



# Tree Canopy in Beacon Hill, Washington

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November 2024

# Notice

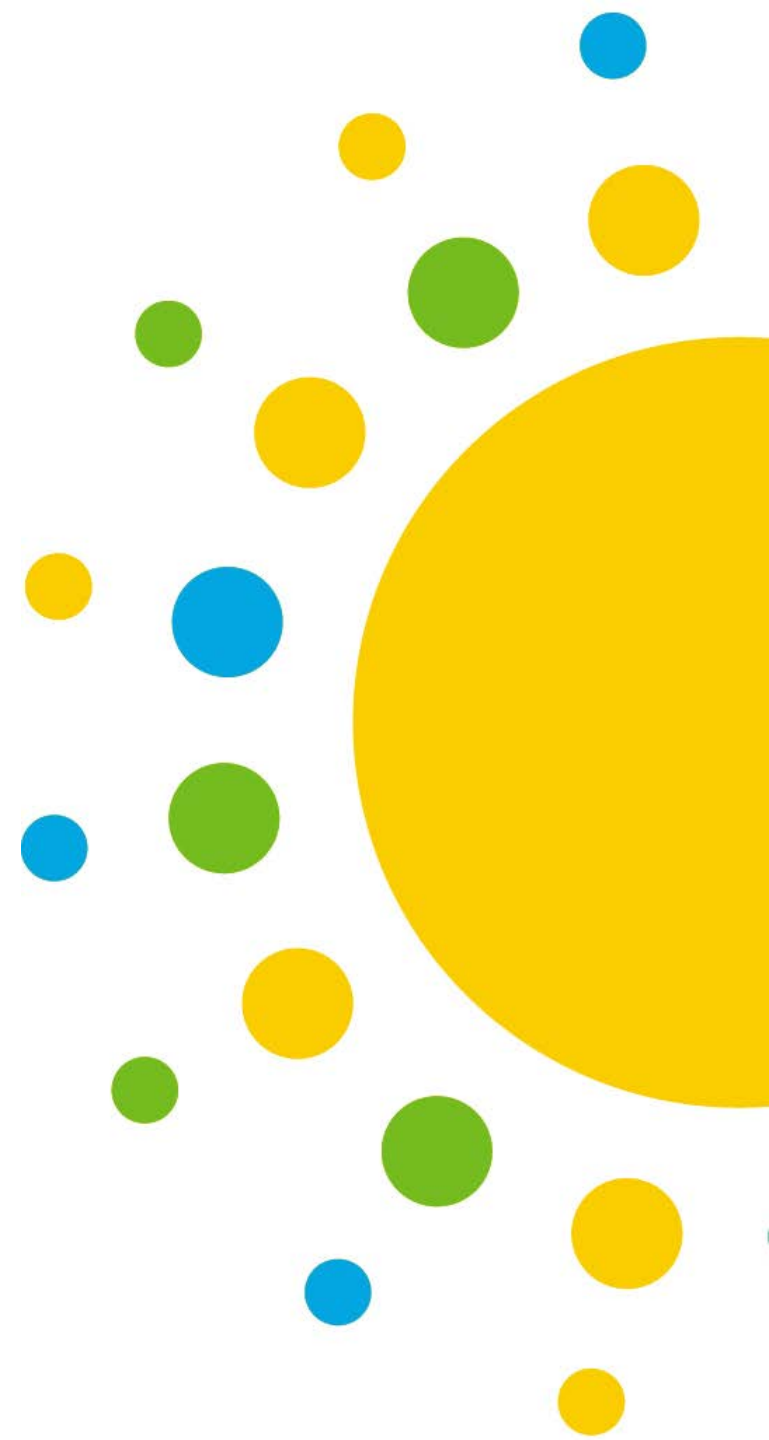
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# Background

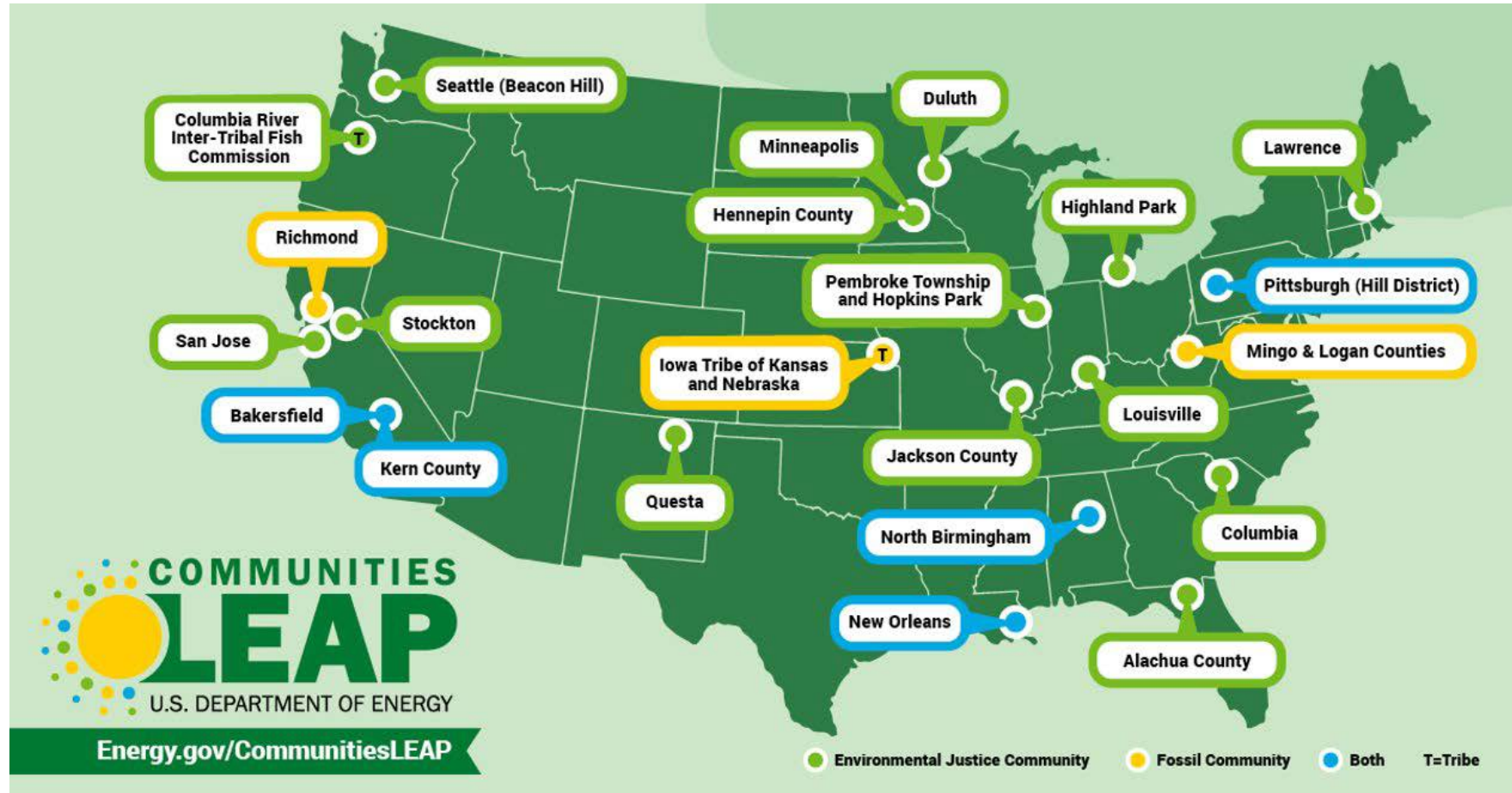
# Communities LEAP Technical Assistance



The Communities LEAP (Local Energy Action Program) pilot aims to facilitate sustained community-wide economic empowerment through clean energy, improve local environmental conditions, and open the way for other benefits primarily through the U.S. Department of Energy's (DOE's) clean energy deployment work.

