CITIES OF THE FUTURE MITIGATING THE EFFECTS OF EXTREME HEAT

MERCEDES BEAUDOIN

Figure 1: Eiffel Tower at sunset during summer time

» Many studies show a correlation between an increase in green areas and a reduction in local temperature. Densely urbanized areas leave sparse room for converting paved areas into vegetated surfaces. Some techniques to try and increase the urban canopy include: tree planting programs along streets and in neighborhoods; creating and connecting linear parks (e.g., the Cheonggyecheon in Seoul, Republic of Korea); and, establishing pocket parks throughout the urban realm. Another option is transforming traditional flat roofs and buildings sides into green roofs and vertical gardens. «

Extreme heat may not be the first emergency disaster to come to mind when discussing major causes of death, yet, extreme heat has caused more deaths in the United States than hurricanes, tornadoes, earthquakes, floods, and lightning combined from 1979 to 2003[1] and Europe's 2003 heat wave killed more than 70,000 people in one summer[2].

Warmer weather may be here to stay for a while. Each of the last three decades has been successively warmer than the change in temperature between any preceding decade since 1850[3]. Though climate change is a large contributor to extreme heat on a macro scale, cities and the attributes of each city, create their own micro climates which influences *city-level* temperatures. As more and more people move to cities (by 2025 some 65% of the world's population is expected to urbanize[4]), it is imperative for urban planners around the world to consider mitigation strategies for this extreme heat phenomena.

This article first provides an overview of the Urban Heat Island (UHI) phenomena. It briefly describes the various public health threats caused by extreme heat. Finally, it discusses the means by which planners around the world are pursing to adapt their cities to mitigate such effects.

URBAN HEAT ISLAND

Urban heat islands are described as municipal areas experiencing higher temperatures during the day and less nighttime cooling abilities than adjacent rural areas. Studies show the annual mean temperature of a city with one million or more people can be 1.8- 5.4° Fahrenheit warmer than its surroundings during the day and as much as 22° Fahrenheit warmer at night[5]. The Urban Heat Island Effect (UHI) is not a traditionally considered a natural disaster, but a hazardous phenomenon created and perpetuated by human-constructed ecosystems – cities.

Aggravating this problem is the fact that global temperatures are forecasted to increase by 2° to 11.5° Fahrenheit in the 21st Century according to a 2007 report by the United Nations Intergovernmental Panel on Climate Change (IPCC). In fact, the same IPCC report projects temperatures to upsurge even more in urban areas than the overall global temperature. As a result, some researchers feel that the Urban Heat island (UHI) is one of the major problems facing humanity and one of the numerous ways cities contribute to climate change.

