Background Documents

Cooling for All

Cooling Solutions for Urban Environments

MARCH 2018

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ADDRESSING DATA LIMITATIONS

Access to cooling is a new area of investigation and, inevitably, when piloting a new approach not all the data one would wish to examine is neatly lined up, especially when it comes to looking for disaggregated data on vulnerability based on gender, health, and education level.

To support this publication, an extensive data gathering exercise and literature review was undertaken, including a call for data to organizations that may have access to enhanced levels of granularity. The data expressed herein draws on a model produced by SEforALL that is based on data received through that process and data which is publicly available, and given limitations is subject to assumptions and margins of error.

In a nascent field such as access to cooling, it is crucial that organizations be empowered to put concerted efforts in the collection of a more extensive set of **granular and verified data at country level**, as well encouraging organizations with significant non- public datasets to make them available to KCEP and selected partners. This would allow for more detailed access gap quantifications with a lower error margin, in order to inform both discussions with key stakeholders as well as future policy and program design. Organizations that may have the knowledge and capacity to undertake such an effort include: GIZ, CLASP, GAVI, Global Cold Chain Alliance, the Global Food Cold Chain Council, UN Habitat, and the IEA,

COOLING OF URBAN ENVIRONMENTS SOLUTIONS

1. POTENTIAL URBAN DESIGN AND PLANNING SOLUTIONS

Reducing or preventing the urban heat island effect, as well reducing the need for active cooling solutions such as air conditioning to cool buildings, other structures, and vehicles in urban areas will require a rethinking of conventional urban planning and design. This may include measures such as reducing the surface area occupied by impervious, dark colored parking spaces and roads, as well as increasing the amount of vegetation cover; applying lighter colored materials, coatings and paintings to create cool roofs and cool pavements; and smartly using urban form and density to promote natural ventilation as well as a reduction in heat build-up. In addition, cities can leverage district-level opportunities to provide efficient cooling at scale.

Trees and other vegetation

Trees can play a vital role in regulating the temperature in cities. They provide shade, reflect heat, and help cool the air through evapotranspiration. Research undertaken by the UK Forestry Commission has shown that **trees and green[1] infrastructure can reduce urban temperatures by 2 to 8°**C.[i]

According to scientists at the Lawrence Berkeley National Laboratory (U.S.), a program that would focus on establishing 3 shade trees per building in U.S. cities, while making all roofs and pavements reflective could decrease the country's cooling demand by as much as 20%. This would reduce building electricity and vehicle fuel consumption for air conditioning and refrigeration, while increasing the number of days per year when no air conditioning would be required to maintain thermal comfort.[ii]

Singapore in this respect, a city known for its hot, humid weather, introduced in 1967 its '**garden vision**', aiming to become a city with lush, abundant greenery through an intensive tree-planting program. In 1975 the Parks and Trees Act mandated government agencies as well as private developers, to set aside spaces for trees and greenery in projects such as the development of housing estates, and construction of roads and carparks. This has now resulted in the city having over 7 million trees, while the total surface area of parks and green spaces has increased more than 10-fold.[iii]

Similarly, in 2008 **Karachi**'s municipal government in Pakistan launched the **Green Karachi Project**, aiming to turn hundreds of acres of waste land in the city into lush parks and plant large numbers of trees along 24 major roads traversing through the city. Under the project around 20 million saplings will be planted in Karachi. The project is intended to reduce the urban heat island effect, create green recreational spaces for the local community, reduce stormwater runoff and offset GHG emissions. As of 2015 only 140,000 out of an intended 2 million trees had been planted, with cited challenges including a lack of planning in the public sector department, limited space to plant trees as well as limited water sources to irrigate them with a tendency for monocultures of exotic trees rather than indigenous multi-species plantings.[iv]

Although tree planting may indeed suffer from challenges such as limited space in existing landscapes and a potential need for irrigation, especially in the beginning after planting - something that can in part be overcome by using native, drought-tolerant species – a 2016 report by the Nature Conservancy in collaboration with C40 showed that in general **cities stand to benefit from tree plantings, both in terms of heat and particulate matter reduction**. Investing US$4 per resident on tree planting along streets in 245 cities studied could improve the health of millions of people, with trees as cost-effective as many other common solutions to achieve the same outcomes. An ambitious tree planting program in the studied cities could currently reduce high temperature-related mortality by 2.4 –5.6%, a number that is likely to go up as climate change is expected to make heat waves worse.

[1] Green infrastructure refers to an approach to solving urban and climatic challenges by using a 'building with nature' approach. Examples are infrastructure such as swales, wetlands, green roofs and green walls, etc

Global Cities

Top 10 Rankings: Urban Tree Planting ROI

REDUCING URBAN HEAT	REDUCING PARTICULATE MATTER
1. Dhaka, Bangladesh	1. Karachi, Pakistan
2. Mumbai, India	2. Dhaka, Bangladesh
3. Karachi, Pakistan	3. Delhi, India
4. Ho Chi Minh, Vietnam	4. Faisalabad, Pakistan
5. Kathmandu, Nepal	5. Mumbai, India
6. Damascus, Syria	6. Dakar, Senegal
7. Freetown, Sierra Leone	7. Ahmadabad, India
8. Port-au-Prince, Haiti	8. Kathmandu, Nepal
9. Dakar, Syria	9. Cairo, Egypt
10. Faisalabad, Pakistan	10. Freetown, Sierra Leone

Figure 1 Top 10 rankings for return on investment of planting trees along streets[v]

The biggest calculated returns on investment (ROI) were in South Asia and Africa, as a result of high pollution levels, warm climates, and trees and labor being relatively cheap. The overview blow shows the top 10 cities that would stand to benefit in terms of highest ROI for tree planting to respectively curb high temperatures or air pollution. [vi]

Urban density and form

Cities will also need to carefully balance urban density and form. Low-density urban sprawl for instance is known to contribute to the urban heat island effect through its inefficient use of land, converting large surface areas into impermeable dark asphalt or concrete surfaces, ranging from roads to surface parking. Very high densities on the other hand can lead to urban 'street canyons', trapping both heat and air pollution. **Compact transport-oriented development[2] and the smart use of infill opportunities** to prevent further sprawl can help preserve green open space and minimize the percentage of land covered by dark, impervious surfaces.

