The Current State of Urban Heat Island Mitigation Policy

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ABSTRACT

Addressing rising temperatures resulting from heat islands and global climate change is one of the biggest urban sustainability challenges of this century. Reducing the threat of excess heat requires a broad multi-disciplinary effort from city leadership. Understanding how officials view, prioritize, and address the challenges of urban heat will help focus research and policy implementation efforts that lead to practical improvements in urban heat responses and foster greater communication between the researchers and policy implementers.

This paper reviews the experiences of select member cities of the Cool Cities Network (CCN) that are working to mitigate excess and extreme urban heat. We identify common themes in urban heat mitigation through three short case studies. The CCN is a unique partnership among more than fifteen large cities around the world that develops, shares, and replicates successful policies and programs to reduce excess urban heat. Network members include cities that are global leaders in reducing climate change as well as cities that are just beginning to understand and address their heat challenges. The case studies presented in this paper are intended to appeal to cities in the early to middle range of experience.

Introduction

Urban temperatures are increasing at twice the global average. This rapid warming trend poses a broad-spectrum public health and environmental threat both to the 3.5 billion people that live in cities worldwide and to adjacent ecosystems. Cities are hotter than non-urbanized areas and warming at an accelerated rate due to the urban heat island effect. Heat islands form because our urban surfaces, which tend to be dark and impermeable, absorb solar energy and radiate it has heat. Heat islands are also a result of waste heat from human activities like space cooling and driving. Cities tend to have fewer vegetated and shaded areas than non-urban spaces and buildings can impede natural wind patterns that would otherwise remove heat. The negative effect of heat on cities appears to be worsening. Cities are rapidly heating just as the world experiences a mass urban migration that will create larger and denser urban areas. The United Nations reports that the percentage of the population living in urban areas will grow from 54% today to 66% by 2050 (United Nations, Department of Economic and Social Affairs, Population Division 2014).

Excess heat impacts nearly every facet of urban life. Heat increases electricity demand for cooling, often at times when the electric grid is experiencing peak demand periods. Up to 10 percent of peak power demands are a direct result of persistently higher temperatures in urban heat islands. Urban heat islands are responsible for up to 20 percent of urban smog formation (Akbari 2005). Poor air quality, combined with extreme heat events, significantly impacts the health and safety of urban residents.

Heat disproportionately impacts vulnerable and minority populations that are the least capable of withstanding its effects. At its extreme, urban heat causes more deaths than any other natural disaster combined. The 1995 Chicago heat wave claimed the lives of 739 people, many of whom lived on the top floor of buildings with a dark roof. The 2003 European heat wave is estimated to have killed more than 70,000 people (Robine, Cheung, and Seu Lan). A new report for the Department of Energy by the National Center for Atmospheric Research and Lawrence Berkeley National Lab likens our future urban heat scenario to "some sort of deadly disease" in our cities (Tebaldi and Wehner 2016).

As a result of these dire trends, rising urban heat is receiving increasing attention from city policymakers from around the world. Many cities are using simple, cost-effective methods to reduce excess urban heat including shifting to roofs with white and/or reflective surfaces, reducing the amount of pavement, making pavements more reflective or permeable, and increasing vegetative cover.

A number of the world's largest cities formed the Cool Cities Network (CCN) to share their experiences addressing excess heat challenges, to support joint strategies to reduce heat, and to collaborate with researchers and other stakeholders to improve monitoring and measurement of progress towards cooler, more live-able cities. The CCN is a partnership of The Global Cool Cities Alliance and C40: Cities and is led by the Washington, DC District government. Active city members include Athens, Barcelona, Dhaka South, Dubai, Durban, Los Angeles, Melbourne, Mexico City, New York, Paris, Rio de Janeiro, Tokyo and Toronto. This paper provides three short case studies that highlight broader themes of what cities are doing to mitigate their urban heat islands.