This opportunity is open to low-income, energy-burdened communities that are also experiencing either direct environmental justice impacts or direct economic impacts from a shift away from historical reliance on fossil fuels.

# Map of LEAP Pilot Communities



# Beacon Hill Stakeholders and Goals

A stakeholder task force working in the Beacon Hill neighborhood of Seattle, Washington, applied for and was selected for the Communities LEAP program. The stakeholders include:

- **Community Stakeholders**
  - El Centro de la Raza
  - Beacon Hill Council
  - Bethany United Church of Christ
- **Supportive Partners**
  - Seattle City Light
  - Seattle Office of Sustainability and Environment

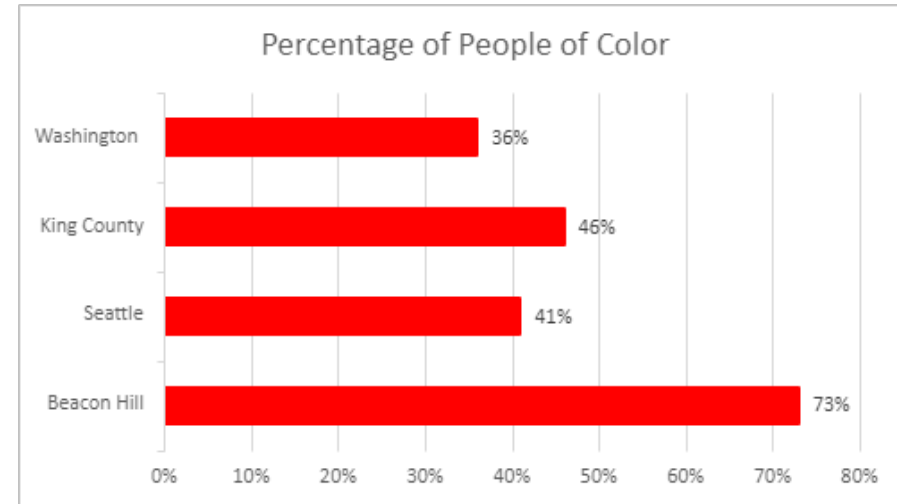
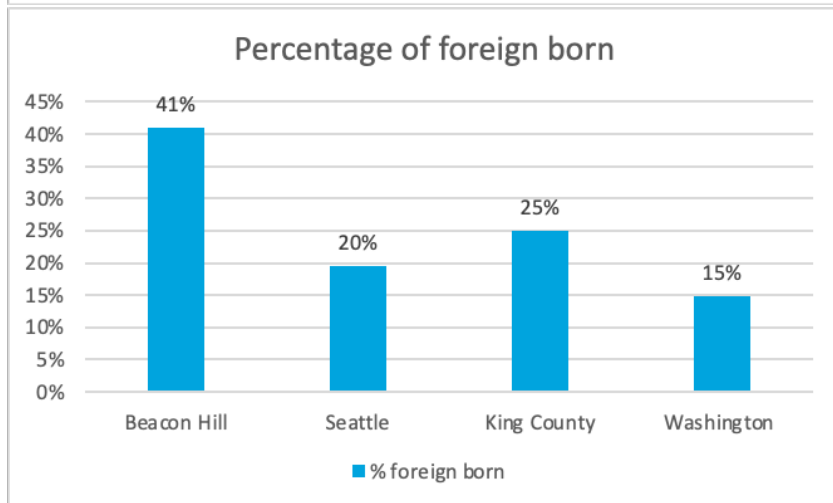
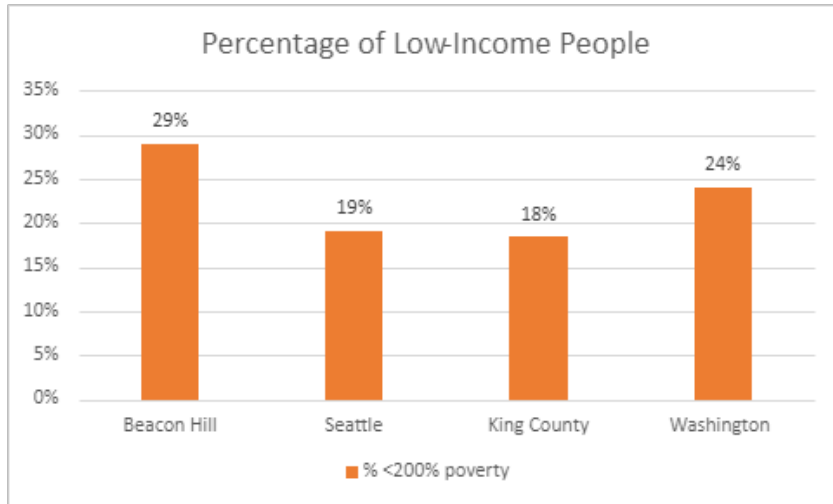
## **Task force goals include:**

- **Health:** Improve the health of Beacon Hill residents by improving indoor and outdoor air quality, reducing noise, and reducing the impacts of extreme heat.
- **Economy:** Increase economic stability and mitigate displacement of Beacon Hill residents by reducing energy bills, exploring anti-displacement/stay-in-place policies, and providing job training and job opportunities.
- **Resilience:** Improve community resilience in the face of climate change impacts such as extreme heat, extreme storms, power outages, and wildfire smoke.
- **Greenhouse gases:** Reduce greenhouse gases and other environmental impacts from fossil fuel extraction and use.

# About Beacon Hill



# Beacon Hill Demographics



- 29% of residents are below 200% of U.S. poverty levels.
- 73% of residents are people of color.
- 41% of residents are immigrants, refugees, and those born outside of the United States.

Source: U.S. Census Bureau: American Community Survey (ACS) 2021 Table S1701 for low-income people; ACS Table DP02 for foreign born; Decennial Census 2020 Table P2 for people of color.

# Environmental Concerns in Beacon Hill

- Air quality and noise are priority issues for the neighborhood due to the airport and nearby highways.
- Indoor air quality is a priority, especially for oil-heated homes.
- Climate change is impacting Beacon Hill residents with extreme heat, extreme cold, and wildfire smoke.

