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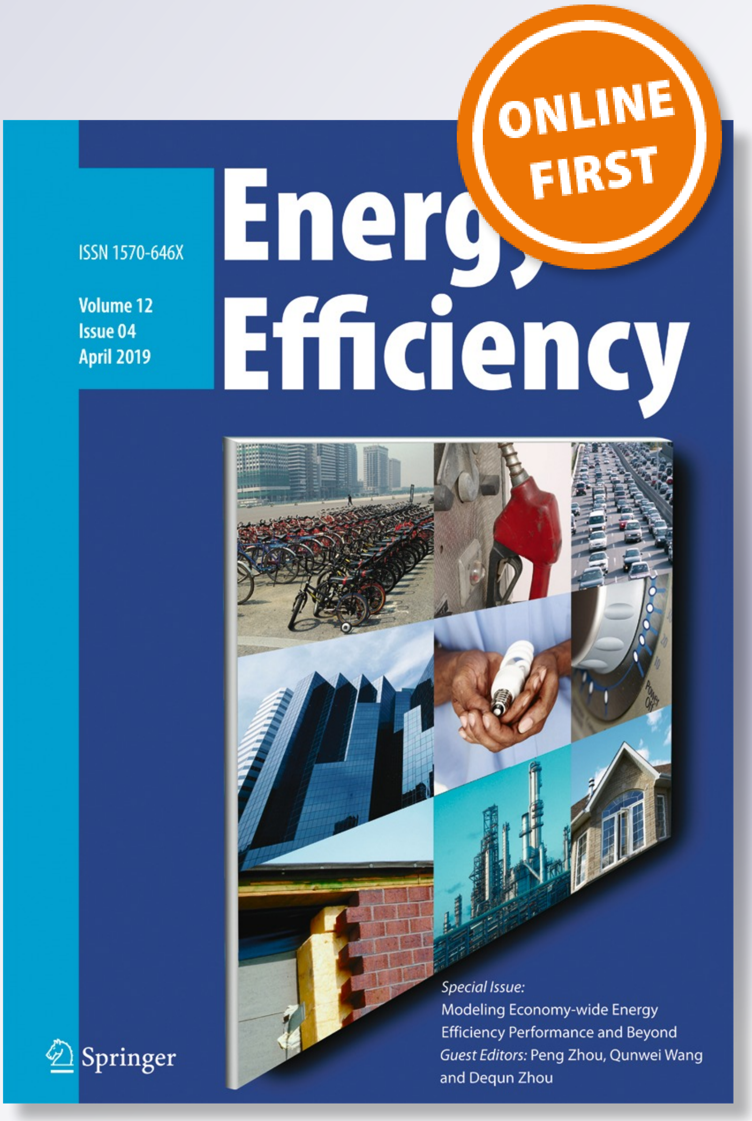

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ORIGINAL ARTICLE

Capturing the true value of trees, cool roofs, and other urban heat island mitigation strategies for utilities

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Abstract A growing body of research values the broad benefits of cooling down cities, such as improved energy efficiency, worker productivity, air quality, health, and equity, at hundreds of millions or even billions of dollars to a single city. However, widespread adoption of urban heat mitigation programs, such as urban greening and reflective surfaces, has been slower than their economic potential suggests it should be. One possible cause for this lag is a lack of robust engagement from important stakeholders like utilities that could fund and implement heat mitigation strategies. This paper highlights the benefits of urban heat mitigation and demonstrates how these benefits fit into private utility programs' standard cost–benefit tests. This paper serves as an introduction on how to include the wide suite of benefits that urban heat mitigation programs provide in cost–benefit tests and concludes with program design guidance.

Keywords Cool roofs · Utilities · Trees · Vegetation · Urban heat island

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Introduction

Rising urban heat is a critical challenge that negatively affects energy use, air quality, quality of life, economic prosperity, and social equity, to name a few. Nearly nine out of ten Americans live in an urbanized area (UNDP 2008) and, on average, urban spaces are heating up at twice the global rate (McCarthy et al. 2010). In the USA, the Fourth National Climate Assessment estimates, with high confidence, that urban heat islands lead to daytime air temperatures 0.9–7.2 °F (0.5–4.0 °C) higher and nighttime air temperatures 1.8–4.5 °F (1.0–2.5 °C) higher in urban areas compared to rural areas, with wider differences in humid regions, larger cities, and areas with higher population density (Wuebbles et al. 2017). The effects of this air temperature disparity will increase as cities grow; by 2050, nearly 70% of the world's population is expected to live in cities, up from 50% in 2007 (UNDP 2008). A recent study of 1700 cities finds that unchecked urban heat will impose a nearly 6% "tax" on the economic output of the median city by 2100 (Estrada et al. 2017).