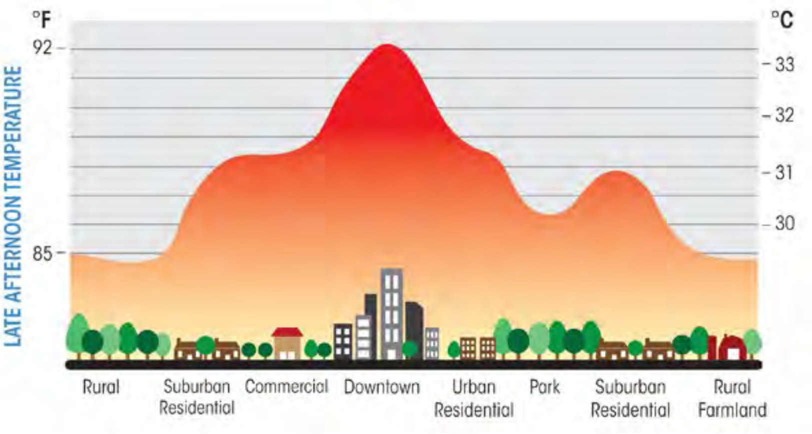

Figure 2: A profile of an urban heat island

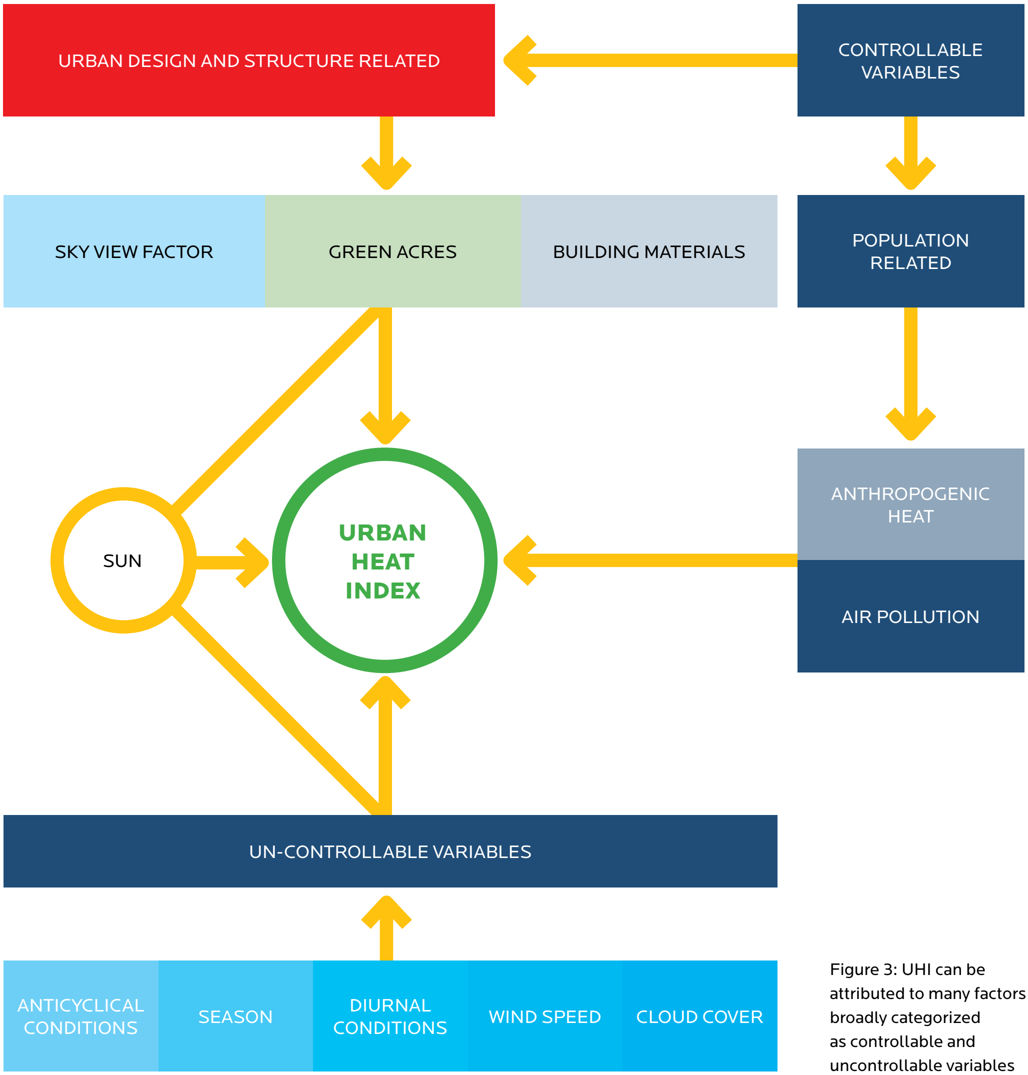

Figure 3: UHI can be attributed to many factors broadly categorized as controllable and uncontrollable variables

Figure 4: High summer temperatures and an abundance of asphalt surfaces in the Central Arizona-Phoenix LTER study area create conditions for urban heat islands[9]

CAUSES OF UHI AND ITS EFFECT ON THE CITY

Urban heat is mainly attributed to anthropogenic sources such as heat released from automobiles, power plants, and air conditioners. These heat sources are caught within the built environment and re-radiated by other large urban structures, such as tall or poorly placed buildings that hinder airflow in and out of cities. Building materials themselves also contribute to the exposure and radiation prospects of heat. Cities lacking in or decreasing albedo—a reflection coefficient used on buildings—also induces heat radiation[6] . Additionally, the type of building and infrastructure material can store heat energy during the day and release that energy into the environment at night. Finally, Land use decisions also plays a major role in how cities impose more or less heat on their citizens. As cities expand, vegetated surfaces such as forests, fields, and valleys are replaced by buildings, roads, and other impervious surfaces fashioned out of materials that store short-wave radiation[7]. Vegetated surfaces, on the contrary, provide social-ecological services such as absorbing and metabolizing such energy, providing shade, and contributing evapotranspiration[8].

