Health Impact Assessment of Green Roofs in Ramsey County, MN

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METROPOLITAN COUNCIL

Resilient Communities Project
UNIVERSITY OF MINNESOTA
Building community-university partnerships for sustainability

The project on which this presentation is based was completed in collaboration with the Metropolitan Council as part of the 2020–2021 Resilient Communities Project (RCP) partnership. RCP is a program at the University of Minnesota's Center for Urban and Regional Affairs (CURA) that connects University faculty and students with Minnesota communities to address strategic projects that advance local resilience and sustainability.

This publication may be available in alternate formats upon request.

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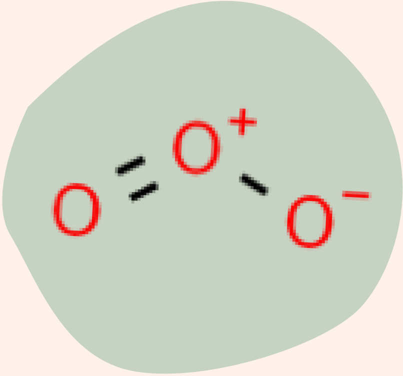
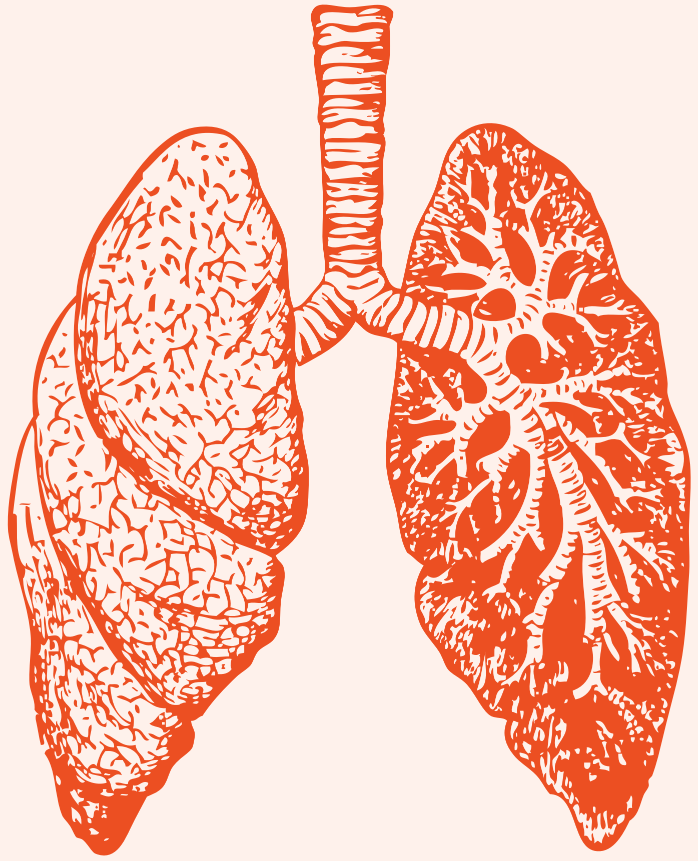
HEALTH IMPACT ASSESSMENT OF GREEN ROOFS IN RAMSEY COUNTY, MN