Theme 1: Cities are leading by example on heat response. Washington DC's *Smart Roof* program systematically evaluated its 11 million square feet of municipal roof space for reflective, vegetative, or solar installations and is now replacing their existing roofs with sustainable, heat-mitigating options.

Theme 2: Cities are incorporating heat into long-term planning. Tokyo included urban heat islands in its Conservation Ordinance, which helped establish a multi-year approach to mitigation as part of a broader buildings initiative.

Theme 3: Cities are mapping data to better target heat program activities. Barcelona undertook a comprehensive GIS-based process to identify where the city is hottest and where its residents are most vulnerable to heat.

Theme 1 – Leading by Example: Washington, DC

Washington DC has a long history of policy leadership on sustainability, captured under an umbrella initiative called Sustainable DC. A key component of that strategy is maximizing the potential for District rooftops to mitigate urban heat islands, manage stormwater, and generate renewable energy. In support of this goal, the District adopted an amended version of the International Energy Conservation Code that included cool roof requirements for some commercial buildings. It has been at or near the top of cities for vegetated roof coverage in Green Roofs for Healthy Cities' Annual Green Roof Industry Survey for many years (Green Roofs for Healthy Cities 2015). In December 2015, the District announced one of the largest municipal onsite solar projects in the United States that will grow solar photovoltaic (PV) generation capacity to 11.4 megawatts on District-owned buildings and parking lots – a 70 percent increase over today.

The roof space on buildings controlled by the District is a substantial potential platform for meeting these goals. The District Department of General Services (DGS) owns or controls

400 buildings with approximately 11 million square feet of roof space. Approximately 9 million square feet of the portfolio is made up of low-sloped roofs.

In 2014, the DGS launched the *Smart Roof* program to assess the potential of each roof in the DGS portfolio to meet its goals for reduced heat islands, improved stormwater retention, and increased solar energy production. Roof consultants Bluefin LLC and Lightbox Energy assessed the physical condition of each roof, and evaluated the economics of each sustainable technology options, the structural load capacity of the roof (necessary for vegetated roofs), the viability for high efficiency solar energy installations, watershed impacts, and existing roof insulation levels. Economic evaluations factored in any available credits for solar energy and stormwater mitigation, as well as the effect of power purchase agreements.

High-end, silicone-base, reflective coatings were typically considered for functioning roofs as a way to considerably extend the life of the roof. Existing roofs with the new silicone coatings received a 20-year warranty. The city installed single-ply white membranes on new and replaced roofs that could not support a vegetated roof. In many cases, DGS installed both a cool roof and solar PV together. The evaluation included a schedule for roof interventions based on estimated remaining roof life and upgrade costs to allow DGS to better plan capital expenditures. Bluefin LLC and Lightbox Energy specify individual projects as needed and manage the bidding process for DGS.

Lightbox Energy reports that, as of February 2015, the program has upgraded 2.2 million square feet of roofs as follows:

- 1.8 million square feet of reflective roofing (275 thousand square feet of silicone coating, 1.6 million square feet of white single-ply membrane)
- 372 thousand square feet of vegetated roofing
- 12 megawatts of solar PV on 2 million square feet

In parallel, DGS undertook a comprehensive cost benefit analysis of the *Smart Roof* program that quantified the net economic impacts of transitioning to sustainable roofing across its portfolio. The analysis was unprecedented in scope, incorporating energy, health, air quality, and carbon considerations for the entire city. It provides the first rigorous and comprehensive methodology to estimate the costs and benefits of cool roofs, green roofs, and rooftop PV. It has involved a range of leading health and policy advisors and the development of a multilevel health and benefits valuation model to quantify the full set of costs and benefits of these technologies. The establishment of this model provides a powerful new platform to address and understand larger city design opportunities.

Per Figure 1, this report’s findings strongly indicate that a city-wide strategy of adoption of these technologies would have private and public benefits on the order of billions of dollars, including providing energy savings for building owners, reducing city peak summer temperatures, improving livability, and providing a large public health benefit. Table 1 shows that, over a 40-year period, transitioning DGS buildings to reflective, vegetated, and/or solar roofs would generate up to $335 million in net benefits for District, with paybacks of approximately 2 years on reflective roofs and 11 years on green roofs (Kats and Glassbrook 2015).