# Beacon Hill: Moderate to High Tree Equity Priority Level

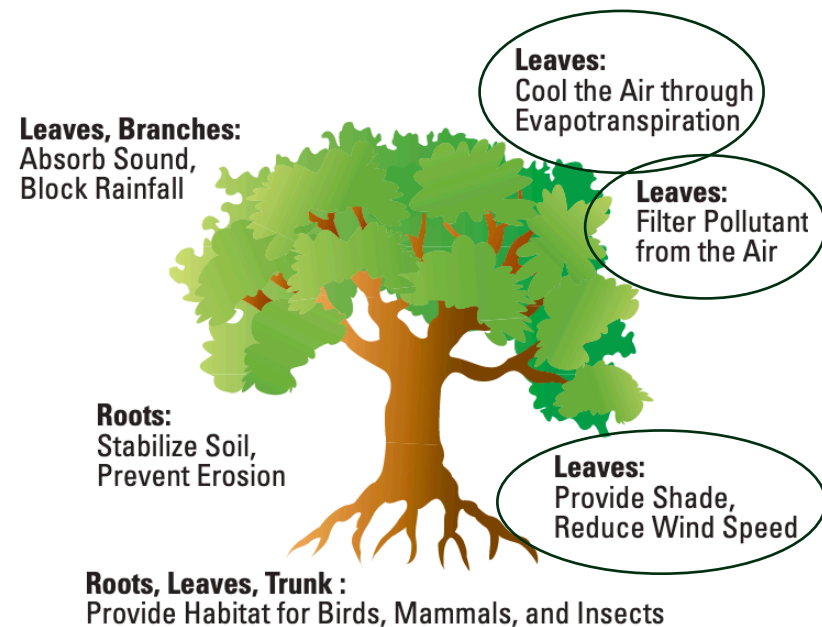
- [Tree Equity Score](#) by American Forests
  - Measures how well the benefits of trees are reaching disadvantaged communities.
  - Helps communities develop projects for funding through federal Justice40 Initiative.
  - A score of 100 means the neighborhood has enough trees.
- Seattle has an average Tree Equity Score of 91 on a scale of 0–100, where the higher the number, the lower the priority to plant more trees (90–99 is a low priority level).
  - Most areas in Beacon Hill have a moderate to high priority level (70–89).
  - Six of 24 block groups in Beacon Hill have a high priority level (70–79). In total there are 25 high priority level block groups in Seattle.
  - 12 of 24 block groups in Beacon Hill have a moderate priority level (80–89). In total there are 125 moderate priority level block groups in Seattle.

# Benefits of Tree Canopy

# Benefits of Trees

Ecosystem service	Description
<u><a href="#">This report focuses on the following ecosystem services:</a></u>	
Air purification	Trees reduce air pollution concentrations.
Shade and heat wave mitigation	Trees reduce ambient air temperatures.
<u>Other ecosystem services include:</u>	
Storm water mitigation	Increase infiltration of stormwater and filter pollutants out of it.
Physical health	Greenspace is used for recreation, and recreation improves people's health.
Mental health	Interacting with nature decreases stress and increases focus.
Recreation and aesthetic benefits	Greenspace is often used for recreation and increases people's perception of beauty.

Source: [McDonald et al. 2016](#)



Source: [U.S. EPA 2003](#)

# Benefits of Trees

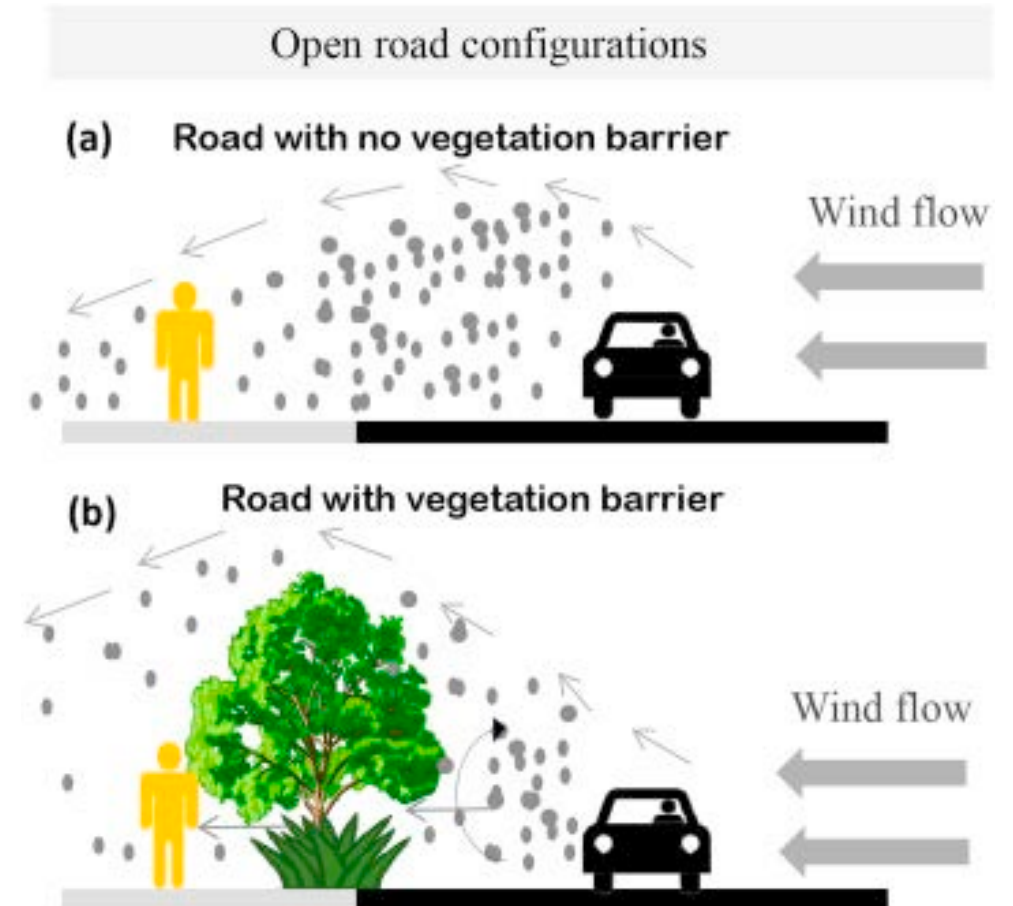
According to [a research finding](#) published online by the U.S. Department of Agriculture Forest Service, “Based upon the U.S. Environmental Protection Agency’s value of a statistical life (\$10.7 million), planting a single urban tree in each of Portland’s 140 census tracts is associated with \$14.2 million in reduced mortality. Furthermore, as the trees matured, the health benefits increased.”

# Benefits of Trees: Improving Air Quality

Trees can improve air quality through the direct removal of air pollutants:

- Gaseous pollutants (e.g.,  $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{O}_3$ ): Uptake via leaf stomata.
- Particle pollutants (e.g.,  $\text{PM}_{2.5}$ ): Deposit on tree leaves; most permanently incorporate into leaf wax or cuticle, some can be resuspended due to wind.
- See Supplemental Information (SI) slides for more information on air pollution basics.

Trees can also serve as a barrier to block airflow moving downwind.



Source: [National Park Service](#)

Source: [Abhijith et al. 2017](#)

# Removal of PM from Planting Street Trees

- Based on the literature:
  - Trees can remove 10%–50% of particulate matter (PM) pollution *nearby*. Most reductions in PM concentrations occur within 30 meters of street trees.
  - Trees can remove 0.1%–3.5% of *region-wide* PM pollution.
- PM removal efficiency of street trees is dependent on ambient PM concentrations, leaf areas, local meteorology conditions, etc.
- See supplemental information slides for more information on methodology to estimate PM removal by trees.

