

# Mitigating Traffic-Related Particle Pollution

Jake Goodwin, Stephen Nerkowski, Claire Victor, and Tim Welch

Copenhagen, Denmark

October 10th, 2019

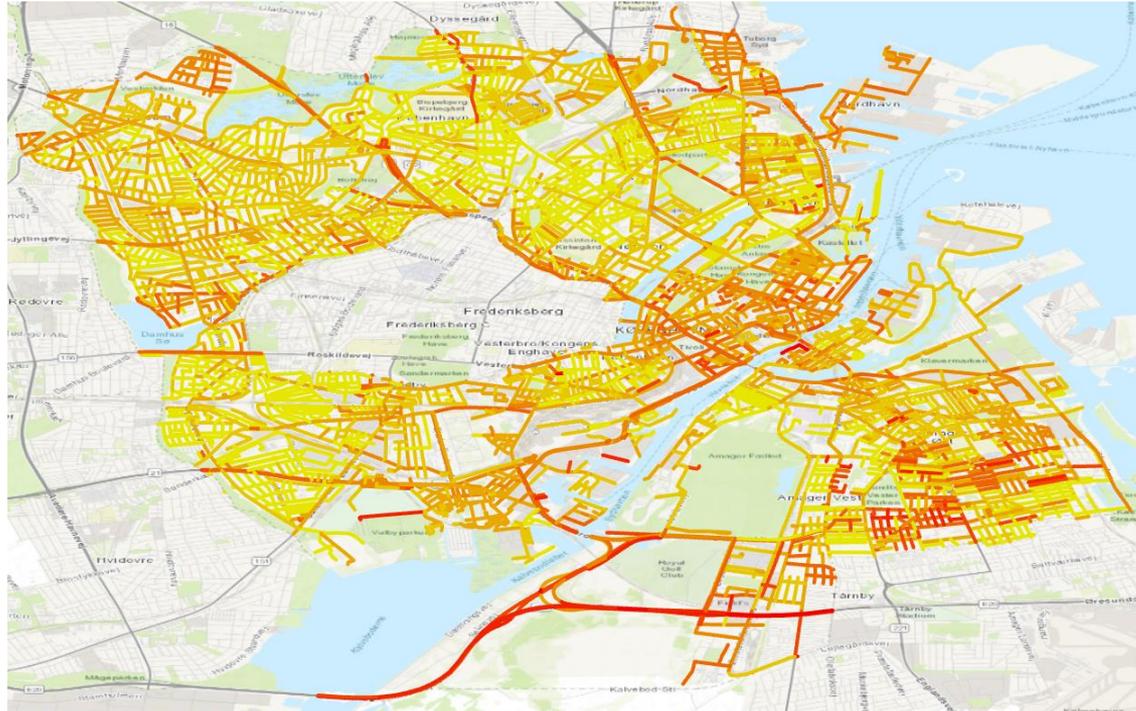


**WPI**

MILJØPUNKT  
INDRE BY & CHRISTIANSHAVN  
AGENDA 21 - FOR ET BÆREDYGTIGT KBH



# Particle Pollution in Copenhagen



# Particle Pollution: Sources and Classification



## Vehicle Emissions

---

Diesel  
Petrol  
(*combustion*)



## Energy Production

---

Coal  
Biomass  
(*combustion*)



