote practices that reduce environmental impact and use less energy while demonstrating marked cost-savings and maintaining competitiveness.

The project is made possible through a public-private-nonprofit partnership. Green Building Alliance convenes a wide range of partners to make the project possible by provided funding, knowledge, and technical resources. Partners are divided into three primary categories: Property, Community, and Resource, with Property Partners receiving a number of benefits to help them meet the 2030 Challenge goals in the form of facilitated meetings with peers, access to innovative technology and funding mechanisms, promotion and outreach to the public, and data analysis.

5) Encourage energy efficiency and conservation in both new and existing buildings through the identification of a geographic district

Applicability

Minneapolis is already actively pursuing energy efficient buildings through a number of policies; they notably have a LEED (Leadership for Energy and Environment Design) Building Policy in place that mandates new municipal buildings or large renovations abide by LEED Silver standards at a minimum, and have recently enacted the previously mentioned energy benchmarking and reporting policy. A 2030 District or similar green building policy applied across a delineated geographic area could serve as a high-performing model of energy efficiency and conservation, spurring property owners, especially of existing buildings, to take on these efforts. At the same time, approaching projects such as this on a concentrated, localized level can bring efficiencies that enacting energy efficiency efforts in individual buildings throughout the City cannot. The 2030 Challenge is voluntary, which of course may detract from the number of adopters, but the fact that Minneapolis already has some foundational policies in place may spur additional participation. Property owners may be more inclined to voluntarily participate since they may already have some efficiency measures in place.

6) Mandate 100% renewable energy use

Background

Like energy efficiency, renewable energy efforts are more often associated with climate change mitigation, seeking to decrease greenhouse gas emissions through a more diverse, less coal-intensive energy mix. However, expanding renewable energy use, especially when that energy is produced by local sources, also has an important role to play in climate adaptation. It contributes to energy security, limits risk of supply interruptions due to extreme weather, and encourages more stable pricing, protecting consumers against potential price and supply fluctuations that might occur due to climate change impacts. Reducing reliance on coal-fired power plants has the added benefit of improving air quality and public health as emissions are reduced. Using renewable sources like solar and wind also reduces the high demand for water that non-renewable sources have, contributing to a more reliable water supply in case of drought or strain on the system due to increased demand elsewhere.

Case Study: Grand Rapids, MI

Grand Rapids has set a goal of using 100% renewable energy, from Michigan sources, by 2020. As of 2010, their renewable energy use was at 20%. The city is working closely with its utility, Consumers Energy, to expand its renewable energy portfolio through the utility's "Green Generation" program. The surcharge to purchase renewable energy through this program was lowered through approval from the Michigan Public Services Commission, making enrollment cost-neutral for the city. To ensure that the city is making progress toward its goal, Grand Rapids has formed a Renewable Energy Team that consists of the Mayor, City Commissioners, and key staff and stakeholders. The Team meets regularly to share updates, report on progress, and plan for ongoing work.

Grand Rapids has taken small-scale steps toward local renewables such as solar panels on the roofs of some city buildings and geothermal heat at fire stations, but the city also realizes that to reach their 100% goal they will likely need to create their own utility and pursue large-scale production such as through a large solar array or wind farm. Plans for these efforts are in the works but have not yet been implemented.

Applicability

Increasing renewable energy projects and use of renewable energy in Minneapolis is already an important focus of the City's sustainability plans. Targets for increasing renewable energy – in the form of renewable electricity used in City operations and permitting renewable energy projects – are included in the City's sustainability indicators and are also called out in the more recent Climate Action Plan. Not only is the City dedicated to increasing solar, wind, biomass, and other renewable options, but the State of Minnesota has a strong renewable energy standard that may be amended in the near future with even more aggressive goals.

7) Encourage residential water conservation

Background

As part of the "energy-water nexus," water conservation efforts can address both climate change impacts on Minneapolis's water supply as well as concerns about reduced energy supply. Proactively reducing water contributes to the decreased likelihood of a water shortage, whether due to drought, low Mississippi River or groundwater levels, or increased water demand for cooling during the City's future hotter summers. Reducing the demand for water also reduces demand for energy. In particular, reducing water usage during the summer when consumption is typically higher can reduce the strain on the electrical grid when energy for cooling is also in high demand.

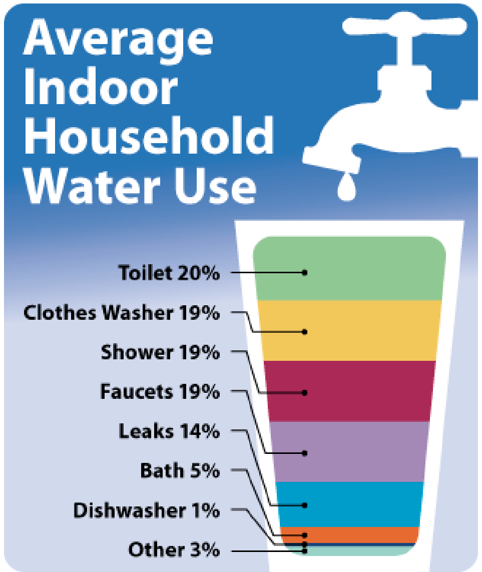
Case Study: El Paso, TX

El Paso launched its "less is the new more" water conservation campaign in 2012. With its dry climate El Paso has been a national leader in water conservation efforts, but the recent campaign made their efforts even more effective, significantly reducing 2012 water use from 2011 levels. The campaign encourages residents to reduce their water usage both inside and outside of their homes through such strategies as planting native vegetation, limiting water when it's windy, and fixing leaky faucets. The campaign's website offers tips, links to resources, showerhead coupons, and lists of appropriate vegetation, while a social media strategy and public workshops provide a forum for broader outreach. El Paso enforces a year-round odd/even watering schedule and has publicized it widely as part of the campaign.

Applicability

Minneapolis has rarely faced water shortages, and in general, water conservation efforts have not been prioritized in the state of 10,000 lakes. However, as concerns increase statewide about more frequent, prolonged droughts, dwindling groundwater supplies, and potentially falling river levels, conservation is becoming more of a focus. Minneapolis does have plans to develop a backup water supply using groundwater wells, so a shortage of supply from the Mississippi River - though relatively unlikely - may not be as dire as it once would have been. However, water conservation could still be an effective way to address potential shortages, as well as reduce the energy usage associated with pumping and distributing water.