Source: [The Nature Conservancy 2016](#)



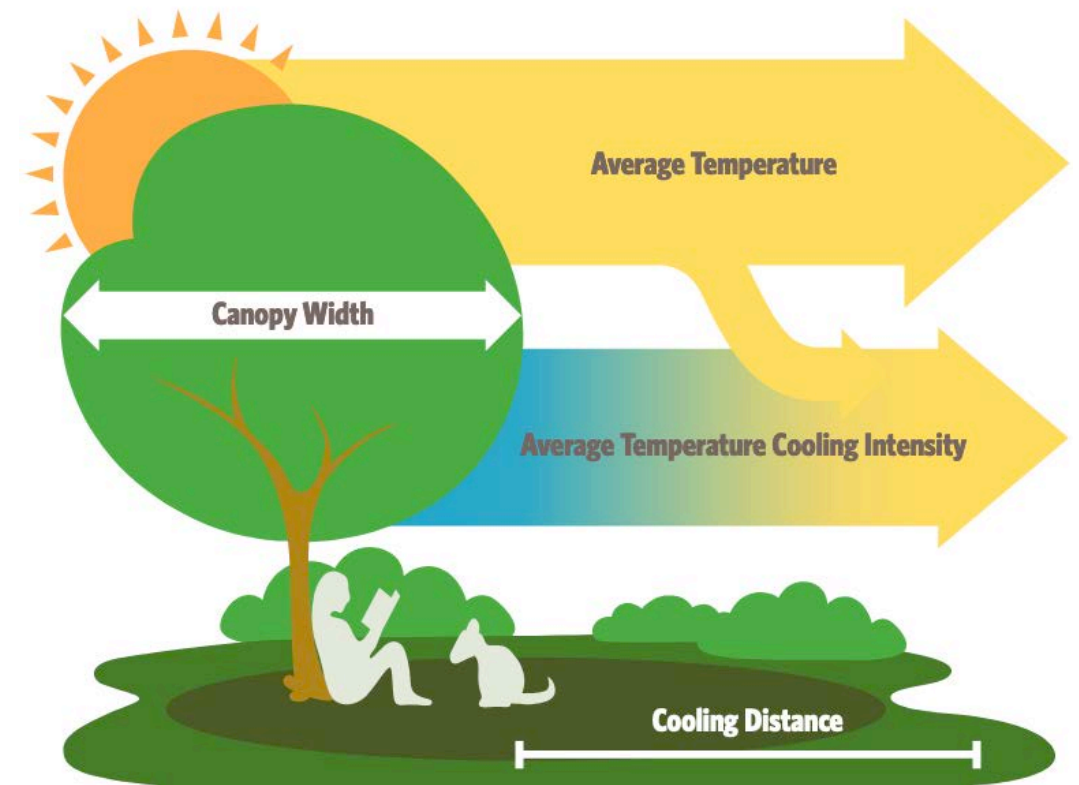
# Notes on the Adverse Impact of Trees on Air Quality

- Trees can block airflow upwind and locally increase PM<sub>2.5</sub> concentrations. Proper location and spacing design are needed.
  - Generally, larger spacing next to major roads and smaller spacing along smaller roads can reduce the adverse effects of trees blocking airflow.
  - Local-scale modeling is needed to understand the optimal spacing.
- Trees can emit volatile organic compounds (VOCs), which can contribute to O<sub>3</sub> and PM<sub>2.5</sub> formation. Choosing low VOC-emitting species can reduce these impacts.
  - VOC emissions are dependent on plant species, meteorology conditions, etc.
  - Example tree species for Seattle: [Trees for Neighborhoods](#)
  - Future field measurements of VOC emission rates are needed to find the local species that best fit Beacon Hill.
  - See SI slides for more information on biogenic VOCs.

Source: [The Nature Conservancy 2016](#) and [DOE Office of Science](#)

# Benefits of Trees: Reducing Urban Heat

- Providing shade:
  - Trees prevent the sun's radiation from reaching the ground.
  - The greater the tree height and the larger the tree canopy width, the higher the cooling effects (both temperature reduction and cooling distance).



Source: [The Nature Conservancy 2016](#)

# Benefits of Trees: Reducing Urban Heat

- **Planting trees helps reduce urban air temperature by increasing latent heat and decreasing sensible heat released from urban surfaces.**
  - Latent heat: Heat that converts liquid water to water vapor without increasing air temperature.
  - By contrast, sensible heat: Heat that increases air temperature.
  - A higher latent-heat-to-sensible-heat ratio is beneficial for keeping the city cool. The effects of increased humidity due to latent heat are not considered here.
  - See SI slides for more information on surface energy balance.



*Photo from Gabriel Boeckman, Marshall Space Flight Center, NASA*

Source: Christopher Bretherton lecture, [Boundary Layer Meteorology, University of Washington](#)

# Temperature Reduction from Planting Street Trees

- Based on the literature:
  - Trees can provide 0.4°C (0.7°F) to 3.0°C (5.4°F) local cooling depending on the site and the time of day.
  - Most cooling effects occur within 30 meters of street trees.

Source: [The Nature Conservancy 2016](#)

# Notes on Planting Trees for Reducing Urban Heat

- More water is likely needed with more trees planted to make sure the trees are growing well.
- Enough water in the soil to be absorbed by the trees is necessary to ensure the benefits of latent heat are realized through evaporation and transpiration.
- The increase in water needed for the trees can be satisfied by rainfall, otherwise, human irrigation is needed.
- Considering species that require less water for growth can reduce water needs.
- Information on soil water needs is provided by [Trees for Neighborhoods](#).

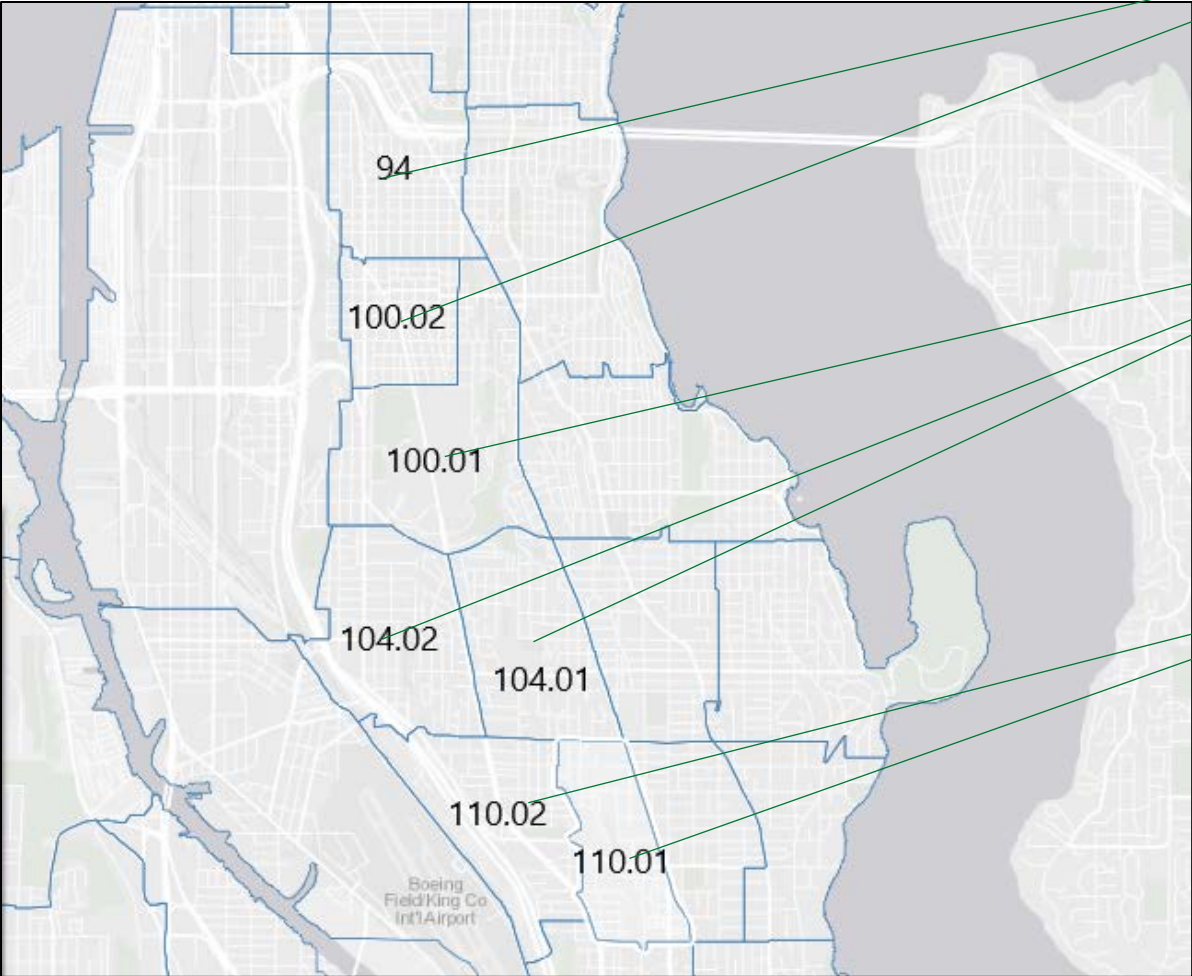
# **Tree Canopy Coverage: Current Status in Beacon Hill**

