GOOD PRACTICE GUIDE

Cool Cities

C40 CITIES
CLIMATE LEADERSHIP GROUP

C40 Cities Climate Leadership Group

The C40 Cities Climate Leadership Group, now in its 10th year, connects more than 80 of the world's greatest cities, representing 600+ million people and one quarter of the global economy. Created and led by cities, C40 is focused on tackling climate change and driving urban action that reduces greenhouse gas emissions and climate risks, while increasing the health, well-being and economic opportunities of urban citizens. www.c40.org

The C40 Cities Climate Leadership Group has developed a series of Good Practice Guides in areas critical for reducing greenhouse gas emissions and climate risk. The Guides provide an overview of the key benefits of a particular climate action and outline successful approaches and strategies cities can employ to implement or effectively scale up these actions. These Guides are based on the experience and lessons learned from C40 cities and on the findings and recommendations of leading organisations and research institutions engaged in these areas. The good practice approaches are relevant for cities engaged in C40 Networks as well as for other cities around the world.

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EXECUTIVE SUMMARY

Cities are 5 to 9 degrees Celsius (9 to 16 degrees Fahrenheit) warmer than rural areas because of several reasons. Not only do built environments emit heat[i] and urban surfaces absorb more sunlight and heat than natural landscapes, but urban areas also lack vegetation to cool through evaporation. This phenomenon, termed "urban heat island effect," triggers an increase in building energy use and air pollution, reduces the quality of urban life, and increases urban health issues and mortality rates, especially when paired with heat waves and uncommon periods of heat.

Surface cooling can deliver significant benefits to cities in addressing both urban heat island effect and heat waves. Surface cooling solutions are often simple, cost-effective, and available throughout the world. Roofs and pavements cover about 60% of urban surfaces (with roofing typically accounting for between 20–25% of urban surface, and paving about 40%), and absorb more than 80% of the sunlight that contacts them and is then converted to heat.[ii] Apart from introducing surface cooling for roofs and pavements, depending on the city, a substantial portion of the remaining surface area can also be utilized, as it presents an opportunity for parkland or other green landscaping.

This Good Practice Guide focuses on the key elements to support cities in the launch and implementation of successful cool surface programs, leading to better economic, social, and environmental outcomes for cities. These good practice approaches include:

- **Make the cool surface business case to property owners**
- **Incorporate cool options with other larger/long-term infrastructure projects**
- **Undertake public outreach and awareness raising**
- **Identify cooling co-benefits and pair with related projects**
- **Offer incentives to implement cool solutions**
- **Develop legislation requiring cool components**

The C40 Cool Cities Network, launched in 2012 in partnership with the Global Cool Cities Alliance[iii], was established to increase C40 cities' understanding of the urban heat island effect and to support the launch and implementation of successful cool surface programs.

The purpose of this Good Practice Guide is to summarise the key elements of cool cities good practices for global dissemination, highlighting the success of C40 cities in planning and delivering cool surface solutions.

1 BACKGROUND

1.1 Purpose

C40 Cities Climate Leadership Group has developed a series of Good Practice Guides in areas critical for reducing GHG emissions and managing climate risks. The C40 Good Practice Guides provide an overview of the key benefits of a particular climate solution and outline good practice principles based on activities and strategies successfully employed by C40 cities. These Guides are based on the experience and lessons learned of C40 cities working together in specific C40 networks, and also draw on findings and recommendations of leading organizations and research institutions engaged in these areas.

The following Good Practice Guide focuses on the key approaches to launch and implement successful cool surface programs, leading to better economic, social, and environmental outcomes for cities. These approaches are drawn from the experiences of cities engaged in the C40 Cool Cities Network and are relevant for cities around the world.

1.2 Introduction

Cities are 5 to 9 degrees Celsius (9 to 16 degrees Fahrenheit) warmer than rural areas because of several reasons. Not only do built environments emit heat[iv] and urban surfaces absorb more sunlight and heat than natural landscapes, but urban areas also lack vegetation to cool through evaporation, Additionally, urban activity – including the use of vehicles, industry and air conditioning – generates excess heat. This phenomenon, termed “urban heat island effect (UHI)”, triggers an increase in building energy use and air pollution, reduces the quality of urban life, and increases urban health issues and mortality rates. As major cities globally are experiencing increasing urban heat island effect and more extreme heat events due to global warming and changing weather patterns, addressing these hazards through cooling techniques and strategies is a key way to undertake urban climate change adaptation while often directly reducing greenhouse gas emissions and offsetting global temperature increases.