Figure 5: Chicago Skyline

HEALTH AND OTHER IMPLICATIONS OF URBAN HEAT ISLANDS

The subject of UHI has become highly interesting for planners and scientists alike due to its adverse environmental, economic, and social impacts on society. The adverse effects of UHI includes the deterioration of the living environment, to an increase in energy consumption[10], a raise in ground-level ozone[11] , and, most tragically, increased illness and mortality rates[12].

The UHI escalates potential health risks by increasing the maximum temperatures citizens are exposed to and by increasing the span of time citizens are exposed to these higher temperatures. Being exposed, even briefly, to elevated temperatures can cause serious heat-related health issues when the human body is incapable of adapting to the heat by properly cooling off. Numerous factors affect the body's ability to cool down during extreme heat including: humidity levels, age of person, obesity, fever, dehydration, heart disease, mental illness, poor circulation, sunburn, and/or prescription drug and alcohol use[13].

Heat-related illnesses range in severity depending on the speed of the body's temperature increase during extreme heat trials. Elevated body temperatures are reported to permanently damage the brain, internal organ system, and respiratory system[14] . Additionally, increased temperatures have been shown to induce heat stroke, heat exhaustion, heat cramps, heat stress, heat rash, and heat syncope in individuals living and working within urban areas[15].

Furthermore, researchers note heat-related illness potentially affect an individual's mobility, awareness, and/or behavior. Secondary health hazards affected by urban heat islands include increased concentrations of air pollutions and impaired water quality, both of which increase morbidity.

As previously mentioned, the UHI is specifically robust at night, reducing the ability of urban residents to cool themselves down during this time of traditional relief. Such a lack of nighttime relief is strongly correlated to increased mortality. In fact, Hoverter (2012) states the average heat-related deaths per year in the

U.S. is 700 and predicts the increase greenhouse gas emissions to surge the prediction to 3,000 to 5,000 deaths annually by 2050. One can imagine these numbers inflated in less-developed countries with poorly-planned megacities unequipped to mitigate such extreme heat. Regardless of region in the world, the most vulnerable populations for heat-related morbidity and mortality are the elderly, infants and children, people with chronic medical conditions, and lower socioeconomic persons.

High UHI levels can also effect a city's infrastructure, such as warping or cracking transportation infrastructure such as roads, airport runways, and even rail lines (U.S. Global Change Research Group, 2014). UHI can also encourage other disasters and emergences in cities such as droughts or fires. Furthermore, urban heat islands can affect daily occurrences and behaviors by increasing energy use, energy costs, and pollution levels for a metropolitan area.

HOW CITIES CAN MITIGATE UHI

Heat-related deaths and illness are preventable, yet many people succumb to the effects of extreme heat. Thus, it is vital planners are aware of the risks of the UHI and the preventative strategies that can be integrated in city plans.

The design of a city affects every social, environmental, and economic characteristic of that city. Implementing a UHI mitigating built environment and planning strategy can reduce the heat impacts of cities including: (1) protecting public health; (2) reducing energy consumption and thus decreasing greenhouse gas emissions; and, (3) potentially providing mutually beneficial environmental effects (e.g., storm water management, improved air quality). These designs and strategies include: albedo designs, increased vegetation cover and connection, climate action plans, and heat-related emergency management plans.

Albedo. Some researchers say temperature rises, including global warming, could be fought with a paint job. This strategy is called the Albedo Effect where painting surfaces of buildings, streets, and other surfaces the color white reflections some of the sun's radiation waves. Using albedo materials can reduce the amount of

Management Strategy	Common Components
Albedo Enhancement	Installation of highly reflective roofing or paving materials
Building Energy Efficiency	Minimum insulation values in building codes with efficient light fixtures and appliances
Climate Action Plan	Adopt a cross-sectoral plan for all climate related phenomena for all strategies
Green Roofs	Installation of vegetative roofing materials
Heat-Related Management	Devise plan with emergency management departments to prepare for heat-related events
Regional Forest Management	Requirements for the protection of regional forest cover in proximity to urbanized areas
Renewable Energy Programs	Requirements for wind, solar, geothermal, or other renewable energy sources
Urban Tree Management	Municipal tree planting programs with requirements for tree protection ordinances
Vehicle Energy Efficiency	Minimum fuel efficiency standards for municipal fleets; acquisition of alternatively fueled vehicles
Vehicle Travel Demand Management	Ride sharing programs, transit investments, provision of pedestrian and cycling facilities

Table 1: Strategies to Mitigate Urban Heat and common components of each strategy

solar radiation absorbed through buildings and urban structures to keep their surfaces cooler. Typically, urban albedos are in the range 0.10 to 0.20 but in some cities these values are exceeded[16]. North African towns are good examples of high albedo urbanized areas (albedos of 0.30 to 0.45) whereas most US and European cities have lower albedos (0.15 to 0.20) according to Taha (1997).

