Development of an Indicator Suite and Winter Adaptation Measures for the Chicago Climate Action Plan

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Problem Addressed

The draft Midwest regional report (S.C. Pryor and D. Scavia. 2013) in the forthcoming Third National Climate Assessment suggests that the major climate change impacts in urban areas within the Great Lakes region include the increased risks of flooding and erosion, more summer heat waves (which pose public health risks for vulnerable populations from both heat stroke and air pollution) and more droughts (with their impacts on natural resources, water resources and crops). Warmer average annual temperatures and a greater frequency of more severe storms will also raise health, safety and ecological concerns because of the consequent shifts in the ranges of disease vectors, plant hardiness zones and habitats, alterations in invasive species, and increased risks of flooding and pollution from urban stormwater runoff. But, by addressing only these major summer season impacts of climate change, the national climate assessments largely ignore the societal and environmental impacts of warmer and possibly shorter winters.

Identifying the potential winter impacts of climate change that can affect the Chicago metro region is important since there has been relatively little attention paid in the climate adaptation literature to either winter season climate changes or their impacts. For example, the Second National Climate Assessment (USGCCRP 2009) forecasts milder winters, earlier loss of ice cover on waterways and waterbodies, and loss of winter recreational opportunities as possible winter climate change impacts for the Midwest region. The Great Lakes Supplement to NOAA's coastal climate adaptation guidebook (Cruce and Yurkovich 2011) also notes that "[S]ince 1951, there has been an upward trend in [lake-effect] snowfall along the southern and eastern shores of the Great Lakes," and identifies an increased number of nonfatal traffic accidents as one impact of this trend. However, most of these winter impacts have only limited relevancy to Chicago since there are few ski resorts in the metro area, the lakefront is largely armored (reducing its storm and erosion susceptibility), and most of Chicago's major traffic and transit corridors (except for Lake Shore Drive) are located inland, outside of the lake-effect zone.The goal of this research project is to better assess the possible impacts of warmer winters on the City of Chicago's facilities and operations, especially those that are already addressed in the Chicago Climate Action Plan (2008) and the Sustainable Chicago 2015 Action Agenda (2012), and to recommend possible changes to existing strategies to better address these impacts. These City of Chicago initiatives were chosen because of Chicago's status as an early adopter of climate change planning in the Great Lakes region. In fact, Chicago's climate programs are the only ones cited within the Great Lakes region in the Adaptation chapter of the most recent draft National Climate Assessment (R Bierbaum, A Lee and J Smith 2013, pp. 992-993). Since the City has long been a regional leader in planning for climate mitigation and adaptation, other Great Lakes communities facing similar climate change impacts can learn from Chicago's policies, programs and outreach efforts.

Approach Taken

The approach taken involves a literature review of winter climate change projections and impacts for the Great Lakes region and the Chicago metro area, assessed by the Midwestern Regional Climate Center (MRCC) and GLISA and the development of recommendations for changes in the City's climate adaptation strategies to address winter climate projections. Information on the City's current strategies was elicited from interviews with City department staff and the staff of sister agencies (i.e., the Chicago Park District and Chicago Public Schools) who participate in monthly meetings convened by the Mayor's Office to promote the initiatives of the 2015 Sustainable Chicago Action Agenda and the Chicago Climate Action Plan. To promote the transferability of the research findings and recommendations, emphasis was placed on identifying those measures and adaptation responses that were relevant not only to the City of Chicago but also to other municipalities in the northern Great Lakes region.

Stakeholder/Decision-Maker Interaction

The scope of this research project was initially negotiated with the City's Department of Environment, which was responsible for the development and administration of the Chicago Climate Action Plan. In 2011, after the election of its new mayor, Rahm Emanuel, Chicago eliminated its Department of Environment (DoE) in an administrative reorganization, reallocating many of DoE's staff to other municipal agencies. A Chief Sustainability Officer position was also created in the Mayor's Office, which assumed management of the Chicago Climate Action Plan and also instituted a new, shorter-range environmental initiative called the 2015 Sustainable Chicago Action Agenda (City of Chicago 2012). The 2015 Sustainable Chicago Action Agenda focuses on economic development and job creation, energy efficiency and clean energy, transportation options, water and wastewater, parks, open space and healthy food, waste and recycling and climate change.