2 SURFACE COOLING AND CLIMATE CHANGE

2.1 Why cool?

Three out of five (or 60%) of C40 cities that reported to CDP[v] in 2014 perceived increased urban heat island effect or more hot days as a serious or extremely serious climate change effect. These heat-related concerns ranked as the second and third most reported climate change effects facing C40 cities, with more frequent heat waves and hotter summers not falling far behind.

At C40, 21 cities have already prioritized heat as a major concern and are working collectively to address urban heat island effect and extreme heat events in their cities through the Cool Cities Network, a collaboration between C40 and the Global Cool Cities Alliance. The Cool Cities Network aims to assist cities in designing and implementing solutions-oriented approaches to promote sustainability by lowering urban temperatures and sharing the benefits of cooling.

2.2 Why focus on surface solutions?

Roofs and pavements cover about 60% of urban surfaces (with roofing covering 20–25% and paving covering about 40%), and absorb more than 80% of the sunlight that contacts them and is then converted to heat.[vi] Depending on the city, a substantial portion of the remaining surface area of the city often presents an opportunity for parkland or other green landscaping. The presence and use of water is another important consideration in the design and deployment of surface cooling.

Surface solutions are often readily deployable, simple, and cost-effective technologies available throughout the world. Surface Cooling Good Practice Design in C40 cities can be classified into two main categories: up on the rooftops, and down on the ground. Solutions at each level mirror one another. In some cases "cool" reflective or otherwise non-vegetative solutions are the best, in others green vegetative solutions are more effective or provide additional benefits. When addressing either type of solution though, the presence or application of water is an important consideration, as it sometimes provides additional cooling benefits while in other cases it can increase the experienced heat.

2.3 Rooftops

Cool roofs: A cool roofing surface is both highly reflective and highly emissive to minimize the amount of light converted into heat and to maximize the amount of heat that is radiated away. Most existing roofs are dark and reflect no more than 20% of incoming sunlight, while a new white roof reflects about 70 to 80% of sunlight. Because of this, new white roofs are typically 28 to 36 degrees Celsius (50 to 65 degrees Fahrenheit) cooler than dark roofs, while aged white roofs are typically 20 to 28 degrees Celsius (35 to 50 degrees Fahrenheit) cooler. In addition to cost savings from reduced air-conditioning, cool roofs also improve the life of the roof and performance of rooftop equipment, such as solar PV panels.[vii]

Green roofs: A green roof is a vegetated landscape built up from a series of layers that are installed on a roof surface. Covering a roof with a layer of vegetation that shades building materials, which would otherwise absorb heat, can reduce temperatures. Evapotranspiration provides cooling effect, as water is evaporated from the soil and plants that transpire by taking water in through roots and releasing it through leaves, a process that uses the ambient heat and consequently lowers surrounding temperatures. Another cooling design feature of green roofs is to leave a gap between the roof and the plantings so that hot air can move up and out of the building by convection, providing passive cooling.[viii]

Green roofs offer numerous benefits in addition to cooling. Green roofs can help to manage and clean stormwater, clean pollutants from the air, extend the lifespan of many roofs by protecting the roofing membrane from solar radiation, allow for the creation and preservation of biodiversity, and provide additional open spaces in a city and/or a space for food production. They have been also found to increase property values[ix].

2.4 On the ground

<u>Cool paving:</u> Conventional paving materials can reach peak summertime temperatures of 50 to 65 degrees Celsius (120 to 150 degrees Fahrenheit), heating the air above them[x]. There are many kinds of paving options that are lighter in colour and create more reflective paved surfaces. Additionally, many kinds of permeable pavements, including reinforced grass pavements, can also cool a pavement surface through the evaporation of moisture stored in the pavement.

<u>Parks and other green landscapes</u>: Planting and maintaining an urban tree canopy is another way to cool cities. Trees cool cities by shading the ground and structures around them but also through evapotranspiration. Studies indicate that tree groves can be 5 degrees Celsius (9 degrees Fahrenheit) cooler than open ground around them.[xi]

2.5 Considering water

In some cases, the application of water creates additional cooling through evaporation and improved evapotranspiration of vegetation. Cities often introduce water features (fountains and pools) or introduce pavement water sprinkling systems or events to cool residents during hot periods. However, in other urban cases, standing water or excess evaporated water increases humidity and can actually lead to higher experienced temperatures. There is also some research underway on the relation of groundwater level and heat that may provide some additional insight to cities with variable water tables.