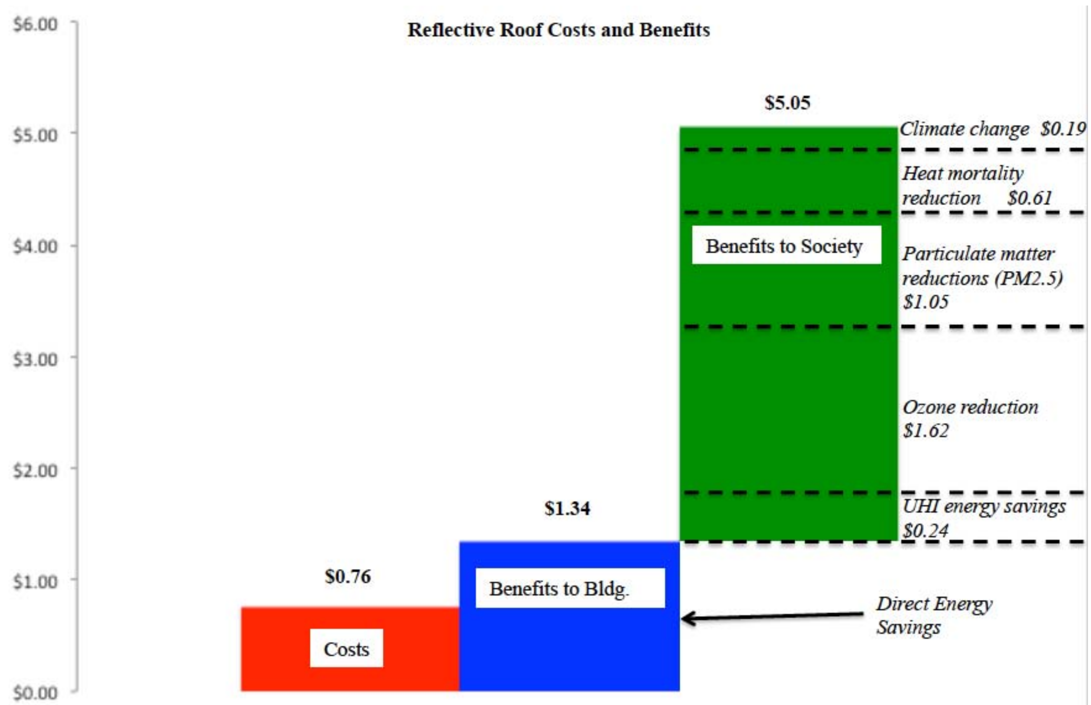

Figure 1: Economic impact of switching from a dark (reflectance of 0.15) to a light roof (reflectance of 0.65). Source Capital-E

Table 1: Cost/benefit comparison of sustainable roofing options to standard dark roofs over 40 years.

Comparison to Standard Dark Roofs	Reflective Roof	Vegetated Roof	Standard Roof with Solar PV (PPA)
Costs	$5,580,000	$203,000,000	$0
Benefits	$52,100,000	$528,000,000	$294,000,000
Net Total	$46,500,000	$335,000,000	$294,000,000
Internal Rate of Return	58%	11%`	N/A
Simple Payback	2 years	11 years	N/A
Benefit to Cost Ratio	6.62	2.65	N/A
Net Present Value per ft^2	$4.28	$37.26	$46.72

Source: Capital-E

Theme 2 – Considering Heat in Long-Term Planning: Tokyo

Over the last century, average temperatures in Tokyo have risen by 3 degrees Celsius, or nearly 5 times the increase in global average temperatures and about 2.5 times faster than in the rural areas surrounding Tokyo. Officials identified a number of negative impacts that they attributed to Tokyo's heat, including an increase in the number of heat stroke incidences requiring a hospital visit. The Tokyo Municipal Government (TMG) has taken measures to mitigate the impacts of the excess urban heat, including covering roofs and walls with greenery and passing the Nature Conservation Ordinance in 2001 (C40 Cities 2015). The Ordinance requires the greening of building roofs and walls for all new construction and existing buildings undergoing renovations, as well as increased vegetated cover on building sites.