Cecilia Pigozzi

Ozone & Health

NO_x + VOCs sunlight =





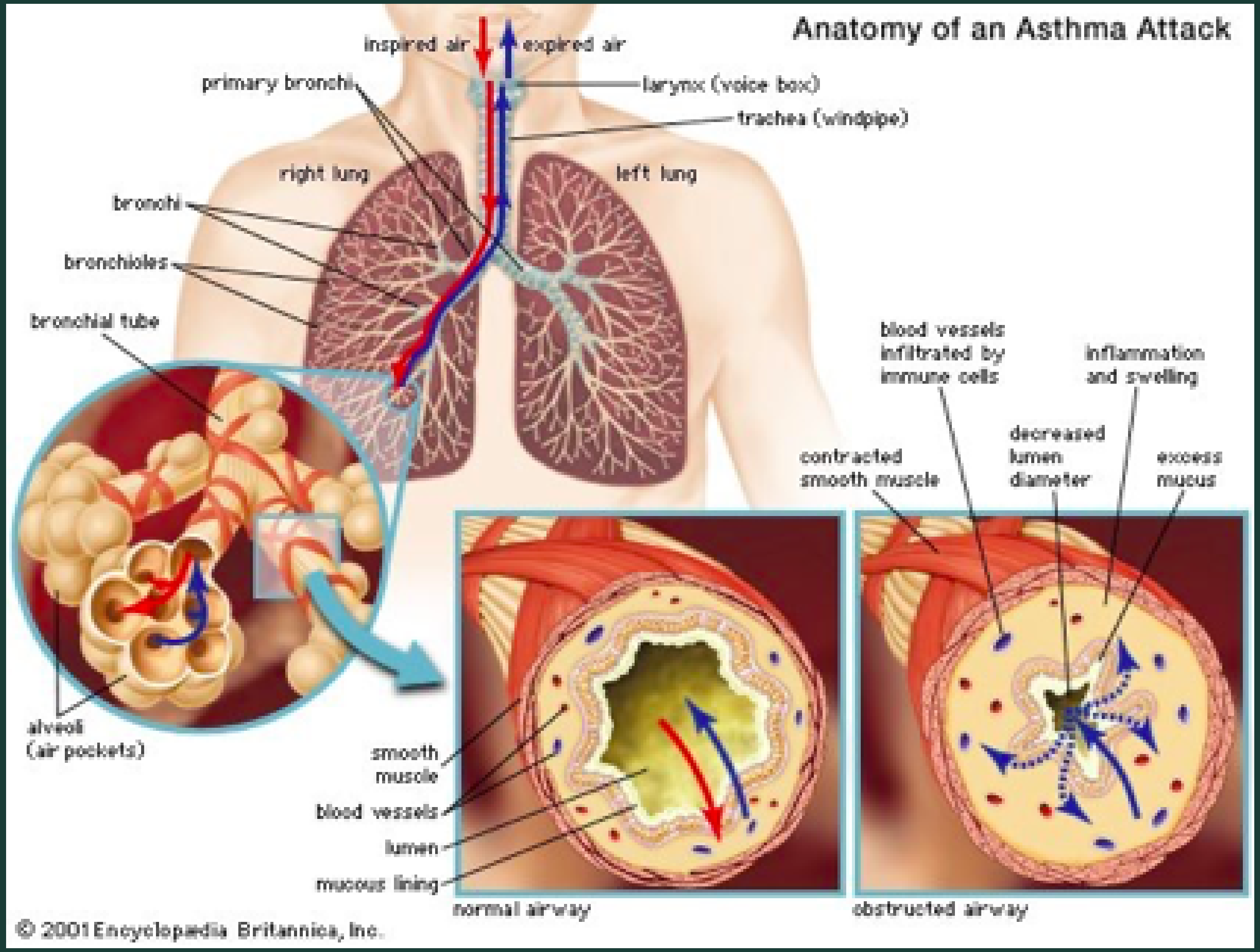
GROUND-LEVEL INTERACTIONS

- Car exhaust, polluting solvents & summer.
- O_3 is an incredibly unstable molecule, and one of the most powerful oxidizing agents.
- 41% of people in the U.S. live in counties with unhealthy levels of O_3 or particulate matter.

HEALTH

- Inflames and damages lung tissue. The airway constricts and traps air in the alveoli.
- In 2013, MN saw O_3 contribute to:

  - 57 cardiopulmonary deaths
  - 55 asthma hospitalizations
  - 300 asthma-related ED visits


Anatomy of an Asthma Attack
inspired air
expired air
primary bronchi
larynx (voice box)
trachea (windpipe)
right lung
left lung
bronchi
bronchioles
bronchial tube
alveoli
(air pockets)
blood vessels
infiltrated by
immune cells
inflammation
and swelling
decreased
lumen
diameter
contracted
smooth muscle
excess
mucus
smooth
muscle
blood vessels
lumen
mucous lining
normal airway
obstructed airway
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Air Pollution and Inequity

US STATISTICS

- 11.2% of African Americans are currently diagnosed with asthma (7.7% of Whites)
- Asthma ED visits 3xs higher in African Americans than Whites
- Nearly 1 in 2 Latinx live in counties below clean air and ozone standards
- Latinx children are twice as likely to die from asthma as non-Latinx Whites

THE REASONS

Structural Inequities of Housing Environments:

- Very little green space
- Proximity to busy roadways and polluting industries
- Racially Restrictive Covenants and The Federal Housing Administration's Redlining practices

CHANGE AND SUSTAINING CHANGE

Initiatives to address these disparities must match the sociopolitical context and cultural values of the people most affected.

