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## Transportation System Impacts on Bicyclists' Air Pollution Risks: Considerations for System Design and Use

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# Transportation System Impacts on Bicyclists' Air Pollution Risks

Considerations for System  
Design and Use

Alex Bigazzi

Miguel Figliozzi

James Pankow

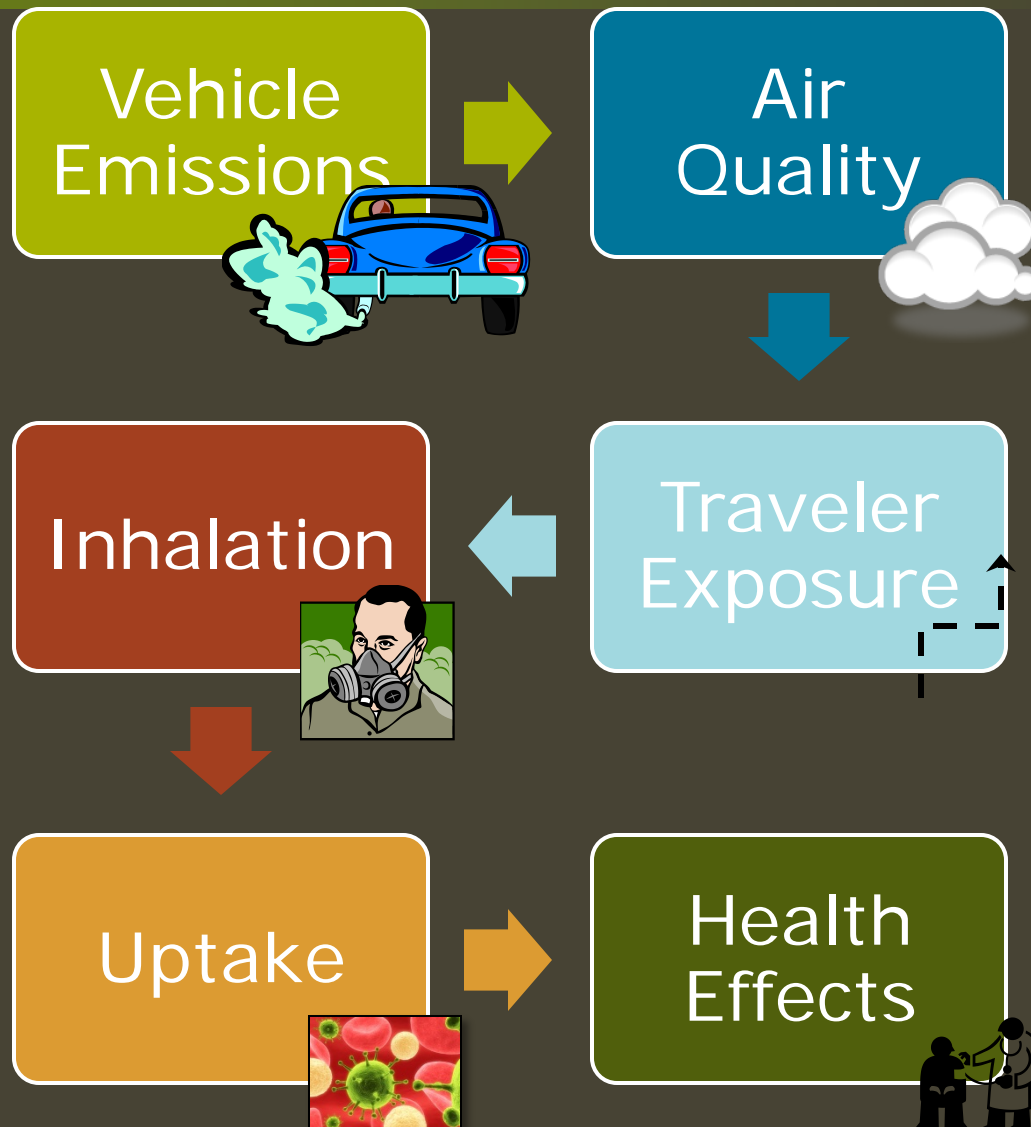
Wentai Luo

PSU Friday Transportation  
Seminar

13 February, 2015



# Framework



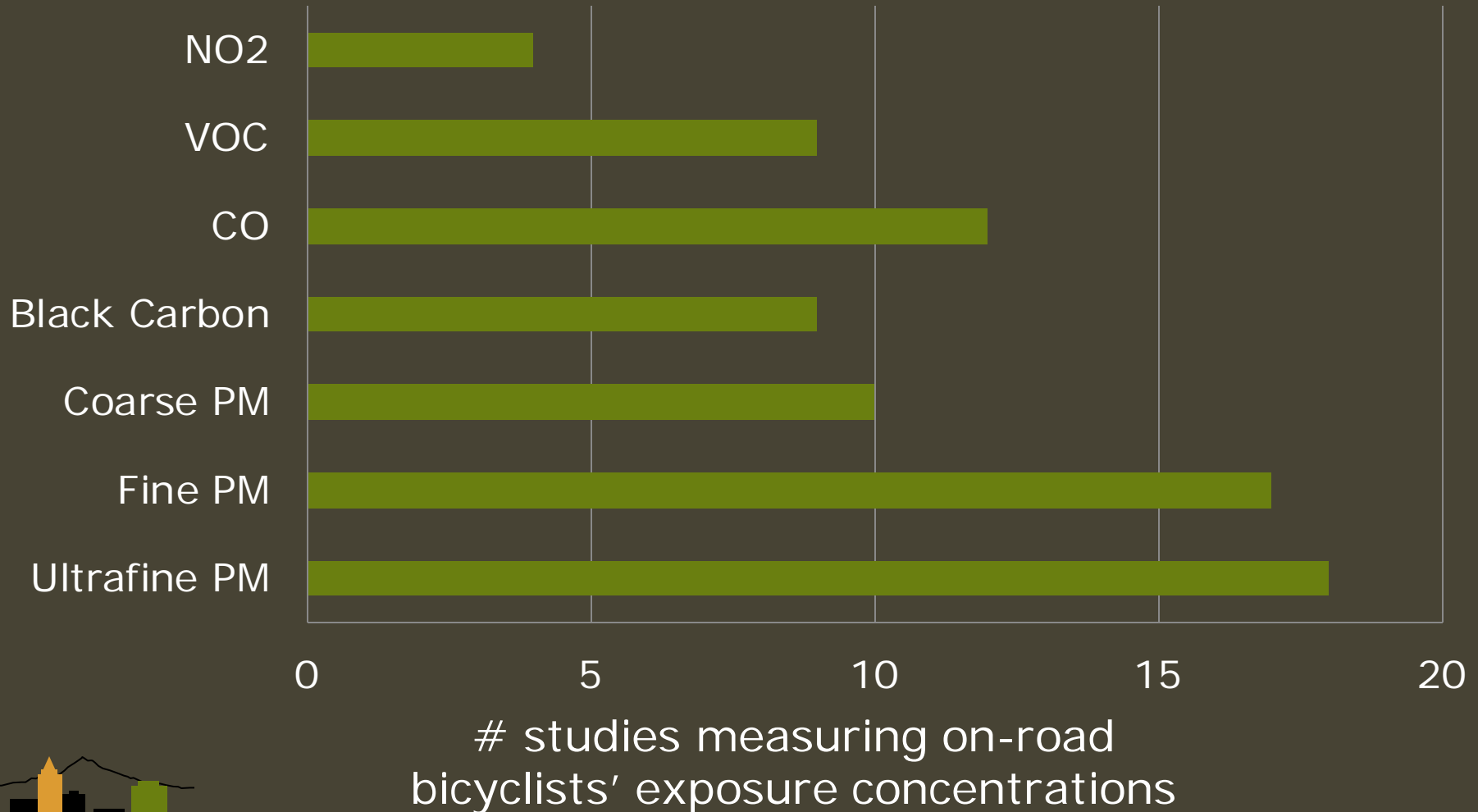
# Background



# Bicyclists' Exposures

42 studies

Pollutant



# Modal Comparisons of Exposure



VS



VS



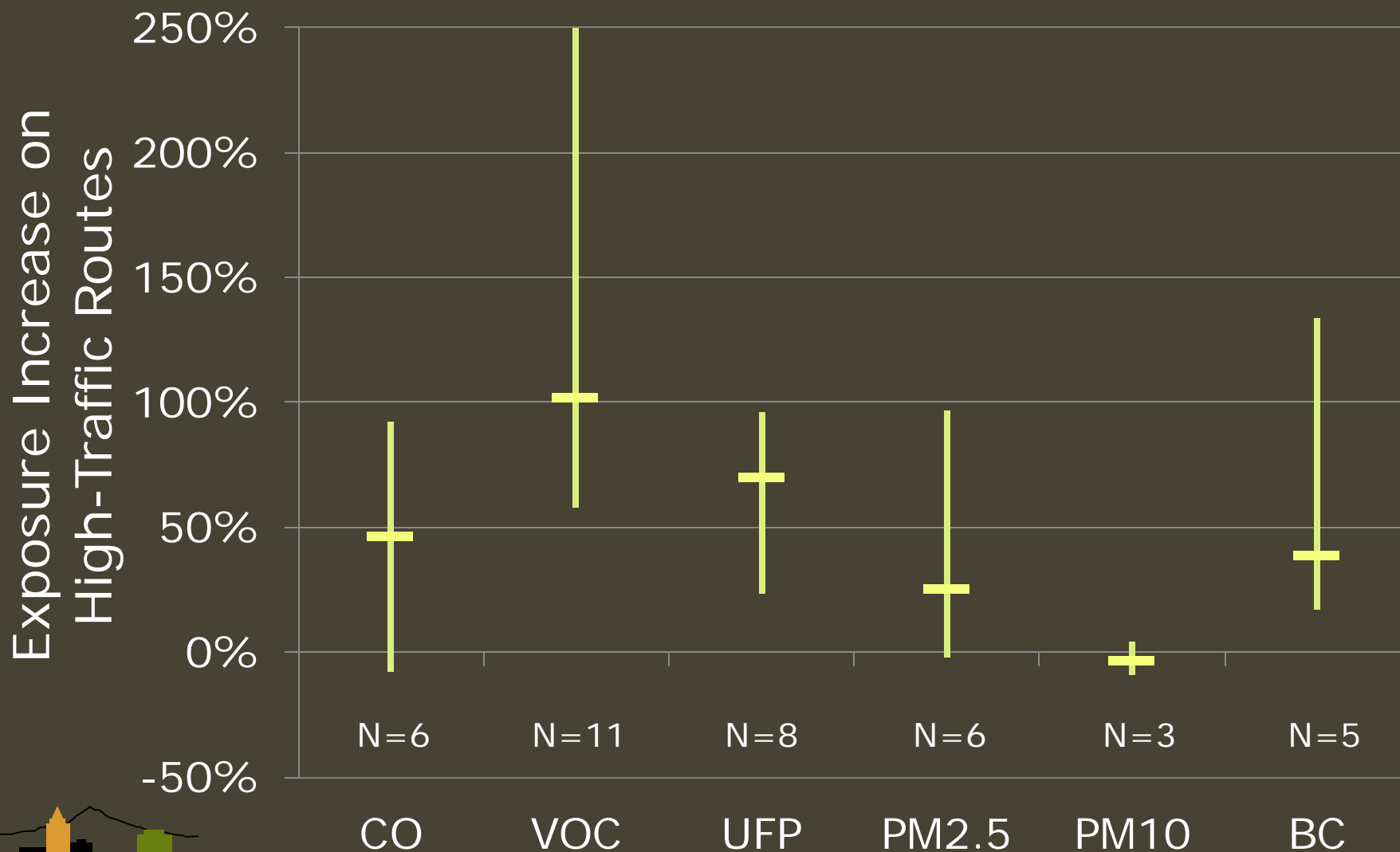
- Is this actionable information?