2.6 Benefits of cooling

Research from the Global Cool Cities Alliance's *Practical Guide to Cool Roofs and Cool Pavements*[xii], has identified among others the following key benefits of cooling, which are confirmed by C40 cities' experience:

<u>Reduced summer heat island effect</u>: Reducing urban temperatures during warm or hot parts of the year makes cities more liveable and leads to healthier populations. Surveys of U.S. cities have found that citywide installations of cool roofs, pavements, and shade trees can reduce ambient air temperature by 2 to 4 degrees Celsius (4 to 9 degrees Fahrenheit) during the warmer summer months.[xiii]

More resistant to heat-related deaths: Cooling is also important to reducing the risk of death during heat waves. Heat waves have claimed thousands of lives in the U.S., France, Russia, India, and elsewhere. Heat and the higher air pollution levels associated with urban heat islands can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, heat stroke, intestinal disease from food spoilage, and heat-related mortality. Urban heat islands exacerbate the impact of heat waves. Vulnerable populations, often children, older adults, and those with existing health conditions, are at particular risk from these events.[xiv]

In the U.S., an average of 400 deaths each year are directly related to heat[xv] and many more—an estimated 1,800—perish from a range of illnesses that are exacerbated by heat stress.[xvi] In the Chicago heat wave of 1995, there were 739 fatalities almost all on the top floors of buildings with dark roofs.[xvii] The average annual death toll from heat far exceeds that of any other natural disaster in the U.S. The District of Columbia is also susceptible to extreme heat events, whose health impacts are exacerbated by the fact that the city is often significantly warmer than surrounding rural areas during the summer. During the decades between 1948 and 2011, an average of 285 people died of heat-related causes. A study done in 2014 by the Global Cool Cities Alliance in partnership with the University of Miami Miller School of Medicine[xviii] found that a 10-percentage point increase in urban surface reflectivity could reduce the number of deaths during heat events by an average of 6%. Adding a 10% increase vegetative cover to the increases in reflectivity yielded an average 7% reduction in mortality during heat events.

Improved air quality*:* Cooling also improves urban air quality because ozone or "smog" forms more rapidly on hot days. Ozone pollution is a major contributing factor to respiratory illness, which the World Health Organization predicts will be the third leading cause of death by 2030.[xix] A simulation done in Los Angeles found that citywide deployment of lighter surfaces and shade trees could cool temperatures and thus reduce smog in concentrations by 10 %.[xx]

Improved thermal comfort: In a building that is not air conditioned, replacing a dark roof with a white roof can cool the top floor of the building by 1 to 2 degrees Celsius (2 to 3 degrees Fahrenheit),[xxi] making the top floors of these buildings more comfortable and safe during heat waves. Cooler roofs can also be used as an extra living space in hotter climates (especially at night).

Energy efficiency and greenhouse gas emissions: One of the key benefits of surface cooling in cities with air-conditioned buildings is the reduction in energy expenditure from air-conditioning (AC) units and in the related greenhouse gas emissions attributed to the energy consumption. In U.S. cities, it has been estimated that urban heat island effect contributes to between 5 and 10% of citywide demand for electricity. Globally, there is a growing market for air conditioning as a first response to hot indoor temperatures, particularly in rapidly developing countries like India and China. Air conditioning is an expensive and energy intensive cooling strategy that taxes electric grids and often results in more heat being generated overall. Cool roofs and pavements are a cheaper alternative that could forestall the purchase of AC units. A cool roof for example can reduce air conditioning costs by as much as 20% in a single-story building.[xxii]