Energy providers are faced with the challenge of meeting rising energy demand that is partly caused by this warming world. Akbari (2005) shows that electricity demand for cooling increases 1.5 to 2.0% for every 1 °F (0.6 °C) increase in air temperature, starting from 68 to 77 °F (20 to 25 °C). Similarly, Santamouris et al. (2015) finds that every 1 °F (0.6 °C) of temperature increase is associated with 0.25 to 2.5% increase in peak electricity demand. These results hold up when considering electricity demand in a single city; Fig. 1 plots

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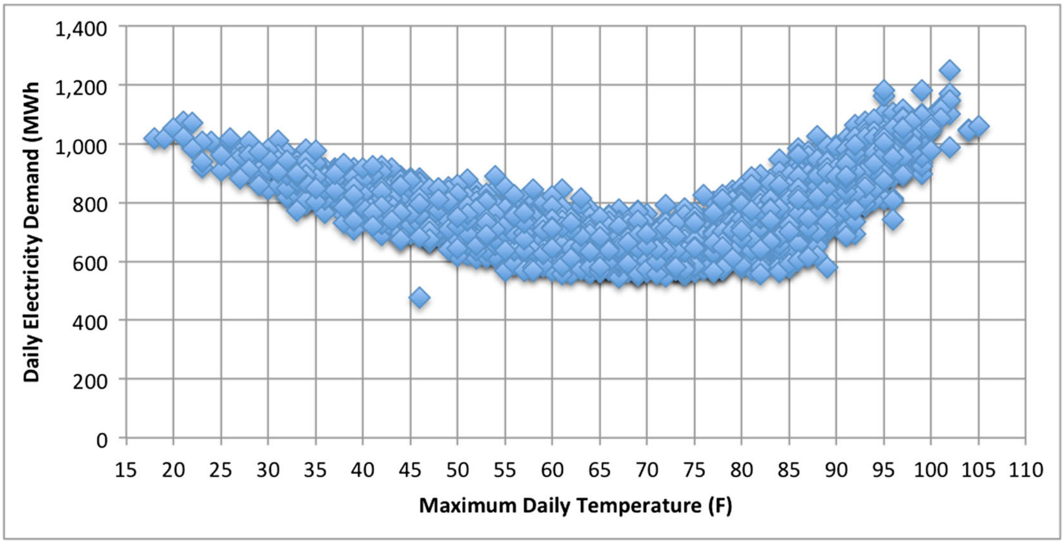

Fig. 1 Max daily temperature versus daily electricity demand for Washington, DC (2009–2017). A day with maximum daily temperatures of 85F and 95F will increase electricity demand by 27% and 55%, respectively. Source: Weather Underground, PJM Interconnection

electricity demand in Washington, DC, against the maximum temperature every day for 6 years (2009–2016). Demand for electricity climbs rapidly above 75 °F (24 °C). When the maximum temperature is 85 °F (29 °C), the city requires 27% more electricity, on average, than on 75 °F (24 °C) days. At 95 °F (35 °C), demand has spiked by nearly 55% over the 75 °F (24 °C) baseline. The graph's shape looks very similar to plots from other cities with high penetrations of air conditioning.

As urban heat islands get more intense in the coming decades, electricity demand in cities will grow which will affect electricity costs and system efficiency. Kolokotroni's (Kolokotroni et al. 2012) study of London's urban heat island suggests that cooling costs in the city could rise as much as 30% by 2050. Bartos et al. (2016) finds that by mid-century (2040–2060), increases in ambient air temperature may reduce average summertime transmission line efficiency by 1.9–5.8% relative to the 1990–2010 reference period. Peak per-capita summertime loads may rise by 4.2–15% on average due to increases in ambient air temperature. Consequently, cost-effective strategies to mitigate urban heat are critical for meeting future energy needs.

This paper focuses on the deployment of highly reflective surfaces and "urban greening" to reduce urban heat, approaches we collectively dub "cool city strategies." Cool, reflective, materials on roofs, walls, and pavements facilitate urban temperature reductions by reflecting a greater degree of solar energy away from surfaces and minimizing heat gain compared to a traditional dark surface. Urban greening, through forestry, green roofs, and other plant-based strategies, cools via evapotranspiration and by increasing shade cover.

How much cooler could our cities become with cool city strategies?