REMOVAL OF OZONE VIA PLANTS

CONCENTRATION GRADIENT

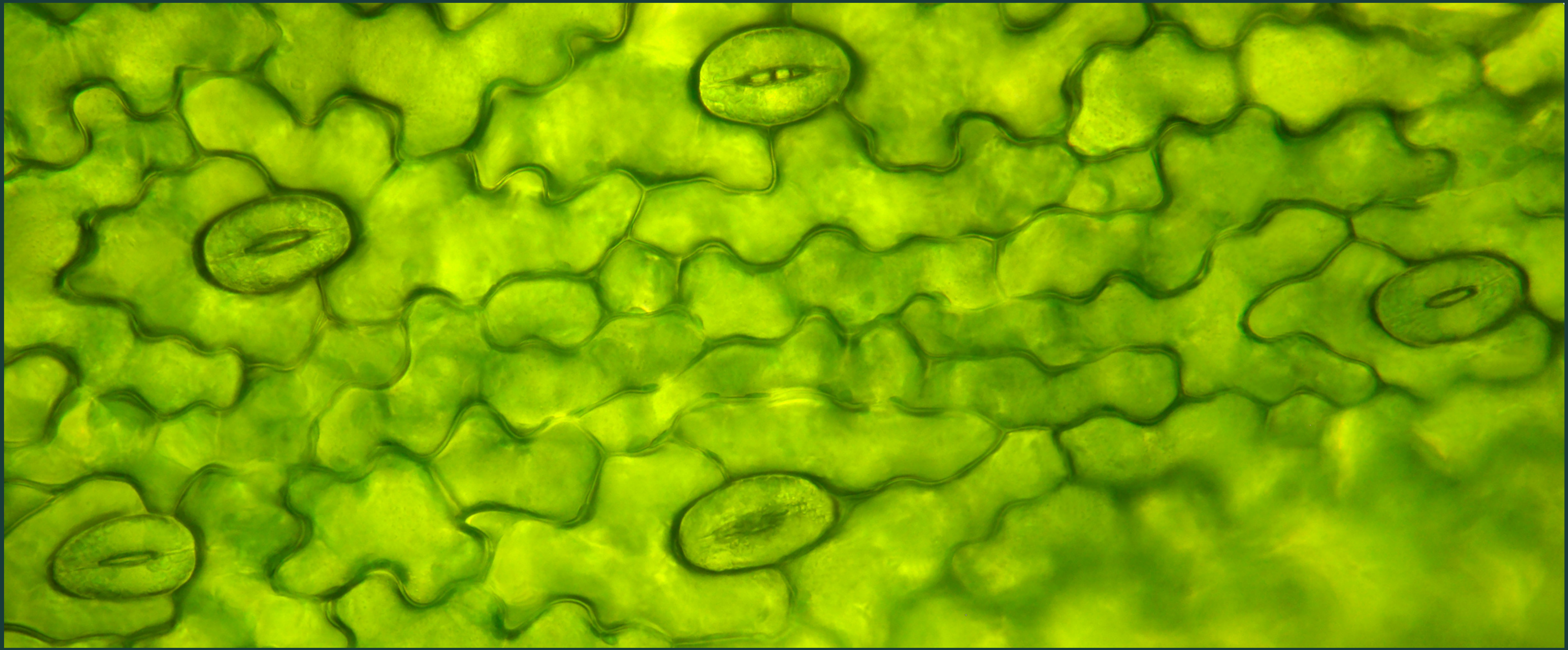
- O_3 enters through their stomata on their leaves
- Diffuses into intercellular spaces where subsequent reactions occur.
- If O_3 levels are high it accumulates in this space, decreasing the total a O_3.

EVAPOTRANSPIRATION

Decreases air temperatures thus minimizing the production of some air pollutants like O_3 in the first place.