Over forty percent of the water produced in the City of Minneapolis goes toward residential uses. Although Minneapolis's residential users do already use less than the national average, the El Paso example suggests that a concerted conservation campaign might be able to drive usage down even further.



Public information campaigns such as this can encourage residents to conserve water.

8) Diversify water supply and plan for potential supply disruptions

Background

Diversifying water sources reduces the likelihood that water supply will be unable to meet demand. Increasing the resilience of the water supply might include employing a mix of both surface and groundwater sources, finding uses for recycled water and/or stormwater capture, or instituting a water-trading system with other providers in the event of a shortage or production disruption.

Climate change may deliver a "double whammy" impact to the ability to deliver water reliably to consumers in many places, potentially affecting both supply and demand. Not only may drought and changing precipitation patterns create disruptions in supply, but hotter summers will likely lead to increased water demand. Continuing to monitor climate outlooks, forecast supply and demand, and communicate with other local water providers are important steps in addressing these potential negative impacts.

Case Study: Portland, OR

Precipitation patterns in Portland and the surrounding area are anticipated to change significantly in the coming years, with more rain than snow in the nearby mountains (which contribute to the City's water supply), leading to increased flow in the winter and corresponding reduced flow in late summer. Spring runoff timing will also likely be influenced by warmer winters and earlier melt dates. Portland relies primarily on this surface water flow to supply water to its residents and businesses, and has been taking action to plan ahead for these potential disruptions and deviations from the typical water supply.

The City's water utility already has a backup water supply in place, drawing on a groundwater source near the Columbia River. The Water Bureau has conducted sophisticated modeling based on future climate scenarios, population growth estimates, and system management tools, and determined that weather conditions may constrain future water supply, with population growth and increased summer demand exacerbating this vulnerability. Drawing as much water as possible from their backup supply could fill the need due to increased population, but will not be sufficient when new weather patterns emerge.

The Bureau is taking a comprehensive approach to address these issues, investigating expanding its groundwater backup and existing water storage systems. These actions are considered a "no regrets" strategy, as they will improve the resiliency of the water system both under current circumstances and in the face of future climate change. They are also looking into "conjunctive use strategies" that allow for optimal, mixed use of both surface and groundwater sources at once. The Bureau is also maintaining flexibility in their plans, recognizing the uncertainties of climate change – staying open, for example, to the increased need for water filtration should more extreme weather events impact the water quality of their surface water source.

8) Diversify water supply and plan for potential supply disruptions

Applicability

Minneapolis, like Portland, draws on surface water to supply its own residents, as well as several neighboring suburbs, the Minneapolis-Saint Paul Airport, and Fort Snelling State Park. Although the Mississippi River is quite likely not as susceptible to decreased water levels due to drought as Portland's watershed, the City might similarly consider "no regrets" strategies to bolster its system's resilience regardless of the severity of impacts brought about by climate change.

Although discussed at various times in the past, a link between Minneapolis and Saint Paul allowing for potential water-sharing in times of need is no longer considered a viable option at this time. Minneapolis does, however, have plans to implement a backup water supply using groundwater wells.

The Mississippi River is Minneapolis's sole source of water.

GOAL 5:
PLAN FOR THE FUTURE

Best Practices

1) Draw on perspectives from all city departments

2) Continue to seek input from city staff and other stakeholders to determine adaptive capacity

3) Work with local climate experts on creating downscaled climate models

4) Promote awareness with public outreach and city "inreach" efforts

5) Establish metrics to assist in adaptation planning and performance evaluation

1) Draw on perspectives from all city departments

Background

A steering committee, planning team, or other formally organized group made up of representatives from all relevant city departments is an important contribution to a city's climate change adaptation planning process. Climate change and associated changes in weather patterns are complex, uncertain, and will have implications that cut across divisions of work that are traditionally siloed. Therefore, discussing climate science and anticipated impacts; sharing knowledge, observations, and best practices; and coordinating actions steps can be much more effective when done with an interdepartmental staff team.

Case Study: Cambridge, MA

The City of Cambridge has recently undertaken a climate change vulnerability assessment, the first step in its climate change adaptation planning process. The year-long assessment process will allow the City to gain a more complete understanding of how climate change will impact the health and daily lives of their residents, physical and natural infrastructure, and economy. The effort is being coordinated by an inter-departmental steering committee made up of representatives from Public Works, Public Health, and Community Development Departments, with support from an external consultant.

While maintaining an internal steering committee has several advantages, including the ability to have more open discussions and a shared understanding of the inner workings of a city, it is also valuable to engage external stakeholders in climate change adaptation planning in order to build public support and supplement a city's perspective with a broader base of knowledge and experience. With this in mind, Cambridge's internal steering committee is supported by a Technical Advisory Committee (TAC) and an Expert Advisory Panel (EAP), both of which include a range of stakeholders representing community groups, academia, utilities, businesses, and others.

Applicability

The City of Minneapolis has already shown their interest in utilizing input and drawing on perspectives from across departments through both the development of the Climate Action Plan, and the preliminary interviews conducted for this project with the Departments of Public Health, Public Works, and City Planning and Economic Development and the Minneapolis Park and Recreation Board. Several interviewees commented on their perceived lack of cross-departmental collaboration around climate change issues, and the fact that adaptation planning might be made easier with a better understanding of the data, which could be informed by information-sharing with other departments.

2) Continue to seek input from city staff and other stakeholders to determine adaptive capacity

Background

Understanding the adaptive capacity of a city, its departments, and systems is an important step in identifying which climate change impacts should be prioritized in adaptation efforts. Adaptive capacity refers to a system's ability to withstand expected climate change impacts with minimal resource investment and minimal disruption in service or operations. Determinants of a specific area's adaptive capacity can be both quantitative and qualitative, and include economic resources, technology, information and skills, social capital, institutions, and equity. As above, consulting with staff from across departments and issue areas will provide a more complete representation of the adaptive capacity of systems throughout the city and allow for a more nuanced understanding of where specific climate change impacts will, or will not be, of significant concern.