# Beacon Hill Census Tracts

North Beacon Hill

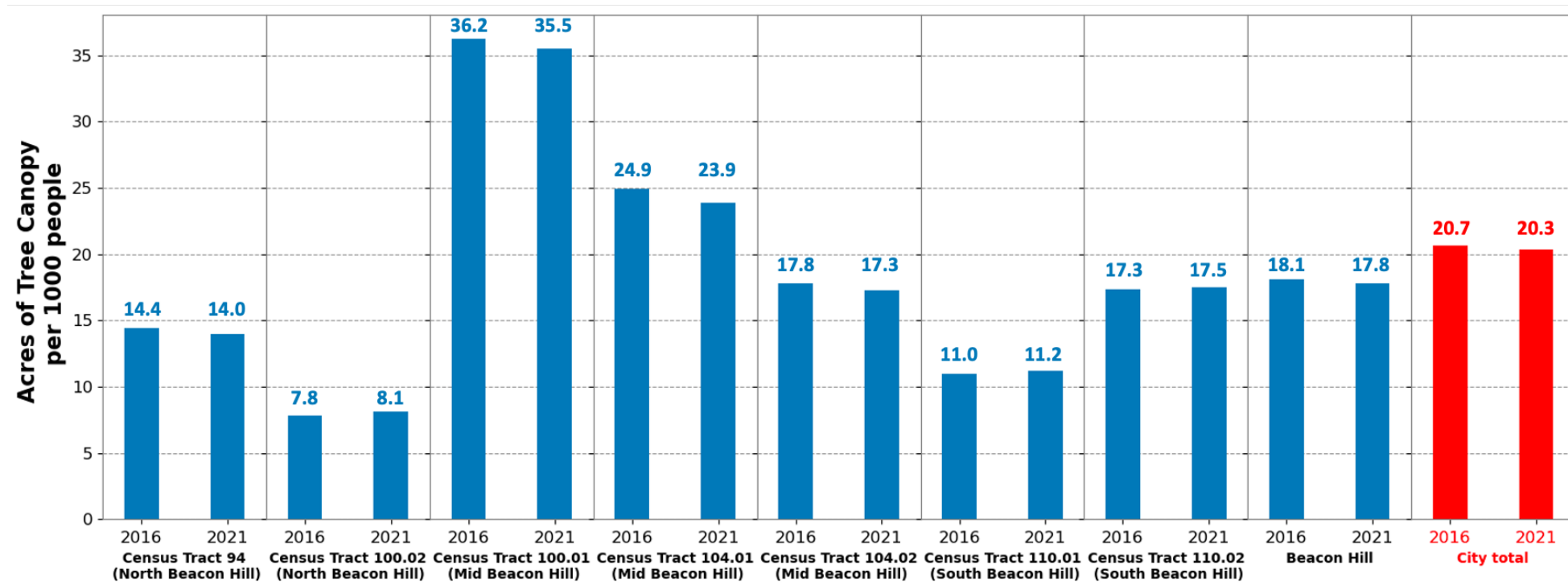
Mid Beacon Hill

South Beacon Hill



Source: [Seattle GeoData](#)

# Tree Canopy Actual Coverage

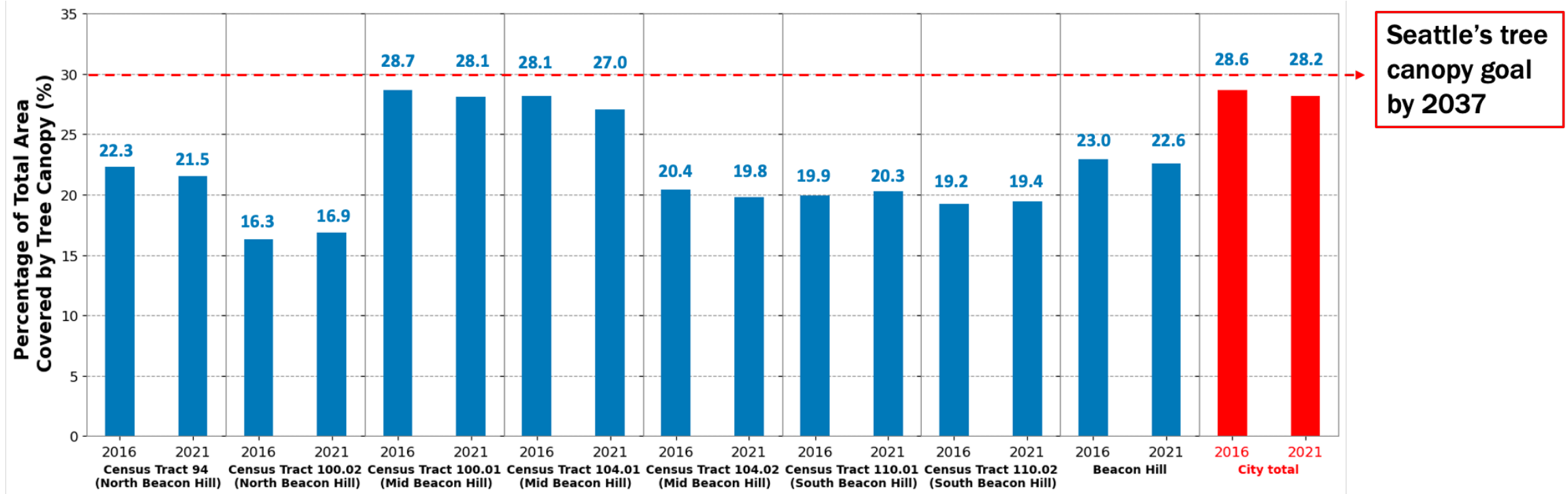


- Overall, there is a decrease in tree canopy cover in Beacon Hill between 2016 and 2021.
- Tree canopy per 1,000 people in Beacon Hill is lower than the city average.
- Five out of seven census tracts have lower population normalized tree canopy cover than the city average.