The Action Agenda's climate change category contains three goals, two of which address the reduction of carbon emissions and pollutants and the last of which expressly addresses climate change adaptation. Its key climate adaptation actions include (p. 35):

- Prepare for the human impacts of climate change by supporting people with information and services, such as cooling centers.
- Prepare the natural environment for climate impacts and maintain biodiversity.
- Prepare the infrastructure for climate change by reducing the urban heat island effect, managing flooding from high intensity storm events, and strengthening resiliency to extreme weather.

As with the Chicago Climate Action Plan, the city's emphasis on climate adaptation within its 2015

Sustainable Chicago Action Agenda remains focused largely on mitigating summer impacts (e.g., providing cooling centers and reducing heat island effects). However, the goals and some of the actions are phrased broadly enough to accommodate many winter climate change impacts as well.

A former staff member of DoE and the City's Deputy Sustainability Officer helped arrange interviews with City staff and with the staff of the Chicago Park District and Chicago Public Schools. The former DoE staff member also attended the interviews and reviewed the interview notes for accuracy as a quality control measure. In October 2013, the interim findings and recommendations of this research were presented to the City and sister agency staff members participating in the City's monthly Sustainability Committee meetings, and, in December 2013, a final report was submitted to the Deputy Sustainability Officer in the Mayor's Office.

Sources of Information

The Chicago Climate Action Plan's background report makes only a few references to forecasting winter season changes and impacts. These involve both the mortality and morbidity risks of warmer winters (which are difficult to quantify) and the impacts of changes in winter snowfalls, which are likely to decrease slightly under the higher emissions scenario and show little change under the lower emissions scenario (p. xii). More recent research by Kunkel et al. (2013) for NOAA, as part of the U.S. Global Change Research Program, found trends toward warmer seasonal temperatures, especially warmer winter and spring seasons, and a low frequency of cold waves in the Midwest since the mid-1990s. These more recent analyses have also found that the frequency and intensity of extreme precipitation in the region has increased (noting a great deal of uncertainty in the modeling of future precipitation changes), with Great Lakes water levels of the combined Lake Michigan-Huron system and ice cover on regional lakes declining. The freeze-free season across the Midwest is also likely to lengthen by 20-30 days, according to climate change modeling.

Research by the Great Lakes Integrated Sciences and Assessments Center (GLISA) at the University of Michigan (L. Briley 2013) and the Midwestern Regional Climate Center (MRCC) (M. Woloszyn 2013 and CMAP, Appendix A 2013) supplemented this relatively brief assessment of winter season climate changes affecting the Chicago metro area. The MRCC assessed winter precipitation changes, snowfall trends, snowfall intensity, snow density and freeze-thaw events for this research project (with GLISA also contributing an analysis and forecast of freezing rain events) – meteorological factors that are typically ignored in national and regional studies of projected future climate change.

Outcomes/Outputs

A literature review of winter climate adaptation measures and policies within local climate adaptation plans turned up only a scant few examples that could possibly be adapted to Chicago's Climate Action Plan and the climate change goals of the Sustainable Chicago Action Agenda. For example:

- The City of Keene, New Hampshire (City of Keene 2007) has examined winter impacts to the local economy (especially winter recreation), plant species' growth cycles, and roof sturdiness under snow loading, adopting policies to encourage more pitched roofs, crowning highways with a tighter design radius to remove water better, examining the use of road materials more tolerant of freeze- thaw cycles, and retraining people who might lose their jobs (snow plowing, maple sugaring) because of climate changes
- NOAA's Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan, undertook a needs assessment of climate changes in the Great Lakes, identifying a need to consider how projected winter impacts will affect various economic sectors – for instance, how a community could reassess its snowplowing operations to respond to the regional trend of heavier but fewer snowstorms (Nelson, Elmer and Robinson 2013).
- The City of Toronto, Canada, has also examined winter climate change adaptation issues. Using climate modeling, the City forecasted its winter climate impacts, focusing on managing stormwater flows and basement flooding risks. Its policies also promote the installation of back-up power generation capability at wastewater and water treatment plants that might be impacted by winter power blackouts. Other winter adaptation measures include improved monitoring for snow and freezing rain conditions, the installation of more resilient traffic signal controllers, and improved design

standards for infrastructure that might be damaged by winter storms (City of Toronto 2011).