A survey of city staff can be an effective method of gathering this type of information. Surveys can generate information related to the current preparededness of systems to address climate change, potential barriers to preparing for climate change, and whether adaptation efforts are already underway. As described above, gathering information from an inter-departmental group of staff allows for a breadth of perspectives and gives those who are "on the ground" a chance to share input and experiences, providing information that those charged with coordinating climate adaptation efforts may not be aware of.

Case Study: King County, WA

Staff working on King County's climate adaptation planning efforts created and distributed to agencies within the county a questionnaire on climate change impacts and adaptation barriers. Respondents included experts representing a range of issue areas managed by the county, including regional water supply, road and bridge infrastructure, salmon recovery and biodiversity, stormwater and wastewater management, agriculture, forestry, public health, coastal management, and flood hazard management. The questionnaire was designed to both explore the adaptive capacity of each area of work, and to identify the sensitivity of each area of work to climate variability. Results indicated that many adaptation efforts were already underway, and the county used this information to inform the adaptation goals identified following the survey.

The questionnaire included seventeen questions, divided in three primary categories. Questions such as "How are your natural or built resources sensitive to present day climate variability?" sought to assess sensitivity. Questions about adaptive capacity asked about existing plans or policies that guard against climate change impacts, and what more could be done. In addition to sensitivity and adaptive capacity, the questionnaire asked about cross-agency and cross-sector interactions related to climate change impacts.

2) Continue to seek input from city staff and other stakeholders to determine adaptive capacity

Applicability

The interviews conducted as a part of this project offer a preliminary glimpse at the adaptive capacity and sensitivity to climate change of a number of City departments, and a survey such as King County's would provide a larger sample set with which to evaluate Minneapolis's ability to adapt to climate change. As demonstrated above, interviewees did point out a number of adaptation efforts currently taking place, although they weren't necessarily labeled as such. With respect to this phenomenon, a questionnaire might prompt staff to consider these efforts in a climate change framework, and potentially draw out even more information about climate adaptation strategies that are already in place.

A questionnaire such as this could also point to different levels of adaptive capacity in different geographic regions, and Minneapolis might consider evaluating both City departments as a whole as well as particular neighborhoods. This will provide a better foundation from which to address environmental justice concerns, encouraging from the outset of adaptation planning efforts an awareness of different levels of vulnerability among different areas and populations in Minneapolis.

3) Work with local climate experts on creating downscaled climate models

Background

Downscaled climate models are invaluable for the creation of effective, locally-specific climate change adaptation plans. Downscaled models typically translate global climate predictions into estimations of regional climate impacts – at a specificity of 25 square kilometers (about 9.7 square miles) or greater – and allow local experts to conduct more detailed analyses of climate change impacts on local communities. Accurate downscaling is particularly relevant when addressing climate change in urban areas, since climate models that cover a larger geographic area often do not take the urban heat island effect into account.

There are many methods and approaches to climate modeling and downscaling. Different models account for different factors or focus on different impact areas (some on weather patterns generally, others on specific topics such as public health); some downscaled models create weather simulations using data from global models applied to regional models, while others draw more on empirical data, using equations to convert global models to a more regional scale. All of these approaches are valid and encouraging collaboration and information-sharing among relevant parties can help paint a more complete picture of climate change on a localized scale.

Case Study: Toronto, Canada

The Toronto Urban Climate Change Network (TUCCN) was formed by the Toronto Environment Office in 2008 in response to a mandate from the Toronto City Council to support partnership and shared research among government, academia, and nonprofits around climate change mitigation and adaptation. The Network sought to identify the various climate change-related research efforts taking place in the area; facilitate communication, data-sharing, and the development of consensus among those researchers; and engage in fundraising and advocacy for climate change research and action.

The group selected ten public, academic, and nonprofit members that were engaged in research on climate change impacts or engaging in mitigation and adaptation efforts. One of TUCCN's primary purposes was to provide valuable climate change knowledge to decision-makers and, in doing sp, operated on a consensus basis; public statements would be released only after a the group had reached majority consensus on the issue. One example of TUCCN's activities was the 2009 "Forum on Infrastructure and Climate Change Adaptation," an event that brought together city staff and researchers to discuss integrating considerations of climate change in city infrastructure projects.

Applicability

As City staff aim to understand with more specificity likely climate change impacts, they have numerous local resources to draw on, including leading climate scientists at the University of Minnesota and a number of state agencies that have undertaken climate change research. Efforts to utilize the best available science and foster consensus among researchers, as was done in Toronto, would not only support more effective adaptation planning, but also provide more incentive to stakeholders and policymakers to take proactive measures. Multiple interviewees expressed uncertainty about climate science and future climate scenarios as one of the primary difficulties of planning ahead for climate change. Especially in a tight economic climate in which budgets and staff capacity are limited, interviewees reported that they would be more inclined to take significant action to plan for climate change, or significantly alter their current processes and strategies, if they had more assurance that they were operating with accurate, specific data.

4) Promote awareness with public outreach and city "inreach" efforts

Background

Adaptation is not, and should not be, a behind-the-scenes effort to build resiliency in a city; rather, it is a citywide adjustment to a "new normal." Cities pursuing climate change adaptation should promote their efforts to as broad an audience as possible. Successful adaptation requires fully preparing residents for changes to our climate, and effective community outreach is critical. Outreach strategies to engage residents could include neighborhood meetings, social media, public seminars and webinars, and person-to-person outreach (including encouraging staff to discuss adaptation with their friends and neighbors).

Similarly, "inreach" efforts such as staff workshops, webinars, and other communication tools can be used to increase internal awareness of climate science, climate change impacts, and relevant adaptation strategies. Training and other skill development programs can be used to increase staff capacity to meet existing and emerging challenges. A dedicated wiki or a similar participatory, dynamic website could be used to share information and discuss adaptation among staff and different departments.

Case Study: The Netherlands

Gamification is increasingly being used as a tool by policymakers and advocates to engage and educate a broader audience about sustainability and climate change issues, especially as the internet and mobile apps become more universally accessible. So-called "serious games" use advanced technology to take into account many variables and their interactions to simulate possible future scenarios, and are therefore well-suited to helping a broad audience understand climate change. Waas City is an interactive game developed in the Netherlands in which teams take on water management near the made-up Waas River for one hundred years. Players must decide how to handle the dire situation of a frequently flooded area that also suffers from low water levels. The game includes both physical and climatic models projecting flood patterns and future climate scenarios, as well as less tangible social systems, such as how the public might react to certain decisions or respond to disasters, and encourages players to understand the consequences of their actions and the complex ways in which they interact.