Santamouris (2014) provides a comprehensive review on cool city strategies and finds that when an overall increase in a city's surface solar reflectance is considered, the expected mean decrease of the average ambient temperature is close to 0.5 °F (0.3 °C) per 0.1 increase in solar reflectance,[1] while the corresponding average decrease of the peak ambient temperature is close to 1.6 °F (0.9 °C). Cool roofs also reduce air temperatures at a height 2-m above the surface (or roughly head height at 6.5 ft) by increasing the reflection of incoming solar radiation. Li et al. (2014) shows that green roofs with relatively abundant moisture cooled 2-m height ambient air temperatures by up to 6 °F (3.5 °C) over the Baltimore, Maryland–Washington, DC metropolitan area,

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[1] Solar reflectance is measured on a scale of 0 to 1. A surface with a 0 solar reflectance rating would absorb all solar energy. A surface with 0.5 solar reflectance would reflect 50% of the solar energy that contacts it and absorb the other 50%.

and a cool roof with a solar reflectance of 0.7 reduced 2-m height ambient air temperatures by 5 °F (3 °C).

More broadly, higher solar reflectance may lead to regional air temperature reductions. Campra (2011) compares weather station data in the Almeria region of Spain to similar surrounding climatic regions. Almeria has a unique tradition of whitewashing its greenhouses and thus reflects more sunlight than neighboring regions. Over the 20 years in the study, researchers find that average air temperatures in Almeria have cooled 0.7 °F (0.4 °C) compared to an increase of 0.6 °F (0.3 °C) in the surrounding regions lacking whitewashed greenhouses.

Urban greening affects local air temperatures via transpirational cooling and shading. Transpirational cooling refers to the process by which trees cool the surrounding air as they transpire, e.g., when trees convert water from a liquid to a vapor. Shading refers to a tree's ability to block the sun's rays from striking and heating impervious surfaces, such as sidewalks. McDonald et al. (2014, p. 29) review 17 studies and show that street trees can cool surrounding areas anywhere from 0.7 °F (0.4 °C) to 5.4 °F (3.0 °C). Gromke et al. (2015) finds that tree-lined avenues in Arnhem, the Netherlands, lower the mean temperature by 0.7 °F (0.4 °C) with a maximum temperature reduction of 2.9 °F (1.6 °C). Ma and Pitman (2018) shows that, in combination, green roofs and cool roofs can reduce 2-m ambient air temperatures by 5–7 °F (3–4 °C) depending on the building characteristics, urban environment, and meteorological and geographical conditions.

Why focus on utilities?

Utilities are already implementing energy efficiency programs as a means of reducing peak energy demands, energy use, and lowering emissions. For example, in 2007, Minnesota passed the Next Generation Energy Act requiring electric utilities to invest 1.5% of their in-state revenue in efficiency savings for households and businesses. Taking the broader case of energy efficiency programs, utility spending on electric efficiency programs grew from $1.6 billion in 2006 to $6.3 billion by 2015, a nearly 300% increase in just 9 years (Berg et al. 2018). These utility expenditures have borne fruit, with projections that efficiency could save as much as a third of the US electrical service demand by 2030 with continued policy implementation or the equivalent of 487 power plants of capacity (Molina et al. 2016).

Cool city strategies are effective strategies to mitigate urban heat and reduce energy demand. To date, however, their implementation has not been rooted in a scalable process that effectively conveys the costs and benefits of these strategies. Utility funding of heat resiliency has been hampered by split incentives, the fact that heat policy has not been a priority for city officials, and, until recently, a relative lack of research into quantifying the co-benefits of heat mitigation for utilities and society as a whole. While cool roofs are incorporated into some programs as a prescriptive approach or a whole-building performance approach, a broad use of cost–benefit tests on cool city strategies has yet to be implemented by utilities. This lack of consideration has led to cool city strategies being undervalued in the market and assigned a lower priority than many other energy efficiency programs.

A similar utility commitment to cool city strategies as utilities make to other energy efficiency programs could unlock large co-benefits in energy demand, air quality, social equity, health, and economic prosperity. While there are examples of utility programs that support cool city strategies, such as Los Angeles' cool roof incentive program, these programs are limited. Thus, there is a need to better articulate the effects of cool city strategies in the context of utility program cost tests to promote their broader adoption in renewable energy and climate change goals. This paper summarizes quantifiable benefits of cool city strategies and evaluates how these effects would fit into some common utility cost test models.