LIMITATIONS

- Non- stomatal uptake via deposition
- Oxidation of the internal leaf decreases the plant's carbon uptake
- Minimal biogenic volatile organic compounds



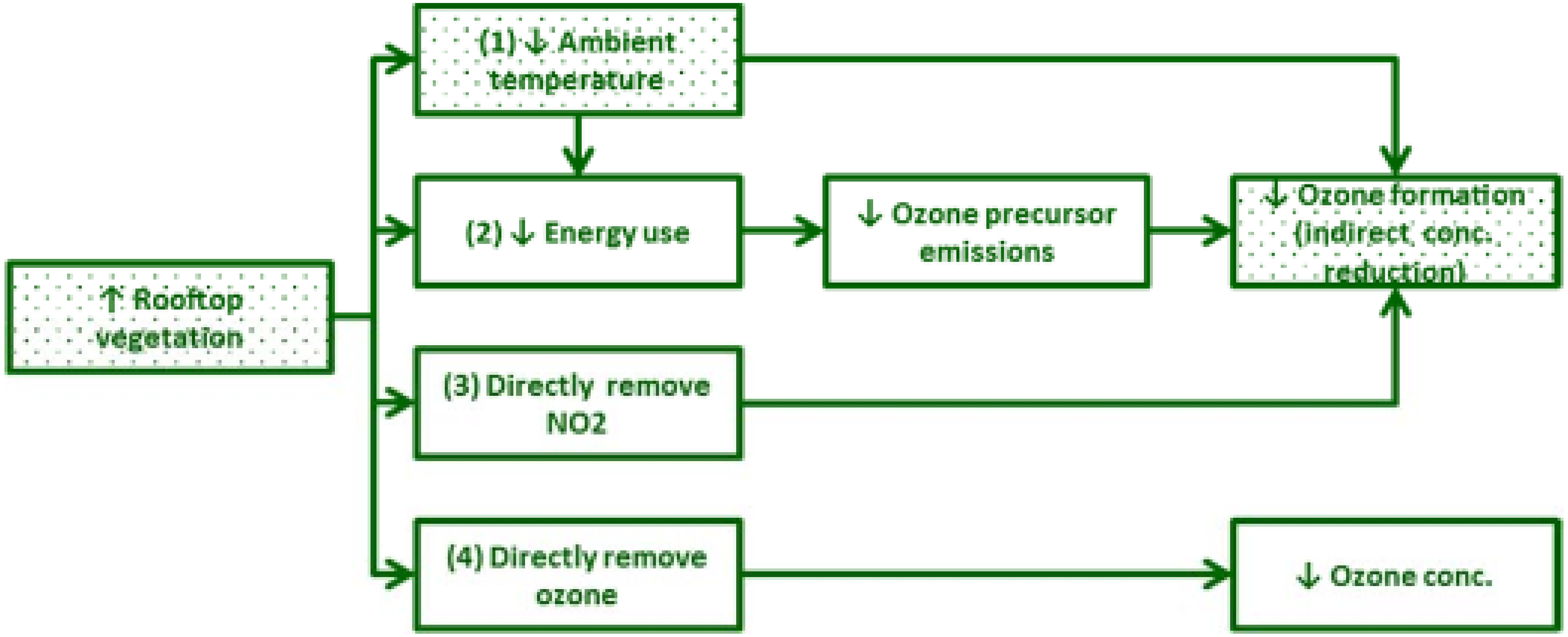


Figure 1: Example of Smart Surface Impact Pathway

(Note: vertical arrows indicate increase or decrease while horizontal arrows indicate direction of impact.)

All Green Roofs are not created equal

TWO DEGREES adapt

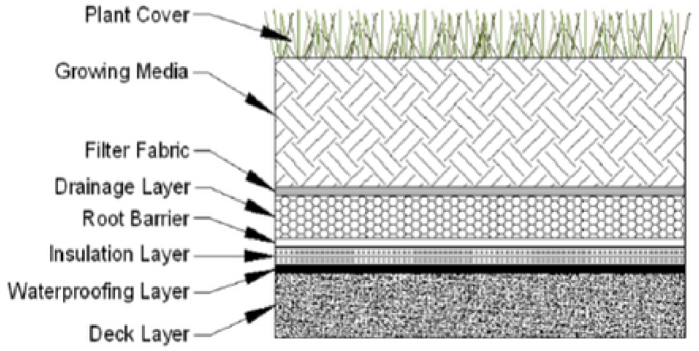


Image Courtesy- US DOE

	Extensive	Semi-intensive	Intensive
Depth of Substrate (mm)	less than 100	100 - 150	Greater than 150
Weight (kg/m^2)	60-100	100-200	200-500
Type of vegetation	Mosses, herbs, grass	Grass, herbs, shrubs	Lawn, perennial plants, shrubs, trees
External Irrigation	None	Periodically	Regularly
Avg Price ($\$/m^2$)*	130	230	350

* Includes capex, installation and annualized O&M

Literature Review

According to the literature reviewed, the annual range of ozone reduced by green roofs falls between 1.2 g/ m2 and 7.17 g/ m2 (Currie & Bass, 2008; Yang et. al., 2008; Jayasooriya et al., 2017).