The Tokyo Metropolitan Government undertook an advertising campaign for the Conservation Ordinance and its compliance requirements and followed it up with strong enforcement practices. Since 2001, more than 5,700 new or existing buildings have added about 19,000,000 square feet of green roofs in Tokyo.

Promoting the greening of existing buildings has not only helped in beatification of the urban landscape, but has also proven to be an effective measure to counter the heat island effect. Research done in 2004 showed that new light-weight green roofs applied to existing buildings could lower the roof surface temperature by 25 degrees Celsius and the temperature on the ceiling of rooms below the roof by 1 to 3 degrees Celsius even under thermal insulation.

TMG is also promoting cool pavements by including cool coating and permeable/porous pavement installation as a part of road maintenance and construction within identified priority areas in central Tokyo. Figure 2 shows that pavement with a cool, reflective coating reduces pavement surface temperatures by approximately 10 degrees Celsius compared to regular asphalt pavement. Data collected by the TMG has found that permeable/porous pavements suppress the temperature rise of road surfaces by a similar amount through water evaporation. The TMG deploys both technologies, typically using permeable/porous pavements in areas where stormwater management is also a priority. TMG has linked the cool pavement programs with the upcoming summer Olympics by installing cool pavements along the marathon routes and on roads around the venues. The city approved cool pavement specifications so that they may be used as a part of road maintenance and repair, if applicable and cost effective. TMG provides subsidy for cool coatings on pavements to encourage their installation. As a result, Tokyo now has development of 52 miles of cool pavements including 40 miles of cool coated pavements and 12 miles of permeable/porous pavements. TMG plans to expand these by 6 miles every year until 2020 with a target of 85 miles of cool pavements by 2020.

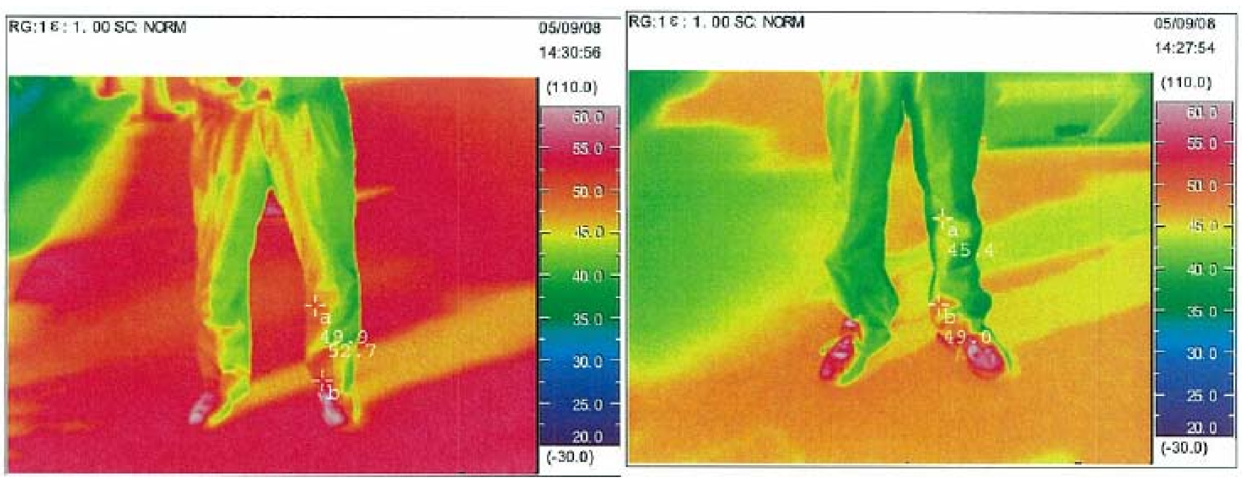

Figure 2: Cool pavement test in Tokyo that demonstrated a 10 degree Celsius reduction in surface temperatures between the standard asphalt pavement (left) and a cool pavement application (right). Source: Japan Paint Manufacturers Association.