There will be some significant municipal impacts to the City of Chicago should more winter snow events take the form of heavier snowstorms comprised of denser snow. High density, wet snow does not drift as much as light snow so highways and roads might be less impaired by blizzards. Wet snow may also require lower deicing salt application rates, reducing chloride levels and pollutant loading in the snowmelt runoff and in road spray from vehicles (Salt Institute 2013). Any reduction in deicing salt application rates might reduce stress on parkway landscaping and street trees, reducing Chicago's tree maintenance and replacement needs. On the other hand, many of the impacts of dense, wet snow would mirror those of heavy ice deposited by ice storms and freezing rain, with the weight of the snow damaging trees and, possibly, automobiles and structures from falling trees and branches (Hauer, Hruska and Dawson 1994). The City of Chicago's urban tree planting lists are currently being re-evaluated in terms of climate change-induced shifts in planting zones, but many of the street trees on Chicago's current planting list do not show up on the list of ice storm-resistant species, so some city trees may be vulnerable to damage from heavy snow density blizzards. Municipal franchise arrangements with utility providers should also specify an increased schedule of tree trimming around above-ground power lines, to account for the higher power blackout risks from heavier snowfalls.

Moreover, structural loading of roofs and buildings is likely to increase from large snowfalls of heavy, wet snow. This may particularly pose problems where green roofs have been installed or retrofitted, structural modifications that already increase the static loading of roof trusses and membranes, and which might also increase the risks of large, heavy snowfalls promoting roof and building failure. Building codes and development regulations governing new development should therefore specify or encourage the underground installation of all utilities to further reduce these power blackout risks and possibly increase the margins of safety in their prescriptive static load standards.

A higher frequency of snowmelt during the winter from warmer average temperatures, coupled with an increased frequency of winter precipitation in the form of rain will likely further increase surface and basement flood risks within City of Chicago. Although the slower rate of snowmelt discharge might reduce some of the peakiness of stormwater contributions to waterways, reducing peak stream levels and their associated flood risks, the higher frequency of winter rainstorms may greatly increase overland flooding risks. These risks are especially an issue if snow storage on parkways and curbs from street plowing blocks street grates and the stored snow also reduces the storage capacity and operational efficiency of on-site stormwater management facilities. Chicago's flood risk models should be modified to accommodate these additional winter stormwater loads to Chicago's currently undersized combined sewer systems.

Rain falling on snow or on frozen ground will also have a higher runoff coefficient than rain falling on bare ground in warmer seasons, further complicating the assessment of winter flood risks. For example, there is less evapotranspiration when plants in rain gardens or vegetated swales are dormant during the winter. Therefore, the rain gardens or vegetated swales might be used for snow storage from plowing, impairing the capacity and operational efficiency of the stormwater management practices. This may require periodically modifying the City's new stormwater ordinance to increase the margin of safety of its stormwater management practices. Moreover, deicing salts carried by snowmelt or winter stormwater runoff can possibly increase the maintenance burden on some green infrastructure practices as plant materials become stressed and need to be replaced. This maintenance burden might be mitigated, however, if warmer winters and heavy, wet snowfalls require lower rates and quantities of deicing salt applications to ensure adequate traffic safety during the winter. Although deicing salt applications might need to be increased during wet snowfalls, simply because of the dilution effect s of denser and wetter snow (Wisconsin Transportation Information Center 2005), the contraction of the main snowfall season to only the mid-winter months and the smaller number of snowstorms per season from warmer winters may still result in substantially less aggregate deicing salt use over the entire snow season.

An increase in snowstorm intensity, coupled with a greater frequency of heavy, wet snowfalls, will also likely lead to more frequent power blackouts and more extensive tree damage during the winter season. Some of the impacts of power blackouts during the winter season were discussed above, but Chicago's responses to the public health risks posed by these events may be different if they occur during the colder winter season rather than during the warmer summer months. For example, reducing some of these public health risks may require establishing emergency heating centers, the same way that the City responds to heat stroke risks to vulnerable populations during heat waves by operating emergency summer cooling centers. Either the same facilities used for emergency cooling during heat waves could be used for emergency heating during winter power blackouts, or alternate strategies could be considered by Chicago's emergency response operations, especially if the cooling/heating centers also become nonfunctional because they are located within an area subject to the power blackout. In such cases, CTA buses may possibly be used for emergency heating until power can be restored to residences, assuming the same larger snowstorm events that took out the power do not also prevent emergency access to vulnerable households to allow such emergency heating services to be provided.

