Hacking Urban Heat

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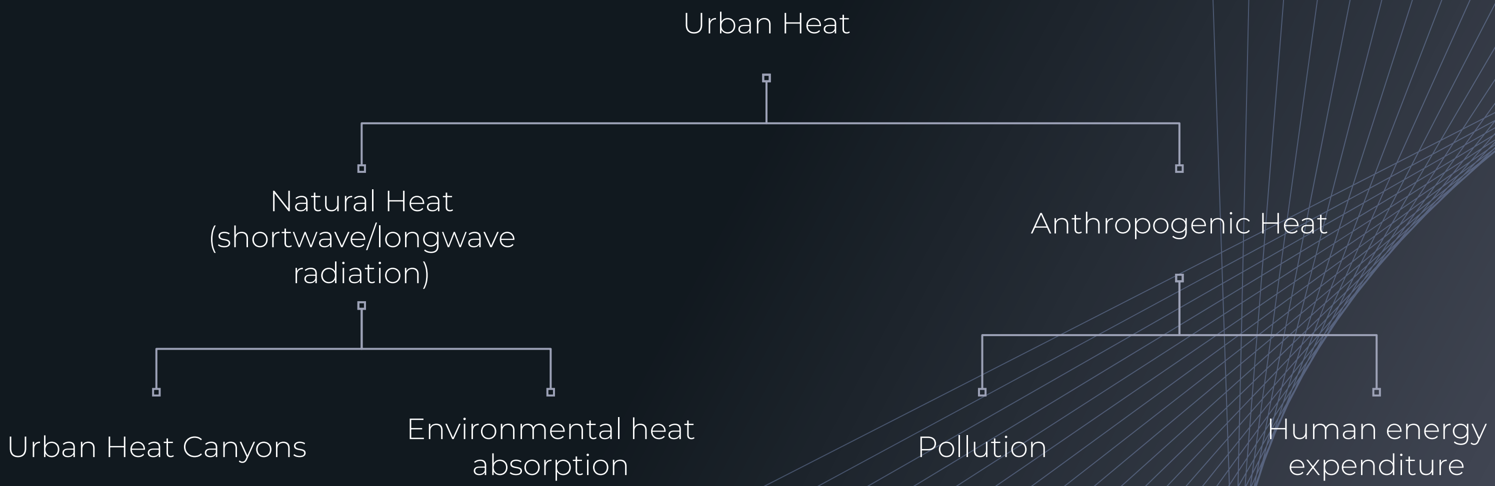
Understanding Urban Heat

Urban Heating, or the Urban Heat Island effect, occurs when an urban area experiences higher temperatures than the surrounding rural area. The measurement of this effect describes the extent to which the Urban area itself has changed the climate of the area it exists in.

Urban heating is caused primarily by longwave and shortwave radiation. Shortwave radiation is the direct sunlight that heats the city, whereas longwave radiation is comprised of the reflection and amplification of that sunlight by buildings and other city structures. Due to city layout and composition, this radiation can cause dangerously high temperatures, thus creating an urban heat island.

What is urban heat?



1.

Determining Root Causes

Creating an equation that we can manipulate to find optimal solutions.

Creating a useful equation

In order to understand how to mitigate the effects of urban heating, it was necessary to create an equation explaining all of the different urban heat factors that have been researched in order to see how they interact with each other. After in depth scrutiny, and mathematical creativity, the following equation was derived, explaining the factors that go into urban heating, and producing a unique urban heat index in useful units (kJ/m^2)

The Urban Heat Index Variable Components Equation

(Created by Jack Perry, Thomas Stewart, Nathan Busath)

$$UHI = \frac{\sqrt{\pi\sigma\alpha\beta} + \gamma}{\theta\omega\lambda}$$

Where

UHI = Our newly created urban heat index (kJ/m^2)

π = Average building material heat capacity (kJ/℃)
σ = Average building surface area (m^2)
α = Number of buildings in the city
β = Average city temperature (℃)
γ = Anthropogenic heat output (kJ)
θ = Average city rainfall (m)
ω = Average city wind speed (m/t)
λ = Total city green space (m^2)

Statistical models save the day

- “All models are wrong; some models are useful” - Julie Moore Secretary of the Agency of Natural Resources Vermont
- The benefit of statistically modeling the UHI is the way it allows key stakeholders to visualize and quantify solutions to decrease urban heating.

This model is the difference between a hypothetical solution that will forever exist only as a slide deck and a solution that will save lives, impact policy, and protect our Mother Earth.

2.