Vegetation. Another strategy cities can pursue is just as easy to pursue: keep and connect as much vegetation as possible. The USDA Forest Service recommends that 40% of urban land should be covered by tree canopy. However, most cities in the U.S. have tree canopies ranging from 16% to 39%, which means that the benefits of tree cover—heat management, air quality, water and energy conservation—are not evenly distributed. This distribution could present a social equity issue.

Effective use of green infrastructure for urban heat management requires a change in our approach to urban planning. In traditional planning, green infrastructure is an afterthought; the focus is on "grey infrastructure" (e.g., roads, buildings, utilities) with green places located in the leftover spaces. In contrast, planning for urban heat management incorporates "green infrastructure" as an essential design element. Such planning begins with an inventory of all assets, both natural and built; then a strategy to protect those assets and a plan for green space is developed before the built elements are located. Both green and grey elements should receive equal priority in planning and funding, with equal expertise in management and design, and are designed as complimentary systems.

Many studies show a correlation between an increase in green areas and a reduction in local temperature[18]. Densely urbanized areas leave sparse room for converting paved areas into vegetated surfaces. Some techniques to try and increase the urban canopy include: tree planting programs along streets and in neighborhoods; creating and connecting linear parks (e.g., the Cheonggyecheon in Seoul, Republic of Korea);