Utility cost tests are a regulated methodology for determining whether a particular program is cost-effective and appropriate for the utility to implement. Each utility cost test prioritizes a different stakeholder's perspective and what key question they are seeking to answer. These differing considerations affect the breadth of costs and benefits included in each test. We focus on three utility cost tests: the utility cost test (UCT), the total resource cost test (TRC), and the societal cost test (SCT).[2] Table 1 summarizes these three tests, and their use across the USA (NESP 2017) provides a

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[2] In this paper, we omit a specific discussion of two other standard cost–benefit tests: the participant cost test and the ratepayer impact measure test. These two tests represent the perspectives of the program participants and non-participants, respectively, which are both included in the total resource cost. Thus, the relevant benefits and costs for these two tests will be discussed in relation to the total resource cost test.

Table 1 Utility cost tests covered in this paper. Source: Woolf et al. 2012, p. 14; National Action Plan for Energy Efficiency 2008, Table 2-2; and Woolf et al. 2017

Test	States using (primary)	Perspective	Benefits covered in this paper
Utility cost test (UCT)	28 (5)	Utility provider	(1) Avoided energy costs, (2) peak demand reduction, (3) increased grid reliability/lower transmission and distribution costs
Total resource cost (TRC)	36 (29)	Program and non-program participants	Above plus (1) energy/capacity price suppression, (2) participant non-energy benefits and effects on low-income communities
Societal cost test (SCT)	17 (6)	Society	Above plus (1) water effects, (2) air quality, (3) health, and (4) other

comprehensive explanation of how utilities typically evaluate energy efficiency investments via cost-effectiveness testing.

The costs and benefits associated with energy efficiency programs will be most narrowly drawn in the UCT and most expansive in the SCT. This paper focuses on the benefits that are unique to cool city strategies as an energy efficiency program. We have omitted discussion of the costs and benefits of cool city strategies that would be a part of cost tests for other utility energy efficiency programs, including program administrative and incentive costs, participant and third-party contributions, energy and water bill savings, and reduced energy-generation emissions from lower energy use.

Utility cost test

The UCT determines whether a program adds to or reduces the private utility's cost to operate its system, including both variable and fixed costs. Variable costs refer to the operations and maintenance costs incurred for the transmission of each kilowatt hour of electricity to a home or business. Fixed costs, or capacity costs, relate to investments in the generation capacity of the entire electric grid. Cool city strategies reduce both variable costs—by decreasing the amount of electricity being delivered in the system—and capacity costs—by avoiding the need to invest in new generation capacity.

Avoided energy costs

Avoided energy costs are the most straightforward benefit of cool city strategies as they directly result from their ability to reduce the ambient air temperature. Pomerantz et al. (2015) finds that increasing solar reflectance of urban surfaces would reduce energy demand by an average of 2 kWh per modified meter squared. Taking the example from Washington, DC, above, each 1 °F (0.5 °C) temperature reduction above 77 °F (25 °C) reduces the need to produce 19,000 MWh of energy. Studies indicate that cool roofs reduce annual cooling energy use by up to 20% (Haberl and Cho 2004). In some cooler parts of the USA, a portion of the cooling energy savings is offset by increases in winter heating energy requirements. Most studies, however, find that this so-called winter heating penalty is minimal, even in the coldest climates (Hosseini and Akbari 2016).

An early study showed that a single 25-ft tall tree can reduce a household's annual heating and cooling costs from 8 to 12% (McPherson and Rowntree 1993). A more recent review on the subject showed that street trees can reduce annual energy costs anywhere from $2.16 per tree per year to $64 per tree per year, depending on local climatic conditions (Mullaney et al. 2015). In addition to providing transpirational cooling and shading, urban greening may reduce building energy needs by buffering ambient wind speeds, which will be especially pronounced in the winter months (Akbari 2002).

Peak demand reductions

The electric grid must be designed to meet electricity demand 24-h a day, particularly at times of peak demand, which varies by both the time of day and the season. Daily demand for electricity tends to peak during the day in business areas and during the evening hours in residential areas. Seasonally, in most regions,

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electricity demand peaks during the summer months when households and business run their air conditioning units. Average daily demand for electricity in the summer typically begins to rise in the early afternoon and peaks in the late afternoon or evening. Cool city strategies are particularly good at reducing summer peak demand because their energy reduction benefits occur when the sun is strongest and temperatures are highest. Peak demand reductions from cool city strategies average 1.6 °F (0.9 °C) and can help utilities avoid electrical transmission and distribution costs by avoiding heat-related line losses (Santamouris 2014). Pomerantz (2018) estimates that increase in roof and road solar reflectance would reduce maximum peak power demand by up to 7%.