Hypothesis

If increasing green roofs in Ramsey County Minnesota reduces ground-level ozone pollution concentrations, then a reduction of air pollution and related health events should occur when replacing impermeable roofs with green roof surfaces.

$$\Delta = yo * (e^{\beta * \Delta x} - 1)z$$

Modeled or monitored air quality data

Population data (z)

Baseline incidence of the health event (yo)

An effect estimate (**β**)

Estimated change in the summary ozone measure (**Δ**X)

ΔX

Table 1. Green Roof Sq ft to ppb Ozone Change

Green Roof Coverage (sq ft)	m^2	$g\ yr^{-1}$	g/day	Daily % Air Quality Improvement	ppb Ozone Change
100% = 449192923	41731370.13	50077644.15-299213923.8	327304.86-1955646.56	0.0300516-0.15620465	0.0165-0.0859
75% = 336894692.3	31298527.59	37558233.11-224410442.8	245478.65-1466734.92	0.02270931-0.12191439	0.0125-0.067
50% = 224596461.5	20865685.06	25038822.08-149606961.9	163652.43-977823.28	0.01525502-0.08471908	0.0084-0.0466
25% = 112298230.8	10432842.53	12519411.04-74803480.9	81826.22-488911.64	0.00768614-0.04423324	0.0042-0.0243

[a] 1 sq ft= 0.092903 m^2

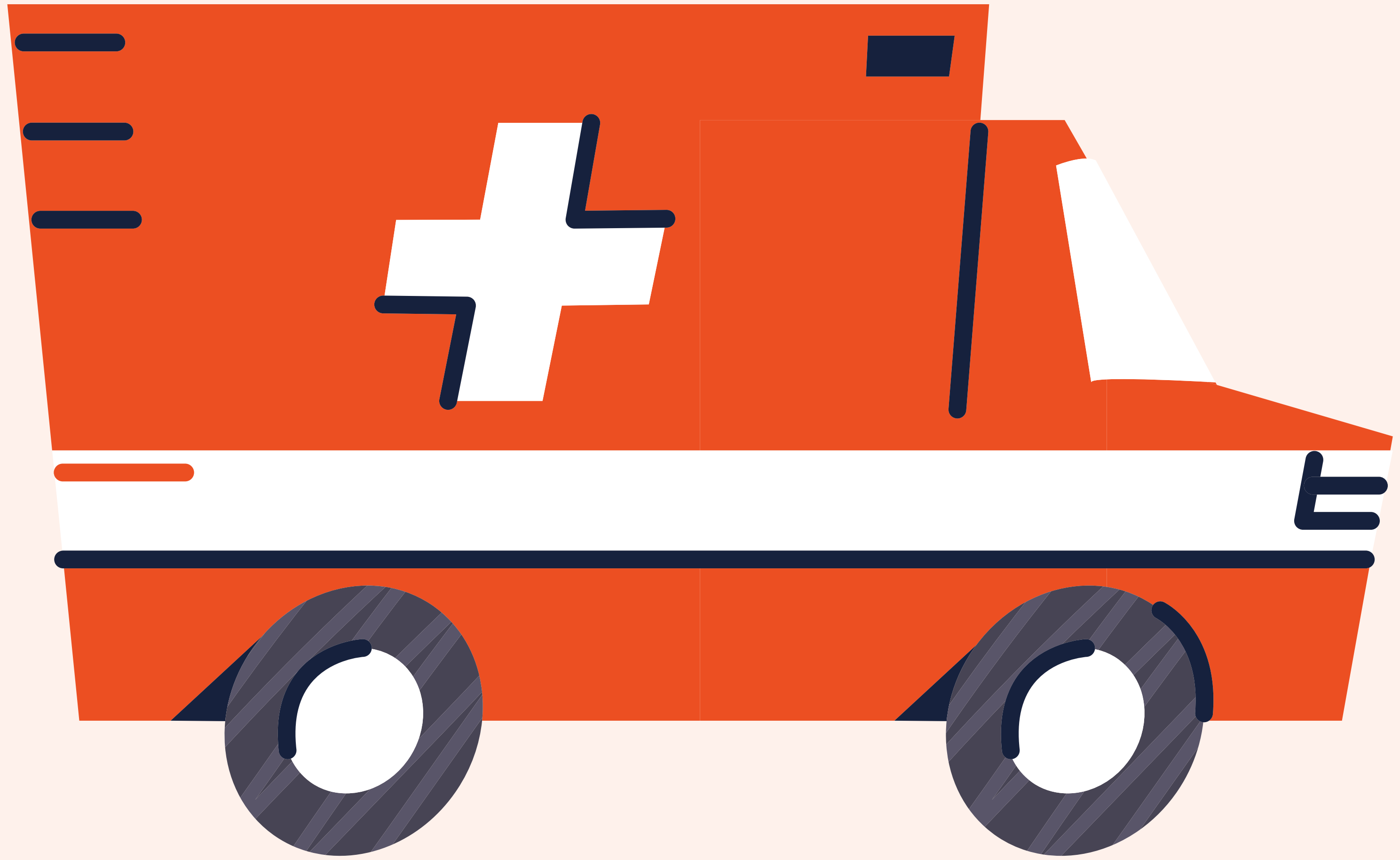
[b] Annual range of ozone reduced by green roofs falls between 1.2 g/ m^2 and 7.17 g/ m^2 (Currie & Bass, 2008; Yang et. al., 2008; Jayasooriya et al., 2017)