In addition, **building massing and height regulations** can also influence interior comfort levels. The city of Dhaka, Bangladesh for instance is becoming increasingly compact and dense as a result of land scarcity. Within its dense residential neighborhoods, thermally comfortable traditional building forms -featuring rooms built around courtyards to receive daylight and cross-ventilation, and continuous covered balconies shading the rooms from direct sun - have gradually become extinct.

Instead, private developers now prefer a building form with maximum built-to-ground exploitation. Zoning regulations did little to enhance this situation, allowing buildings to be spaced less than 3m apart, reducing opportunities for natural ventilation. To overcome the adverse situation, the Dhaka Metropolitan Building Construction Act was enacted in 2008, which restricts the maximum buildable area and floor area ratio. The Act also specifies a mandatory open area to be preserved in the lot, with specific values assigned based on site conditions.[vii]

This goes to show that local planning regulations can beneficially impact on cooling needs by specifying e.g. the (maximum) height of facilities, the land area to or not to be built on, the size, depth and width of plots, and the provisions and locations for tree planting.

[2] Transport-oriented development (TOD) refers to a type of urban development, which incorporate a mixture of residences, office, retail and/or other amenities integrated into a walkable neighborhood and located within a short distance of quality public transportation

Natural cooling by wind and water

In Tokyo, researchers have studied how to incorporate **ventilation paths** that bring sea breeze into the city into urban design. Since the 1990s, many skyscrapers have been densely built along the city's waterfront area, creating the so-called 'Tokyo Wall', which blocks the cool sea breeze. Using examples from German city planning to create urban ventilation paths for mountain and valley winds to mitigate both air pollution and urban heat island effects in inland German cities such as Stuttgart, the Japanese researchers have modelled and piloted ways of optimizing the use of sea breeze to lower Tokyo's ambient air temperatures. Observational data have shown that the sea breeze in the Tokyo Bay Area can reduce air temperatures within a 2km stretch or more of the sea coast.[viii]

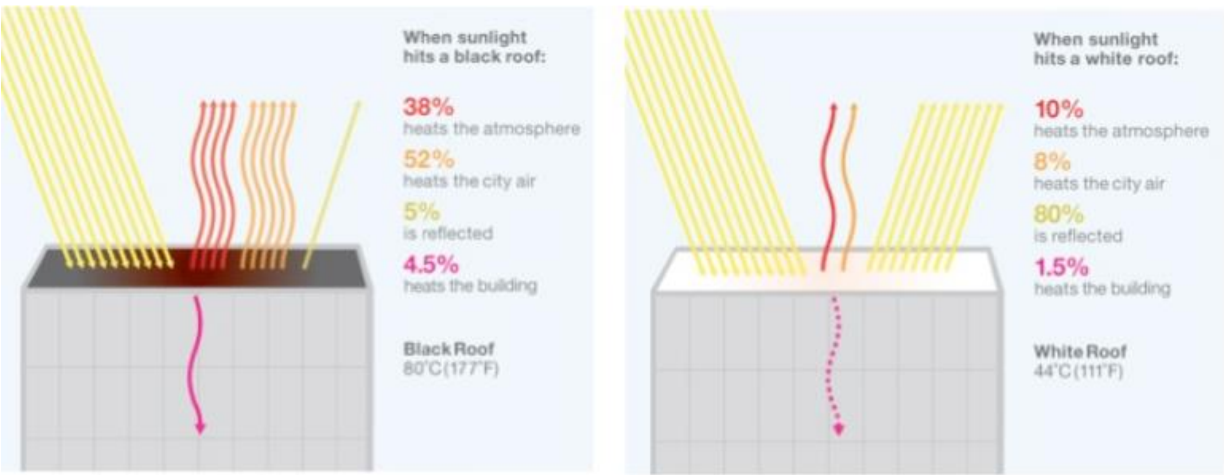
Water features can also provide meaningful natural cooling, as shown by Seoul in South-Korea which in the mid-2000s restored an 11km long stream. The stream had been covered up from the late 1950s with concrete and in the mid-1970s an elevated highway was built on top. Although the area was initially seen as an example of successful industrialization and modernization, in 2003 the then-mayor embarked on a project to remove the highway and restore the stream. The project has been lauded as a major success for urban renewal, now serving as a popular recreational area while reducing the number of vehicles entering downtown Seoul and local air pollution levels. The stream also helps to cool down temperatures in nearby areas by an average 3.6 °C versus other parts of Seoul.[ix]

Cool roofs, pavements and walls

Another relatively low-tech albeit effective means of cooling urban environments is by creating cool roofs and cool pavements. **Cool roofs** are considered to be roofs that stay cool when directly exposed to the sun by minimizing solar absorption (that is, having a high ability to reflect sunlight) and maximizing thermal emittance (high ability to radiate heat).[x] Cool roofs have high albedo values, which can be achieved for instance by using lighter colored roofs – something known since ancient times through the practice of 'white washing' buildings.[xi] Lighter colored surfaces may also suffer less damage from UV radiation and from daily thermal expansion and contraction.[xii]

Painting roofs white isn't the only way though for creating a cool roof. In India's slums, successful approaches include using layers of locally easily available materials like tarpaulin, foam sheets, aluminum foil, transparent plastic sheets, paper waste, coconut husks and paddy husks to create (modular) sandwich roofs, which can bring down temperatures inside by 3 to 8ºC.[xiii]

Cool roof projects and policies are growing in popularity, with solutions for most residential and commercial roof types, and there are many examples globally. In the U.S. alone, over half of states have some cool roof requirement, with cities such as New York, Philadelphia, and Chicago having specific bylaws relating to cool roofs. Other approaches include cool roof procurement schemes (such as in Washington, D.C., and the rebate system used in Toronto, Canada.