Hoff (2014) evaluates cool roofs' ability to deliver energy cost savings by reducing peak demand charges for commercial and industrial customers. Figure 2 summarizes Hoff's (2014) energy cost savings analysis by climate zone, which can lead to significant savings for commercial, industrial, institutional, and, in some cases, residential buildings across the USA. Demand charges are typically based on the maximum energy demanded (measured in kilowatts) in a given time period, rather than on the total amount of power demanded (measured in kilowatt hours). For some customers, the peak charge can be 50% or more of the total bill. Hoff notes that despite the energy cost savings across the USA the economic effect of reduced peak energy usage is often omitted from cost–benefit calculations.

While the peak demand reductions of cool city strategies are largest during the periods of greatest cooling demand, they are not "dispatchable" in the same way as other demand response programs. Because some utilities do not count demand response unless its timing can be controlled, there is a chance that this substantial benefit of cool city strategies is not being counted.

ASHRAE Climate Zone	Annual Net Peak Energy Cost Savings	
	Low Range	High Range
1	$1,640	$3,040
2	$1,340	$2,250
3	$1,270	$1,870
4	$950	$1,490
5	$800	$1,220
6	$620	$1,150
7-9	$280	$880

Fig. 2 Net peak energy savings (cooling energy savings less increases in heating energy demand) by climate zone (20,000 ft^2 building). Source: Energy Information Agency and Hoff 2014

Increased grid reliability, lower transmission, and distribution costs

Cool city strategies can improve the efficiency of certain types of generation. High ambient air temperatures lower atmospheric pressures and oxygen concentrations and reduce the fuel efficiency of natural gas, oil, and nuclear electricity generation assets (Rademaekers et al. 2011). Transmission and distribution systems, like generation facilities, lose efficiency in high temperatures; as metal electrical resistance increases, electric flow decreases due to lower hanging transmission lines and other factors (Ward 2013). The transformers' capacity declines 1% for every 1.8 °F (1 °C) increase in air temperature and in copper lines for every 1.8 °F (1 °C) increase in air temperature the resistance increases 0.4%. Overall, network losses increase 1% for every 5.4 °F (3 °C) increase in air temperature; these increases occur in systems that already have initial losses of 8% (Rademaekers et al. 2011). Dr. Ray Klump highlights these unique challenges of heat on the electric grid in his article, "Why Does Hot Weather Cause Power Outages" (Lewis University 2013): "In other words, there are some rather nasty feedback mechanisms that take place that cause the grid a lot of stress when we all turn our air conditioners on. Power system operators traditionally have had a very limited number of controls to counteract these bad behaviors."

Total resource cost test

The TRC is primarily interested in determining how a program adds to or reduces costs for utility customers—both program participants and non-participants. The benefits of cool city strategies applicable to the UCT are also considered in the TRC. Regulators using the TRC could also consider several additional benefits when evaluating cool city strategies, such as price suppression and positive effects on program participants and low-income customers.

Energy/capacity price suppression

In jurisdictions with competitive wholesale energy and/or capacity markets, prices will be a function of the magnitude of demand. Thus, increased investment in energy efficiency resources benefits all consumers through its dampening of demand for electricity, which will reduce market clearing prices (at least to some extent and for some period of time). Conversely, extreme heat can push wholesale energy prices far above normal levels. For example, an August 2011 heat wave in Texas produced day-ahead, on-peak wholesale power prices in the Electric Reliability Council of Texas (the wholesale market operator for most of the State) that were five to six times higher than prices in the previous five Augusts (U.S. Energy Information Agency (EIA) 2011).

Participant non-energy benefits and effects on low-income communities

The TRC may also value some non-energy benefits such as water quality or health improvements that accrue to program participants. These non-energy benefits are discussed in more detail in"Societal cost test."

Cool city strategies reduce energy use that can strengthen the finances of middle- and lower-income households (whose energy bills can be 10% to over 50% of their monthly expenses) and help utilities reduce credit and collection costs (Drehobl and Ross 2016; and Chandler 2016). Improving building comfort and efficiency also has significant effects on middle- to low-income families and communities of color. Jesdale et al. (2013) show that low-income, minority communities tend to experience the worst effects of heat due to a lack of vegetation, old housing stock, and other factors. Reducing these costs is a non-trivial way to improve the economics of the most vulnerable families.

Societal cost test

The SCT considers the broadest set of effects of cool city strategies. Regulators using the SCT to evaluate cool city strategies could include all of the effects described above, as well as a number of other substantial societal benefits that are highlighted below.

Water quantity and water quality effects

Urban greening efforts reduce stormwater runoff in cities. Stormwater from cities often contains harmful pollutants, such as nitrogen and phosphorus from fertilizers and pet and yard waste, which can then be directly discharged into nearby surface water. Trees not only draw water from the soil for photosynthesis but will also absorb other harmful pollutants from the soil and intercept rainfall, causing less rain to hit the ground. Armson et al. (2013) find that trees can reduce runoff from asphalt by as much as 62%.