## Context-dependent results

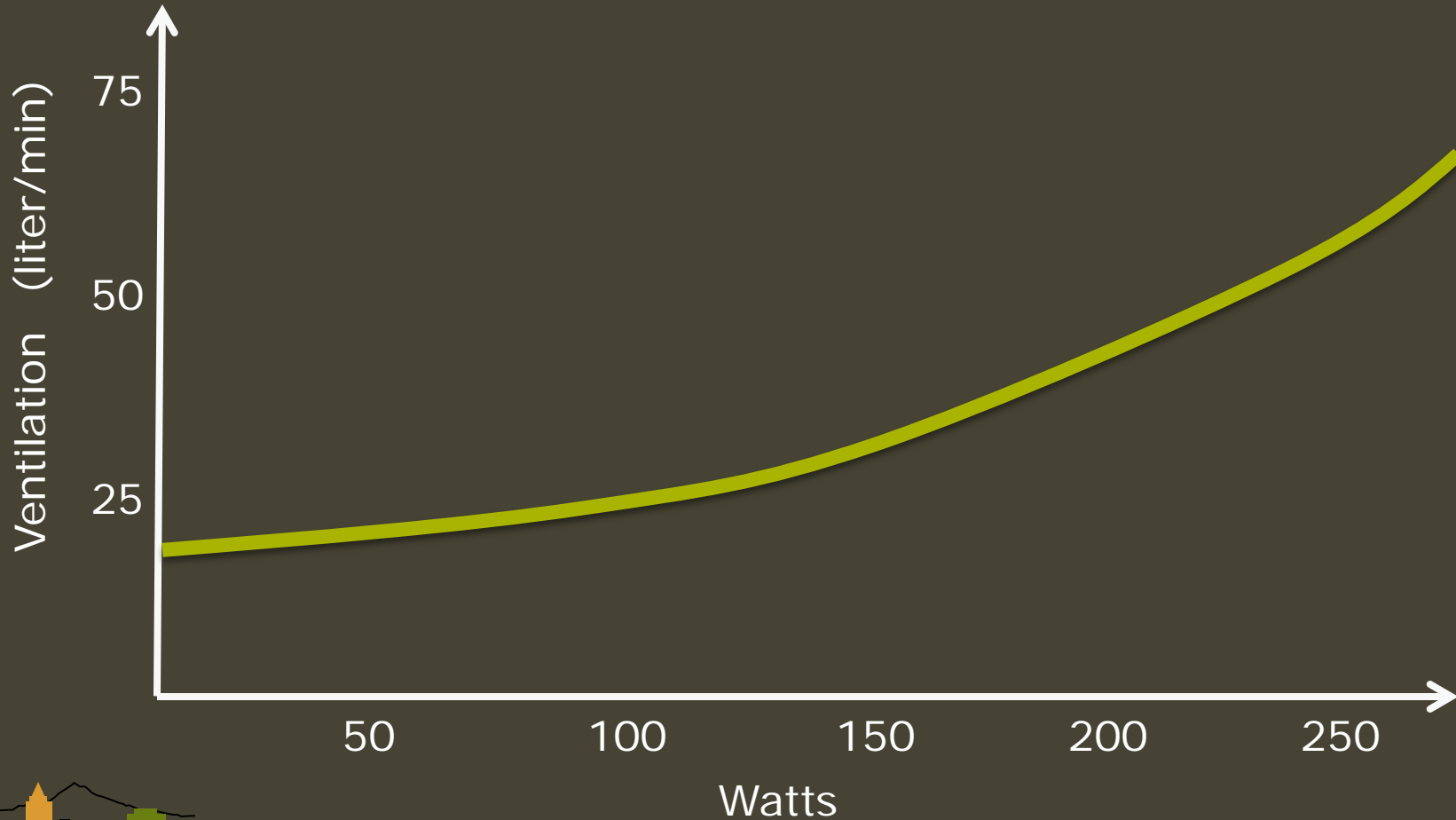
- Bicyclists lower if separated



# High-Traffic/Low-Traffic Routes



# Ventilation and Exercise





# Ventilation & Bicycle Studies

57 studies assess bicyclists' exposure

Ventilation:

Ignored  
38

Constant  
16

Variable  
3

Assumed/  
Modeled  
15

Measured  
1

Modeled  
2

Measured  
1



# Bicyclist Uptake Studies

2 studies of biomarkers:

- VOC: blood & urine
  - Urban bikers > rural bikers
- BC: induced sputum
  - Bicyclists > transit riders