Data Source: [Gallery for City of Seattle ArcGIS Online](#)



# Percentage Tree Canopy Coverage



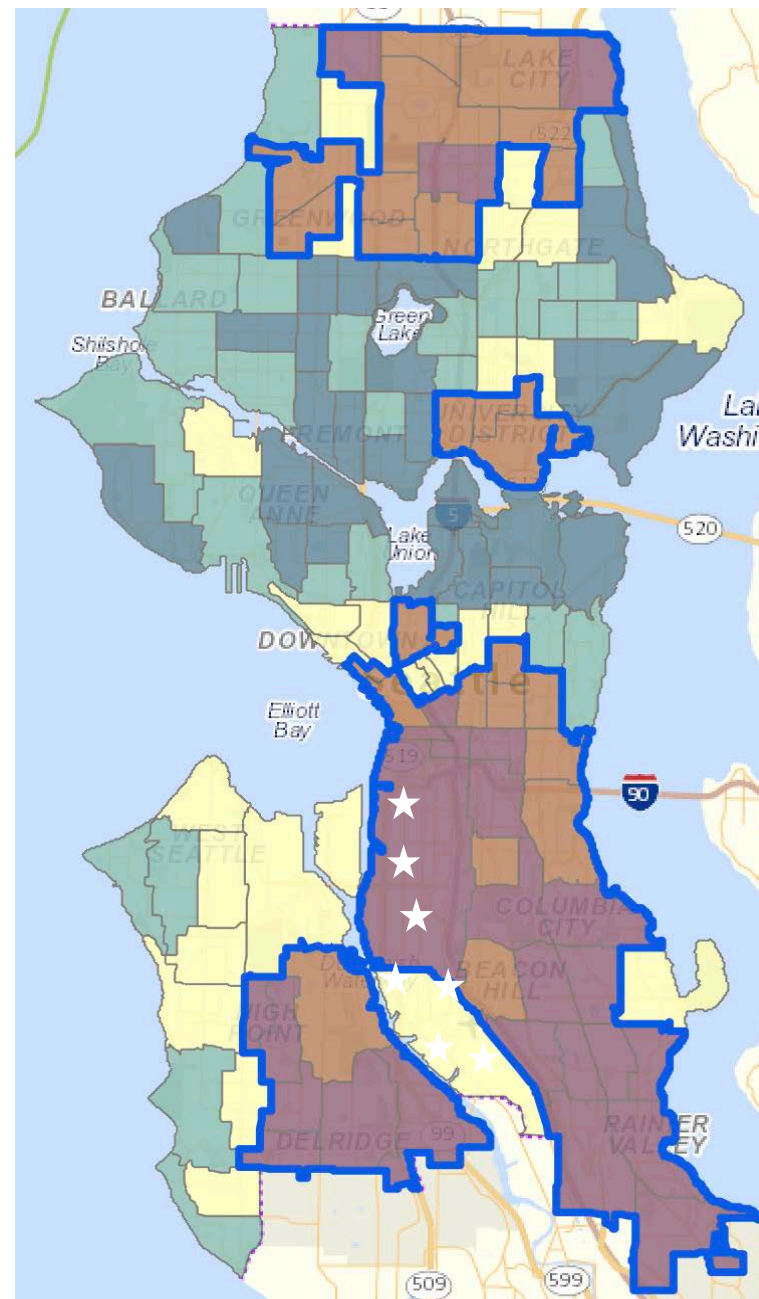
- All Beacon Hill census tracts have lower percentage tree canopy coverage than the city average except census tract 100.01 in year 2016.

Data Source: [Gallery for City of Seattle ArcGIS Online](#)

# Beacon Hill is Among the Highest Environmental Justice (EJ) Priority Areas

The blue borders on the map delineate EJ priority areas. The white stars denote Beacon Hill census tracts. Five out of seven census tracts in Beacon Hill are classified as highest EJ priority tracts, while the other two census tracts are classified as second-highest EJ priority tracts. No area of Beacon Hill has a lower EJ priority.

EJ priority areas are determined based on factors including race, language, origin, socio-economic disadvantage, and health disadvantage.



Environmental Justice Priority Areas



Census Tracts Composite Quintile



- Highest priority/Most disadvantaged
- Second highest
- Middle
- Second lowest
- Lowest

Source: [Gallery for City of Seattle ArcGIS Online](#)

# Beacon Hill: Highest EJ Priority, but Lowest Tree Cover Percentage

The blue borders on the map delineate EJ priority areas. The white stars denote Beacon Hill census tracts. The colors denote level of existing tree canopy and EJ priority level. Five out of seven census tracts in Beacon Hill are identified as having both high EJ priority level and a low level of tree canopy coverage.

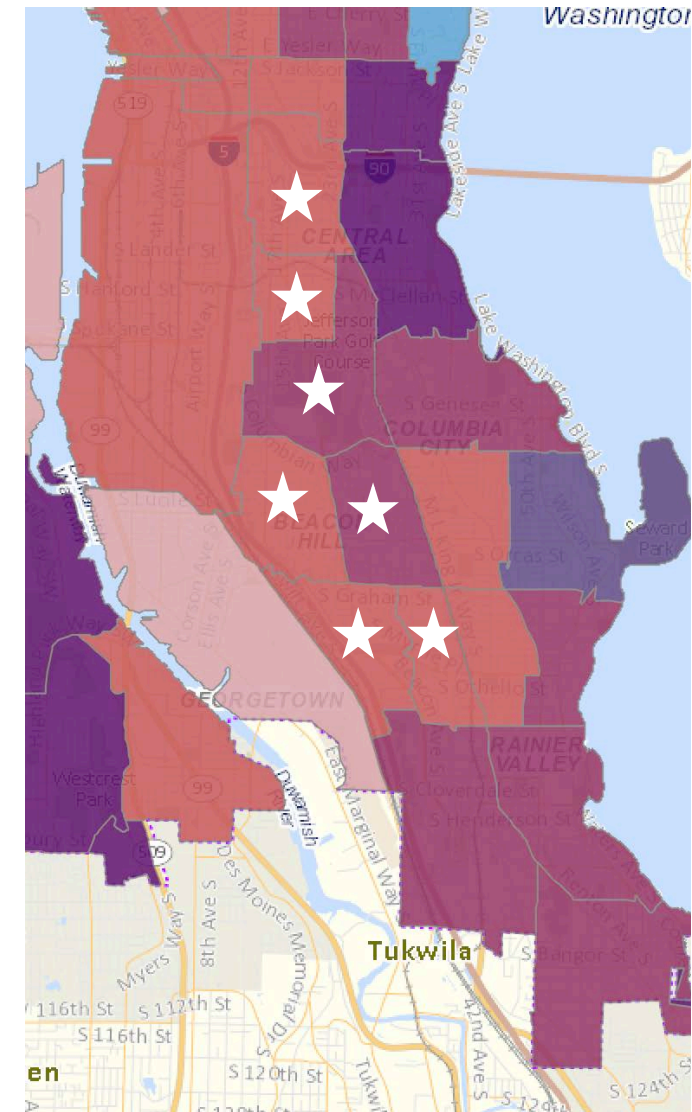
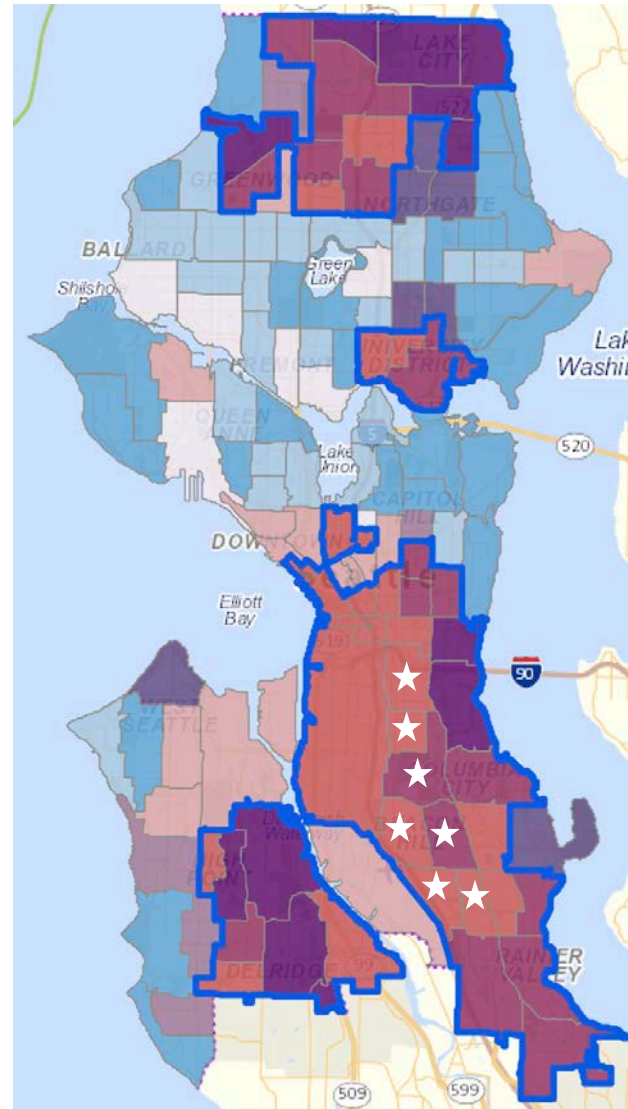
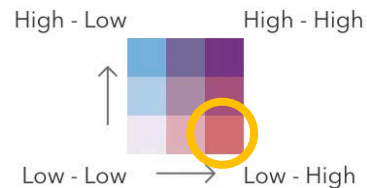
Environmental Justice Priority Areas