TMG attributes the success of these cooling projects to its ability to link them to larger infrastructure projects. These projects tended to be well-funded, high-profile undertakings that would help raise the profile of the environmental benefits of the technologies while providing a pilot for how the technologies could be implemented on a city-scale. The linkage significantly reduced the burden of making a business case for cool infrastructure and helped securing funding that otherwise might not have been available for a cooling project.

Theme 3 – Mapping data to better understand the impact of heat: Barcelona

Nearly 70% of the expected global impacts of climate change are already being experienced in Barcelona, and they are expected to increase in intensity and frequency. Mortality rates on heat waves have increased drastically, which has triggered city's work on heat island effect.

Barcelona is following a holistic approach to manage their excess heat. The city started with a mapping initiative to pinpoint where heat impacts are most intense. City officials collected its urban heat island data based on land use, weather, physics, thermodynamics, anthropogenic heat, and urban morphology factors such as sky view factor, albedo and Normalized Difference Vegetation Index (NDVI). Figure 3 shows how the city has identified and mapped the vulnerable hot spots and categorizes them based on their extreme heat risk.

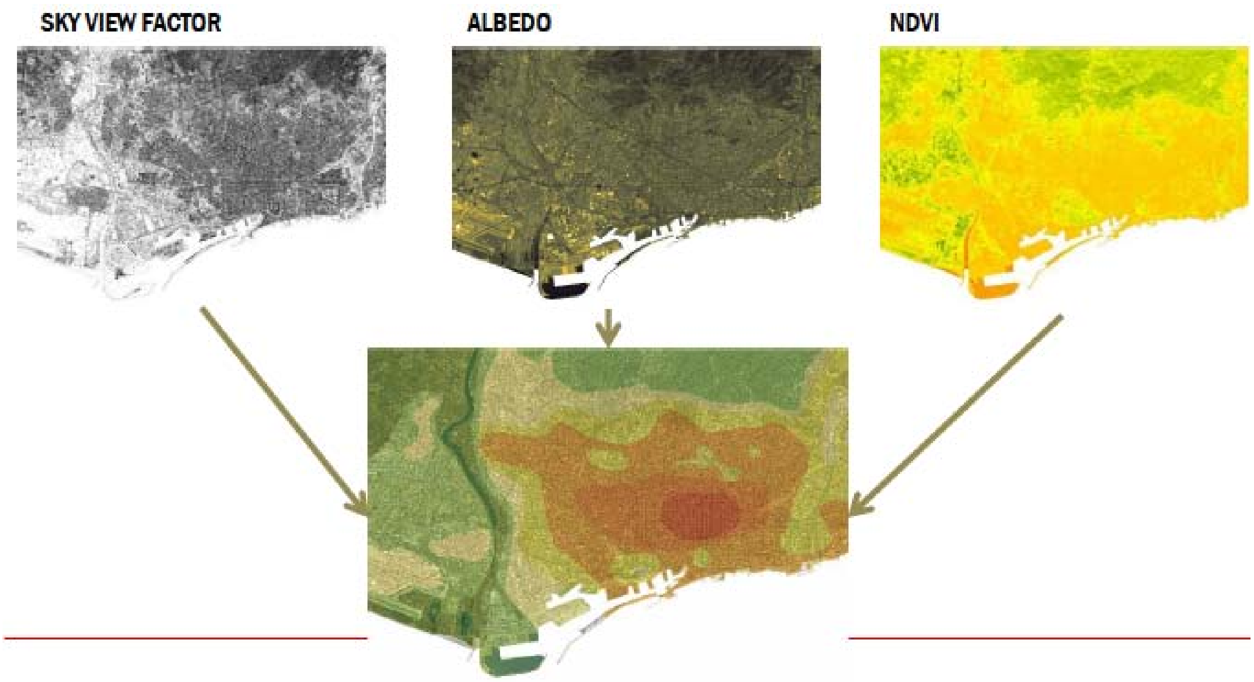

Figure 3: The data components used by Barcelona to better characterize and locate its hot spots and areas of heat vulnerability. Source: Irma Ventayol, City of Barcelona