# Research Questions

1. How does uptake vary with roadway and travel conditions?
2. Can transport strategies reduce bicyclist uptake?



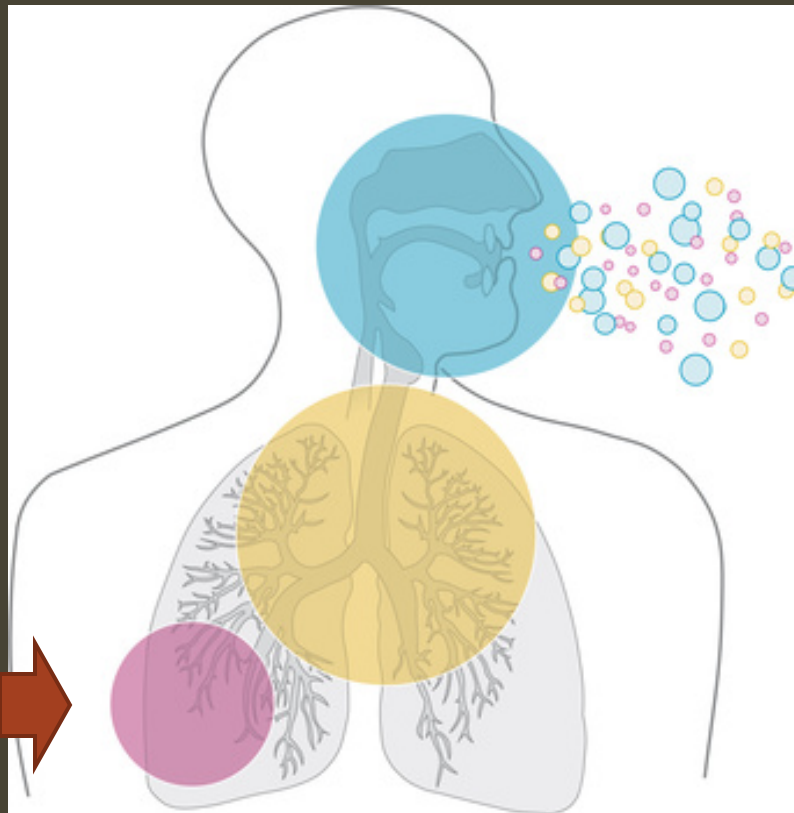
# Data & Methods



# Breath Biomarkers

Exhaled breath is a good proxy for blood concentrations of VOC

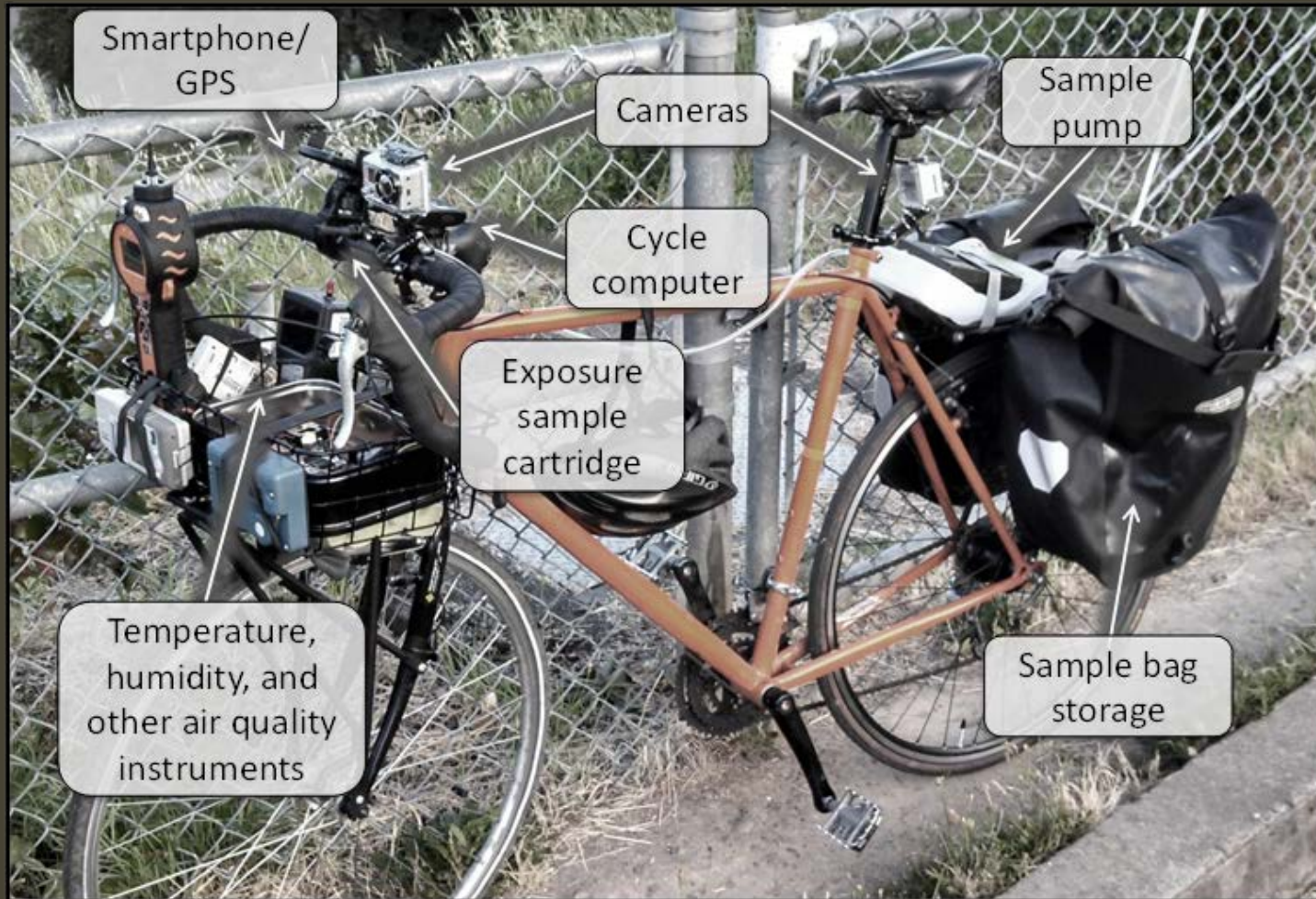
VOC in blood



alphasenszor.com



# Sampling Equipment



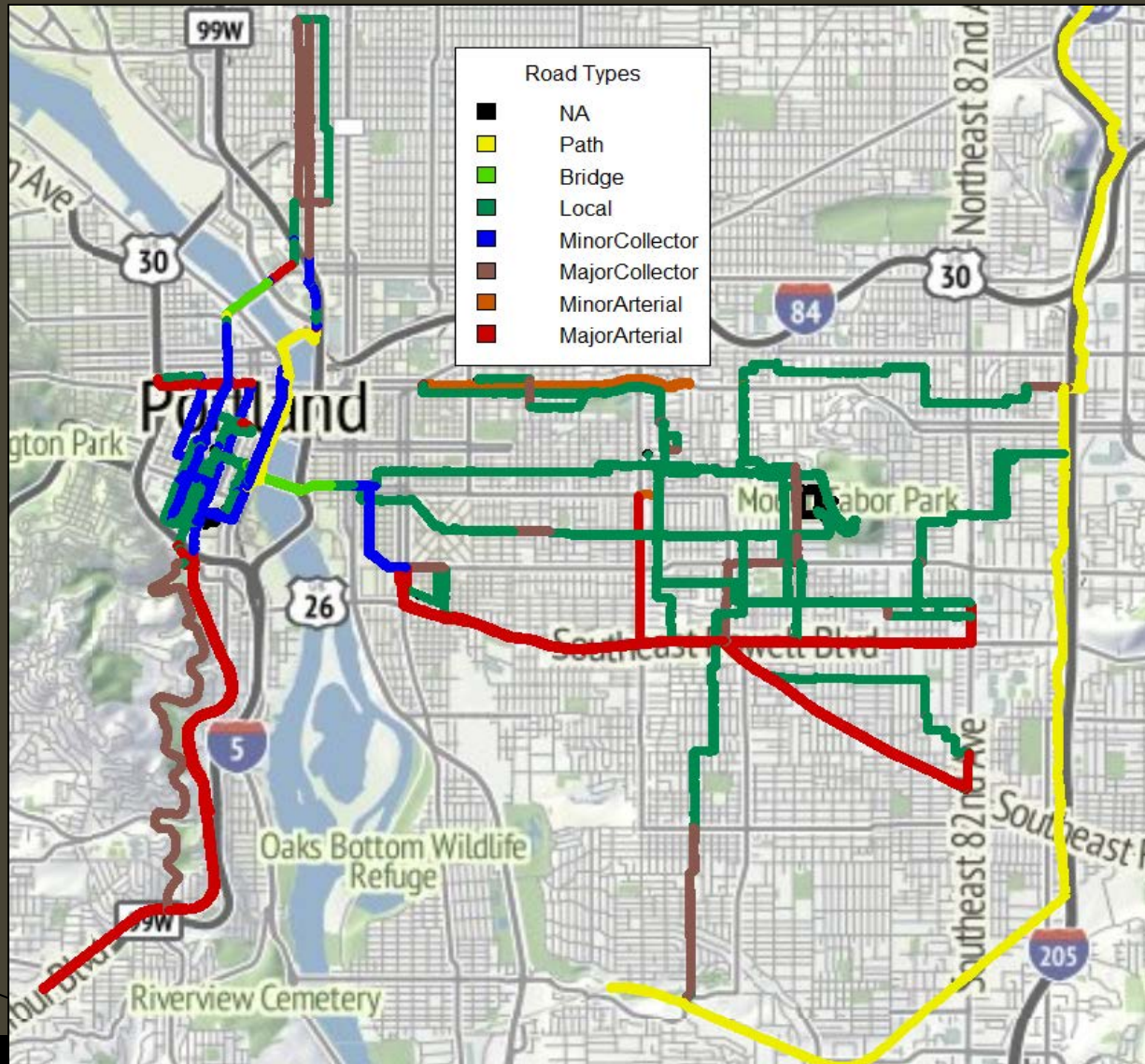
# On-Road Sampling Segments



20-30 minutes, 3-5 miles  
Exposure & breath VOC  
Paired subjects



# Exposure Data coverage



74 breath samples

3 subjects

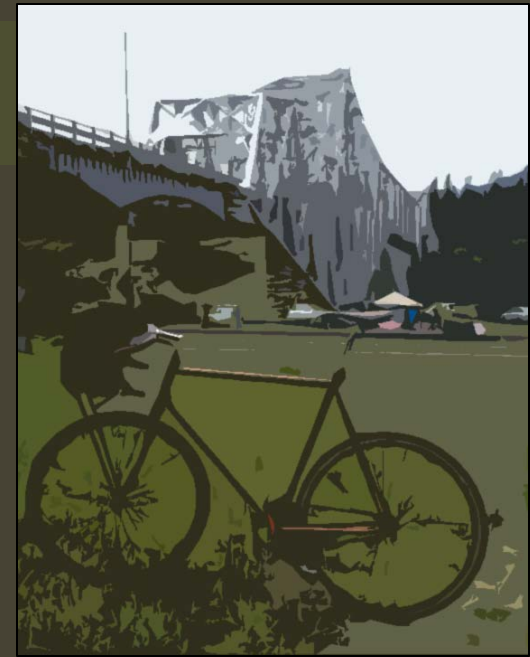
9 days

~40 hours of data



# Model Development

- Exposure concentrations
- Ventilation
- Breath concentrations
  - ~ exposure + ventilation
  - ~ weather + roadway + travel conditions



# Results

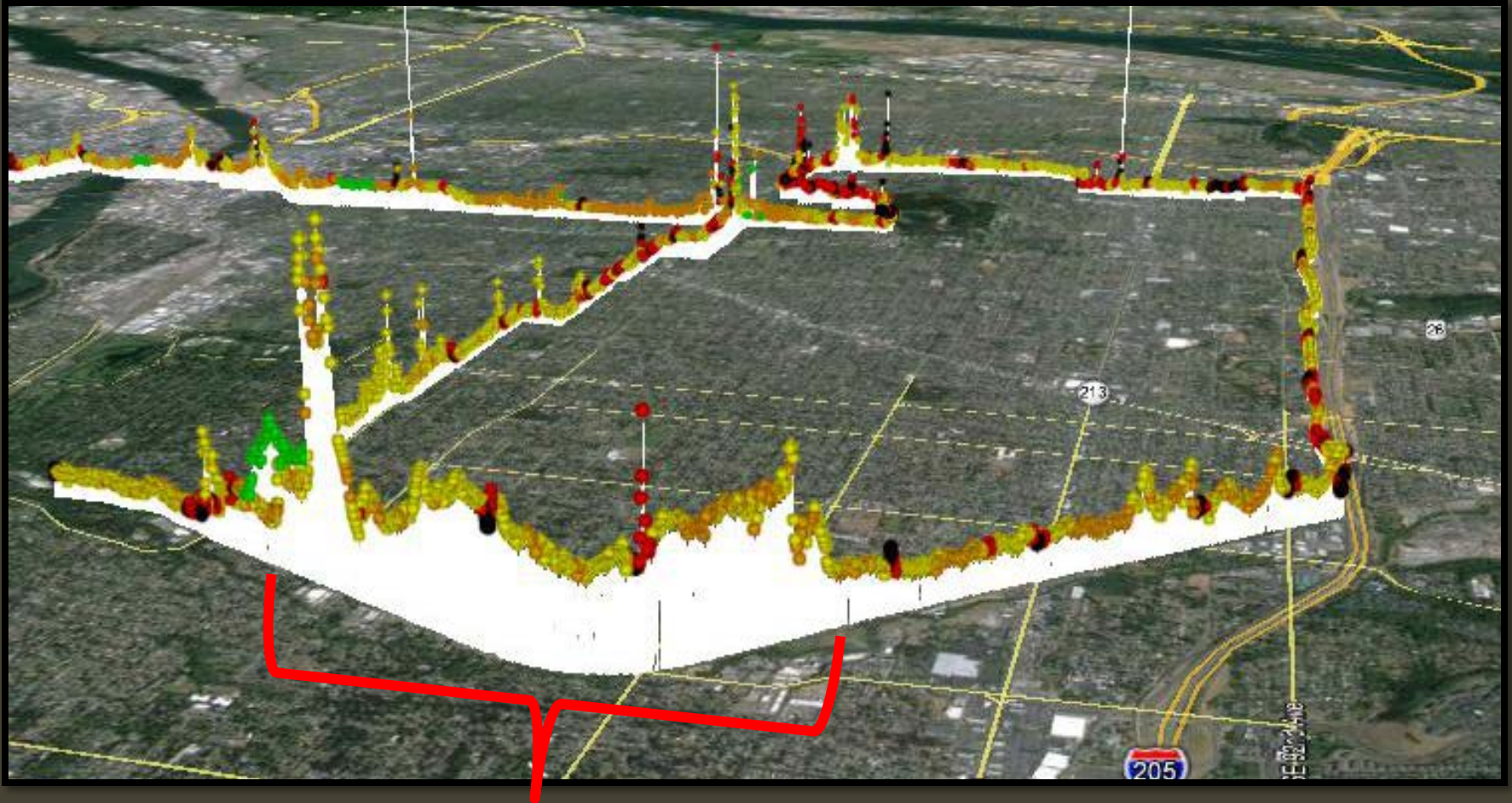


# Results: VOC Exposure Models

- +2% per 1,000 ADT
- +20-30% in stop-and-go riding
- Off-street path +300% in industrial corridor



# Industrial Corridor



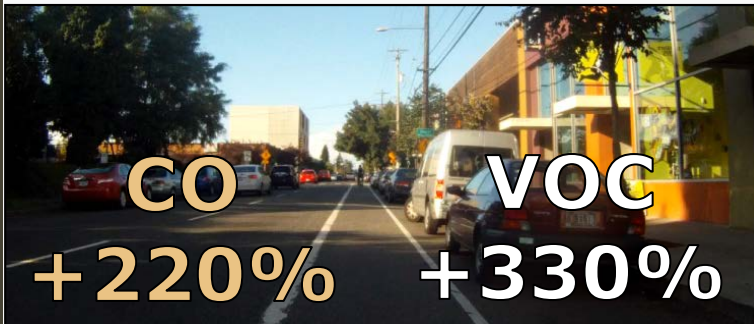
# Parallel Path Comparison



E Burnside St.