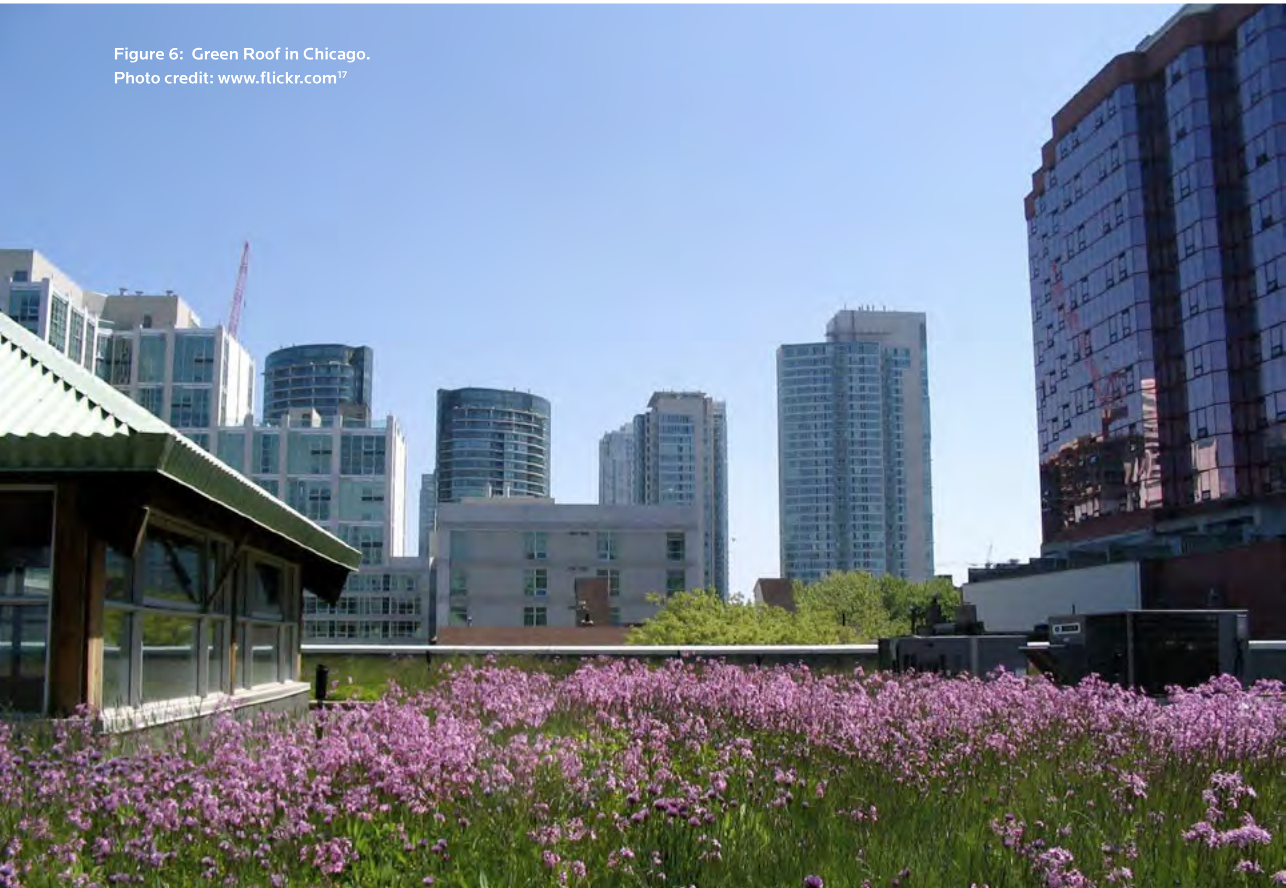

Figure 6: Green Roof in Chicago.
Photo credit: www.flickr.com[17]

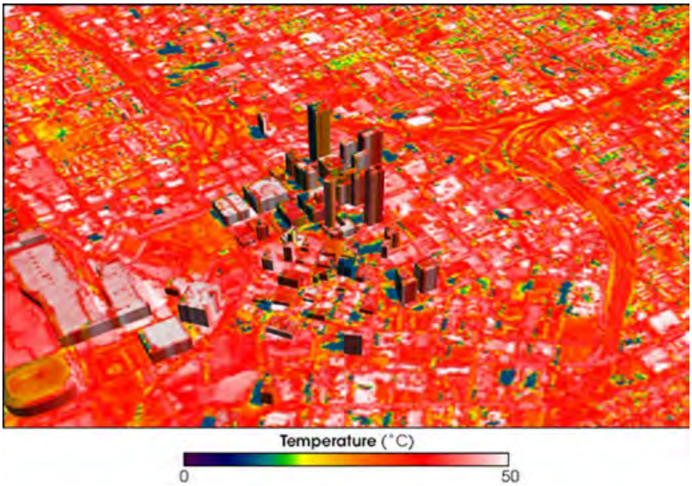

Figure 7: Thermal heat mapped in Atlanta, Georgia. Temperatures can rise by 10-12 degrees during the day time

and, establishing pocket parks throughout the urban realm. Another option is transforming traditional flat roofs and buildings sides into green roofs and vertical gardens.

Akbari, Shea Rose, and Taha, (2003) have estimated roofs to constitute 20-25% of the surface area in urban environments. For public health effects, a mass conversion to vegetated roofs potentially reduces the UHI, improves air quality and storm-water management, provides biodiversity, and fosters a location of urban amenities[19]. As for the infrastructure of the city, such a conversion would increase the lifespan of building materials underneath the soil, decrease building energy consumption, and reduce noise pollution from entering the building[20]. Though mass conversion seems unlikely due to pre-existing buildings' structural support issues, several existing roofs could be converted into green roofs without issues[21]. Toronto, Canada has led the pack in North American for becoming the continent's first city to adopt a green-roof policy. In 2015, France approved a law requiring newly built commercially zoned buildings to at least partially cover roofs in plants or solar panels.

Even though Susca, Gaffin, and Osso, (2011) and others have reported significant decreases in temperature around albedo and vegetated- replaced surfaces throughout cities, and it seems a simple a strategy, such mass conversions are a lofty investment for local governments to pursue. However, since cities are the economic engines of the world, without this investment the health and welfare of said urban environments could potential diminish via heat thereby reducing their economic competitive advantage. Additionally, since a city's planning department and emergency management department both want to reduce the UHI, it is imperative these agencies work together and share resources.