Reduced peak electricity demand: During extreme heat events, an excess demand for air conditioning can overload electricity supply systems and cause blackouts or lead to rolling brownouts.[xxiii] Research indicates that peak electricity demand increases by 2 to 4% for every 0.5 degrees Celsius (1.8 degrees Fahrenheit) increase in temperature above a threshold of about 15 to 20 degrees Celsius.[xxiv] Cool surfacing, through reducing the demand for air conditioning during these peak heat periods, can improve power utility capacity utilization, reduce transmission lines congestion, avoid congestion pricing, and eliminate the need for additional investments in peaking generation capacity. A study in Los Angeles found that a reduction of 3 degrees Celsius (5.4 degrees Fahrenheit) through cool surfaces could reduce peak power demand by 1.6 Gigawatts, resulting in savings of about $175 million per year (at 1996 energy prices).[xxv]

Global greenhouse gas reduction potential: Replacing the world's roofs and pavements with highly reflective materials could have a one-time cooling effect equivalent to removing 44 billion tonnes of CO_2 from the atmosphere, an amount roughly equal to one year of global man-made emissions.[xxvi] Assuming the average car emits 4 tonnes of CO_2 per year, the combined "offset" potential of replacing the world's roofs and pavements with highly reflective materials is equivalent to taking all of the world's approximately 600 million cars off the road for 20 years.[xxvii]

These findings are supported by case studies and examples emerging from across C40 cities, some of which are detailed below.

3 GOOD PRACTICE APPROACHES TO SURFACE COOLING

3.1 Categories of best practice

Within the Cool Cities Network, several complementary approaches have been identified for using cool and green roofs and surfaces to reduce the urban heat island effect within cities. The mix of strategies a city chooses to deploy to reach its goal depends on:

- Powers that cities have over building codes or other building regulation
- Building types and ownership structures
- Public interest and political will
- Degree of experience, capacity and resources within a city government
- Interest in possible co-benefits of the project (economic returns, energy savings, health and mortality, comfort)

- Degree of long-term vs. short term urban development planning
- Climate conditions/seasonal variation
- Market availability of urban heat reducing technologies and services
- Cost of energy (for cooling)

In order to address these issues and deliver effective cooling, a few key best practice approaches that cities have highlighted include:

- **Make the cool surface business case to property owners**
- **Incorporate cool options with other larger/long-term infrastructure projects**
- **Undertake public outreach and awareness raising**
- **Identify cooling co-benefits and pair with related projects**
- **Offer incentives to implement cool solutions**
- **Develop legislation requiring cool components**

C40 has identified case studies that sit in each of these categories, and demonstrate best practice for the cities in the Cool Cities Network.

3.2 Make the cool surface business case to property owners

Making the business case for private-sector action is an effective strategy when a cooling project would generate economic returns to the building or infrastructure owner or occupant, but where they are otherwise unaware of the opportunity or unconvinced of the potential returns. The business case can be a useful approach especially when dealing with private property owners and managers, where economic returns can be generated from reductions of air-conditioning energy consumption, from extended roof or building equipment life and performance, and/or increased amenity space or property value.

In this approach, city government can directly perform opportunity audits, or work with a third party to assess the business case potential of introducing cool surface solutions in individual cases.

Case study: *London*[xxviii] *- Greening the BIDs*

Summary: The Greater London Authority (GLA) is working with Business Improvement Districts (BIDs) in central London to identify and then deliver opportunities for increasing green cover. The 'Greening the BIDs' project has supported 15 green infrastructure audits and part-funded demonstration projects with the aim of catalysing urban greening in central London. This will help deliver Mayoral objectives to increase green cover to reduce the Urban Heat Island effect and tackle local surface water flooding, while enhancing the beauty of London.

Results: In total over 500 hectares have been audited through Greening the BIDs, identifying the potential for over 300 rain gardens, 200 green walls and more than 100 hectares of green roofs, as well as other small-scale interventions such as planters and window boxes. These audits have revealed the potential to introduce 1 million m^2 of new green cover. Greening the BIDs has successfully generated interest in and awareness of urban greening. This in turn encourages businesses to invest in green infrastructure as part of their longer-term refurbishment and regeneration strategies.

Reasons for success: This project was a success because it put the co-benefits of greening at the forefront, showing that "greening is good for business". Increasing green infrastructure not only makes areas more attractive to business – both workers and clients/shoppers, but also increases property value and rental incomes, while helping urban areas to be more resilient to extreme weather events, thus helping to preserve economic sustainability. Another reason for the success of the project was that it approached it from the angle of economic value, rather than just environmental impacts, and the implementers spent time confirming that value was what BID managers were looking for before launching the project.