Applicability

The use of games and technology to engage and educate the public could be an effective tool for the City of Minneapolis, especially as they begin the initial stages of climate adaptation planning. Being transparent about the uncertainties and risks involved in planning for climate change and providing an opportunity for the public and other stakeholders to understand the complexities involved would likely make for a more robust, more widely-accepted adaptation plan. The City could also use a serious game as a way to begin conversation with stakeholders about what climate change risks and adaptation actions are most important, as the game encourages the understanding that sacrifices sometimes do need to be made in adaptation. This would work toward helping the City prioritize adaptation strategies.

5) Establish metrics to assist in adaptation planning and performance evaluation

Background

Adaptation metrics can be used both during the planning process and to evaluate progress as adaptation efforts continue. Upon initiating climate change adaptation planning, well defined metrics can help to prioritize strategies and encourage the implementation of the most efficient or effective strategies first. These decision criteria can be both quantitative and qualitative and might include such factors as level of risk, cost of mplementation, impact on vulnerable populations, and feasibility.

Climate change impacts are, of course, expected to take place over a long period of time and adaptation efforts may not yield "results" until far into the future, but metrics can still be used to evaluate both the implementation process (e.g. whether costs adhered to budget) and any more immediate outcomes associated with an adaptation strategy.

Case Study: Berkeley, CA

Berkeley has identified three key performance metrics to evaluate their adaptation strategies: annual net tree gain, annual water consumption, and graywater/rainwater harvesting. Of the three, only net tree gain has a specific target associated with it (to plant at least 500 street and park trees annually). All three are tracked on the Office of Energy and Sustainable Development's website, each with a description of the steps the city has taken in that specific area and, in the case of tree gain, an indicator of whether or not they are on target to meet the annual goal. These indicators of course are not directly tracking the city's progress toward meeting its long-term goal of becoming resilient to climate change impacts, since a state of "resiliency" is nearly impossible to measure. They do, however, track intermediate progress toward activities that are anticipated to increase resiliency over the long term.

Applicability

Minneapolis has already developed targets for GHG emissions to address climate change mitigation, as well as a number of other sustainability indicators. Like Berkeley, staff track progress toward these goals in their Sustainability Office, promoting transparency and also providing information about how the public can get involved in meeting these goals. In a way, the ambiguity of resiliency and the difficulty in identifying metrics points to their value: without concrete goals to work toward, adaptation efforts could be diminished or not prioritized. This sentiment was echoed indirectly through our interviews, as staff commented that more specific data – and presumably, more specific goals – would facilitate their taking action to plan for climate change.

Appendix A - Best Practices Resources

1. Manage heat

1.) Improve methods of tracking heat-related illness and death to ensure ability to accommodate increased patients and appropriately target extreme heat responses
1. Homeland Security: Syndromic Surveillance
http://library.ahima.org/xpedio/groups/public/documents/ahima/bok1_023187.hcsp?dDocName=bok1_023187
2. Michigan Emergency Department Syndromic Surveillance
http://www.michigan.gov/mdch/0,4612,7-132-2945_5104_31274-107091--,00.html
3. Clean Air Partnership: Syndromic Surveillance
http://www.cleanairpartnership.org/files/4%20Case%20Study.pdf

2.) Expand access to pools, misting stations, and other cooling opportunities for those particularly at risk of suffering from heat-related illness
1. Detroit: Access to Cooling Centers
http://www.imagin.org/awards/sppc/2013/2013_sppc_paper_kisner_mulder_vangessel.pdf
2. Wicomico County: Extreme Heat Preparedness and Response
http://www.wicomicohealth.org/files/0/0/Extreme%20Heat%20Preparedness%20and%20Response%20Plan%20SIGNED%202012.Website%20Version.pdf
3. Toronto: Preparing for Climate Change
http://www.toronto.ca/teo/pdf/ahead_of_the_storm.pdf

3.) Implement cool pavements to reduce urban heat island effect
1.Georgetown Climate Center: Adapting to Urban Heat
http://kresge.org/sites/default/files/climate-adaptation-urban-heat.pdf
2. EPA: Heat Island Mitigation
http://www.epa.gov/heatisland/mitigation/pavements.htm
3. EPA: Cool Pavements
http://www.epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf#page=8
4. Science Daily: Cool Pavements
http://www.sciencedaily.com/releases/2012/11/121108141022.htm
5. Berkeley Lab: Cool Pavements Bill Signed Into Law
http://eetd.lbl.gov/news/article/24746/cool-pavements-bill-signed-into-law

4.) Increase green roofs to reduce urban heat island effect
1. Georgetown Climate Center: Adapting to Urban Heat
http://kresge.org/sites/default/files/climate-adaptation-urban-heat.pdf
2. London Green Roofs
http://www.cityoflondon.gov.uk/services/environment-and-planning/planning/heritage-and-design / Documents/Green-roof-case-studies-28Nov11.pdf
3. EPA: Green Roofs
http://www.epa.gov/heatisland/mitigation/greenroofs.htm
4. Toronto Green Roofs
http://www.toronto.ca/greenroofs/
5. EPA: Reducing Urban Heat Islands
http://www.epa.gov/heatisland/resources/pdf/GreenRoofsCompendium.pdf

2. Preserve the natural environment

1) Adapt recreation opportunities to the changing climate
1. Vermont - Impacts of Climate Change on Recreation http://www.anr.state.vt.us/anr/climatechange/Pubs/VTCCAdaptRecreation.pdf

2) Increase urban tree canopy
1.Chicago Tree Initiative - Overview
http://www.chicagotrees.net/chicago-trees-initiative/
2.Chicago Tree Initiative - List of suitable trees for urban planting
http://www.chicagoclimateaction.org/filebin/pdf/ChicagoUrbanTreePlantingList2010.pdf
3. Minneapolis - Current Tree Canopy, Interactive Map
http://cityoflakes.maps.arcgis.com/apps/OnePane/basicviewer/index.html?&extent={%22xmin%22:-10398363.226572616,%22ymin%22:5589279.015221217,%22xmax%22:-10339736.025877965,%22ymax%22:5643396.431247049,%22spatialReference%22:{%22wkid%22:102100}}&&extent={%22xmin%22:-10397961.93217412,%22ymin%22:5601623.595289256,%22xmax%22:-10359858.07357401,%22ymax%22:5631051.851179009,%22spatialReference%22:{%22wkid%22:102100}}&appid=c41894bb3e03432bbceea3ef5a19760e