[c] 1 year = approx.153 days of ozone events

[d] Daily % Air Quality Improvement = grams removed/ (grams removed + grams in atmosphere) (Nowak et al., 2006)

[e] ppb ozone change= Daily % Air Quality Improvement multiplied by ozone monitor EPA ID: 27-053-0962

Correlating Air Quality Changes with Population Health Outcome



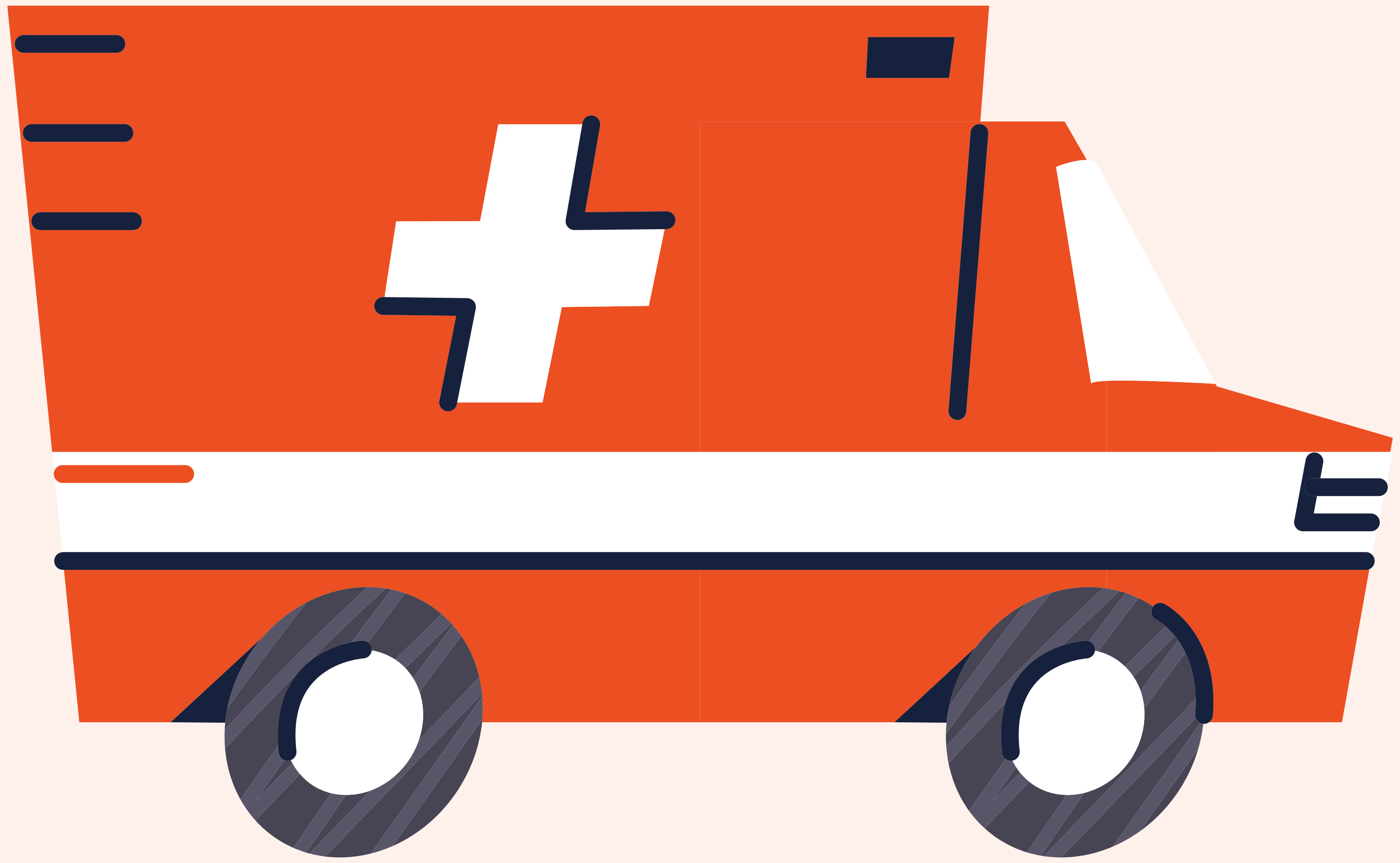
Effect Estimates

Asthmatic Hospitalization/ED Visits:
Relative risk (RR) of 1.009 CI95% (1.006–1.011) per 10 ppb increase in ozone for individuals of all ages (Zheng et al.,2015).

All-Cause Mortality:
Di et al. (2017), found that each short-term increase of 10 ppb in warm season ozone (after adjusting for PM2.5) resulted in a 0.51% increase in daily mortality CI95% (1.0041–1.0061).