Existing Tree Canopy % and Environmental Justice Priority Level

Relationship

- ↑ Existing Tree Canopy %
- Environmental Justice Priority Level

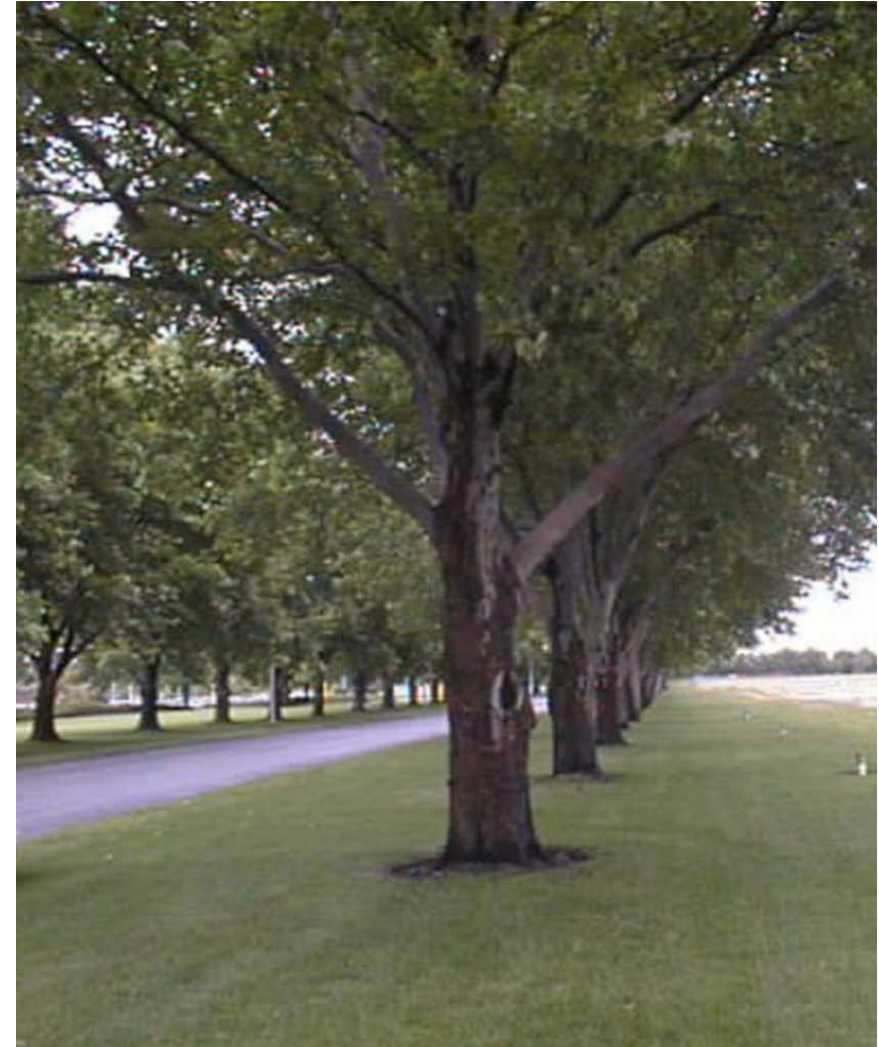


Source: [Gallery for City of Seattle ArcGIS Online](#)

# **Tree Planting Programs in Seattle**

# Trees for Seattle

- Website link:  
<https://www.seattle.gov/trees>
- Provides basic information on:
  - Current tree canopy status
  - Tree planting 101
  - Tree regulations
  - [Trees for Neighborhoods](#)
    - Eligibility: Private citizens, businesses, community organizations
    - Prioritized application for underserved communities.



*Photo from Gabriel Boeckman, Pacific Northwest National Laboratory*

# Trees for Seattle



*Photo by Nancy Carlisle, NREL*

Trees for Seattle provides different tree species options in its Trees for Neighborhoods program, some of which are appropriate for a yard, others for the street, and others for both.

# Seattle's New Tree Protection Ordinance

- [Ordinance 126821](#) (Effective on July 30, 2023)
- Goals:
  - Achieve at least 30% tree canopy cover city-wide by 2037.
  - Safeguard 157,000 more trees by limiting removal of trees on properties not undergoing redevelopment and requiring replacement for any tree removed with a trunk that is 12 inches or greater in diameter.
  - Address inequities in canopy coverage by planting new trees in historically underserved neighborhoods.
- Selected tools:
  - [One Seattle Tree Plan](#): Grow and foster an equitable tree canopy on public land.
  - [Trees for Neighborhoods program](#): Support households to plant on private property or along the sidewalk.

# King County Conservation Futures

- [King County Conservation Futures](#) is an open space acquisition grant program.
- Goal: Help buy parks and open spaces such as natural lands, urban greenspaces, forests, community gardens, farms, and trails.
- In identified underserved areas, the grants may be able to cover 100% of the acquisition costs for some projects.
- Application round for 2025 funding is now closed (February 2024 deadline).



# Three Million Trees (King County)



Website link: <https://kingcounty.gov/services/environment/stewardship/three-million-trees.aspx>



Goal: Plant, protect, and prepare a combined 3 million trees by the end of 2025 according to the King County's 2020 Strategic Climate Action Plan.



Tree planting location will be informed by a heat mapping project conducted by King County and City of Seattle to identify which areas are experiencing the most harmful effects of rising temperatures.



[Results of the heat mapping project](#) (Takeaway: **Beacon Hill has relatively high heat index compared to rest of the county, thus it should be prioritized for tree planting.**)

# Conclusion

Based on the 2021 City of Seattle Tree Canopy Assessment, utilizing tree canopy coverage geospatial data and demographics, most of Beacon Hill is classified as having the highest Environmental Justice Priority index and the lowest percentage of tree canopy coverage. According to same tree canopy coverage geospatial data, Beacon Hill's tree canopy coverage decreased during the period of 2016 to 2021 and all census tracts have a lower percentage of tree canopy coverage than the city average. Given Beacon Hill's environmental concerns of poor air quality, noise pollution, and climate change effects such as extreme heat, planting trees could be beneficial because:

- Trees can help in the removal of air pollutants, improving air quality.
- Trees can increase latent heat, reducing urban air temperature.
- Trees can also improve physical and mental health outcomes, provide storm water mitigation, and have recreational and aesthetic benefits.

Beacon Hill community leaders could leverage existing policies and programs to encourage tree planting.