When/why a city might adopt an approach like this: This approach works well where cities have limited control over building regulation or there is limited popular support or understanding of co-benefits of greening (including cooling). It also requires a high degree of capacity within government to undertake these audits or collaborate with a third party to perform the audits.

3.3 Incorporate cool options with other larger/long-term infrastructure projects

Incorporating cool infrastructure options with other larger or long-term infrastructure projects can provide easy opportunity to develop cool solutions. This can simplify the process of making a business case for cool solutions and securing funding.

Case study: *Tokyo - Thermal-barrier Coating and Water-retentive Pavement*

Summary: Tokyo Metropolitan Government (TMG) is promoting cool pavements by including thermal-barrier coating and water-retentive pavement installation as a part of road maintenance and construction within the priority areas in central Tokyo. TMG has coupled these innovative pavements with the upcoming summer Olympics by building them along the marathon tracks for the games and on roads around the venues. Since the Metropolitan roads were being updated, the city has incorporated the pavements as a part of road maintenance and construction. For the municipality roads, TMG is providing subsidy for Thermal Barrier Coating pavements.

Results: The project has supported development of 84 kilometres of cool pavements with 65 kilometres of thermal-barrier coating pavements and 19 kilometres of water-retentive pavements. TMG plans to expand these by 10 kilometres every year until 2020 with a target of 136 kilometres of cool pavements by 2020. The thermal barrier coating reduces the surface temperature and makes it at most 8 degrees Celsius cooler than a regular asphalt pavement.

On the other hand, water-retentive pavements suppress the temperature rise of road surfaces to a maximum of 10 degree Celsius through water evaporation.

Reasons for success: This project was a success because it coupled the environmental benefits of cool pavements with larger infrastructure projects. Incorporating the cool pavements into the development plans for the Olympic games and providing subsidies for municipality roads made the project easier to implement. It 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. In addition, the availability of cutting edge technology, such as water-retentive pavements, was also a considerable factor in making it a success.

When/why a city might adopt an approach like this: This approach works well in cities where large/long-term infrastructure projects are underway or planned, and the city has control over the technology and procurement decisions for these projects. It also requires access to technology in order to implement an array of solutions.

3.4 Undertake public outreach and awareness raising

Engaging in public outreach and awareness raising through demonstration projects or dissemination of “how to” cooling guidelines and standards can provide an impetus for voluntary public uptake.

Case study: *Melbourne*[xxix] *- Growing Green Guide*

Summary: Melbourne released the Growing Green Guide[xxx] in February 2014 to promote green surfaces and provide technical advice on how to design, build and manage green roofs, walls and facades so they can provide multiple long-term benefits for building owners and the wider community. The Guide has been developed as a first policy response for Melbourne, which is facing a doubling of population over the next 30 years and increased urban heat island effect, and is therefore highly at risk from heat-related deaths in the future.

Results: There are currently around 50 green walls, 100 green roofs and many green facades across Melbourne – and the numbers are growing.

Reasons for success: Melbourne conducted extensive public review through public meetings and sharing the guide with the citizens. An active review period was allowed for input from multiple stakeholders. The Guide is accessible to public and does not assume significant prior knowledge.

When/why a city might dsopt an approach like this: Cities that plan to introduce heat mitigation policy can develop guidelines that share a range of research, practical advice, and models of how to implement vegetation cover in their cities. This strategy works in a variety of conditions, but is especially effective when regulatory codes or other public guidance and resources may be lacking, but there is otherwise public ability, interest and willingness to undertake cool surfacing. To be effective, this strategy requires high public communication capacity of the government or the assistance of a third party. Public engagement is likely to be most effective when the business case can be made or other co-benefits identified. This is also a good solution where there may be limited regulatory authority over buildings.

3.5 Identify cooling co-benefits and pair with related projects

Identifying the co-benefits of a cooling project is an excellent strategy to increase enthusiasm and political will, as well as to identify the budgetary resources needed to undertake cooling projects. For example, if the health, water management, energy reduction, and job creation opportunities or other benefits of cooling strategies can be clearly expressed, cross-agency collaboration and co-resourcing becomes possible.

Case study: *New York[xxxi] - NYC °CoolRoofs Programme*

Summary: The NYC °CoolRoofs programme[xxxii] encourages and facilitates the cooling of New York City's rooftops through its "Cool It Yourself" [xxxiii] programme for private installations and through volunteer and green workforce programmes for public buildings and properties that may not otherwise have access to energy-saving benefits.