$$\beta = \frac{\ln(RR)}{\Delta PM}$$

Correlating Air Quality Changes with Population Health Outcome

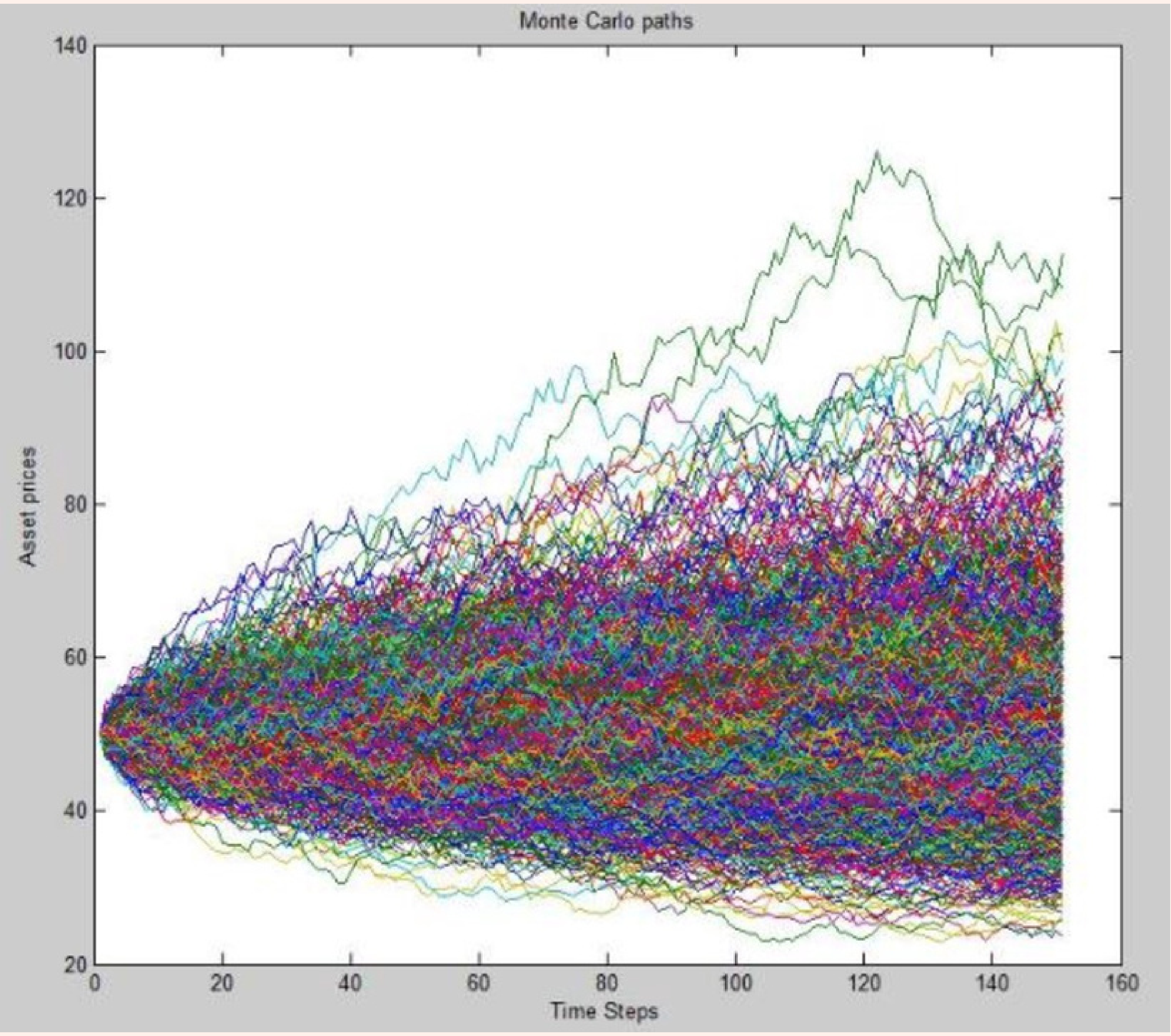


Population & Baseline Incidences

Population Size (z):
550,321 people
Asthmatic Hospitalization/ED Visits:
77 per 100,000 residents
All-Cause Mortality:
677.6 per 100,000

$$\Delta = 0.00077 * (e^{0.0008959741 * \Delta x} - 1)550321$$
$$\Delta = 0.006776 * (e^{0.0005087039 * \Delta x} - 1)550321$$

Statistical Analysis



Monte Carlo

- Each effect estimate pulled from the epidemiological literature had an associated 95% confidence interval.
- Monte Carlo simulation substitutes a range of values (the probability distribution) to model all possible results for this factor of uncertainty. By repeating the simulation numerous times a distribution of the output of interest is established; where estimates of measures of center (i.e., mean) can be ascertained

Triangular Distribution

The three parameters of mean value (from the literature's relative risks), minimum and maximum (from the literature's confidence intervals) were used to calculate the most likely value and distribution.

Results

100% COVERAGE

0.032 (0.025-0.037) ozone-related asthmatic hospitalizations and 0.163 (0.141-0.184) all-cause mortalities can be avoided.

75% COVERAGE

0.020 (0.025-0.029) ozone-related asthmatic hospitalizations and 0.126 (0.110-0.144) all-cause mortalities can be avoided.

50% COVERAGE

0.017 (0.013-0.020) ozone-related asthmatic hospitalizations and 0.088 (0.077-0.099) all-cause mortalities can be avoided

25% COVERAGE

0.009 (0.007- 0.011) ozone-related asthmatic hospitalizations and 0.047 (0.040-0.052) all-cause mortalities can be avoided.

SCOPE AND PRACTICAL SIGNIFICANCE