Alongside the climatic conditions, the city is also looking to incorporate social characteristics of residents that increase vulnerability to negative heat health outcomes. These include individual characteristics such as age, poverty, physical impairments and community characteristics such as poor housing constructions, and access to air conditioning.

Barcelona spelled out a three-pronged approach in its emergency response plan called "Action Plan to Prevent the Effects of Heat Waves on Health[1]" that includes:

- Prioritize heat vulnerable populations;
- Increase environmental services from green infrastructure; and,
- Incorporate environmental criteria in urban planning.

Barcelona has scaled their emergency response to a heat wave into four phases: preventive phase I, preventive phase II, alert and emergency phase. Each successive phase is launched when conditions reach certain intensity (such as maximum daily or overnight temperatures) or duration (multiple days with high minimum and maximum temperatures).

The city has also prepared a Green Infrastructure and Biodiversity Plan that defines the challenges, goals and commitments of the city to preserve and improve the conservation of green spaces and ecological diversity[2]. The plan defines long-term actions to achieve ecological infrastructure producing environmental and social benefits to the citizens. It aims to have more green surfaces, more biomass, and more quality of life in the city.

Barcelona is developing the Ciutadella-Collserola green corridor in Passeig de Sant Joan neighborhood. This corridor, shown in Figure 4, is one of the first green corridors to be implemented that connects several isolated natural areas in Barcelona. It aims to benefit the wildlife of the area while facilitating easy mobility and providing spaces for recreation. The proposed project includes sidewalks, a boulevard, incorporates new alignments to existing trees providing shade for recreation areas, public LED lighting and fiber optics, sensors and wireless as well as other smart elements. The reduced sidewalk also becomes a pacified traffic zone including a bus lane and a bike lane. [3] The city encourages development of green roofs, decks and courtyard in existing as well as new buildings. The city has also developed an interactive map with geo-location of existing green cover. It has also gathered data on how many buildings (private and public) are fit for green roofs (existing and potential).[4]

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[1]Generalitat de Catalunya. 2012. *Action Plan to Prevent the Effects of Heat Waves on Health*. http://canalsalut.gencat.cat/ca/home_ciutadania/eines_i_recursos/campanyes/pla_dactuacio_per_prevenir_els_efectes_de_lonada_de_calor_sobre_la_salut/

[2] Generalitat de Catalunya. *Green Infrastructure and Biodiversity Plan*. http://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/green-and-biodiversity-plan

[3] Generalitat de Catalunya. *Green Corridors: Passeig de Sant Joan*. http://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/green-corridors-passeig-de-sant-joan

[4] Generalitat de Catalunya. *Living Roofs and Green Covers*. http://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/living-roofs-and-green-covers

Figure 4: Ciutadella-Collserola green corridor, before and after. Photo: Irma Ventayol

Barcelona is committed to its sustainability goals and has planned its next steps to improve the UHI mitigation. The city council is looking into assessing the environmental and social benefits of the existing and planned measures. As mentioned earlier, they are also looking at the potential green roofs that can be installed in the city in the coming years. The city further plans to run models based on different cooling techniques with and without climate change. Examples of these scenarios are: 'green roofs' vs. 'cool roofs' vs. 'climate change + cool roofs' vs. 'climate change + green roofs'.

Conclusion

Excess heat is a challenging problem for many cities. Global trends indicate that heat will be a significant urban challenge for the rest of this century and beyond. While its characteristics and impacts differ by city, there are some common approaches that cities take to respond to this challenge. This paper highlights those approaches with examples from cities participating in the Cool Cities Network.