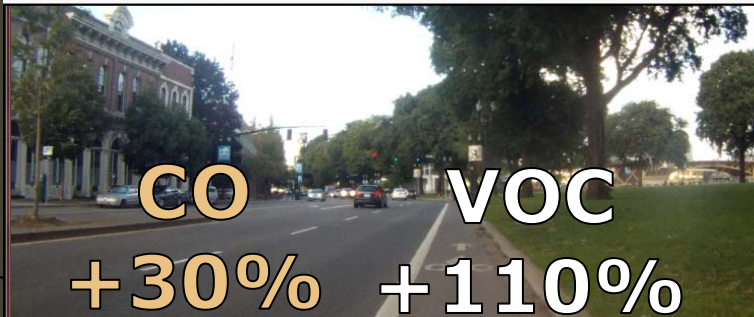
SE Ankeney St.



N Williams Ave.



NE Rodney Ave.



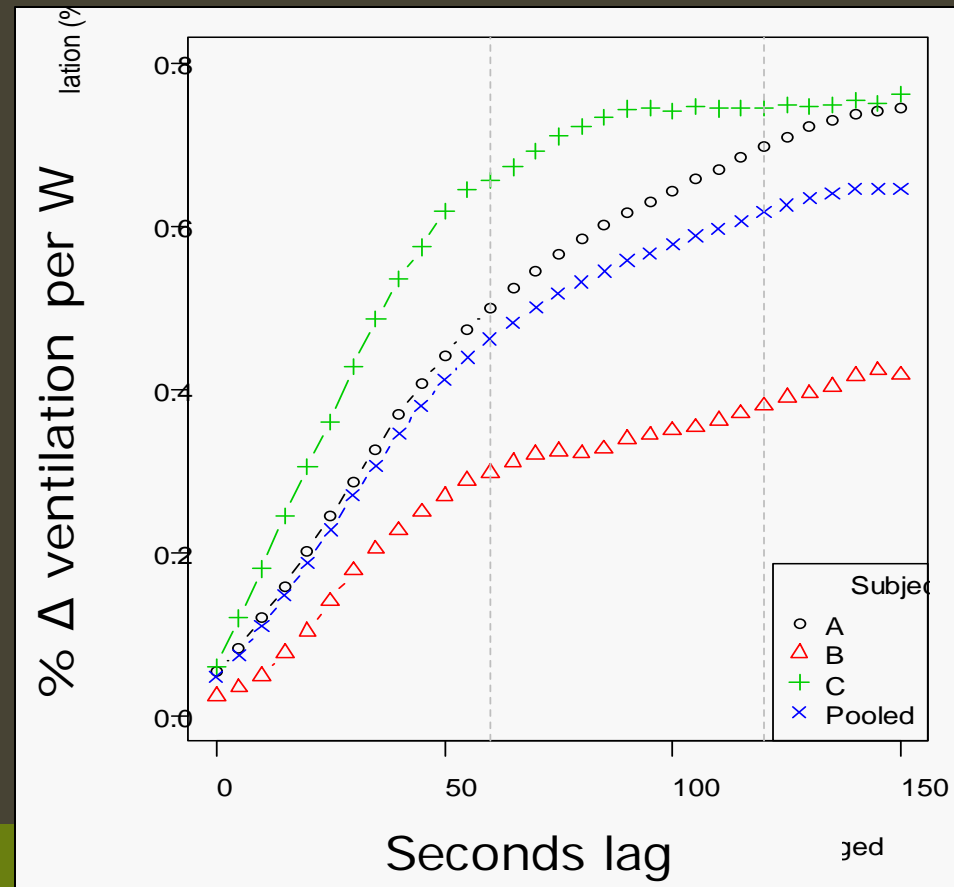
Naito Pkwy.