LARGER POPULATION

A greater affected population means a greater impacted population would receive the beneficial health factors of green roofs.

MORE DIVERSITY, MORE IMPACT

Given the inequity of asthma and housing, more diverse areas with higher baseline incidences would benefit a great deal more.

ADDITIONAL AIR POLLUTANTS

If more air pollutants were considered, potentially larger effect estimates could show greater avoided hospitalization and all-cause mortality, especially when combined with ground-level ozone.

Other Considerations

BVOCS

- Biogenic volatile organic compounds (BVOCs) that can lead to secondary air pollutant formation under higher stomatal conductance (Alonso et al., 2011).
- Deciduous trees are responsible for up to 90% of O_3 removal, likely because they emit minimal BVOCs

NO2

- Ozone also requires a nitrogenous base (NO_x), where reduction in nitrogen oxides also reduces concentrations of ozone in the urban environment.
- Plants which contain more elevated leaf ascorbate concentrations can remove more NO_2 air pollution (Jim & Chen, 2008).

DROUGHT TOLERANCE

Drought stress in the summer months tends to decrease stomatal conductance, lowering O_3 deposition (Alonso et al., 2011).

CONCLUSION

EXPANSION ON SCOPE

The application of these methods to larger and more diverse populations sizes along with the addition of other pollutants may give a more holistic picture of avoided negative health outcomes via the conversion of impervious surfaces to green roofs.

PLANT SELECTION

To see the most health impacts I believe the intensive system, particularly with deciduous tree/shrub species would be the most impactful system for the Twin Cities

THANK YOU