3) Conduct Vulnerability Study of Natural Ecosystems
1. Santa Cruz - Climate Change Vulnerability Assessment
http://www.cityofsantacruz.com/Modules/ShowDocument.aspx?documentid=21198

4) Engage residents in environmental stewardship of their property
1. Chicago - Sustainable http://www.sustainablebackyards.org/

5) Manage Invasive and Native Species
1. Portland - Invasive Species Management Program
http://www.portlandoregon.gov/bes/45696

3. Manage stormwater

1.) Control runoff with rain gardens and bioretention
1. MPCA Stormwater Manual, Bioretention
http://stormwater.pca.state.mn.us/index.php/Bioretention
2. City of Maplewood Rainwater Gardens Program
http://www.ci.maplewood.mn.us/index.aspx?NID=456
3. Seattle's Street Edge Alternatives Program
http://www.seattle.gov/util/MyServices/DrainageSewer/Projects/GreenStormwaterInfrastructure/CompletedGSIProjects/StreetEdgeAlternatives/index.htm
4. Seattle's Stormwater Policies http://www.seattle.gov/util/EnvironmentConservation/Projects/DrainageSystem/GreenStormwaterInfrastructure/StormwaterCode/CityPoliciesRequiringRelatedtousingGSI/index.htm
5. University of Minnesota, Center for Urban & Regional Affairs - Remediating Compacted Urban Soils
http://www.cura.umn.edu/sites/cura.advantagelabs.com/files/publications/Reporter-41-3&4-Gullliver.pdf

2.) Harvest rainwater to control runoff and derease water demand
1. EPA Rainwater Harvesting Policy Guide http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_munichandbook_harvesting.pdf
2. San Diego Rain Barrel/Downspout Disconnect Best Management Practice and Effectiveness Monitoring and Operations Program
http://www.sandiego.gov/thinkblue/pdf/rainbarrelfinalreport.pdf
3. San Diego Rainwater Harvesting Information
http://www.sandiego.gov/water/conservation/rainwater.shtml

3.) Expand surface detention capacity to reduce runoff volumes
1. Rotterdam - Water Plaza Overview
http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein
2. Rotterdam - Water Plaza Background
http://www.rotterdamclimateinitiative.nl/en/english_2011_design/news/design_of_benthemplein_water_square_revealed?news_id=856

3. New York City - Bluebelt Program
http://www.nyc.gov/html/dep/html/stormwater/bluebelt.shtml
4. EPA Stormwater BMPs - Dry Detention Pond
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

4.) Reduce impervious surface coverage with permeable pavements
1. Chicago - Green Alleys Program Overview
http://www.stormh2o.com/SW/Articles/2191.aspx
2. Chicago - Green Alleys Handbook/Design Guide \
http://www.chicagoclimateaction.org/filebin/pdf/greenalleyhandbook.pdf
3. Duluth - Permeable Pavement Background
http://www.lakesuperiorstreams.org/stormwater/toolkit/paving.html
4. Portland - Permeable Pavement Projects
http://www.portlandoregon.gov/bes/article/77074
5. Seattle - Natural Drainage System Project
http://www.seattle.gov/util/MyServices/DrainageSewer/Projects/GreenStormwaterInfrastructure/CompletedGSIProjects/HighPointNaturalDrainageSystem/index.htm
6. Minnesota Department of Transportation - Pavement Research Projects
http://www.dot.state.mn.us/mnroad/projects/
7. University of New Hampshire Stormwater Center - Permeable Pavement Research
http://www.unh.edu/unhsc/pubs-specs-info
8. EPA Stormwater BMPs - Pervious Concrete Pavement; Porous Asphalt Pavement; Permeable Interlocking Concrete Pavement
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/

5.) Maintain and expand traditional infrastructure to control runoff from heaviest storms
1. Minnehaha Creek Watershed District - Weater, Extreme Trends Study
http://www.minnehahacreek.org/project/weather-extreme-trends
2. Philadelphia - Traditional Infrastructure Program
http://phillywatersheds.org/what_were_doing/traditional_infrastructure
3. Philadelphia - Green City, Clean Water Comprehensive Monitoring Program
http://phillywatersheds.org/ltcpu/GCCW%20Comprehensive%20Monitoring%20Plan%20Sections%201-10.pdf

4. Ensure a reliable water and energy supply

1) Understand the energy use patterns and needs of homeowners in order to implement comprehensive smart grid technology on a localized scale.
1. Pecan Street Project Program
http://www.pecanstreet.org/projects/smart-grid-demonstration/
2. Pecan Street Project Overview
http://www.greenbiz.com/blog/2012/07/11/pecan-street-test-smart-grid
3. Xcel Smart Grid Program in Boulder, CO - Overview and Problems
http://finance-commerce.com/2013/04/the-lessons-of-smart-grid-test-in-boulder/

2) Incentivize microgrid projects
1. Microgrid Background and Overview http://science.howstuffworks.com/environmental/energy/microgrid1.htm
2. Stamford, CT - Microgrid Program Overview http://www.forbes.com/sites/williampentland/2010/11/09/microgrids/
3. Benefits of Microgrids http://theenergycollective.com/katherinetweed/210736/where-s-my-microgrid

3) Incentivize cool roofs on new/existing buildings
1. New York City - Cool Roofs Program
http://www.nyc.gov/html/coolroofs/html/about/faq.shtml
2. EPA - Cool Roof Overview
http://www.epa.gov/heatisland/mitigation/coolroofs.htm
3. Chicago - Green Roof Improvement Fund Overview
http://www.energycodes.gov/resource-center/policy/green-roof-improvement-fund-chicago-il-2006
4. Cool Roof Toolkit
http://www.coolrooftoolkit.org/wp-content/pdfs/CoolRoofToolkit_Full.pdf
5. Overview of "Eco" Roofs (Green, Blue, Cool)
http://ccap.org/assets/THE-VALUE-OF-GREEN-INFRASTRUCTURE-FOR-URBAN-CLIMATE-ADAPTATION_CCAP-February-2011.pdf