# Supplemental Information

# Air Pollution 101

- Ozone (O<sub>3</sub>): Ground-level ozone, generated by chemical reactions between oxides of nitrogen (NO<sub>x</sub>) and volatile organic compounds (VOCs); can lead to asthma.
- Fine Particulate Matter (PM<sub>2.5</sub>): Particles less than 2.5 μg in diameter. Generated from combustion product of fossil fuels, road or construction dust and secondary formation; can lead to cardiovascular disease.
- Volatile Organic Compounds (VOCs): Organic chemical compounds that can evaporate under normal atmospheric conditions; have both anthropogenic and biogenic sources.
- Oxides of nitrogen (NO<sub>x</sub>): Generated from combustion product of fossil fuels; can lead to respiratory irritation.

Source: [Duvall and Freed 2020](#) and [American Lung Association 2024](#)

# Equations to Estimate PM Removal from Urban Trees: Region-Wide Estimation

- Region-level PM removal from trees can be estimated based on average annual PM removal rate per square meter of tree canopy (unit:  $g \cdot yr^{-1} \cdot m^{-2}$ ) and the total area of tree canopy.
- Average annual PM removal rate per square meter tree canopy can be converted from PM fluxes ( $F_p$ , unit:  $\mu g \cdot s^{-1} \cdot m^{-2}$ ).
- $F_p = v_d \times C_p$
- $v_d$ : PM deposition velocity, dependent on species and type of site, unit:  $cm \cdot s^{-1}$
- $C_p$ : Atmospheric PM concentration, unit:  $\mu g \cdot m^{-3}$

Source: Kroeger et al 2018

# Equations to Estimate PM Removal from Urban Trees: Local-Level Estimation

- Equation:  $C_x = C_0 \times e^{-kx}$
- $C_x$ : PM mass concentrations (unit:  $\mu\text{g}/\text{m}^3$ ) at horizontal distance  $x$  (unit: m) from the source
- $C_0$ : PM mass concentrations (unit:  $\mu\text{g}/\text{m}^3$ ) at the source
- $k$ : Depletion coefficient, e.g., 0.019 for mixed urban forest stand, 0.035 for tall dense oak and cedar trees from past literatures.

Source: Kroeger et al 2018

# Biogenic VOC Emissions from Urban Trees

- Biogenic VOCs (BVOCs) can be grouped into three categories: isoprene, monoterpenes, and other VOCs.
- Isoprene emission rate is dependent on tree species, foliar density (i.e., foliage area divided by canopy volume), environmental influence of temperature, light and season variation, and CO<sub>2</sub> inhibition on isoprene emissions.
- Monoterpene and other VOCs emission rates are dependent on tree species, foliar density, environmental influence of temperature, and season variation.
- Generally speaking, trees produce more isoprene at daytime than nighttime (because of more sunlight and higher temperature), during dry season more than wet season.

Source: [DOE Office of Science 2018](#)

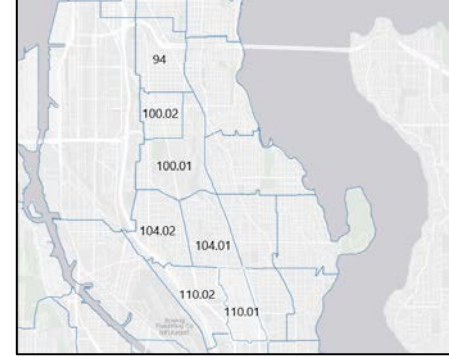
# Surface Energy Balance

- The basic surface energy balance requires:
  - $R_N = H_S + H_L + H_G$
- $R_N$ : Net downward radiative flux (shortwave radiation from the sun and longwave radiation from the atmosphere; shortwave dominates).
- $H_S$ : Upward surface sensible heat flux, which warms the air close to the surface.
- $H_L$ : Upward surface latent heat flux, energy associated with the evaporation of water vapor without warming the air.
- $H_G$ : Downward ground heat flux into the subsurface medium.
- The ratio between  $H_S$  and  $H_L$  (i.e.,  $H_S/H_L$ ) is called the Bowen ratio. The smaller Bowen ratio is, the more energy is transferred to the atmosphere in the form of latent heat.

Source: Bretherton n.d



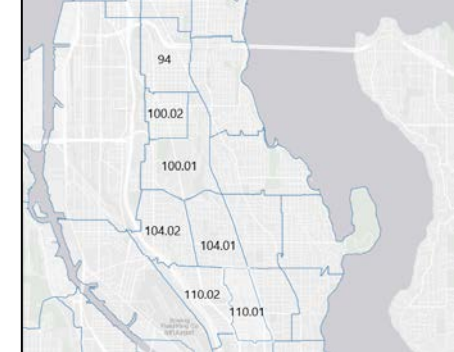
# Tree Canopy Actual Coverage in Beacon Hill



	Census Tract	Population	Total Area (Acres)	Tree Canopy 2016 (Acres)	Tree Canopy 2021 (Acres)	% Change in Tree Canopy
North Beacon Hill	94	6,566	425.8	94.8	91.6	-3.3
	100.02	4,861	234.3	38.1	39.5	3.7
Mid Beacon Hill	100.01	4,526	571.8	164.0	160.8	-1.9
	104.01	4,514	399.5	112.4	107.9	-4.0
	104.02	5,097	444.5	90.8	88.1	-3.0
South Beacon Hill	110.01	4,790	264.6	52.6	53.7	2.0
	110.02	4,590	414.2	79.5	80.5	1.2
Beacon Hill	/	34,944	2754.7	632.3	622.2	-1.6
City-wide	/	737,015	53256.8	15243.7	14992.0	-1.6

Sources: Gallery for City of Seattle GIS Program; U.S. Census Bureau (American Community Survey 2020, 2021; Decennial Census 2020)

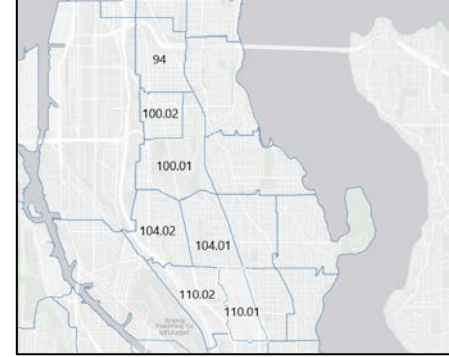
# Tree Canopy Percentage Coverage in Beacon Hill



	Census Tract	Tree Canopy % 2016	Tree Canopy % 2021	Absolute % Change
North Beacon Hill	94	22.26	21.53	-0.74
	100.02	16.28	16.87	0.60
Mid Beacon Hill	100.01	28.68	28.12	-0.56
	104.01	28.14	27.01	-1.12
	104.02	20.44	19.82	-6.2
South Beacon Hill	110.01	19.89	20.29	0.39
	110.02	19.20	19.43	0.23
Beacon Hill	/	22.96	22.58	-0.37
City-wide	/	28.62	28.15	-0.47

Data Source: [Gallery for City of Seattle ArcGIS Online](#)

# Beacon Hill is Among the Most Disadvantaged Areas



	Census Tract	Census Tracts Composite Quintile
North Beacon Hill	94	Highest priority/Most disadvantaged
	100.02	Second highest
Mid Beacon Hill	100.01	Highest priority/Most disadvantaged
	104.01	Highest priority/Most disadvantaged
	104.02	Second highest
South Beacon Hill	110.01	Highest priority/Most disadvantaged
	110.02	Highest priority/Most disadvantaged

Data Source: [Gallery for City of Seattle ArcGIS Online](#)

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# Thank you!

[www.energy.gov/communitiesLEAP](http://www.energy.gov/communitiesLEAP)

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