## Abrasion Surfaces

---

Tires  
Brakes  
Roadware



## Construction Sites

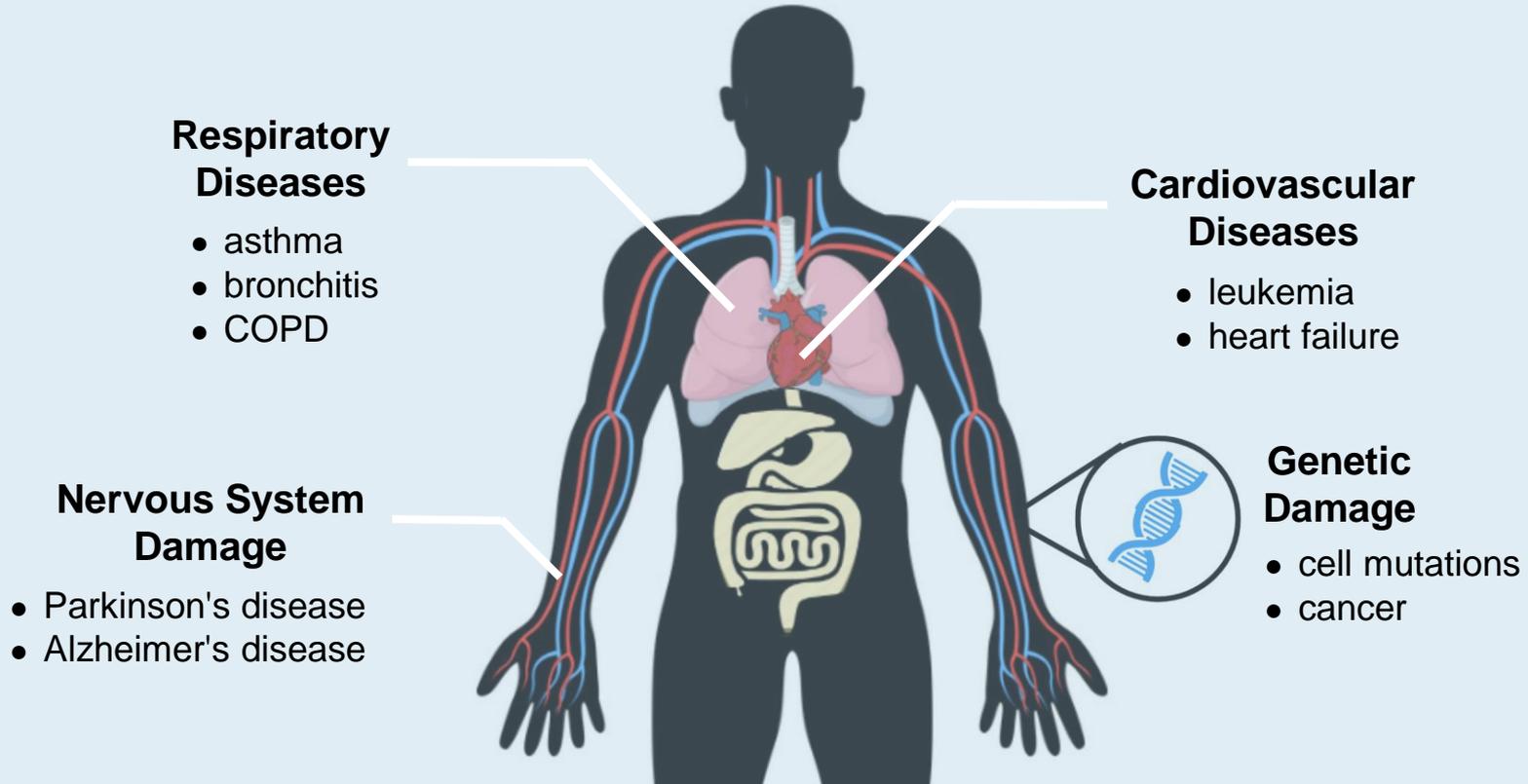
---

Machinery  
Earthworks  
Demolition

# Particle Pollution: Sources and Classification

PARTICLE TYPE	ABBREVIATION	DIAMETER ( $\mu\text{m}$ )	METRIC
coarse particles	PM <sub>10</sub>	2.5 - 10	$\mu\text{g}/\text{m}^3$
fine particles	PM <sub>2.5</sub>	< 2.5	$\mu\text{g}/\text{m}^3$
ultrafine particles	PM <sub>0.1</sub>	< 0.1	number/ $\text{m}^3$
nanoparticles	PM <sub>0.02</sub>	< 0.02	number/ $\text{m}^3$