Results: The NYC °CoolRoofs Programme, launched in 2009, has coated over 5.7 million ft^2 (around 530,000 m^2) of rooftop (626 buildings) with a white, reflective coating, offsetting the urban heat island effect and thereby cooling the city. The programme provides benefits and savings directly to the building owner by reducing cooling costs by 10-30% and has proved to be an effective way to help tackle the urban heat island effect and reduce GHG emissions.

Reasons for success: The successful uptake of the NYC °CoolRoofs Programme has resulted, in part, from low-income, non-profit, and public building owners having no costs, or overheads to bear during the installation process. In addition to the environmental benefits, there are social benefits to New York due to the unique social design that coordinates civic-minded volunteerism and provides green job training. This type of arrangement can be effective even when there is limited regulatory authority over the building sector (which, however, is not the case in New York).

When/why a city might adopt an approach like this: This type of solution works well when a city does not have a budget earmarked for cooling but has other resources to contribute – such as a volunteer force or training programmes that can be mobilized and matched with building owners. The City of Pittsburgh[xxxiv], and the City of Phoenix[xxxv] have both found elements of this approach useful and have introduced Cool Roofs Volunteer Programs.

3.6 Offer incentives to implement cool solutions

Offering incentives (financial or non-financial) works well when the business case is not strong or otherwise financing cool surfaces is a barrier. Financial incentives can be direct, such as a subsidy or a grant, or indirect, such as a rebate. The financing strategy works when economic returns from a project do not outweigh costs, but with additional subsidy, the project breaks even or is otherwise attractive to the property owner. Non-financial incentives -- such as an extra allowance of buildable floor area -- works when private real estate developers and property owners are looking for development bonuses and are especially effective in cities with significant new development.

Case study: *Toronto*[xxxvi] *- Eco-Roof Incentive Programme*

Summary: The City of Toronto launched the Eco-Roof Incentive Programme[xxxvii] in 2009 to encourage the uptake of eco-roofs by building owners, make buildings more sustainable and promote the creation of green jobs. The Programme provides grant funding for building owners to install new roofing materials – green roofs with living plants and cool roofs that reflect solar heat – that provide environmental benefits and build resilience. Eligible buildings include existing residential, industrial, commercial and institutional buildings, as well as new buildings not subject to the Green Roof Bylaw (otherwise requiring green roofs on new construction over 2,000 m^2)[xxxviii].

Results: Since the introduction of the Eco-Roof Incentive Programme in 2009, the programme has avoided 106 tonnes of GHG emissions and established 233,000 m^2 (2,507,991 ft^2) of eco-roof space (cool + green).

Reasons for success: The programme is self-sustaining with funding coming from fees paid by developers under the cash-in-lieu policy of the Green Roof Bylaw. Additional reasons for success include the inclusion of new smaller buildings (under 2,000 m^2) that are not required to build a green roof under the Green Roof Bylaw and might otherwise struggle with the costs of the eco/green-roofs. There was also consultation done with the roofing sector to raise awareness of the grant program.

When/why a city might adopt an approach like this: This approach may be particularly effective for cities with the budget to provide financial incentives or creative offset schemes to pass along the revenues from fees or fines by those who cannot meet the greening requirements to those that can. It can also be used by cities without strong planning powers or by any city looking to target existing buildings or smaller buildings that might struggle with the costs of eco/green-roofs.

3.7 Develop legislation requiring cool components

If a city has enough legislative authority, it can introduce certain cooling requirements into its building code, energy code or through other decrees, codes or ordinances. If this falls outside the municipality's power, the state or a regional legislative body can be leveraged to introduce greening, green roofs, cool roofs or cool pavements as part of a larger regional strategy.

Case study: *Tokyo*[xxxix] *- Nature Conservation Ordinance*

Summary: Since 2000, the City of Tokyo has been taking measures to mitigate the impacts of the urban heat island effect, including covering roofs and walls with greenery in order to lower the surface temperature of buildings. To further these efforts, the Tokyo Metropolitan Government passed the Nature Conservation Ordinance in 2001, requiring the greening of building roofs and walls in addition to ground-level greenings for all new construction and existing buildings undergoing renovations.