Air quality effects

Cool city strategies positively impact air quality in three key ways. First, the energy efficiency benefits of cool city strategies directly reduce pollutants emitted from power plants in many parts of the country. Levinson and Akbari (2010) details this benefit down to a zip code level for the USA.

Second, reduced ambient air temperature lowers the likelihood that smog and ozone will form. There is a very clear link between heat and smog formation, so lowering air temperatures can go a long way to reducing the formation of smog (Kenwood 2014). The relationship between heat and smog formation is not linear. Similar to energy use, there is a threshold air temperature, often between 75 and 80 °F (24 °C and 27 °C) that triggers smog formation. That means that every small reduction in air temperature, especially on warmer days, can have a significant impact on air quality. Ozone pollution is a major contributing factor to respiratory illness. The World Health Organization (2018) predicts ozone pollution will be the third leading cause of death by 2030. Traditionally, air quality improvement efforts have focused on reducing the emission of those precursor chemicals, but turning down urban air temperatures would also play an important role.

Third, urban greening removes particulate matter from the atmosphere through a process known as dry deposition. Dry deposition is when the particulate matter deposits itself on the tree's surface, where most of it becomes incorporated into leaf wax or cuticle, and is thus removed from the air. Nowak et al. (2013) surveys ten cities in the USA and finds that, in some cities, trees currently remove as much as 64 t of fine particulate matter measuring less than 2.5 μm in diameter ($PM_{2.5}$) a year. More broadly, a review of seven different scientific studies by The Nature Conservancy found that urban trees reduce nearby concentrations of $PM_{2.5}$ anywhere from 9 to 50% with the largest effects within 30 m of the tree (McDonald et al. 2014, p. 29).

Health effects

Cool city strategies improve health outcomes via improved air quality and improved water quality. The SCT values beneficial health effects that accrue to society at large—including individuals participating in a utility program and those that are not participating. Reducing urban heat can have a wide variety of benefits to health, including reduced heat stress and improved outcomes for people suffering from diseases of the heart, lungs, kidney, or diabetes (Martin Perera et al. 2012). Most importantly, cool city strategies can substantially reduce deaths during extreme heat days. Kalkstein et al. (2013) finds that a 0.1 increase in urban surface solar reflectance could reduce the number of deaths during heat events by an average of 6%. Similarly, he finds that a 10% increase in vegetative cover to the city yields and, on average, a 7% reduction in mortality during heat events.

A number of programs have demonstrated that reflective surfaces can reduce indoor air temperatures. In Philadelphia, the Energy Coordinating Agency upgraded rowhomes with a white roof coating and taught residents the proper use of window fans. They find air temperature reductions from these upgrades in the upstairs rooms of 5 °F (2.7 °C) (Kirn 2006).

As noted in the previous section, urban greening efforts reduce the concentrations of particulate matter in the atmosphere, which lowers the risk of cardiovascular and heart disease. Fine particulate matter, measuring less than 2.5 μm in diameter (e.g., $PM_{2.5}$), is the most harmful as their small size allows them to lodge deep inside the lungs. In a survey of nearly 1600 cities, the World Health Organization (2018) finds that only 12% of the urban population lives in areas that are below recommended $PM_{2.5}$ levels. Over 700,000 premature deaths globally each year are attributed to exposure to $PM_{2.5}$ (The World Health Organization 2018). Anderson et al. (2012) review the literature from the last 30 years on the health effects of $PM_{2.5}$ and conclude that the particles have a "consistent and significant" effect on human health, most prominently through their link to cardiovascular disease, that results in a "large global public health burden" (p. 172). McDonald et al. (2014, p. 29) estimates that tree planting could reduce $PM_{2.5}$-related deaths by as much as 8%, not considering potential reductions in other cardiovascular diseases.

Limiting the scope of health effects to avoided deaths, cool city strategies have the potential to generate large monetary savings; the U.S. Environmental Protection Agency (EPA) (n.d.) values a statistical life at $9.2 million (2016 USD) to measure mortality risk reductions in its own cost–benefit analyses. For example, Mills and Kalkstein (2009) evaluate Philadelphia's urban heat mitigation plan and find that reduced mortality from extreme heat would be valued between $0.74 billion and $1.69 billion ($2006).

Other benefits

Urban heat, if left unchecked, will increase the cost of climate change for cities by 260% by 2100. Estrada et al. (2017) study 1700 cities and find that local climate change and urban heat will cost the median city approximately 5.6% of their gross domestic product (GDP)—a price tag measured in hundreds of billions or even trillions of dollars globally.