# Particle pollution has many serious adverse health effects



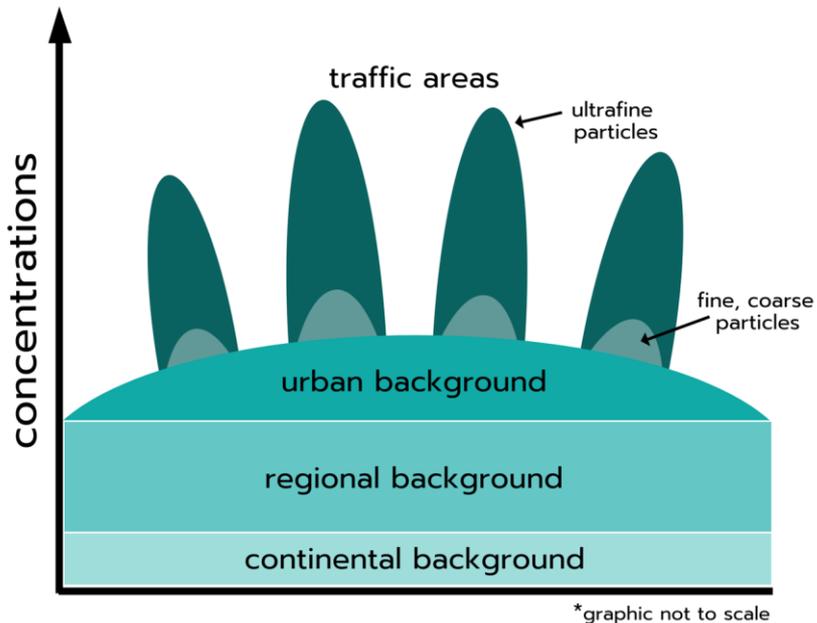
# PM concentration limits hide the urgency of reducing PM pollution in Copenhagen, especially UFPs

PARTICLE TYPE		EU Limit ( $\mu\text{g}/\text{m}^3$ )	WHO Limit ( $\mu\text{g}/\text{m}^3$ )	HC Andersens Blvd. ( $\mu\text{g}/\text{m}^3$ )
coarse particles	PM <sub>10</sub>	40	20	25
fine particles	PM <sub>2.5</sub>	25	10	13
ultrafine particles	PM <sub>0.1</sub>	?	?	13,000 part./cm <sup>3</sup>

**“4,000 Danes die [prematurely] every year due to fine particle pollution. That’s 7% of all Danish death[s]... That makes fine particles in outdoor air our **third highest risk factor**”**