Results: The building sector is heeding local government's requirements to implement green roofs. Thanks to the Ordinance, more than 5,700 new or existing buildings have added about 180 hectares (1,800,000 m^2) of green roofs. Promoting the greening of existing buildings has 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 surface temperature by 25 degrees Celsius and ceiling temperature by 1 to 3 degrees Celsius even under thermal insulation.

Reasons for success: In this case, strong regulatory authority that enabled a mandatory requirement to implement green roofs was heeded by the building sector. The Tokyo Metropolitan Government also did media outreach and advertised the Conservation Ordinance and compliance requirements widely.

When/why a city might adopt an approach like this: This type of approach works best when a city has strong legislative authority and enforcement over the building sector. Apart from that, having a strong regulatory authority to ensure adoption of the regulation - and if necessary enforcement of the regulation - is crucial to the success of similar measures.

4 FURTHER READING

A number of external organizations, including C40 partners, have published best practice guidance in several cooling-related areas, including:

- A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance, available at http://www.coolrooftoolkit.org/read-the-guide/

- The Global Cool Cities Alliance Toolkit, which contains a collection of cool roof and cool pavement solutions and strategies, available at http://www.coolrooftoolkit.org/

- The United States Environmental Protection Agency's Reducing Urban Heat Islands: Compendium of Strategies, available at http://www.epa.gov/heatisland/resources/pdf/BasicsCompendium.pdf

- Growing Green Guide: A Guide to Green Roofs, Walls and Facades in Melbourne, Australia. February 2014 (State of Victoria through the Department of Environment and Primary Industries 2014), available at http://www.growinggreenguide.org/

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[i] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Akbari, H. Rosenfeld, A., & Menon, S., (2009). Global cooling: Increasing world-wide urban albedos to offset CO2. Climatic Change 94 (3-4), pg 5

[ii] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Akbari, H. Rosenfeld, A., & Menon, S., (2009). Global cooling: Increasing worldwide urban albedos to offset CO2. Climatic Change 94 (3-4), 275-286.

[iii] http://www.globalcoolcities.org

[iv] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Akbari, H. Rosenfeld, A., & Menon, S., (2009). Global cooling: Increasing world-wide urban albedos to offset CO2. Climatic Change 94 (3-4), pg 5

[v] https://www.cdp.net/en-US/Respond/Pages/CDP-Cities.aspx

[vi] Akbari, H. Rosenfeld, A., & Menon, S., (2009). Global cooling: Increasing worldwide urban albedos to offset CO2. Climatic Change 94 (3-4), 275-286 and A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012).

[vii] Cool Cities Primer, p 13.

[viii] Growing Green Guide: A Guide to Green Roofs, Walls and Facades in Melbourne, Australia. February 2014 (State of Victoria through the Department of Environment and Primary Industries 2014)

[ix] http://www.nps.gov/tps/sustainability/new-technology/green-roofs/benefits.htm

[x] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Akbari, H. Rosenfeld, A., & Menon, S., (2009). Global cooling: Increasing worldwide urban albedos to offset CO2. Climatic Change 94 (3-4), pg 14

[xi] For more information on the costs and benefits of the tree programs see 'Reducing Urban Heat Islands: Compendium of Strategies: Trees and Vegetation' by the U.S. Environmental Protection Agency: http://www.epa.gov/sites/production/files/2014-06/documents/basicscompendium.pdf

[xii] http://www.coolrooftoolkit.org/wp-content/pdfs/CoolRoofToolkit_Full.pdf

[xiii] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas. Solar Energy, 70 (3), 295-310.

[xiv] USEPA Compendium, page 14-15.

[xv] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Allen, A., & Segal-Gidan, F. (2007). Heat-related illness in the elderly. Clinical Geriatrics, 15 (7), 37-45.

[xvi] A Practical Guide to Cool Roofs and Cool Pavements Primer, Global Cool Cities Alliance (January 2012) and Carlson, A. (2007). Heat Waves, Global Warming & Mitigation. Issues in Legal Scholarship, Catastrophic Risks: Prevention, Compensation, and Recovery. Article 7. Retrieved Dec. 2 2011 at www.bepress.com/ils/iss10/art7.

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[xviii] http://www.coolrooftoolkit.org/knowledgebase/health-impacts-of-uhi-reduction-strategies-in-dc/

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