Riverside Path

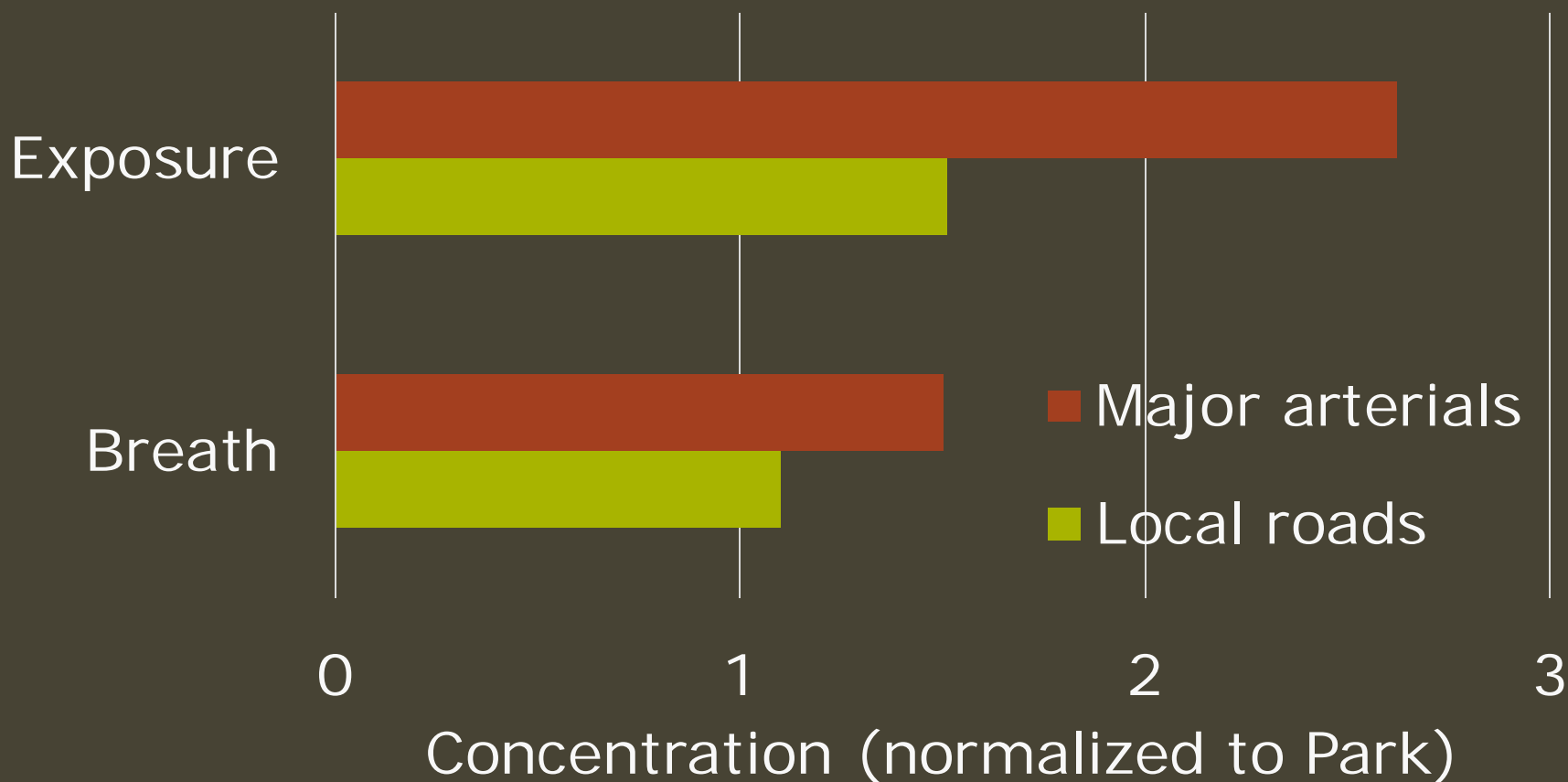
# Results: Ventilation Models

- 4-8% increase in ventilation per 10 W
- Mean lag ~50 sec



# Breath and Exposure Concentrations

## Toluene



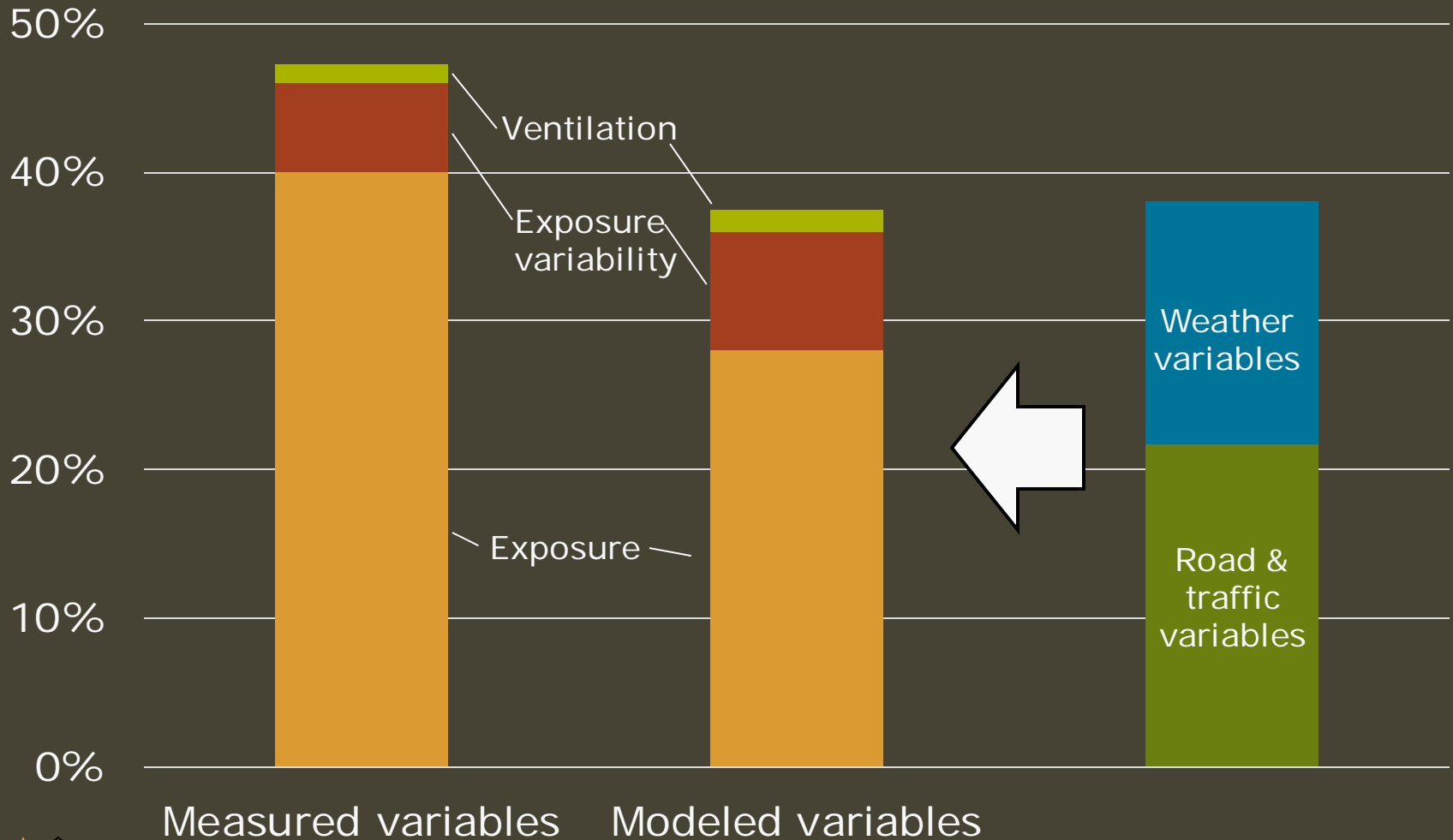
# Results: Breath Biomarkers

- 8 aromatic hydrocarbons were biomarkers of traffic exposure
- Issues
  - Background concentrations
  - Endogenous production
  - High water solubility