Air Temperature 37°C (99°F)

Figure 2 Difference in heat dispersal on a black roof versus a white roof[xiv]

Pavements such as roads, sidewalks, and parking areas, are also major contributors to the urban heat island effect, cover 29-39% of the urban fabric in U.S. cities when viewed from above the urban tree canopy or 36–45% viewed under the canopy. **Cool pavements** are mainly based on the use of surfaces with high albedo and high thermal emissivity (reflective pavements), or by using water evaporation to decrease surface and ambient temperature (water retention pavements, applicable in humid climates). Both technologies are well developed and many commercial products are available in mature construction markets. [xv]

A project in Singapore for instance to develop a dark pigmented coating with high albedo showed that the coating was able to reduce asphalt surface temperatures by as much as 17°C as compared to a normal asphalt surface, preventing asphalt roads from becoming a heat sink. If applied onto all pavements surrounding a building, a potential annual reduction in electricity demand of 3.5% was modelled. [xvi]

Although less common, some cities are also working on creating **cool walls**. Ahmedabad in India is putting white tiles on the walls of select government buildings to reduce heat absorption. In Paris, France, the city started an initiative called "Des jardins sur les murs" or "Garden on the walls" when more than 21,000 Parisians voted for it through a citizen referendum on the city's participatory budget in 2014. Between 2001 to 2013, the city already developed planted 118 green walls, and has now committed to building 100 hectares of green walls and roofs by 2020, one-third of which will be dedicated to urban agriculture.[xvii]

High albedo roofs and pavements have the potential to increase the average albedo of urban areas by as much as 10%. If this were to be implemented globally across all urban areas, it would create a cooling effect equivalent to an estimated 44 gigatons[3] of CO_2 emissions from avoided electricity and fuel consumption.[xviii] A new study also suggests that **changing a fifth of a city's roofs and half of the pavements to 'cool' versions** could lead to cost savings 12 times the cost of installation and maintenance, while reducing air temperatures by an average 0.8ºC.[xix]

Nonetheless, Lawrence Berkeley National Laboratory found that cool pavement materials may require more energy to manufacture than conventional pavement materials, potentially nullifying part of the carbon gains. This points to a need to develop affordable cool pavement materials with lower life-cycle energy and carbon impacts.[xx] Opportunities may also exist to (instead) capture heat from pavements, for example by using a piping system with a fluid combined with high conductivity layers to capture solar heat for beneficial use.[xxi]

Green roofs

Green roofs are roofs that are purposely fitted or cultivated with vegetation. They can be extensive, defined as low maintenance, drought-tolerant, self-seeding vegetated roof covers; or intensive, providing actual roof gardens that are much more heavy than extensive green roof systems and require far more maintenance.[xxii]

In green roofs, solar radiation, external temperature and relative humidity are reduced as they pass through the vegetation layer. The plants also provide cooling through evapotranspiration.[xxiii] Whereas temperatures on a black flat roof can reach up to 100ºC, **a green roof can vastly reduce these temperature fluctuations to around 20 to 25 ºC.**[xxiv]

Capital costs for extensive green roofs however are generally 150-200% more expensive than traditional black roofs, while intensive green roofs also need a stronger supporting structure to carry the increased loads. Both also have ongoing maintenance costs related to ensuring vegetation does not die off. The high initial investment in green roofs acts as a barrier to more widespread use.[xxv]

Mexico City's government for example has been investing in green roofs on public buildings to help absorb air pollution within the city, although these roofs will have the added benefit of cooling their surroundings. By 2015, more than 23,000 square meters of green roofs were speckled throughout the

[3] Of which 24Gt by roofs, and 20Gt CO_2CO2-e emissions by pavements

city, found on e.g. hospitals, schools and municipal buildings, with the government increasing funding in order to install more.

Also in the city of Dhaka, Bangladesh, green roofs are increasingly being installed on institutional, hospital, commercial, and residential developments. With rapid urbanization and high population growth, the greater Dhaka area has seen a significant decline in agricultural lands, green spaces, and access to potable water. Green roofs are gaining popularity as acts as a natural cooling system, reducing a building's energy demand, and also increases local food security by supplying fresh fruit and vegetables. [xxvi]

Planning for heat stress

Increasingly cities are formulating plans, strategies and policies to help vulnerable people cope with heat stress. As part of **New York City**'s resilience strategy for instance, heat is acknowledged as a silent health threat, particularly for low-income residents, the elderly, and people of color. The city has been working to link heat stress to certain risk profiles by developing a **Heat Vulnerability Index**, mapping the city's neighborhoods based on metrics such as the percentage of residents receiving public assistance; percentage of non-Hispanic black residents; the average surface temperature; and the percentage vegetative cover. High risk neighborhoods on this map turned out to closely mirror those neighborhoods where people were most likely to die from or become hospitalized due to excess heat.

The city is now targeting its heat mitigation efforts, such as painting roofs white and planting trees, more towards the neighborhoods where they are most needed. In addition, the city is introducing a buddy system, whereby residents and community groups volunteer to keep an eye on vulnerable New Yorkers, and is supporting climate risk training for Home Health Aides, who support residents with health issues that often keep them home bound.[xxvii]