4) Pursue an "urban cap-and-trade" policy to encourage energy conservation and energy efficiency retrofits in buildings
1. Energy Efficiency as a Climate Adaptation Tool http://www.ase.org/resources/energy-efficiency-tool-climate-change-adaptation-alliance-white-paper
2. Tokyo - Cap-and-Trade Program, 1st Year Results
http://newswatch.nationalgeographic.com/2012/07/18/spotlight-on-tokyo-worlds-first-urban-cap-and-trade-program-yields-promising-first-year-results/
3. Tokyo - Cap-and-Trade Program, 2nd Year Results http://www.environmentalleader.com/2013/01/24/tokyo-cap-and-trade-cuts-co2-23-in-second-year/

5) Encourage energy efficiency and conservation in both new and existing buildings through the identification of a geographic district
1. Pittsburgh - Green Building Alliance District 2030 Overview
http://www.good.is/posts/power-shift-downtown-pittsburgh-to-halve-energy-consumption-by-2030
2. Pittsburgh - 2030 District Program
http://www.2030district.org/pittsburgh/about
3. Pittsburgh - 2030 District Program Resources & Tools
http://2030district.org/pittsburgh/district-partner-resources

6) Mandate 100% renewable energy use
1. Renewable Energy as Adaptation Strategy
http://blogs.worldwatch.org/revolt/for-vulnerable-regions-renewable-energy-is-key-to-climate-adaptation/
2. Grand Rapids Commitment to 100% Renewable Energy by 2020
http://www.mlive.com/news/grand-rapids/index.ssf/2012/04/mayor_heartwell_grand_rapids_m.html
3. City of Grand Rapids Renewable Energy Program Overview
http://grcity.us/enterprise-services/officeofenergyandsustainability/Pages/About-Us.aspx
4. EPA - Grand Rapids Renewable Energy Program
www.epa.gov/greenpower/documents/events/15oct09_alibasic.pdf

7) Encourage residential water conservation
1. ICLEI - El Paso Water Conservation Program Overview
http://www.icleiusa.org/action-center/learn-from-others/local-governments-extreme-weather-and-climate-change-2012
2. El Paso - Water Conservation Program
http://www.epwu.org/conservation/

8) Diversify water supply and plan for potential supply disruptions
1. EPA - Adaptation Strategies Guide for Water Utilities
http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k13001.pdf
2. Climate Change and Water Resources: A Primer for Municipal Water Providers
http://waterinstitute.ufl.edu/WorkingGroups/downloads/WRF%20Climate%20Change%20DocumentsSHARE/Project%202973%20-%20Climate%20Change%20and%20Water%20Resources.pdf

5. Plan for the future

1) Draw on perspectives from all city departments
1. ICLEI Canada - Changing Climates, Changing Communities
http://www.icleicanada.org/resources/item/3-changing-climate-changing-communities
2.Cambridge, MA - Climate Change Vulnerability Assessment
http://www.cambridgema.gov/CDD/Projects/Climate/climatechangeresilianceandadaptation.aspx

2) Continue to seek input from city staff and other stakeholders to determine adaptive capacity
1. Climate Impacts Group - Preparing for Climate Change: A Guide for Local, Regional, and State Governments
http://cses.washington.edu/db/pdf/snoveretalgb574ch8.pdf
2. http://onlinelibrary.wiley.com/doi/10.1111/nyas.2010.1196.issue-1/issuetoc
http://onlinelibrary.wiley.com/doi/10.1111/nyas.2010.1196.issue-1/issuetoc

3) Work with local climate experts on creating "downscaled" climate models
1. Downscaling Climate Models: Sharpening the Focus on Local-Level Changes - Catherine M. Cooney, Environmental Health Perspectives
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3261962/
2. Toronto Urban Climate Change Network
www.tuccn.org
3. Climate Change Adaptation Planning in Toronto: Progress and Challenges - Jennifer Penney, et al.
http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1342044185050/8756911-1342044630817/V2Chap20.pdf

4) Public outreach and city "inreach" to promote awareness
1. City of Toronto - Public Engagement on Climate Change
http://www.toronto.ca/changeisintheair/involved.htm
2. Minnesota Climate Adaptation Working Group
http://mnclimateadaptation.ning.com/
3. Climate Management: Its a Serious Game - Bram Vermeer, Change Magazine

5) Establish metrics to assist in adaptation planning and evaluating performance
1. City of Berkeley - Energy & Sustainable Development
http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=70986
2. Center for Climate Strategies Adaptation Guidebook Comprehensive Climate Action
www.climatestrategies.us/library/library/download/908

Appendix B - Interview Questions

1) What impacts of climate change do you already see affecting your particular area of concentration?

2) What sort of geographic and socio-economic impacts do you see climate change having on Minneapolis?

3) Who will be impacted? How will this impact different parts of the city?

4) Does your area of expertise have long-term plans to adapt to climate change?

5) Are there any impacts that you may know of we haven't touched upon?

6) What additional research or data would be useful to help you do your job better?

7) Do you know of any adaptation techniques occur in other cities that could be applied to Minneapolis?

8) Are there any unique climate change adaptation circumstances pertinent to Minneapolis vs. other cities?

9) What do you feel the city is doing well to adapt? What could be improved?

References - Climate Impacts

1. Midwestern Regional Climate Center. “Climate Change and Variability.” Last modified 2013. http://mrcc.isws.illinois.edu/climate_midwest/mwclimate_change.htm.

2. Pryor, Sara C. and Donald Scavia. “Third National Climate Assessment.” National Oceanic and Atmospheric Administration. Last modified 2013. http://ncadac.globalchange.gov/

3. World Meteorological Organization. “WMO Provisional Statement on the State of global Climate in 2012.” Embargo 1130 GMT (1430 Doha). 28 November 2012. http://www.wmo.int/pages/mediacentre/press_releases/documents/966_WMOstatement.pdf

4. Pryor, Sara C. and Donald Scavia. “Third National Climate Assessment.” National Oceanic and Atmospheric Administration. Last modified 2013. http://ncadac.globalchange.gov/

5. Wilby, RL. “A Review of Climate Change Impacts on the Built Environment.” Built Environment, 33 (2007): 31-35.

6. Minnehaha Creek Wastershed. “Weather – Extreme Trends.” Last modified 2013. http://www.minnehahacreek.org/projects/studies/weather-extreme-trends

7. Wilby, RL. “A review of climate change impacts on the built environment.” Built Environment, 33 (2007): 31-35.

8. Galatowitsch, Susan, Lee Frelich, and Laura Phillips-Mao. “Regional Climate Change Adaptation Strategies for Biodiversity Conservation in a Midcontinental Region of North America.” Biological Conservation, 142. (2009): 2012-2022.