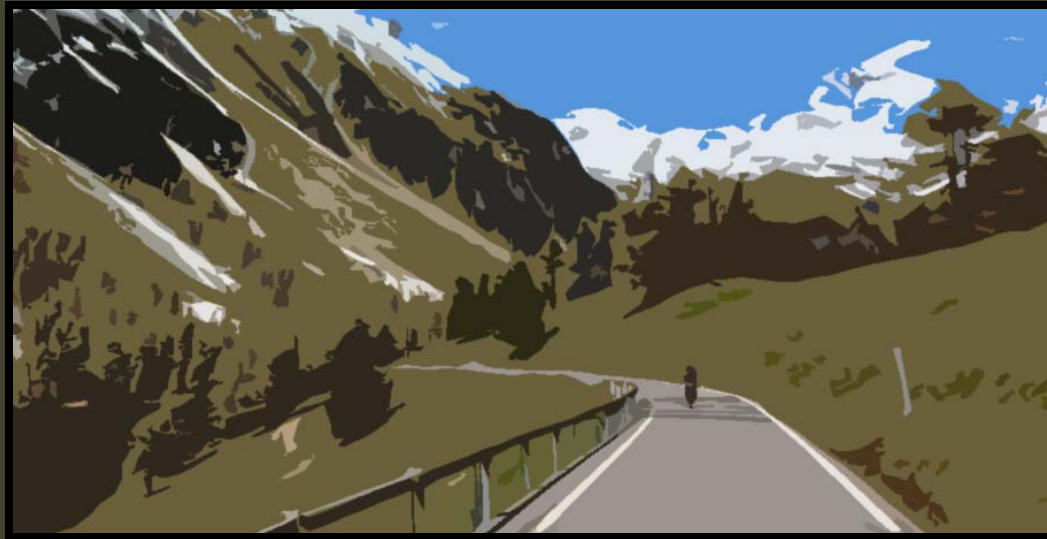




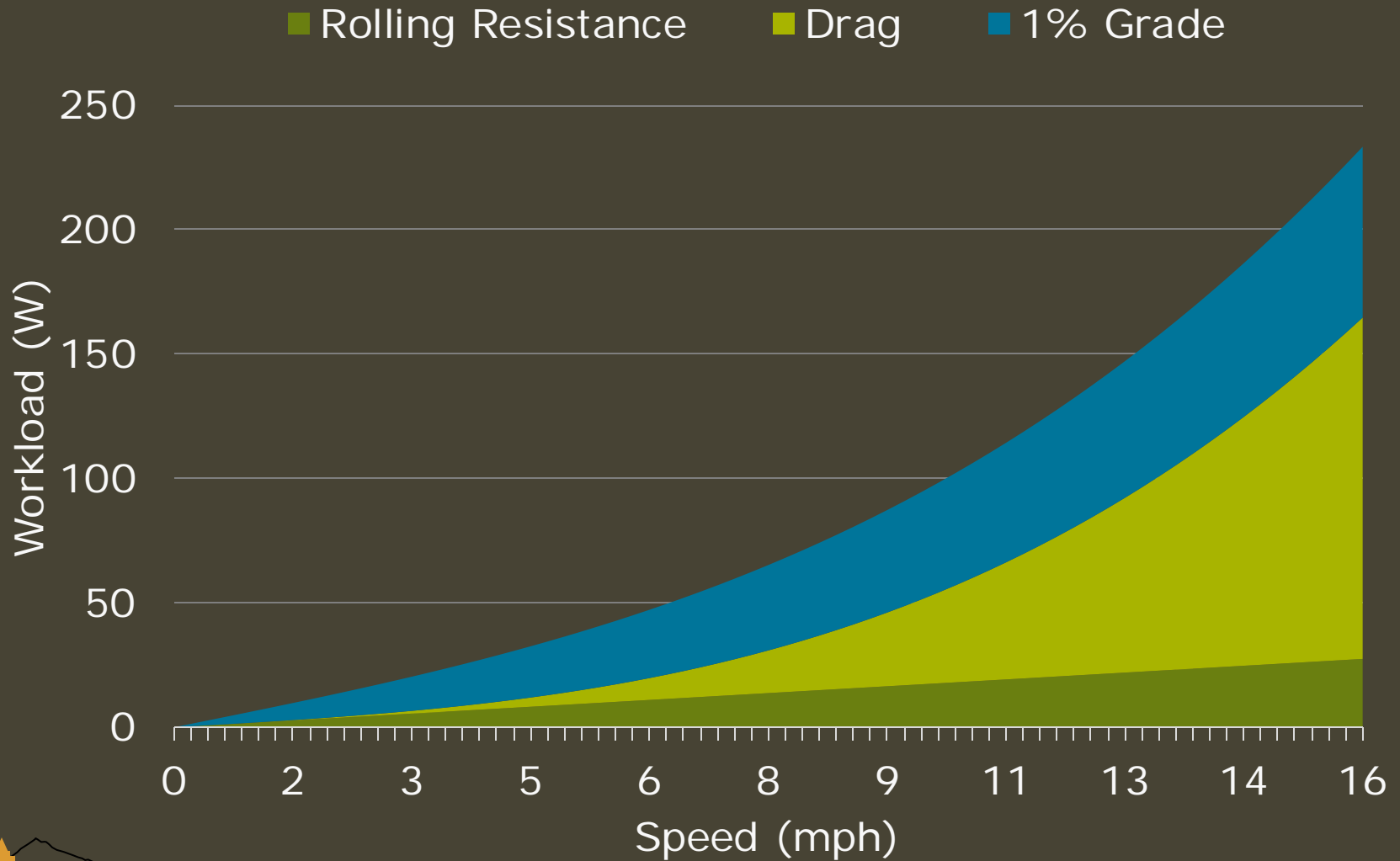
# Explained variance in breath BTEX



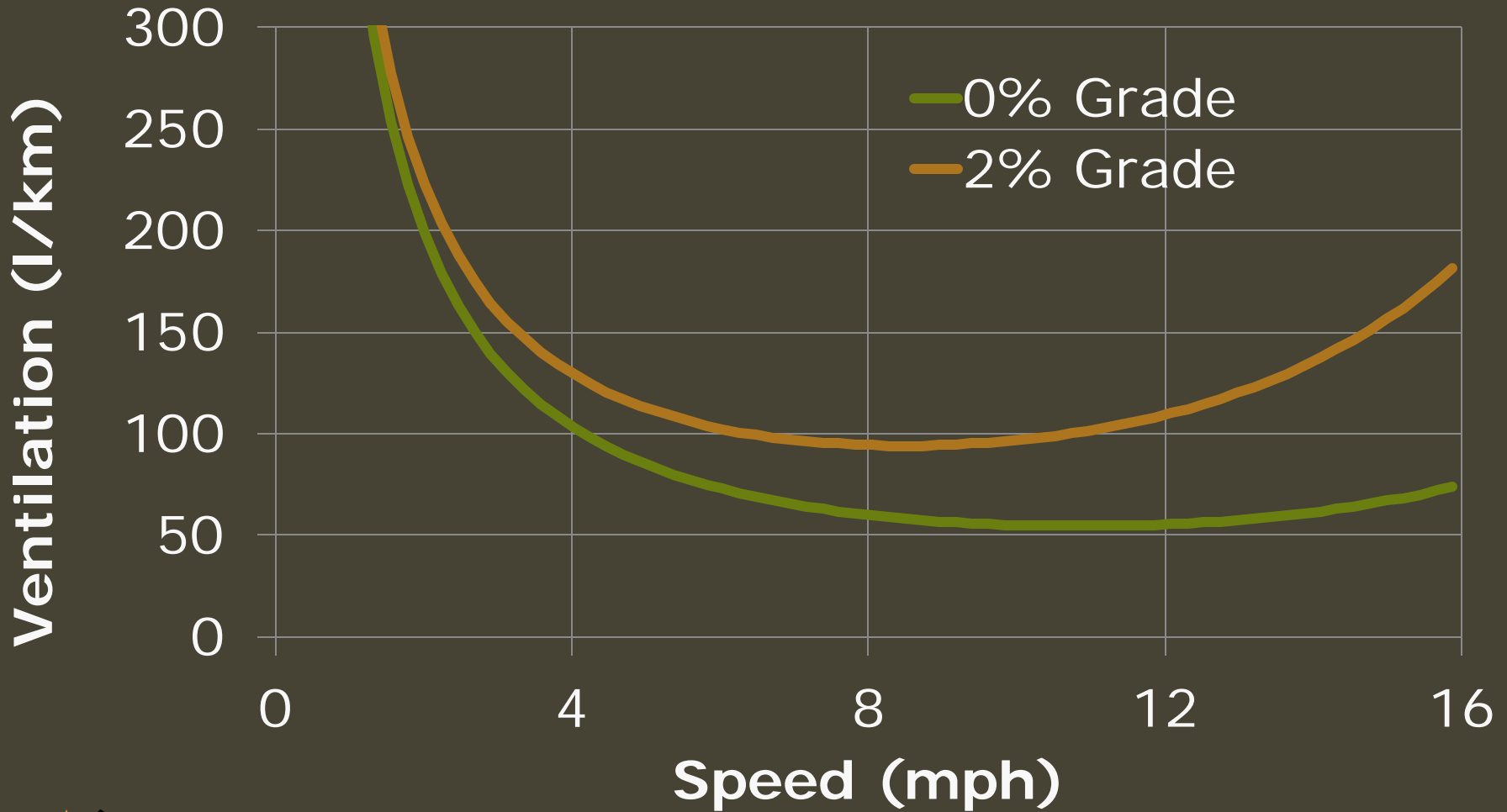
# Applications



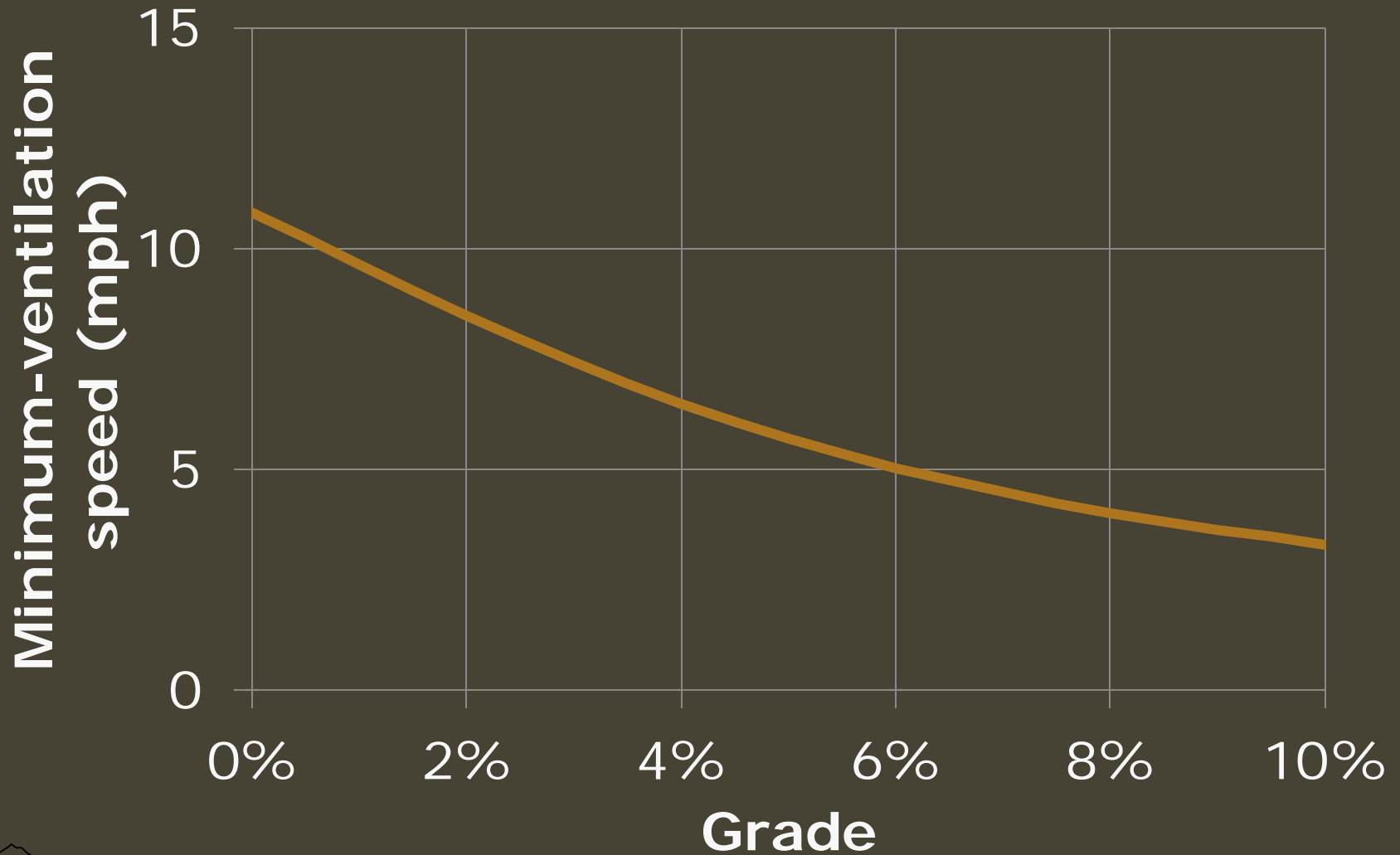
# Steady-state biking work



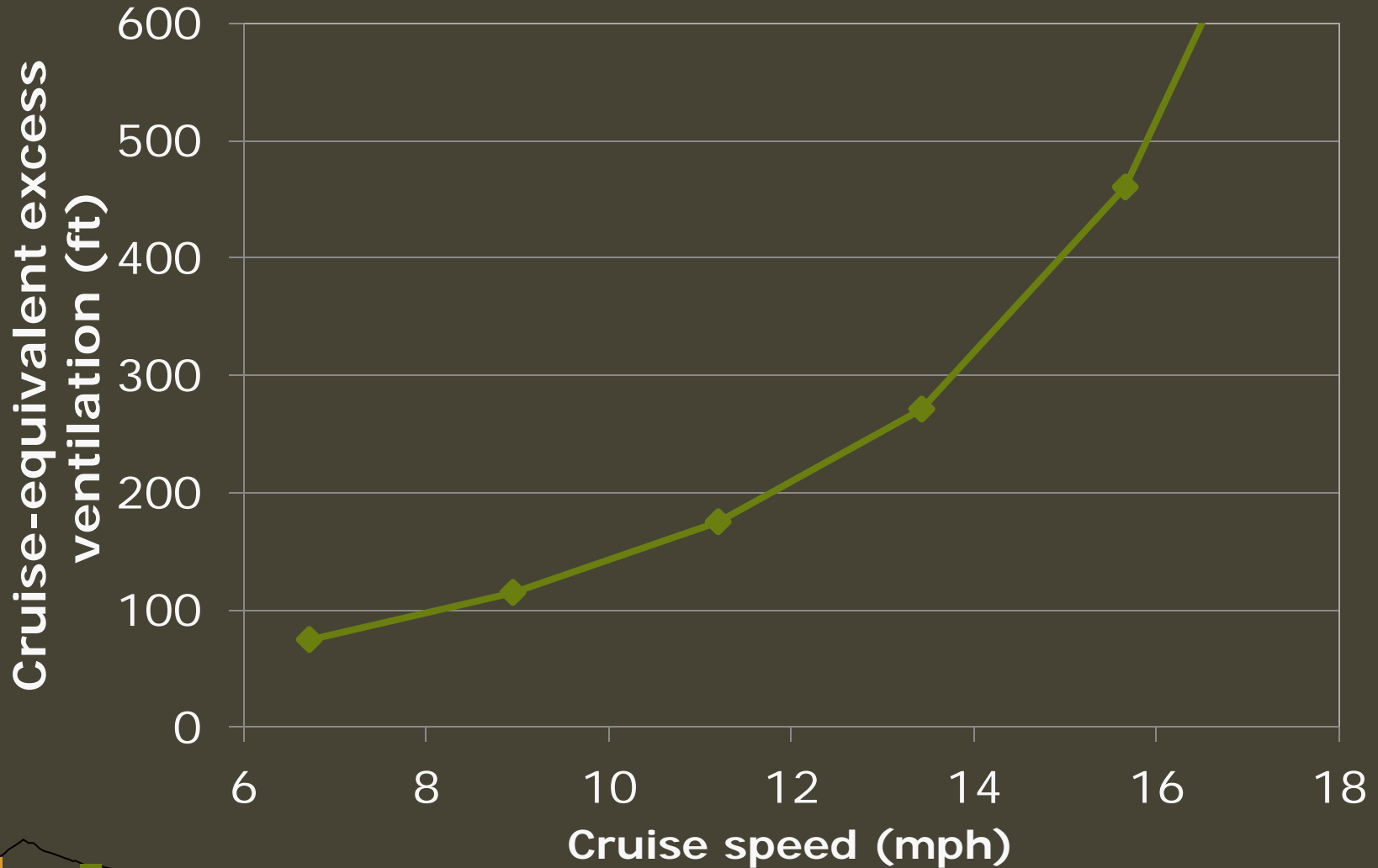
# Inhalation and Speed



# Minimum-Inhalation Speed

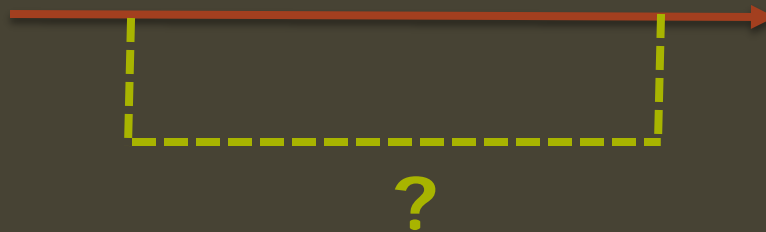


# Inhalation and Stops



# Route Choice

- Detour 1 block to a bikeway vs.
  - 1.6 blocks on a major arterial
  - 4.3 blocks on a minor arterial



# Comparison with Preferences

Will bicyclists naturally minimize inhaled dose over a trip?