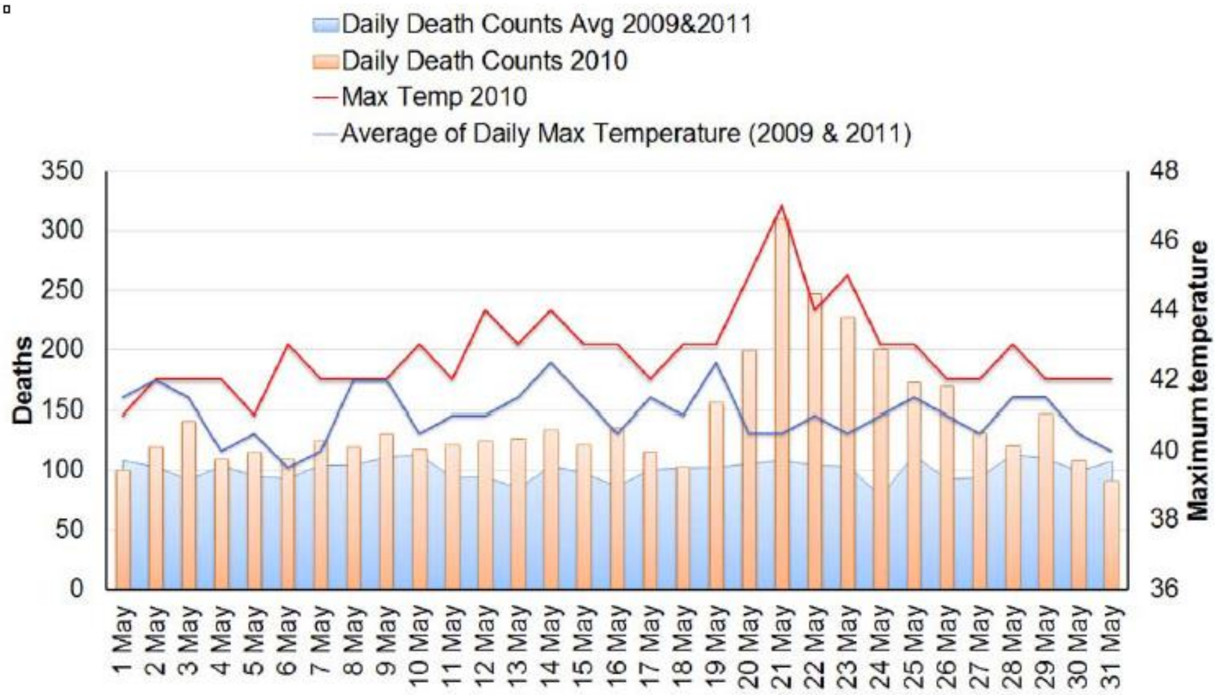


Figure 3 Temperature and all-cause mortality correlation during 2010 heat wave in Ahmedabad as compared to 2009 and 2011[xxviii]

Ahmedabad in India on the other hand was the first city in South-Asia to formulate a **Heat Action Plan** after a devastating heat wave hit the city in 2010. The plan was developed in collaboration with external partners, such as Natural Resource Defense Council (NRDC) and the Indian Institute of Public Health (IPH). Local authorities mapped areas with populations at high risk of heat stress including slums, and developed an easy to understand, early-warning system as well as a strategy for mobilizing the city in advance of impending heat waves. This includes color-coded heat warnings being announced in the media, phone companies sending out SMS warnings, and social workers going into the slums to hand out rehydration packets and pamphlets on heat safety.[xxix]

Meanwhile hospitals prepare ice packs and heat wards, water stations are set up on street corners, and temples, mosques, and malls double as cooling centers. Especially slum inhabitants frequently face power outages and interrupted drinking water supplies, so even those who may be able to afford it, cannot rely on electricity or sufficient fresh water to be available when they need it most. Which is why the city focuses heavily on providing emergency access, both in terms of shelter and for the distribution of free drinking water.

In 2015, when heat waves killed more than 2,500 people across India, Ahmedabad reported fewer than 20 heat-related deaths, proving that the system is effective. At the same time, if a heatwave lingers for more than a few days, hospitals' heat wards might run out of space while the poor would still have to go out to earn an income.[xxx]

Ahmedabad is therefore not only adding measures that help the city's vulnerable people cope with extreme heat, but which also help reduce the heat. With a quarter of the city's population living in slums, often in small concrete boxes with tin roofs, the city has begun painting these roofs white, while covering public buildings with reflective white mosaic tiles. These efforts rely in part on volunteers, donating their time and energy to helping out the city's poorest. Modest measures such as these can help lower temperatures by a few degrees, not enough to feel cool but it may ward off deadly temperatures rises.[xxxi]

Tokyo, Japan, is also working on providing the citizens solace from extreme heat in summer. In order to identify the most vulnerable areas, the city conducted a **heat-mapping exercise**, dividing the city into 500-meter grids and identifying priority areas. One of the measures implemented is 'dry mist', whereby sensor-controlled nozzles spray small amounts of (rain)water on the road, which evaporates as soon as it comes in contact with the atmosphere. The latent heat of evaporation creates a cooling effect. This taps into an age-old Japanese tradition of sprinkling water on streets during summer months to keep the area cool.[xxxii]

Cooling centers

As part of a heat stress plan, or as a general provision more and more cities are **designating certain public spaces to act as cooling centers in case of heat waves**. A cooling center is usually an air-conditioned public space set up by local authorities to temporarily deal with the health effects of a heat wave and prevent hyperthermia caused by factors such as heat, humidity, and increased smog levels. The cooling centers are usually aimed at at-risk populations, such as the elderly, homeless, and lower-income households living in poorly cooled housing. Some cooling centers provide not only shade and lower temperatures, but also free drinking water, medical attention and even referrals to social services. may also be offered.

Cooling centers are increasingly used in larger North-American cities such as Los Angeles, New York, San Francisco, Chicago, Boston, and Toronto. Common places are public libraries, community centers, senior centers, and police stations. Sometimes operational hours of public swimming pools are extended as well.

The city of Ahmedabad, India, has also set up cooling centers as part of its Heat Action Plan, although in general dedicated cooling centers remain rare in major cities located in developing and emerging countries.

District cooling

District cooling systems deliver chilled water from a central plant through an underground pipe network to multiple buildings. Such systems offer cities a more sustainable active cooling option by supplying efficient cooling at scale to commercial and high-density residential buildings with far lower CO_2 emissions, particularly if integrated with sources of 'free' cooling such as river or sea water, or even treated sewage effluent.