Heat-Related Emergency Management. A less holistic approach is to integrate a city's comprehensive master plan and its emergency management plan to provide a plethora of resources, and strategies to adapt cities for heat increases. U.S. cities such as Chicago, Philadelphia, Phoenix, and Milwaukee have developed heat emergency response plans[22]. Cities in oth-

Figure 8: An Iraqi man shows a thermometer reading more than fifty degrees Celsius on July 30, 2015 in the capital Baghdad. Photo credit: Ahmad Al-Rubaye (Ahmad Al-Rubaye/ AFP/Getty Images)[23]

er countries include Ahmedabad in India and Vancouver in Canada. Most European countries have nation-wide heat related emergency management plans.

Ahmedabad's plan is the first heat-health action plan in South Asia. This plan creates both immediate and long term actions to increase preparedness, information-sharing, and response coordination with the aim of reducing the health impacts of extreme heat on their population. Ahmedabad's plan consists of four key strategies. The first is simple: create public awareness and community outreach to communicate the risks of heat waves and how to prevent such heat-related illness and death. The second strategy is initiating an early warning system and inter-agency coordination to warn residents of rising temperatures. The third strategy is capacity building among health care professionals to better recognize and respond accordingly to heat-related illness during times of extreme heat. The final strategy in this plan is reducing populations' exposure to heat and promoting adaptive measures. This final strategy is where planners can really help as their strategy includes mapping high-risk areas, potable water, and cooler spaces around the city for populations to locate during heat waves. Such geographical information can make the difference between life and death.

Though such strategies are critical for public health when dealing with heat waves and heat islands, emergency response plans cannot single-handedly save all of the most vulnerable populations. Such plans cannot help residents during summer months when the temperature is simply hot and not depicted as an emergency [24]. Moreover, emergency response plans are not holistic because they fail to address baseline causes of urban heat including air pollution and economic costs of cooling mechanisms. Thus, emergency response must be paired with urban design and planning strategy.

Climate Action Plan. The (US) National Science Academy[25] defines resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." A city's climate action plan can be broad to encompass the other effects of climate change (e.g., sea level rise), but should have strategies dedicated to all climate-related events. Given the difficulties cities face when attempting to pursue UHI mitigation strategies, this analysis suggests more cities adopt a cross-sectoral approach to planning for heat emergencies. Once all viewpoints are taken into account, a climate action plan can be pursued.

Chicago, famous for its deadly 1995 heat wave, has a Climate Action Plan that outlines five strategies to mitigate and plan for intense heat events: (1) energy efficient buildings, (2) clean and renewable energy sources, (3) improved transportation options, (4) reduced waste and industrial pollution, and (5) adaptation. In addition to the strategies mentioned in

Figure 9: Millennium Park in Chicago, Illinois, with the Lurie Garden, BP Pedestrian Bridge, and part of the Jay Pritzker Pavilion visible. Photo credit: Carolyn Torma

this paper, Chicago's plan not only includes the support of UHI research and mitigation strategies, but also includes an emphasis on public engagement. Chicago's plan includes details steps for the city itself, for organizations within the city, and for residents. Thus, as all entities of a city are stakeholders, each can be informed of how they can play a part of mitigating and preparing for any future heat events. ◆

ENDNOTES

1 Center for Disease Control & Prevention, 2014

2 Robine, Cheung, Le Roy, Van Oyen, Griffiths, Michel, and Herrmann, 2008

3 WHO, 2016

4 Schell and Ulijaszek, 1999

5 Environmental Protection Agency, 2008

6 Akbari & Konopacki, 2005

7 Solecki, Rosenzweig, Parshall, Pope, Clark, Cox, & Wiencke, 2005

8 Takebayashi & Moriyama, 2007; Luber & McGeehin, 2008; Imhoff, Zhang, Wolfe, & Bounoua, 2010

9 Retrieved 19 July 2016 from https://lternet.edu/research/keyfindings/urban-heat-island-effects

10 Konopacki and Akbari, 2002

11 Rosenfeld et al., 1998

12 Changnon et al., 1996

13 CDC, 2014

14 Ibid

15 Hoverter, 2012; CDC, 2014

16 Taha, 1997

17 Retrieved 19 July 21016 from https://www.flickr.com/photos/sookie/156954114/

18 Takebayashi and Moriyama, 2007

19 Oberndorfer, Lundholm, Bass, Coffman, Doshi, Dunnett, Gaffin, Köhler, Liu, & Rowe, 2007

20 Saiz, Kennedy, Bass, Pressnail, 2006

21 Castleton, Stovin, Beck, & Davison, 2010; Johnston & Newton, 1996

22 Environmental Protection Agency, 2011

23 Retrieved on 19 July 2016 from http://www.theblaze.com/stories/2015/08/03/one-of-the-most-extreme-readings-ever-in-the-world-iranian-city-records-insanely-high-heat-index/