Bike boulevard  
or  
neighborhood greenway

VS.

Bike lane

- Balance on collectors (6-10k ADT)
- Under-avoid arterials

VS.

Minor arterial  
(no bike lane)

- Slightly over-avoid

VS.

Major arterial  
(no bike lane)

- Greatly over-avoid



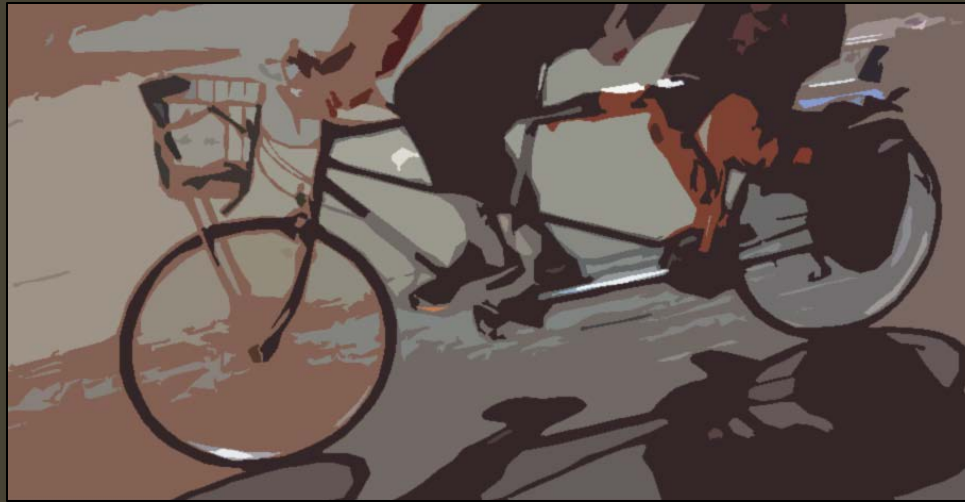


# Exercise and Uptake

- Inhalation rate: 2-5x higher
- PM uptake:  $\geq 2-5x$  higher
- VOC uptake: 1.5-2x higher
  - Limited by blood/air equilibrium



# Conclusions



# Findings

## Determining factors

- ADT
- Stop-and-go riding
- Industrial corridors
- Speed & grade
- Exposure & ventilation

## Mitigation

- Low-volume streets
- Travel speed choice
- Reducing stops
- Separated facilities

# Take-Away Principles

## 1. Bicyclist Exposure

- a) Many different pollutants
- b) Traffic, weather, and land-use all important
- c) Benefits of separation from traffic

## 2. Bicyclist Inhalation

- a) Varies greatly with workload (speed, grade)
- b) Breath response spread out over 1-2 min

## 3. Bicyclist Uptake

- a) For particles, highly sensitive to breathing
- b) For some gases, more sensitive to duration



# Bikeway Design Considerations

Bike lane

- High-traffic streets
- Some lateral separation
- Dedicated lane reduces duration in congestion

Bike boulevard

- Low-traffic streets
- Additional benefits from traffic calming
- Fewer stops reduces uptake

Cycle track

- Lateral separation
- Fewer stops reduces uptake

Off-street path

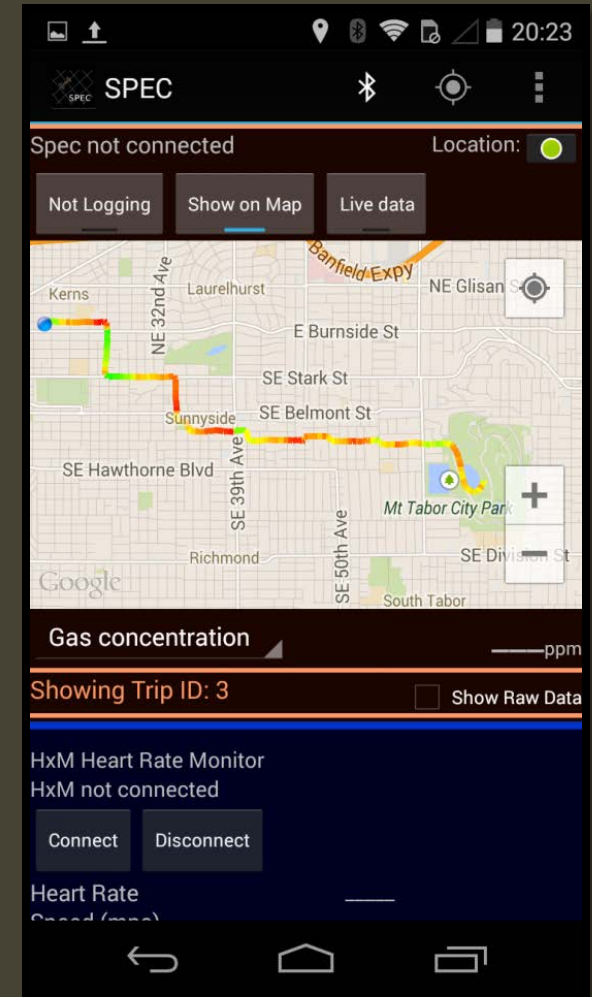
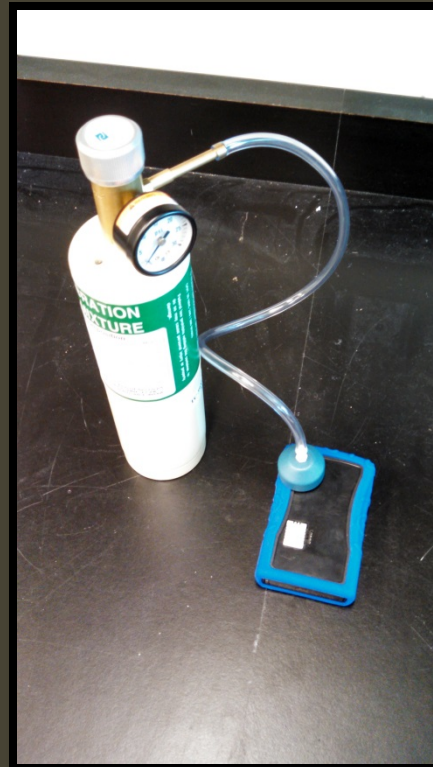
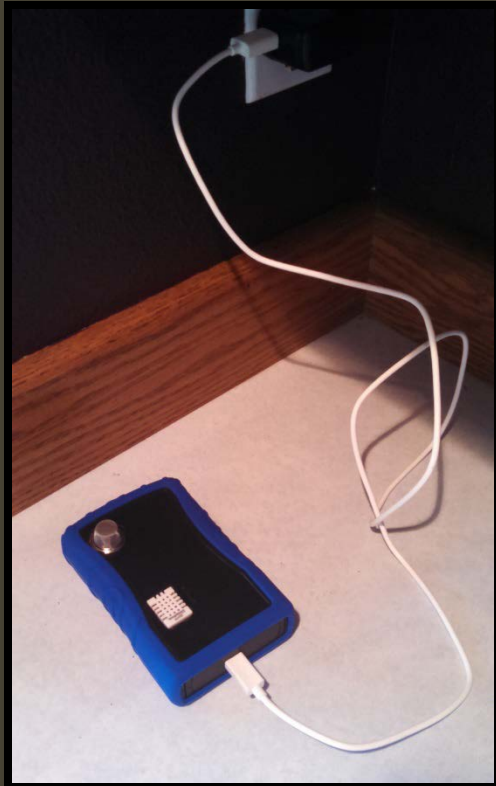
- Low exposure (nearby industry?)
- Fewer stops reduces uptake

# Next Steps

- Abstraction for HIA & CBA
- Additional biomarkers
- Characterizations of urban bicyclists
- Similar study for pedestrians
- Crowd-source pollution data



# Crowd-Sourced Pollution Data



# Questions?



David Jeffrey Barnum · ★ Top Commenter · Rio Americano High

So he figured out that with more cars comes more exhaust. And that was Ph.D.-worthy?

Reply · Like · Follow Post · 21 hours ago

## Acknowledgments

- Dissertation committee: Miguel Figliozi, Jim Pankow, Robert Bertini, Jennifer Dill
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- NSF and OTREC fellowships

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National Science Foundation  
WHERE DISCOVERIES BEGIN