The energy needed to drive the plant's chillers can come from multiple sources including waste heat from power plants or industrial processes. In addition to being more energy efficient than traditional building air conditioning, **district cooling can significantly help reduce electricity use during peak demand periods** through decreased power consumption and the use of thermal storage. Excess variable electricity production, such as wind and solar for instance, can be utilized and stored using district energy.[xxxiii]

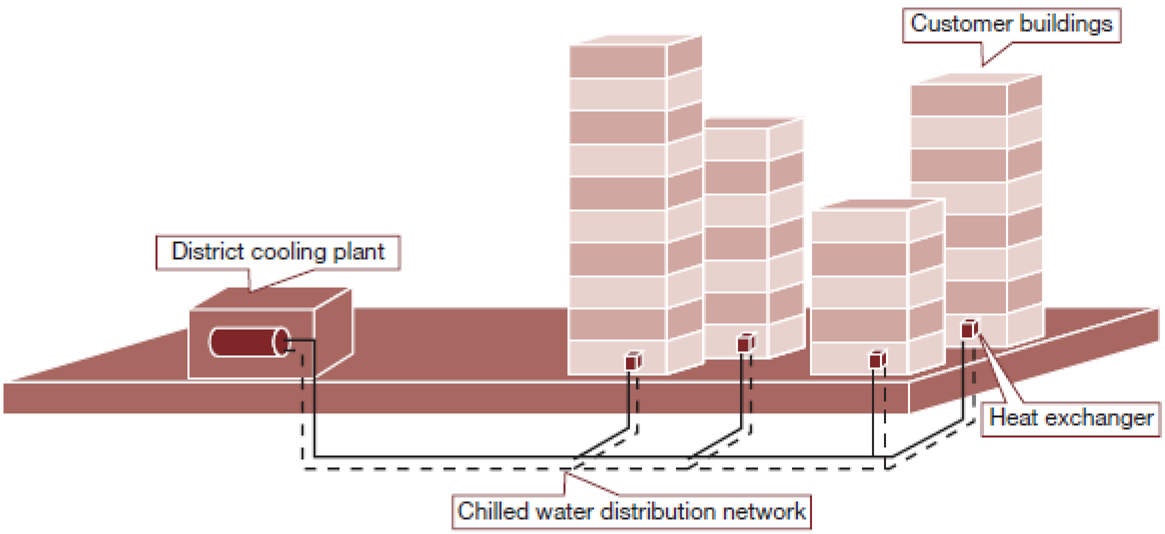


Figure 4 Schematic of a district cooling system[xxxiv]

District energy thus offers **several core benefits**: an energy requirement typically 40-50% lower for every refrigeration tonne hour than conventional in-building technologies; more efficient capacity use, typically needing around 15% less capacity for the same cooling loads; and peak-period saving potential through its thermal storage capability, storing up to 30% of potential output by holding chilled water in tanks. As the ratio of cooling load to unit of land area served increases through district cooling, the per user cost of the network decline as well, although it's important to note that district cooling is economically attractive only if it serves a sufficiently dense area and can be difficult to modify as usage needs evolve.[xxxv]

District cooling is rapidly taking off in particularly the Middle East, which installed 7 million m^2 of district cooling capacity in 2014 alone. Dubai has developed the world's largest district cooling network, aiming to meet 40% of its cooling demand through district cooling by 2030, while reducing the city's power consumption for air conditioning by 50% and reducing peak energy demand.

In other parts of the world, district cooling is also slowly becoming more widespread. UN Environment for example has been studying **several models for implementing district energy systems** in a 2015 report, identifying 45 'champion cities', including the city of Port Louis in Mauritius which is developing a seawater district cooling system, the first in Africa, as well as GIFT city[4] in the state of Gujarat in India is also developing a district cooling system with the aim of creating a replicable demonstration project, as an extra estimated 400 million people are expected to move to India's urban centers by 2050. [xxxvi]

Moreover, the global district cooling market is expected to reach a value of US$17.3 billion in 2024 up from just over US$11 billion in 2015, as more and more cities in both developed and in developing and emerging countries are expected to develop district cooling systems, including countries such as Malaysia, Indonesia, the Philippines, India, Mexico and Brazil.[xxxvii]

[4] Gujarat International Finance Tec-City or GIFT is an under-construction central business district between Ahmedabad and Gandhinagar in the Indian state of Gujarat

2. POTENTIAL POLICY AND BUSINESS MODEL SOLUTIONS

Policy examples to increase vegetation cover

Various examples exist in the U.S. of **local governments encouraging vegetation cover in residential and commercial areas** for cooling purposes. These include the following:

- Baltimore County provides coupons to homeowners toward the purchase of trees at local nurseries. In order to validate their coupons, buyers provide information including tree type and location planted to allows the county to integrate the data with future tree canopy studies;
- In Sacramento, the Municipal Utility District[5] has been providing free shade trees to residents to encourage them to strategically plant vegetation around their homes to reduce energy consumption. Since 1983 its zoning code also requires enough trees to be planted to shade 50% of new, or significantly altered, parking lots after 15 years of tree growth;
- The city of Chicago has a landscape ordinance that requires planting trees or shrubs on parkways and landscaping parking lots, loading docks, and other vehicular use areas. The ordinance applies to most new building construction, as well as to building retrofits and enlargements;
- Seattle requires certain new developments in its business districts to provide for vegetative cover equivalent to at least 30% of the applicable property. Developers can use a menu of strategies, including planting or preserving trees, and installing green roofs or walls to meet the target.[xxxviii] Specifying a green area ratio for new developments is a quite common measure, either requiring developers to retain existing trees during development, or by allowing them to choose how they meet the target;
- Chicago has adopted an open space impact fee ordinance, requiring new residential development to contribute a proportionate amount of green space, or instead pay fees towards them;[xxxix]
- The city of Houston has since 2007 provided grants to incentivize green walls for city center properties. The grants also support exceptional landscaping that adds significant evapotranspiration and shade for blank walls, parking garages, and sidewalks. Grants cannot exceed half of the total project cost at a capped amount, and contributions can also be in kind.[xl]

Other examples of how tree planting can be promoted and/or financed include:[xli]