The societal impacts of an increase in denser, wetter snowstorm events from warmer winters have not yet been fully explored in the climate adaptation literature. Shoveling heavy "heart attack" snow certainly poses direct health risks to the person doing the shoveling, especially if there is a family history of premature heart disease (Nichols et al. 2012). There can also be secondary public health risks posed by the associated winter power blackouts as well. For example, food poisoning risks might also increase during power blackouts as stored or frozen food spoils as temperatures rise in non-functioning refrigerators and freezers, similar to the food safety issues that often arise with summer season power blackouts (Lin et al. 2011, Marx et al. 2003). Public service announcements issued by the Chicago Department of Public Health as to which frozen or refrigerated foods are still safe for consumption after blackouts would go far in reducing such risks (USDA 2006). Unlike the food poisoning hazards typically encountered during summer season power blackouts, the colder outdoor temperatures found in the Great Lakes region during the winter season might mitigate some of these health risks. For example, outdoor temperature-related guidelines could be developed for interim food storage outdoors or in the non-heated areas of residential buildings (such as in porches, garages, etc.).

With an increase in freeze-thaw cycles, municipal road and transit maintenance budgets may need to increase, as well as the frequencies of roadway inspections and resurfacing projects.

Alternatively, different types of road construction (or reconstruction) can be used to improve drainage of precipitation and reduce the saturation of the paving materials by freezing water -- permeable concrete, for example, tends to perform well during freeze-thaw cycles since water tends not to be retained in the material's voids, unless the permeable paving is clogged or its underlying soils freeze, impairing drainage and allowing the permeable paving material to remain saturated (NRMCA 2004). Deicing of elevated train stations and switching gear might also need to occur more often as the number of freeze-thaw events increase with climate change, with concurrent increases in equipment corrosion and maintenance.

An increase in the frequency of winter freeze-thaw events is likely to impose greater stress on the built environment, especially if entrapped water freezes and expands within a saturated medium (such as concrete) or within the intersection of two different media (such as concrete and asphalt). This condition will likely result in a higher probability of roadway pothole formation, the spalling of concrete, masonry or other similar structural surfaces, and the increased loading (by ice expansion) of structural fasteners on building exteriors or on projections over sidewalks and other public ways. These freeze- thaw events can result in increased road repairs and structural inspection and maintenance costs.

One policy to address these risks is for the City of Chicago to promote the improved inter-departmental coordination with respect to infrastructure repair and replacement and roadway resurfacing projects. Infrastructure repair and replacement often requires the digging up of paved streets and the use of asphalt patching after the subsurface maintenance. Since asphalt and concrete have different coefficients of expansion during seasonal temperature changes, there are opportunities for water to breach the point of connection between the two materials, creating structural failure as the water freezes and thaws. Better scheduling of subsurface infrastructure repair that is coordinated with street resurfacing projects can minimize patching and ensure the roadway's surface integrity against freeze-thaw stresses for a longer duration. The use of innovative paving materials, such as permeable paving, to help control stormwater runoff by encouraging its percolation into subsurface storage vaults or soils may also reduce freeze-thaw stress by removing the water from the paving material's pores before it can freeze and expand (provided these materials do not become saturated). But this paving strategy may also require increased maintenance (such as periodic street sweeping or vacuuming to prevent clogging from fine sediments), which must be offset against the savings from avoided pothole repairs.

Structural vulnerability from freeze-thaw cycles can be addressed by an increase in the structural inspection frequency of vulnerable buildings (e.g., those with terra cotta cladding) and with those buildings that have obstructions over sidewalks and public ways. These may pose the greatest risks to pedestrians should water breach the exterior cladding or structural fasteners and then expand when frozen. Measures to address these risks can include mandatory insurance requirements for buildings with projections over public ways, more frequent inspections of structural and glazing integrity, and possibly even the encouragement of building design features to reduce pedestrian exposure (such as incentives for building setbacks that increase with building height or pedestrian arcades, both of which will "shelter" pedestrians from falling debris).

Lessons Learned

We probably know a bit more about winter climate adaptation issues now than in the past, but local adaptation plans still emphasize summer climate change impacts over winter ones. There is a need within the Great Lakes region to consider both summer and winter climate changes in assessing municipal vulnerability to climate change. Many of the climate changes projected for the Chicago metropolitan region are also relevant to other areas of the Great Lakes basin, and many of the possible winter climate change adaptation measures are also likely to be transferable to other, smaller communities within the region. These changes include warmer winters, a likelihood of more winter rainfall (with attendant higher flood risks), more frequent blizzards and intense snowstorm events (with more of the precipitation likely to be in the form of denser, wetter and heavier snow), and more freeze- thaw cycles (with more stress on roads and structures). Local climate adaptation policies and practices should recognize these winter season climate changes and their impacts and propose appropriate responses to these winter impacts.

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