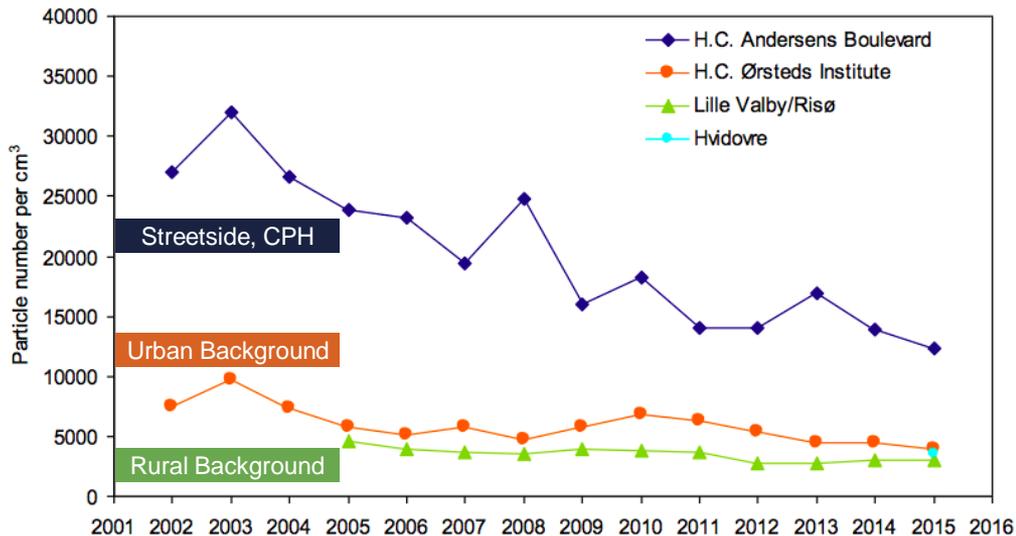
— Kåre Press-Kristensen

# Traffic is the most significant contributor to dangerous levels of Copenhagen's roadside UFP pollution



\*graphic not to scale

## Particle Number (UFP) Concentrations in Denmark



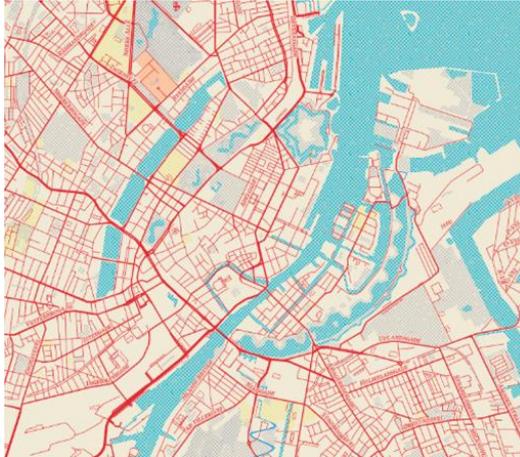
# Project Objectives

## 1 International Study



- Global Efforts
- Existing Trends
- New Strategies

## 2 Local Investigation



 *Copenhagen, DK*

## 3 Identifying Solutions



Regulation & Enforcement



Effective Technology



Social Adoption

# Project Tasks

## LITERATURE REVIEW

- policy
- technology
- practice

## KEY INTERVIEWS

- technical
- academic
- political
- public interests
- private interests

## DATA COLLECTION

- busy street
- bus stop
- idling taxis

## INFORMATION ANALYSIS

- cross-verification
- prioritization
- feasibility

## Filter technology & emissions tests of many on-road diesel passenger cars are not effective (pt. 1)



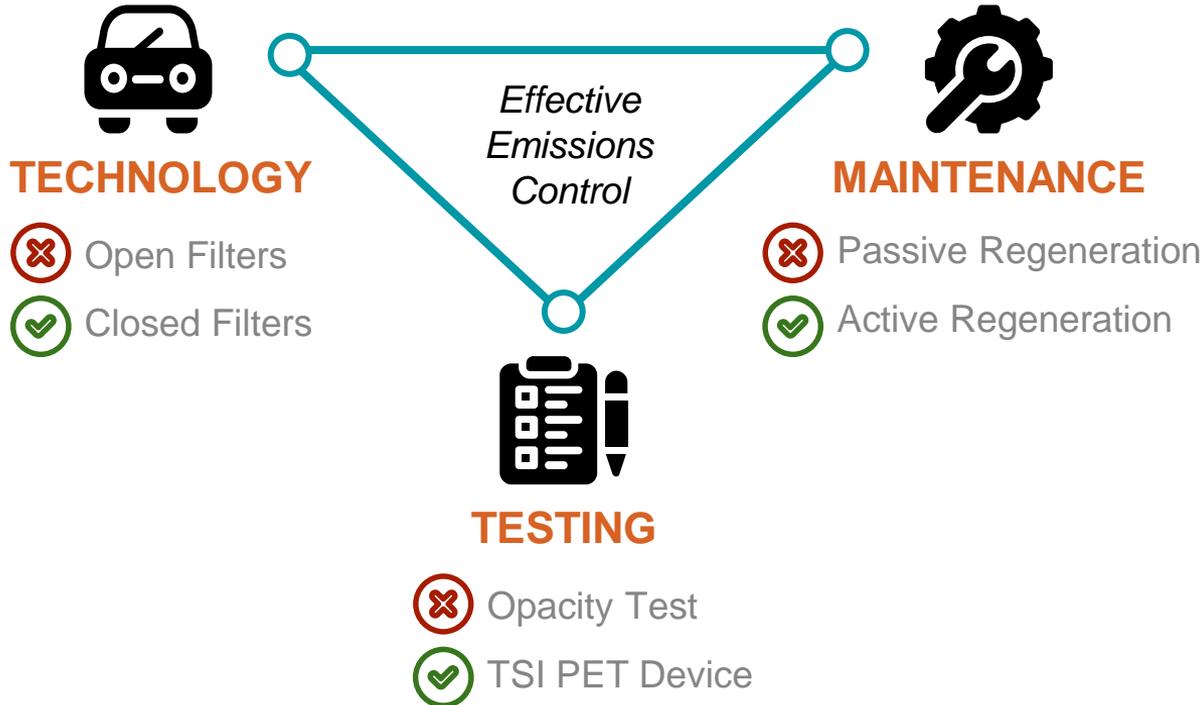
### TECHNOLOGY

 Open Filters

 Closed Filters

	Diesel Vehicle	Effective Date Factory/Sale	Particle Mass Limits	Particle Number Limits
<b>Euro 1</b>	Passenger Car	1992/1993	140 mg/km	--
<b>Euro 2</b>	Passenger Car	1996/1997	100 mg/km	--
<b>Euro 3</b>	Passenger Car	2000/2001	50 mg/km	--
	Truck/Bus	2000/2001	100 mg/km	--
<b>Euro 4</b>	Passenger Car	2005/2006	25 mg/km	--
	Truck/Bus	2005/2006	20 mg/km	--
<b>Euro 5</b>	Passenger Car	2009/2010	5 mg/km	6e11 part./km
	Truck/Bus	2009/2010	20 mg/km	--
<b>Euro 6</b>	Passenger Car	2014/2015	5 mg/km	6e11 part./km
	Truck/Bus	2013/2013	10 mg/km	8e11 part./kWh