9. Seeley, Mark. “Climate Change in Minnesota.” Presented 20 February 2013. http://www.minnpost.com/sites/default/files/attachments/mark-seeley-presentation.pdf.

10. Minnesota Climatology Working Group. “Ice Out Summary, 2012.” Last modified 11 December 2012. http://climate.umn.edu/doc/journal/ice_out_recap_2012.htm.

11. Seeley, Mark. “Climate Change in Minnesota.” Presented 20 February 2013. http://www.minnpost.com/sites/default/files/attachments/mark-seeley-presentation.pdf.

12. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

13. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

14. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

15. Minnesota Department of Health. “Introduction to Extreme Heat Events.” 2012. http://www.health.state.mn.us/divs/climatechange/docs/toolkit_chapter1.pdf.

16.Wisconsin Initiative on Climate Change Impacts. “Water Resources.” 2011. http://www.wicci.wisc.edu/publications.php

17. Seeley, Mark. “Climate Trends Associated with Precipitation in Minnesota.” Prepared for Minnehaha Creek Watershed. 2012. http://www.minnehahacreek.org/sites/minnehahacreek.org/files/events/minnehaha_creek_2012.pdf

18. Galatowitsch, Susan, Lee Frelich, and Laura Phillips-Mao. “Regional Climate Change Adaptation Strategies for Biodiversity Conservation in a Midcontinental Region of North America.” Biological Conservation, 142. (2009): 2012-2022.

19. Galatowitsch, Susan, Lee Frelich, and Laura Phillips-Mao. “Regional Climate Change Adaptation Strategies for Biodiversity Conservation in a Midcontinental Region of North America.” Biological Conservation, 142. (2009): 2012-2022.

20. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

21. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

22. Groisman, Pavel Ya., R.W. Knight, T.R. Karl, D.R. Easterling, B. Sun, and J.H. Lawrimore. “Contemporary Changes of the Hydrological Cycle Over the Contiguous United States, Trends Derived From in Situ Observations.” Journal of Hydrometeorology, 5. (2004): 64-85.

23. Wisconsin Initiative on Climate Change Impacts. “Stormwater.” 2011. http://www.wicci.wisc.edu/publications.php

24. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

25. U.S. Environmental Protection Agency. “Heat Island Impacts.” Last modified 2013. http://www.epa.gov/hiri/impacts/index.htm.

26. Centers for Disease Control. “Extreme Heat: A Prevention Guide to Promote Your Personal Health and Safety.” Last modified 31 July 2009. http://www.bt.cdc.gov/disasters/extremeheat/heat_guide.asp.

27. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

28. U.S. Environmental Protection Agency. “Basic Information: Ground Level Ozone.” Last modified 1 November 2012. http://www.epa.gov/glo/basic.html

29. U.S. Environmental Protection Agency. “Basic Information: Ground Level Ozone.” Last modified 1 November 2012. http://www.epa.gov/glo/basic.html

30. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

31. Minnesota Pollution Control Agency. “Fine Particle Pollution. ”Last Modified March 12, 2013. http://www.pca.state.mn.us/index.php/air/air-quality-and-pollutants/air-pollutants/fine-particle-pollution/index.html

32. Union of Concerned Scientists. “Confronting Climate Change in the U.S. Midwest: Minnesota.” July 2009. http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

33. U.S. Environmental Protection Agency. “Midwest Impacts and Adaptation.” Last modified 2012. http://www.epa.gov/climatechange/impacts-adaptation/midwest.html

34. U. S. Environmental Protection Agency. “Human Health Impacts and Adaptation.” Last modified 2012. http://www.epa.gov/climatechange/impacts-adaptation/health.html

35. Staudinger, Michelle D, et al. “Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment.” Cooperative Report to the 2013 National Climate Assessment. July 2012. http://assessment.globalchange.gov

36. Groffman, Peter M., et al. “Ecosystems, Biodiversity, and Ecosystem Services.” National Climate Assessment and Development Advisory Committee Draft Climate Assessment Report. 11 January 2013. http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap8-ecosystems.pdf

References - Climate Impacts

37. Minnesota Department of Natural Resources. "Minnesota's Forest Invaders – A Guide to Invasive Species". Sustainable Forestry Initiative. (n.d.) http://files.dnr.state.mn.us/assistance/backyard/treecare/forest_health/invasivespeciesinsert.pdf

38. Bauer, Marvin, Donald Kilberg, and Molly Martin. "Mapping Minneapolis Urban Tree Canopy." University of Minnesota. 2009. http://www.minneapolismn.gov/sustainability/action/canopy/sustainability_docs_minneapolistreesummary

39. McPherson, Gregory E, et al. "City of Minneapolis, Minnesota: Municipal Tree Resource Analysis." Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. 2005. http://www.itreetools.org/resources/reports/Minneapolis%20Municipal%20Tree%20Resource%20Analysis.pdf

40. Groffman, Peter M., et al. "Ecosystems, Biodiversity, and Ecosystem Services." National Climate Assessment and Development Advisory Committee Draft Climate Assessment Report. 11 January 2013. http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap8-ecosystems.pdf

41. City of Minneapolis. "Tree Canopy," 2013. http://www.minneapolismn.gov/sustainability/indicators/WCMS1P-081056

42. McPherson, Gregory E, et al. "City of Minneapolis, Minnesota: Municipal Tree Resource Analysis." Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. 2005. http://www.itreetools.org/resources/reports/Minneapolis%20Municipal%20Tree%20Resource%20Analysis.pdf

43. Groffman, Peter M., et al. "Ecosystems, Biodiversity, and Ecosystem Services." National Climate Assessment and Development Advisory Committee Draft Climate Assessment Report. 11 January 2013. http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap8-ecosystems.pdf

44. Stault, Amanda, et al. "Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services". Technical Input to the 2013 National Climate Assessment. 2012.