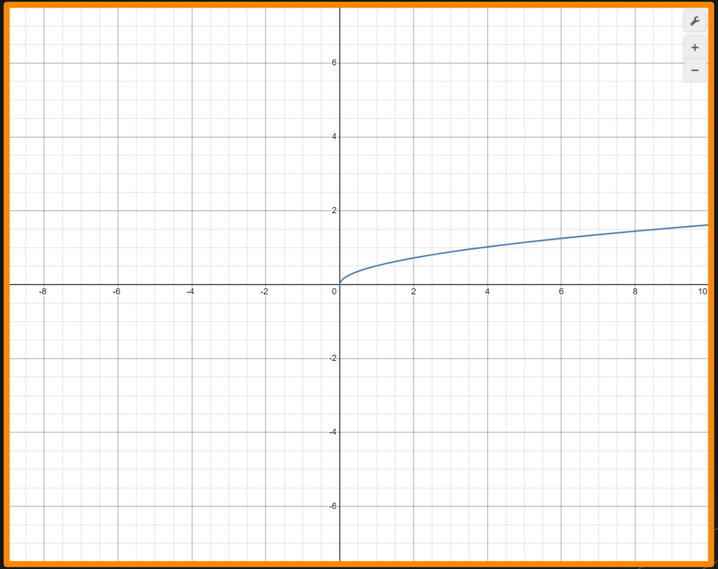
Identifying Solutions with the Greatest Impact

Using our equation to identify factors that can be changed to most efficiently reduce UHI.

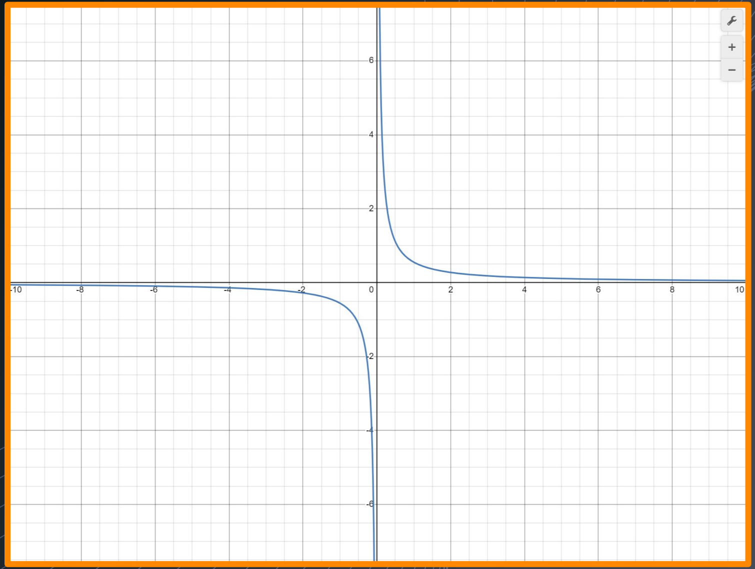
Tracking Individual Causes:

Graphs showing how a change in heat causing variables (building material heat capacity, building surface area, number of buildings, city temperature, and anthropogenic heat output) or heat reducing variables (rainfall, wind speed, and green space) would have an impact on overall UHI.

Change in heat causing variables:



Change in heat reducing variables



What factors play the largest role?

- From our model, we have found that an increase in heat reducing variables has a greater immediate impact than reducing heat causing variables.
- This is important because an effective solution to the urban heating problem must be retroactive in nature for it to make a change on a large scale. Most proposed solutions to urban heating are expensive and can only prevent more heating in the future.
- Our model shows that a solution to reverse the effect of urban heating must come on the heat reducing variable side of the equation, not the heat causing variable side.

Where will a solution come from?

Rainfall

Solutions could include rainwater collection, permeable pavement, and strategically designed watersheds.

Wind Speed

Solutions could range from optimally designed city layout to retrofitted aerodynamic fins on buildings.

Green Space

Solutions range from cheap to expensive. Parks, green roofs, and tree lined streets are examples of retroactive implementations.

The solution that would work best depends on the geography, climate, and budget of the city. A solution for New York City may be less effective for Bend, Oregon and vice versa.

3.

Solutions in Action

Taking our potential solutions and theoretically implementing them in a city that experiences a high UHI.

New York City: A case study

Using New York-specific values in our equation to determine what the city can do to mitigate its UHI.

Using the new UHI equation

π = 0.840 kJ/℃

σ = 1858 m^2

α = 7000 high rise buildings

□ = 28.88 ℃

γ = 3.534E12 kJ

θ = 1.18 m

ω = 10.9 m/t

λ = 5.53E9 m^2

- With these values, we get a UHI value of 49.69 for New York City.
- We can also see that New York's value is mostly determined by green space and human energy consumption.
- Therefore, a solution for New York's urban heat problem would be a reduction of energy consumption, and an increase in green space.