Cities are leading by example by incorporating heat mitigation technologies on their buildings and public spaces. Washington DC's *Smart Roof* program is a data-driven approach to using municipally controlled roofs to meet its goals to improve efficiency, increase renewable energy, and mitigate excess urban heat. The program will result in millions of dollars of economic benefits in the form of energy savings, improved air quality, and fewer negative health incidences and it is gathering performance data that will help make the case for sustainable roofing to the private sector.

Cities are considering heat in their long-term planning. Tokyo recognized that excess heat was resulting in negative health impacts and increased energy use and sought strategies to cool off. The city embedded heat measurement and mitigation into its long-term planning, which allowed them to tap funding streams and implement a coherent multi-year strategy. As a result, the city has led the way on cooler pavement technologies.

Cities are using GIS mapping to visualize the problem of excess heat and to inform specific program and policy priority areas. Barcelona sought to better understand where its most heat vulnerable residents were by mapping the components of heat and vulnerability. The resulting map of the city allows officials to target heat interventions and plan heat emergency responses.

References

Akbari, H. 2005. *Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation*. Accessed on March 1, 2016 at http://www.osti.gov/scitech/servlets/purl/860475

Barcelona City Council. 2012. *Citizen Commitment to Sustainability 2012-2022*. Barcelona: Barcelona City Council. Accessed on March 8, 2016 at http://www.sostenibilitatbcn.cat/attachments/article/413/Commitment_22_UK_web.pdf

C40 Cites. 2015. Case study: Nature Conservation Ordinance is Greening Tokyo's Buildings. Accessed on March 9, 2016 http://www.c40.org/case_studies/nature-conservation-ordinance-is-greening-tokyo-s-buildings

Green Roofs for Healthy Cities. 2015. *2014 Annual Green Roof Industry Study*. Accessed on March 5, 2016 at http://www.greenroofs.org/resources/GreenRoofIndustrySurveyReport2014.pdf.

Generalitat de Catalunya. 2012. *Action Plan to Prevent the Effects of Heat Waves on Health*. Accessed on March 9, 2016 http://canalsalut.gencat.cat/ca/home_ciutadania/eines_i_recursos/campanyes/pla_dactuacio_per_prevenir_els_efectes_de_lonada_de_calor_sobre_la_salut/

Generalitat de Catalunya. *Green Corridors: Passeig de Sant Joan*. Accessed on March 8, 2016 http://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/green-corridors-passeig-de-sant-joan

Generalitat de Catalunya. *Green Infrastructure and Biodiversity Plan*. Accessed on March 8, 2016 http://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/green-and-biodiversity-plan

Generalitat de Catalunya. *Living Roofs and Green Covers*. Accessed on March 7, 2016 http://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/living-roofs-and-green-covers

Kats, G. and K. Glassbrook. 2015. *Washington, DC Smart Roof Cost Benefit Report*. Accessed on March 5, 2016 at http://cap-e.com/dc-smart-roof/

Lanning, P. Personal communication. March 9, 2016.

Robine, J.M., S. Cheung, S. Le Roy, H. Van Oyen, C. Griffiths, J.P. Michel, F.R. Herrmann. 2008. "Death toll exceeded 70,000 in Europe during the summer of 2003". Comptes Rendus Biologies **331** (2): 171–178. doi:10.1016/j.crvi.2007.12.001. ISSN 1631-0691. PMID 18241810. Retrieved May 5, 2016.

Shickman, K. and A. Dickie. 2012. *Cool Roofs and Pavements Toolkit*. Accessed on May 5 at www.coolrooftoolkit.org.

Tebaldi, C. and M. Wehner. 2016. *Benefits of Migration for Future Heat Extremes Under RCP4.5 Compared to RCP8.5. Climatic Change*, pp 1-13. DOI 10.1007/s10584-016-1605-5

United Nations, Department of Economic and Social Affairs, Population Division 2014. *World Urbanization Prospects: The 2014 Revision.*