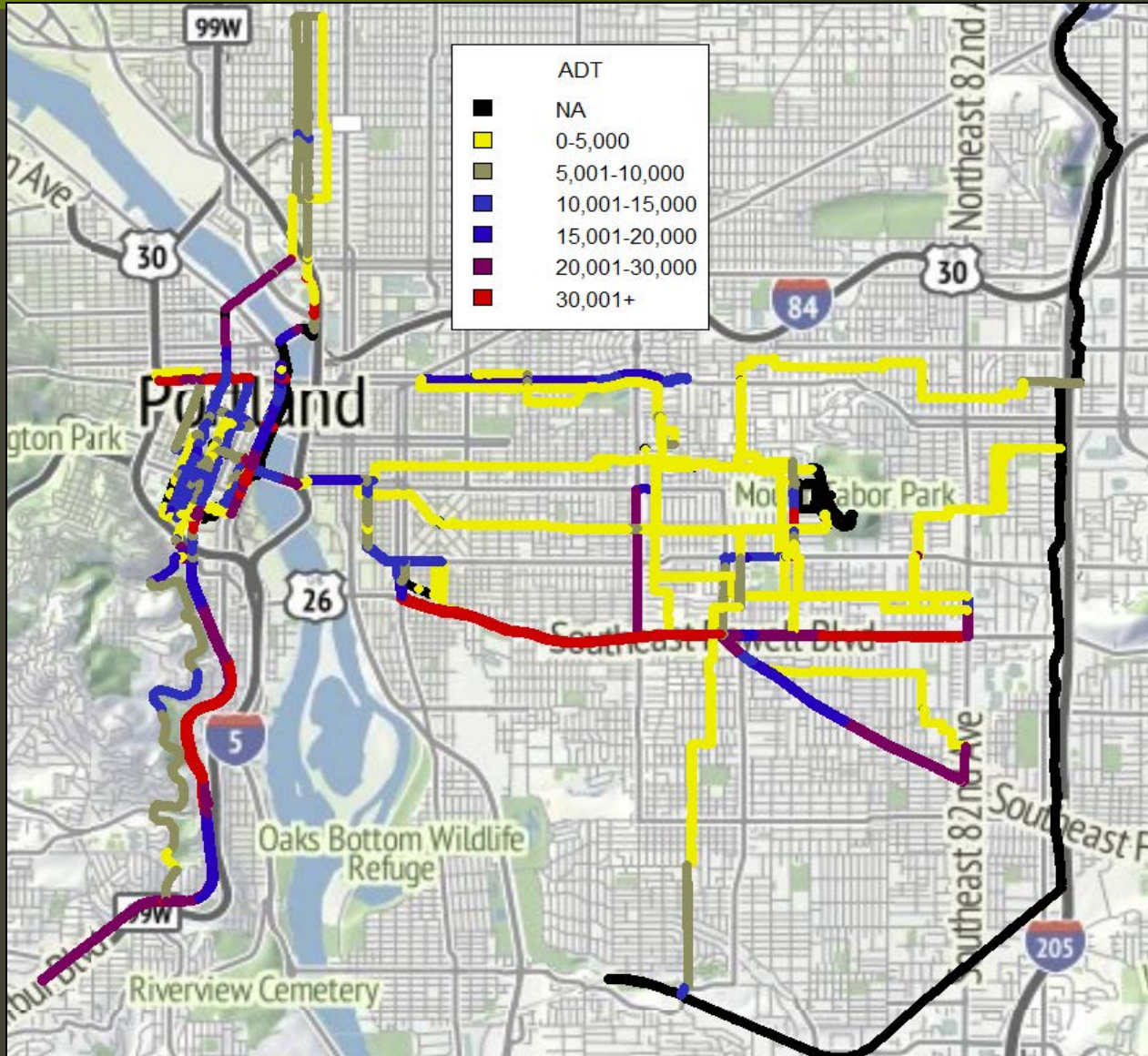
**OTREC**  
OREGON TRANSPORTATION RESEARCH  
AND EDUCATION CONSORTIUM



# Bonus Slides!



# ADT

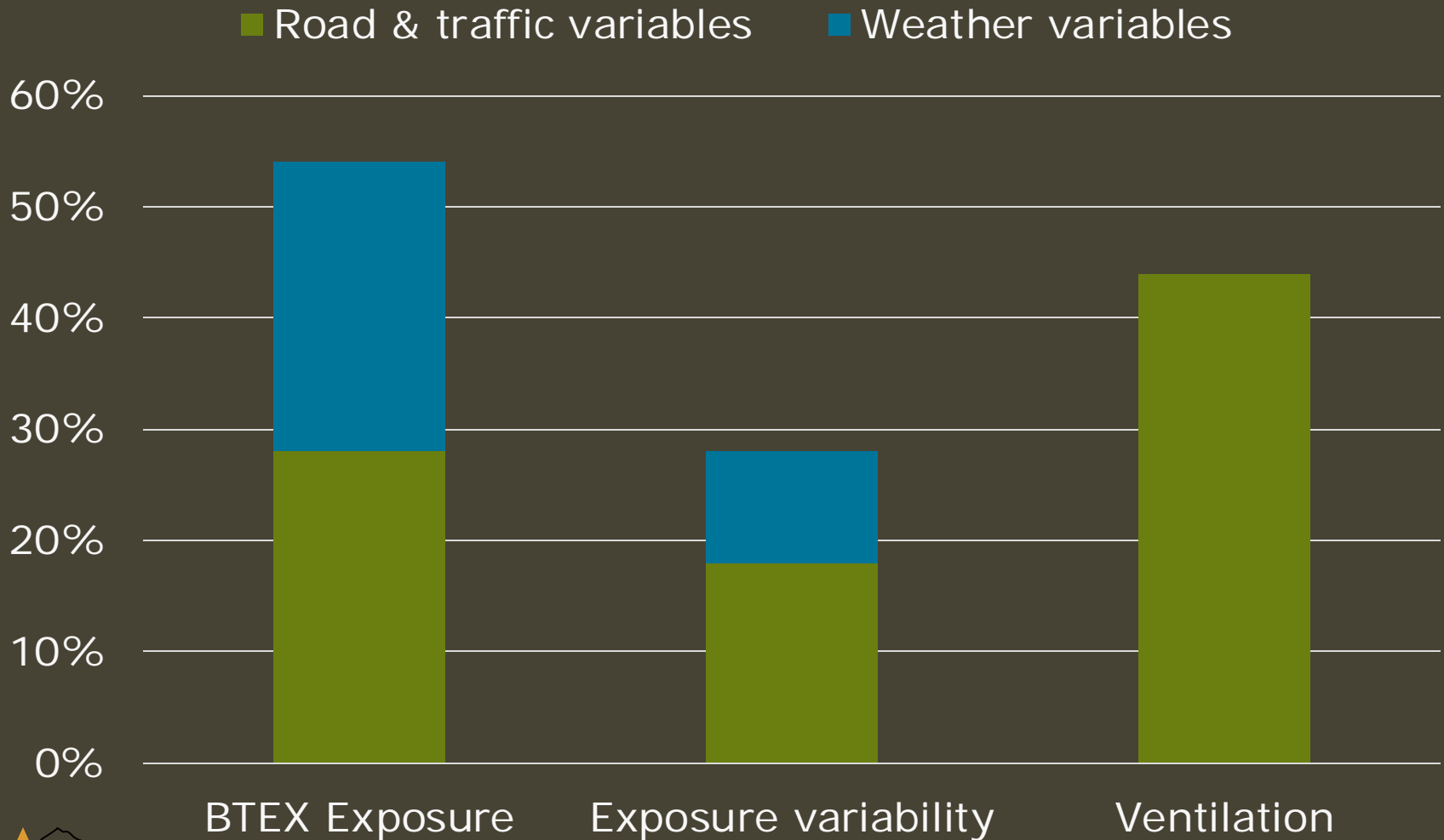


# Parallel Paths

- Burnside > Ankeny
  - 51% TVOC, 201% CO, 9% PM<sub>2.5</sub>
- Williams > Rodney
  - 329% TVOC, 221% CO
- Naito > McCall path
  - 112% TVOC, 30% CO, 4% PM<sub>2.5</sub>



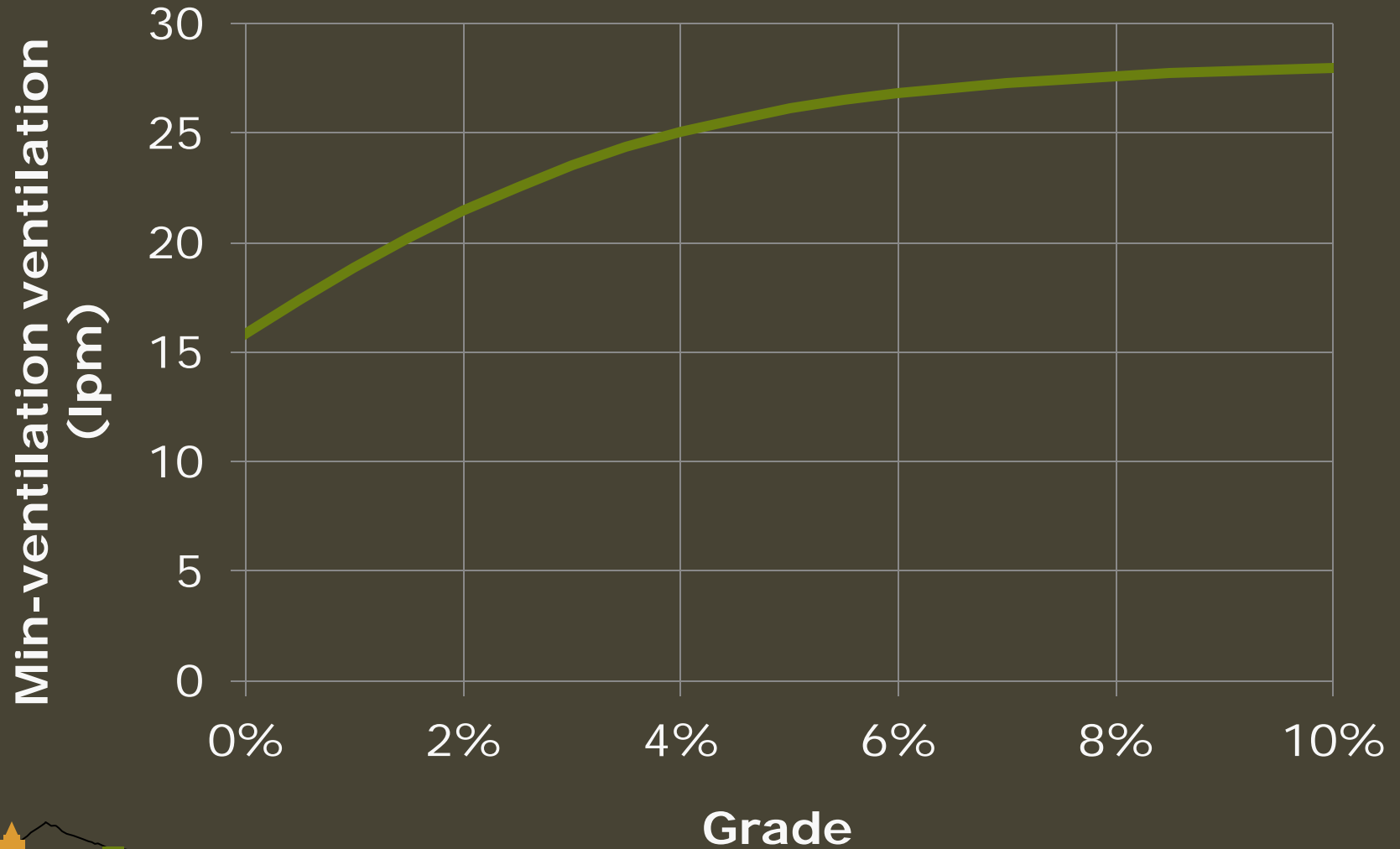
# Explained Variance



# Inhalation and Grade



# Minimum-ventilation envelope



# Results: Uptake Models

- Elasticity of breath to exposure  $\sim 0.5$ 
  - $\Delta$  Breath  $\sim \frac{1}{2} \Delta$  Exposure
  - No significant difference by subject
- Ventilation effect small but significant for some compounds
  - Elasticity of 0.1-0.2