- In some cities, the link between the shade that trees provide and the benefits in terms of reduced electricity use have encouraged utilities to make this link tangible with utility bill donations or incentives. A utility may for instance provide tree saplings to property owners who must agree to maintain the trees in return for a small reduction on their electric bills;
- Instead of incentivizing residents to plant trees, the city can also charge them for the cost of the municipality planting trees on their behalf. The assessed property on streets with trees are higher than those without. By using a parcel tax, the city treats trees as public infrastructure to provide to citizens and taxes citizens for it, similarly to other infrastructure taxes and fees such as sewerage and waste collection;

Policy examples to install cool roofs and pavements

Similarly, **U.S. cities and states** have been encouraging the installation of cool roofs or pavements through a variety of policy measures:

- The city of Tucson, Arizona requires air-conditioned city owned facilities to use cool roofing materials for most new construction and roof replacements;
- Georgia was the first U.S. state to add cool roofs to its energy code, in 1995, allowing reduced roof insulation if a cool roof with a 75% minimum solar reflectance and thermal emittance is installed;
- Chicago began a Green Alley initiative in 2007 that encourages the use of porous paving whenever an alley needs to be re-paved. Ultimately, about 3,000 km of alleyways will be made permeable;
- Chicago has also established a green and cool roof grant program since 2005.[xlii] Furthermore, its energy code requires roof installation installed on or prior to December 31, 2008 to have a

[5] A municipal utility district is a special-purpose district or other jurisdiction that provides services to district residents

minimum solar reflectance of 25%, while from 2009 contractors must use roofing products that meet or exceed the minimum cool roof criteria to qualify for an Energy Star[6] label;[xliii]

- The city of Houston has included cool-roof requirement in its Commercial Energy Conservation Code of 2008, which requires air-conditioned government, commercial, and multifamily residential buildings which install or replace low-slope roofs to have a minimum initial solar reflectance of 0.70 and a minimum thermal emittance of 0.75.[xliv] The city also targets alternative pavement options for highways and parking lots where possible, and embeds cool pavement incentives into related programs and regulations, such as to meet Clean Air or Clean Water Act standards;[xlv]
- The state of California through its building energy code has since 2005 been mandating cool roofs for all new non-residential construction and reroofing projects over 190m^2 or for 50% and over replacements. This was preceded from 2001 by a Cool Savings Program which provided rebates to building owners for installing cool roofs, with the highest rebates available for roofs on air-conditioned buildings.[xlvi]
- The city of New York, launched its CoolRoofs Program in 2009 as a "Cool it Yourself" program encouraging building owners to paint their rooftops white. The Mayor's office has supported the program by coordinating a corps of volunteers while later evolving the program into a job-training initiative.

The **cities of Seoul and Busan** in South-Korea have also been using municipal budgets and volunteers to promote cool roofs and paint them white for free. The programs are particularly targeting socially marginalized groups and community centers for senior citizens in Busan[xlvii], and young as well as elderly citizens living in 'rooftop slums' in Seoul.[xlviii] In **South-Africa, the Cool Surfaces Project**, is also targeting low-income housing – particularly those without access to electricity for cooling – to conduct demonstration projects for cool roofs and pavements.[xlix]

In **India**, government has been active in developing a number of cool roofs initiatives. The city of Hyderabad is together with local and overseas partners such as NRDC currently developing the Hyderabad Cool Roofs Initiative, which will pilot cool roofs in low-income housing communities of the city. It also aims to develop sustainable financing solutions to scale cool roofs application for low-income housing, understand what incentives to use, and link these solutions to existing institutional frameworks such as India's Smart Cities program.[l]

In Delhi a "Cool Roofs for Cool Delhi" design manual was published in 2011, structured to be a source of information for different stakeholders. The Indian cities of Indore and Surat have run pilot case studies with cool roofs on residential buildings in both cities, in order to create local success stories that can help inform policy development. The cities of Delhi, Ahmedabad, and Hyderabad are also rolling out initiatives to adopt cool roofs on public and government buildings, while considering the inclusion of cool roof strategies in their respective state Energy Conservation Building Codes for large commercial and public buildings.

The most compelling example so far in India comes from Ahmedabad as part of its Heat Action Plan. It has designed dedicated content on cool roofs for educational, information and communication purposes to increase community awareness; used pilot projects in collaboration with private sector partners to showcase the benefits; recruited students to volunteer painting roofs white; leading by example through converting municipal and other publicly owned buildings to cool roofs and including cool roofs in their procurement criteria; partnered with local businesses for implementation; and is discussing allocating a dedicated budget to cool roofs as part of the Heat Action Plan. [li]

Policy examples to address enhance cooling by smart use of urban density, wind and water

Local local planning regulations can beneficially or adversely impact on cooling needs by specifying e.g. the (maximum) height of facilities, the land area to or not to be built on, as well as the size, depth and width of plots. The municipal government of Dhaka, Bangladesh did exactly that when enacting the **Dhaka Metropolitan Building Construction Act** in 2008, which **restricts the maximum buildable area and floor area ratio**, and **specifies a mandatory open area** to be preserved in the lot, with specific values assigned based on-site conditions. This helps improve natural cooling for low-income households living in high-density apartment buildings.[lii]

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[6] Energy Star is an international standard for energy efficient consumer products originated in the United States, created in 1992 by the U.S. Environmental Protection Agency

Other cities are actively using wind and water features as policy instruments to help cool their cities, an example of which is the Germany city of **Stuttgart**. Its location in a valley basin, warm summers and low wind speeds, combined with industrial activity and high volumes of traffic have made it susceptible to both poor air quality and a worsening of the urban heat island effect. The city has therefore made it a key objective to **facilitate air exchange** in the city, thereby enhancing the potential for cool air to flow from the hills towards the urban areas on the valley floor – the so called 'ventilation paths'.

In 2008 the city mapped its regional wind patterns, flows of cold air, air pollution concentrations, and other relevant information required to inform urban planners. The mapping exercise also included an area classification based on the role that different locations play in air exchange and cool airflow in the region, on the basis of their topography, development density and character, and provision of green space. This has result in eight categories of areas being distinguished, with different planning measures and recommendations provided for each of them.[liii] Researchers in Tokyo have used this approach to understand and develop recommendations for urban planners on how to increase the flow of sea breeze into the city, which is currently increasingly being blocked by a wall of skyscrapers.