Even at moderate levels of deployment, cool city strategies can deliver energy savings, peak electricity demand reductions, improvements to health and air quality, and other benefits accruing from installations that are worth billions of dollars to local economies. Increasing the solar reflectance of just 20% of a city's roofs and half of its pavements could save up to 12 times what they cost to install and maintain and reduce air temperatures by about 1.5 °F (0.8 °C) (Estrada et al. 2017). For the average city, such an outcome would generate over a $1 billion in net economic benefits and is a very realistic target if existing cool city strategies best practices are adopted.

The improvements in air quality resulting from reductions in urban air temperatures that are possible from moderate deployment of cool city strategies also have a substantial economic benefit. Akbari (2005) summarizes some of the economic impact studies of reduced health care costs and improved productivity that result from reducing air temperatures in cities. McDonald et al. (2014) points to similarly substantial economic benefits from improved air quality. One analysis finds that converting a 1 ft^2 of dark roof to a reflective surface would generate $2.67 ($29.02 per m^2) of economic benefit,

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just from reduced particulate and ozone concentrations (Kats and Glassbrook 2016). Overall, Kats and Glassbrook (2016) find a cool roof delivers over $5 a square foot ($54 per square meter) in net benefits. Kardan et al. (2015) finds that people that live in areas with higher densities of trees have higher health perceptions; the addition of ten trees on a city block can improve an individual's health perception in a way that is comparable to a $10,000 increase in annual income.

Other effects of heat on utilities

This paper focuses on making the case for customer-focused programs to reduce excess heat through the lenses of various cost-effectiveness tests. This section looks at some additional reasons why utility efforts to mitigate excess heat would make sense.

Improving accuracy of capital planning

Heat mitigation efforts may be viewed as part of a bigger strategy to reduce utility capital investment requirements. Changes in local climates, particularly rapid heating, will dramatically impact demand for energy in the future. Globally, the demand for air conditioning will require a multi-trillion dollar investment in new generation that will equal the installed capacity of the USA, Europe, and India combined (Organization of Economic Cooperation and Development (OECD) and International Energy Agency 2018). There is increasing understanding that the climate prevalent historically will likely not reflect the climates of the future and that "backcasting" for demand predictions will systematically underestimate the energy needs of the future. As efficiency programs have long demonstrated, it is less expensive to not produce a kilowatt-hour than to produce one.

Reduced utility business risk

Beyond the grid resilience effects noted in the program section above, heat mitigation programs can benefit utility efforts to reduce wildfires and effects of planned and unplanned outages on customers and potentially reduce utility liability risks from wildfires. In 2018, the State of California determined that electric power and distribution lines, conductors, and power poles caused 12 wildfires in Northern California in 2017 (California Department of Forestry and Fire Protection 2018). Williams et al. (2015) showed that nighttime increases in surface temperature, driven, in part, by urbanization, were associated with increased cloud height and a reduction in fog occurrences in the Los Angeles area. Reduced cloud cover has been associated with increased risk of wildfires in the same area (Williams et al. 2018).

Reduced credit risk

A number of the effects of excess urban heat included in the cost-effectiveness tests could also have an impact on the credit risk of the utility itself. On the balance sheet, excess heat puts transmission and distribution infrastructure at greater risk of failure that could result in impaired assets for the utility. The burdens of financing new generation to meet cooling energy demand may have negative effects on borrowing capacity and increase liabilities. The broader negative economic impact of unchecked urban heat will limit willingness and ability of customers to support future rate increases. If utilities have a harder time securing timely rate increases to fund the necessary generation capacity needed to meet unchecked urban heat, it could leave them in a challenging performance dilemma. Investor organizations such as the Institutional Investors Group on Climate Change and the Investor Network on Climate Risk have called on utilities to undertake "stress tests" to assess how their portfolio and practices will contribute to limiting global temperature increases to under 2 °C in order to manage carbon asset risk. Programs contributing to urban heat mitigation could contribute to a utility's performance on such a stress test (Investor Network on Climate Risk 2016). Implementing even marginal steps to reduce the need for climate regulation will be a valuable mitigation effort. Taken together, these factors could weigh negatively on risk assessments by credit rating agencies and have substantial effects on the viability of utilities.

High level recommendations

Rebate programs

Rebates can help defray the cost premium that still exists for certain types of cool roof options over traditional ones (primarily in asphalt shingle markets). While rebates have been paid out of general municipal funds in some places (e.g., Louisville, Toronto), they have been funded out of utility funds in others (e.g., Los Angeles Department of Water and Power, Pacific Gas and Electric, Sacramento Municipal Utility District, Progress Energy Florida, Public Service Enterprise Group Long Island). The Cool Roof Rating Council website has gathered an even larger number of municipal and state government programs that subsidize cool roofs as part of broader residential and commercial energy performance programs (Cool Roof Rating Council n.d.).