24 Hoverter, 2012

25 Cutter, Ahearn, Amadei, Crawford, Eide, Galloway, & Zoback, 2013

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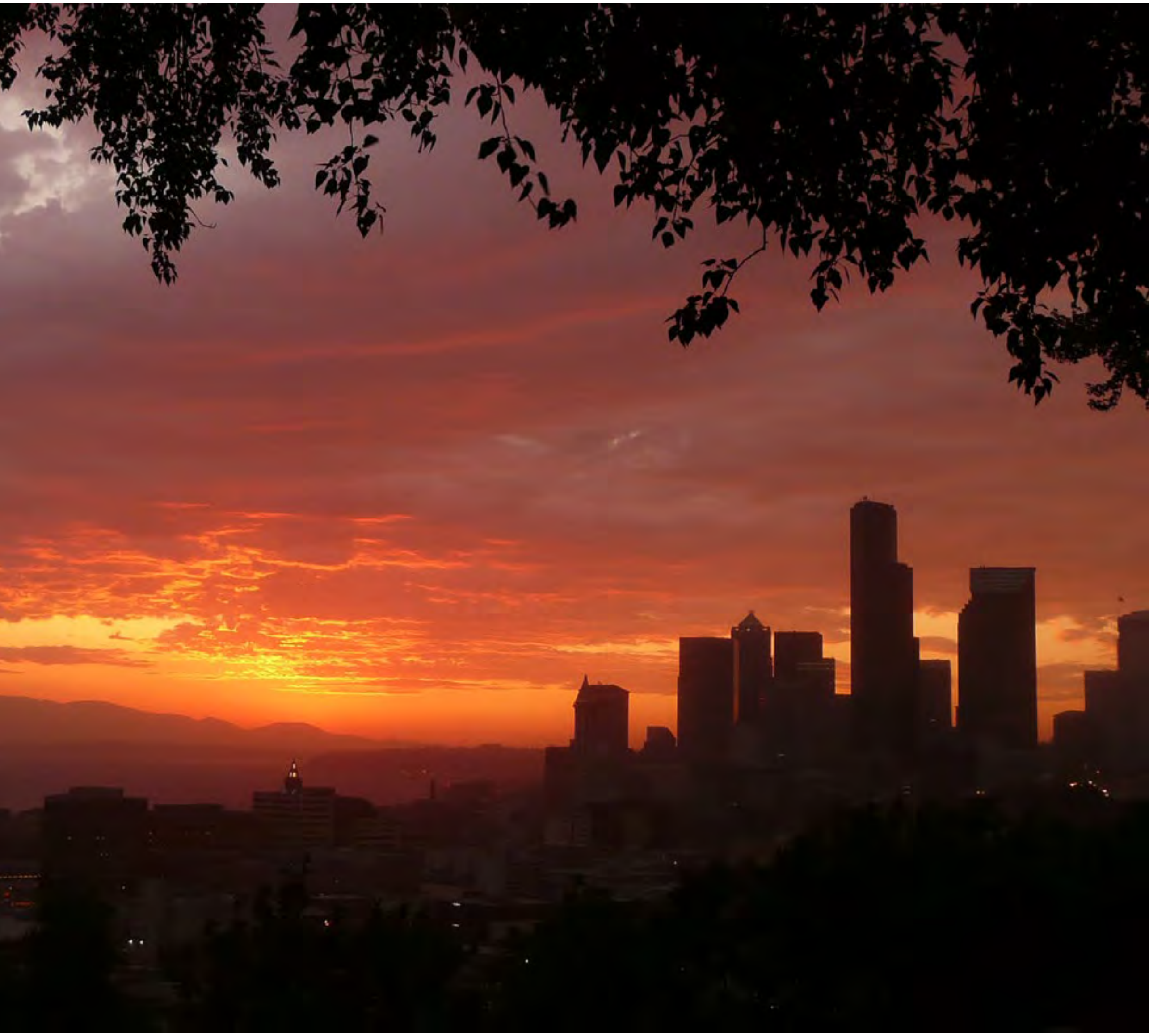

Figure 10: Heat over city