Implementation

By understanding the variables that contribute to urban heating, a list of relevant action items can be produced that would help to mitigate the effects of urban heating.

One of the largest contributors according to our equation was green spaces. By implementing policy, green spaces can be built around the city.

Building materials can be changed or enhanced so that they reflect sunlight away from the ground below, which helps to avoid the dangerous heat canyons created in cities. Volunteer groups, for example, have worked on painting the tops of buildings white to better reflect light and decrease city temperature.

A better world for disenfranchised communities

Many disenfranchised communities find themselves placed near industrial areas of cities that are prone to urban heating.

By prioritizing green space instead of industrial expansion, these communities will not only be less subject to the damaging environment, but will have a place to spend time and enjoy being outside.

Making an impact: *La familia Rodriguez*

The Rodriguez Family: living in an urban heat nightmare

The Rodriguez family might be fictional but their story isn't unlike other families searching for relief and respite in today's urban heat crisis. As temperatures rise in their humble New York City neighborhood both providers for the family are eliminated from the workplace. Jorge is unable to work as daytime temperatures soar past 28 °C due to high blood pressure exacerbated by the heat. His wife Sara must stay at home constantly attending her aging mother placing one cool rag after another on her dear mother's wrinkled forehead. The nearest park is miles away and the Rodriguez's young children spend hellish afternoons trying to nap on the families only mattress. There is no escape for the most disadvantaged among us.

Solutions to save the most vulnerable

Green Space initiatives

Statistical analysis using our UHI equation shows the impact that green space can make in the lives of citizens - from the richest among us to the most systematically disadvantaged

Urban Parks

The integration of parks into low income communities will revitalize low-income communities. Reduction of stifling urban heat will promote economic growth and social interaction

Reflective shades

Implementation of shades that are designed to block sunlight off of buildings away from the ground below can prevent the buildup of heat in the urban valleys created by these high rise buildings

Pollution prevention

Capping the amount of pollution that is permitted to be released by cities is a good way of preventing the amount of anthropomorphic heat that is released into the environment

Rain collection

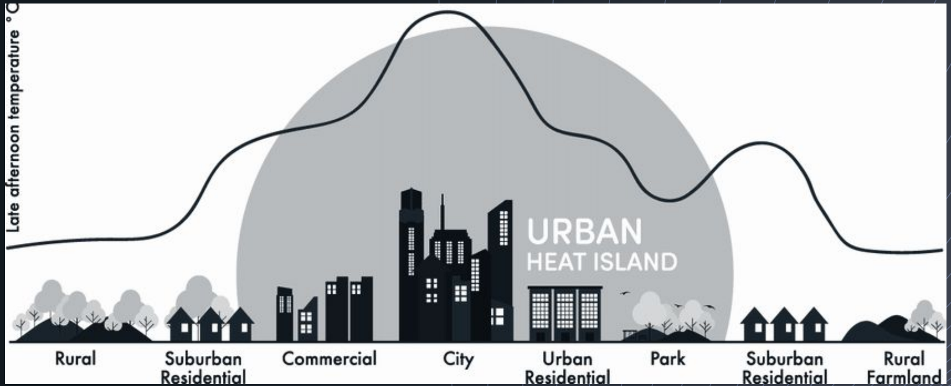
As cities grow, they can build a more sophisticated water collection system wherein water can be stored across the city. The mere presence of excess water in the city will help to fight urban heat

Futuristic biological tool

With enough ingenuity and gene editing technology, one day buildings and roads can be covered in a biological coating (i.e a bacteria or algae) that absorbs sunlight and produces oxygen

Public Policy

Advocacy Groups



There are groups everywhere that are currently fighting to impose high quality pieces of legislation that are targeted at fixing the damaging effects of urban heating. There are hundreds of people every year who die of this preventable occurrence, and many more are impacted indirectly by the effects of urban heating.

By becoming involved in the political process and advocating for the creation and passing of positive legislation, everyday individuals can have a positive impact on their communities.

Conclusion

Amongst the numerous societal difficulties plaguing the United States of America, the horrifying atrocities caused by urban heating undoubtedly rank among the most severe. Tens of thousands of individuals struggle with living, working and sometimes merely surviving in highly populated urban areas that amplify solar shortwave radiation.

It is our responsibility as citizens of this nation to improve the quality of life for our fellow Americans. Working together to build creative, equitable, solutions to this problem will provide a path forward to a brighter, more environmentally sustainable future.

Credits

Special thanks to Peter Trapa and Kyla Welch for hosting the hackathon and inspiring a future generation of climate scientists.

Sources

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