Tree planting and maintenance programs

To date, a number of public utilities have adopted shade tree programs. The oldest and the largest of these programs is the Sacramento Shade Tree Program, commonly referred to as Sacramento Shade, which began in 1990. To date, Sacramento Shade has planted over half a million trees throughout Sacramento County. Sacramento Shade continues to run today; current Sacramento Municipal Utility District (SMUD) customers are eligible for up to ten free shade trees for their property (SMUD 2018). Ko et al. (2015) analyzed 22 years of tree survival, tree growth, and energy savings related to the program. The authors found that Sacramento Shade had a 22-year post-planting tree survival rate of 42% and that annual energy savings related to the program were 107 kWh per property and 80 kWh per tree. Since 1990, other utilities have followed suit and adopted their own shade tree programs, such as Salt River Project (AZ), Cedar Falls Utilities (IA), Tacoma Public Utilities (WA), Burbank Water and Power (CA), Columbia Water & Light (MO), and Riverside Public Utilities (CA).[3] To date, there are far fewer examples of shade tree programs being adopted by private utilities which is, in part, a sign of reluctance to incorporate trees into cost–benefit analyses.

Customer outreach and awareness

Roofing decisions are infrequent and, particularly for residential customers, informed solely by the contractor doing the work. Utilities have unique access to customers in the form of the monthly bill that could be leveraged to message cool roofing options. Utilities may also message cool roofing as part of a number of efficiency improvements that can help building owners reduce monthly costs or to qualify for whole building energy performance incentive programs. There is a similar opportunity related to trees. In order for trees to be most effective at reducing energy costs, the appropriate tree must be selected and it must be planted in the appropriate place. For example, one needs to ensure that the mature height of tree is enough to provide adequate shade and that the tree is placed in the best location for residential shading. To help overcome these challenges, many of the public utility shade tree programs require participating households to receive a home visit from a trained arborist or forester who helps them choose the appropriate location for the tree. In Burbank, CA, participating households are charged $90 if they do not plant their shade tree in the pre-determined site (Burbank Water and Power 2019, see footnote 3). Mailed coupons can also make it easy for households to participate in a shade tree program. In Cedar Falls, IA, residential customers are only required to ask the retailer for the "Cedar Falls TREES Plant-A-Tree" discount when purchasing a tree from a participating retailer (Cedar Falls Utilities 2019, see footnote 3). In all cities, engaging households so that they understand the importance of shade trees, and how to best care for their shade trees, is critical to the success of the program.

Participating in inter-agency collaborations

A number of cities, including Los Angeles, New York, Louisville, and Washington, DC, have established multi-agency platforms for evaluating and acting on the challenge of excess heat. These efforts are organized in a variety of different ways, ranging from informal working groups to official technical advisory groups. Utilities have an important role to play in the process by providing energy data, access to customer communications channels, and implementation options.

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[3] Examples are based on a review of utility websites. See: Salt River Project: https://www.srpnet.com/energy/rebates/shadeTrees.aspx; Cedar Falls Utilities: https://www.cfu.net/save-energy/shade-tree-discounts/; Tacoma Public Utilities: https://www.mytpu.org/save-energy-money/shade-tree-program.htm; Burbank Water and Power: https://www.burbankwaterandpower.com/incentives-for-residents/shade-tree-program; Columbia Water and Light: http://www.columbiapowerpartners.com/residential/residential-tree-power/; and Riverside Public Utilities: https://www.riversideca.gov/utilities/pdf/NewsLetter/2016/March-2016-Back-of-Bil.pdf. Last accessed March 4, 2019.

Conclusion

Cool city strategies offer energy efficiency improvements with a broad and substantial set of additional co-benefits but, currently, are not widely implemented through private utility programs. In addition to the benefits of reduced energy use, cool city strategies deliver societal benefits such as health improvements, air and water quality improvements, and enhanced resiliency to climate change. This paper highlights the direct and measurable benefits unique to cool city strategies as an energy efficiency program, such as base and peak energy demand reductions, energy price suppression, and utility system resiliency, and layers on additional utility-relevant benefits to health, air and water quality, stormwater management, and equity. Taken together, the benefits of cool city strategies present a significant economic opportunity for utilities and their customers. Future work to refine designs for cool city utility programs with this body of research in mind is a priority next step.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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