The still developing **Masdar City** project **near Abu Dhabi** also uses wind to cool urban environments, having adapted an ancient design that has proven its worth till this day in desert regions such as Iran. Masdar City has built an almost 30 meter high **wind tower**. As hot air rises, a tall cylinder such as this wind tower is able to provoke a convection current resulting in hot air being removed from street level and cooler winds being funneled down to Masdar's streets, creating a constant cooling breeze. By adjusting the louvres, the tower can catch any prevailing winds, lowering the perceived temperatures by as much as 5ºC. The tower works particularly well because of the deliberately narrow streets of Masdar City, designed to minimize the amount of direct sunlight hitting them, while channeling the breeze more tightly, making it faster and more effective.[liv]

Cities can also use financial or non-financial incentives to entice project developers to enhance their designs for natural cooling. Some examples of **non-financial incentives** that have worked well in the work fields of green buildings and building energy efficiency include the following:

- Hong Kong provides an allowance to project developers for extra height or floor area for new building developments that meet certain green building or energy efficiency standards. Developers can receive a Gross Floor Area (GFA), concession of up to 10% if they pursue certification under BEAM Plus, which is Hong Kong's local green building rating and certification scheme. Singapore and Tokyo have similar non-financial incentives allowing for extra floor area; [lv]
- Expedited building permits, otherwise known as fast-track permitting, with priority processing are another common type of non-financial incentive offered by cities such as Seattle, San Francisco and Chicago; [lvi]
- Delhi requires sustainability measures to be included in the layout plans of new buildings for plots measuring 3,000 square meters and above. To promote these features, density bonus incentives of 1% to 4% extra ground coverage and FAR (floor area ratio) can be awarded by local bodies to project developers. Incentive amounts are based on the buildings performance as achieved under the Indian 'Green Rating for Integrated Habitat Assessment' (GRIHA) scheme;[lvii]
- The Changwon City Government in South Korea governs the Carbon Mileage System - an energy efficiency point system, wherein households or companies earn points for their water and energy savings. The government incentivizes the program by providing cashback, coupons for various goods and Nubija rewards (Changwon's Bike Share Program). The more points a participant earns, the more rewards they can receive. [lviii]

Developing a heat action plan

Ahmedabad in India was the first city in South-Asia to develop a heat action plan triggered by a major heatwave in 2010. First Ahmedabad analyzed the factors, that made in particular its **slum population more vulnerable to extreme heat** while simultaneously hampering efforts to protect residents' health. The factors listed below are likely to hold truth for other cities with large slum populations and make slum inhabitants more likely to become seriously ill or even die from heat waves, further aggravated by the urban heat island effect:[lix]

- Poverty, resulting in lower access to essential services;
- Limited or unreliable access to drinking water;

- Poor housing, including heat-trapping building materials such as tin roofs, asbestos, plastic coverings, PVC tarps, and bricks; cooking stoves and/or open fires are usually located in a room that serves multiple purposes; crowding and a lack of open space;
- Unreliable electricity supply, for those residents who can afford power;
- Lack of greenery and shade around slums, including trees and parks;
- Lack of access to cool spaces such as buildings with air-conditioning;
- Limited access to Information;
- Occupations that may involve more outdoor exposure to the heat;
- Lower perception of high temperatures as a health risk.

Analyzing the resulting **Ahmedabad Heat Action Plan**, the plan has **five key elements** – first of all which is the early warning system based on predictions of maximum temperatures for next seven days. The second element is a system to issues alerts to various municipal departments and the community when a heatwave is predicted. This also involves appointing a nodal officer and a communication network. Care has to be taken hereby that a mix of communication channels are selected which also reach out to those, who do not possess cell phones and may not even be able to read. Third is creating community awareness on the dangers of heat, how to avoid them, recognize early symptoms, and how and where to seek primary and preventive care for heat stroke. Next is to train healthcare providers to recognize the early symptoms of heat related illnesses and treat patients rapidly and appropriately. In addition, healthcare staff are learning to recognize the dangers of heat exacerbating the symptoms of (elderly) people with pre-existing medical conditions.[lx]

Thursday 23 May 2013 - YELLOW ALERT LEVEL

Current Forecast (Created 22-May)	23-May	24-May	25-May	26-May	27-May	28-May	29-May
Alert Level	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Likelihood of Crossing Threshold	High	High	High	High	High	High	High
Maximum Temp (+/- 1 SD)	42.5°C (41.9-43.2)	42.6°C (42.1-43.2)	42.2°C (41.4-42.9)	42.5°C (42.0-43.2)	42.4°C (41.5-43.4)	42.2°C (41.5-43.1)	42.1°C (40.8-43.2)
Probability of "Safe Day"	0%	2%	6%	4%	6%	8%	22%
Probability of "Hot Day"	88%	86%	90%	82%	82%	90%	71%
Probability of "Very Hot Day"	12%	12%	4%	14%	12%	2%	8%
Probability of "Extreme Heat Day"	0%	0%	0%	0%	0%	0%	0%

Alert Levels:	Safe <41°C	Hot 41.2°C - 43.4°C	Very Hot 43.5°C - 45°C	Extreme Heat >45°C	Likelihood of Crossing Threshold High>75% Med 50-75% Low<50%

Figure 5 Example of Ahmedabad's early warning system (first element of the Heat Action Plan)[lxi]

The fifth and final element is to evaluate its effect on mortality and morbidity using scientific statistical methods and to revise the city's approach going forward using this information. A challenge hereby are the unreliability of data when it comes to recording and analyzing causes of death, hampering city officials' ability to accurately estimate the total number of deaths due to a heat wave. Easy-to-identify cases of what is called 'exertional' heat stroke tend to get attributed to heat waves, but 'non-exertional' heat stress deaths among elderly and vulnerable groups often gets overlooked as having been caused by elevated temperatures.