45. IPCC. "Climate Change and Biodiversity." 2002. http://www.ipcc.ch/pdf/technical-papers/climate-changes-biodiversity-en.pdf.

46. Hellman, Jessica, et al. "Climate Change and Chicago – Ecosystem Impacts." Nov 2007.

47. U. S. Environmental Protection Agency. "Ecosystems Impacts & Adaptation." (n.d.) http://www.epa.gov/climatechange/impacts-adaptation/ecosystems.html

48. U.S. Global Change Research Program. "Global Climate Change Impacts in the United States: Midwest." 2009. http://nca2009.globalchange.gov/midwest.

49. U. S. Environmental Protection Agency. "Ecosystems Impacts & Adaptation." (n.d.) http://www.epa.gov/climatechange/impacts-adaptation/ecosystems.html

50. Minneapolis Public Works. "Minneapolis Combined Sewer Overflow Annual Report." 2012.

51. Moore, Trisha. University of Minnesota, St. Anthony Falls Laboratory, and Minnehaha Creek Watershed. "Evaluating Stormwater Infrastructure." 2012. http://www.minnehahacreek.org/sites/minnehahacreek.org/files/attachments/WET_Fall%20Newsletter_0.pdf

52. Wisconsin Initiative on Climate Change Impacts. "Stormwater." 2011. http://www.wicci.wisc.edu/publications.php

53. Wisconsin Initiative on Climate Change Impacts. "Stormwater." 2011. http://www.wicci.wisc.edu/publications.php

54. Erickson, Timothy and Heinz G. Stefan. University of Minnesota, St. Anthony Falls Laboratory. "Groundwater Recharge from a Changing Landscape." 2007.

55. Fletcher, T.D., H. Andrieu, and P. Hamel. "Understanding, management, and modelling of urban hydrology and its consequences for receiving waters." Advances in Water Resources. 51. (2013): 261-279.

56. Herb, William, Omid Mohseni, and Heinz Stefan. University of Minnesota, St. Anthony Falls Laboratory, "Heat Export and Runoff Temperature Analysis for Rainfall Event Selection." 2007.

57. Hadley, S. W., D. J. Erickson III, J. L. Hernandez, C. T. Broniak, and T. J. Blasing, "Responses of Energy Use to climate change: A climate modeling study." Geophys. Res. Lett., 33, 2006.

58. Midwest National Climate Assessment. 2011. http://glisa.msu.edu/great_lakes_climate/nca.php

59. Scott, M. J. and Y. J. Huang, "Effects of Climate Change on Energy Use in the United States." Effects of Climate Change on Energy Production and Use in the United States. U.S. Climate Change Science Program and the subcommittee on Global Change Research. 2007. http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf

60. Scott, M. J. and Y. J. Huang, "Effects of Climate Change on Energy Use in the United States." Effects of Climate Change on Energy Production and Use in the United States. U.S. Climate Change Science Program and the subcommittee on Global Change Research. 2007. http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf

61. Scott, M. J. and Y. J. Huang, "Effects of Climate Change on Energy Use in the United States." Effects of Climate Change on Energy Production and Use in the United States. U.S. Climate Change Science Program and the subcommittee on Global Change Research. 2007. http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf

62. Midwest National Climate Assessment. 2011. http://glisa.msu.edu/great_lakes_climate/nca.php

63. Scott, M. J. and Y. J. Huang, "Effects of Climate Change on Energy Use in the United States." Effects of Climate Change on Energy Production and Use in the United States. U.S. Climate Change Science Program and the subcommittee on Global Change Research. 2007. http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf

64. U. S. Environmental Protection Agency. "Energy and You." Last modified October 17, 2012. http://oaspub.epa.gov/powpro/ept_pack.charts

65. Minneapolis Public Works. "City of Minneapolis, Sanitary Sewer Plan." 2008. http://www.minneapolismn.gov/www/groups/public/@cped/documents/webcontent/convert_255671.pdf

66. Metropolitan Council. "Master Water Supply Plan." 2010. http://www.metrocouncil.org/environment/watersupply/masterplan.htm.

67. U. S. Environmental Protection Agency. "Energy Impacts and Adaptation." Last Modified April 22, 2013. http://www.epa.gov/climatechange/impacts-adaptation/energy.html#ref2

68. Center for Science in the Earth System (The Climate Impacts Group). "Preparing for climate Change: A Guidebook for Local, Regional, and State Governments." In association with ICLEI. September 2007.

Photo Credits

1. Cover - *365twincitiesfamily.com*
2. Executive Summary - *minneapolis.org*
3. Climate Impacts - *gregbenzphotography.com*
4. Page 2 - *enerchange.org*
5. Page 6 - *minneapolis.publicradio.org*
6. Page 8 - *emeraldashborer.info*
7. Page 9 - *dnr.state.mn.us*
8. Page 14 - *eccentric-t-shirt.blogspot.com*
9. Page 20 - *commons.wikimedia.org*
10. Page 24 - *ouruptown.com*
11. Page 29 - *heatisland.lbl.gov*
12. Page 31 - *christopherfowler.co.uk/blog*
13. Page 32 - *picstopin.com*
14. Page 33 - *scjack.blogspot.com*
15. Page 36 - *lincolnsquare.patch.com*
16. Page 38 - *cityofsantacruz.com*
17. Page 40 - *sustainablebackyards.org*
18. Page 41 - *sustainablebackyards.org*
19. Page 43 - *www.mnartists.org*
20. Page 46 - *raingardennetwork.com, watershedcouncil.org*
21. Page 47 - *exploringthemillcity.wordpress.com*
22. Page 49 - *maxigreen.eu*
23. Page 50 - *www.msaudcolumbia.org*
24. Page 52 - *extension.umd.edu, www.homewyse.com, www.cityofchicago.org*
25. Page 56 - *renewableenergyworld.com*
26. Page 58 - *peaconstreet.org*
27. Page 59 - *energy.gov*
28. Page 61 - *colourcoil.com*
29. Page 63 - *architecture2030.org*
30. Page 66 - *wateruseitwisely.com*
31. Page 68 - *adventuresinarchitecture.blogspot.com*
32. Page 69 - *www.ci.minneapolis.mn.us*