Furthermore, the Ahmedabad Heat Action Plan **assigns a range of specific activities to each municipal stakeholder** – such as the nodal officer, press officer, and health department - throughout the year, from Phase 1 (pre-heat season) to Phase 2 (heat season) to Phase 3 (post-heat season), ranging from preparation and training to post-heat season evaluation. [lxii]

In addition, the plan has been expanded to also include **measures that help prevent deadly heat**, such as painting the tin roofs of slum buildings white with the help of volunteers, and covering public buildings with reflective white mosaic tiles. This can create temperature reductions of about 3ºC inside people's home, a modest reduction although pending circumstances it can make the difference between deadly and still survivable heat. The city also does all it can to ensure the city has sufficient water supply and will not suffer from power cuts during the hottest days.

The city has been pro-active in sharing its experience with other stakeholders, including through the facilitation of several workshops. This has now led to India's National Disaster Management Authority to come up with a **set of guidelines for managing heat waves**, encouraging state and city authorities to formulate heat action plans like Ahmedabad's. The guidelines promote four key strategies:

- Forecasting heat waves and enabling an early warning system;
- Building capacity of healthcare professionals to deal with heat-related emergencies;
- Community outreach through various media; and
- Inter-agency cooperation as well as engagement with other civil society organizations in the region.

Nonetheless, only few Asian cities have followed suit since Ahmedabad successfully developed and implemented its Heat Action Plan. These include the Indian city of Nagpur, which regularly sees the scales tip 45ºC and over in summer, while Karachi in Pakistan is also starting to develop a plan. In sub-Saharan Africa temperatures are expected to increase by 4°- 6°C in sub-tropical regions and by 3°-5°C in tropical regions by the end of the century, but response systems such as heat action or management plans are still highly uncommon.

Appointing a dedicated cooling lead or coordinator

Although many cities in developing and emerging countries may not have the financial means and institutional capacity to establish a dedicated team to deal with urban heating and heat stress, **having a lead agency or at least an in-house coordinating expert** who reinforces and drives the message home and coordinates between the cities' agencies and institutions can be critical to success.

Having a coordinating agency or expert also helps engage a larger citizen base, leverage departmental expertise, and realize more co-benefits.

A useful example is provided by the **City Energy Project** in the U.S., focusing on improving energy efficiency policy and plans. In 2014, ten cities were selected for the first phase of the project in 2014, with a second round of 10 U.S. cities selected for the second phase in late 2016. A dedicated, full-time energy efficiency "**City Advisor**" (or even two) has been placed within each of these cities. This City Advisor is being paid for through the program and coordinates within as well as between his or her city, various local stakeholders, other City Energy Project participants, and the central City Energy Project Hub staff.

The Advisors have a full-time job helping to engage stakeholders, coordinate, and design, build support for, and implement energy efficiency policy, programs and plans. The City Advisors are also involved in a peer network that further enhances participants' support, allows capturing and sharing of lessons learned, and to disseminate success stories and related resources for replication of the solutions to cities within and outside of the project. The City Advisors have also become primary local points of contact and leaders in the field, evidenced by dozens of speaking and media requests. Many City Advisors are also taking leadership roles in various broader city peer-to-peer learning networks. The thus-established 'community of practice' is helping to transform the nature of policy discussions beyond the boundaries of Project.

The City Advisors are viewed as one of the most valuable aspects of the program in providing needed expertise and capacity for doing this day-to-day work. City Advisors require a spectrum of skills however to succeed and be effective, from an aptitude for political strategy to a keen mind for developing technical policies and implementation mechanisms. Meanwhile, it can be challenging to find sufficient funding for such a position in the long-term within city government budgets, and requires conversations about funding to start early, engaging a broad range of potential partners who also stand to benefit from having the advisor in place.[lxiii]

District cooling business models

Business models for district energy (both cooling and heating) range from fully publicly owned systems, to cooperative models and public-private partnerships, as well as privately owned systems. **In many cities hybrid business models are most dominant**, ranging from privately operated concessions to public-private joint ventures.

Since 1927 for instance, the **Paris Urban Heating Company** (CPCU), a utility 33% owned by the city, has provided district heating under a **concession contract**. This model allows Paris to maintain a fairly high degree of control, while also benefiting from capital investment by the private sector. The concession contract sets a maximum price for the heat delivered, indexed against the share of renewable heat generated with a target of 60%. The city also can enforce a special low price for those in social housing.[lxiv]

In **Dubai**, where air conditioning represents over 70% of electricity consumption, the **publicly owned electricity utility is integrated into the city's district cooling business model**. In practice, this means that the city's district cooling network has been established as a public-private partnership (PPP) between a real estate develope, and the public utility, which holds 70% ownership. This PPP operates the network under a 25-year concession contract with an anticipated return on investment of 10-12%.

The majority ownership lets the city have a strong say in the objectives the network needs to fulfill, such as being expandable and flexible; using innovative technology to replace potable water with recycled water; and applying energy efficiency measures to reduce cooling demand. Both PPP partners also provide anchor cooling loads for the system through buildings they own. This has been combined with regulations requiring new developments to connect to the district cooling system. [lxv] As utilities are publicly owned in many developing and emerging countries, PPPs can provide opportunities for utilities to become involved in district cooling, generating extra income while helping a city realize the macro-economic benefits of establishing a district cooling network. [lxvi]

Taxes and other penalties on the other hand have played an important role in expanding district energy systems in China, where a national-level regulation empowers provincial authorities to fine cities for high levels of air pollutants. This can result in a payback period for district cooling as low as three years due to the avoided penalties on pollution and the reductions in coal purchases for electricity generation. Where taxes are not in place, national governments may offer **grants and subsidies** to accelerate district energy uptake. The city of Rotterdam, The Netherlands, for example, secured an almost US$34 million grant from the Dutch government for developing district heating, reflecting the equivalent avoided social costs of CO_2 and NOX emissions.[lxvii]

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