# Filter technology & emissions tests of many on-road diesel passenger cars are not effective (pt. 2)



## Movia's public bus fleet contains many diesel buses with outdated, ineffective filter technology



### TECHNOLOGY

- Open Filters
- Closed Filters



### MAINTENANCE

- Passive Regeneration
- Active Regeneration

VEHICLE TYPE	TECHNOLOGY SPECIFICATION	# OF BUSES
Euro 2	CRT	1 *
Euro 3	CRT	73 *
Euro 4	----	96 *
	SCRT Retrofitted to Euro 6	12
Euro 5	----	93 *
	SCRT Retrofitted to Euro 6	7
EEV	----	400 *
	SCRT Retrofitted to Euro 6	179
Euro 6	----	453
Electric	----	78
<b>Total</b>		<b>1,392</b>

CRT = Continuous Regeneration Technology  
 SCRT = Selective Catalytic Reduction Technology  
 EEV = "Enhanced Environmentally-Friendly Vehicle"

**6%** of buses are electric  
 78 Electric / 1,392 total

**50%** of diesel buses use old filters  
 663 buses / 1314 diesel buses

At minimum,  
**74** buses use passive regeneration filters

## Traffic companies often supplement the EU regulated emissions tests with their own procedure



### TESTING

-  Opacity Test
-  On-Board Diagnostics Test
-  Particle Number Count

Opacity



OBD

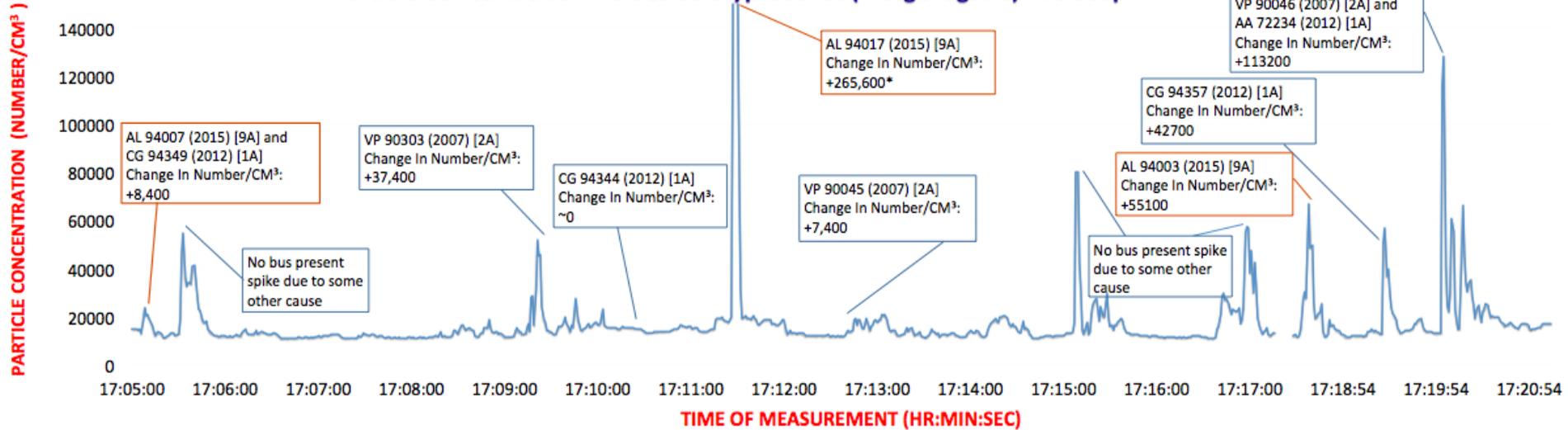


Miljøsyn



# Streetside Data Collection: Public Buses

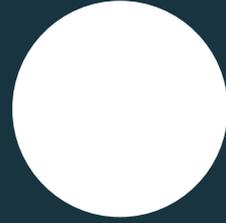
## Particle Concentration Values at Glyptoteket (Tietgensgade) Bus Stop



# Streetside Data Collection: Public Buses

Euro Norm	License Plate Number	Particle Count (Number/cm <sup>3</sup> )
<b>Euro 6</b>	AL 94007	8,400*
	AL 94021	42,900*
	AL 94003	55,100
	AL 94013	208,100
	AL 94017	265,600

\*Indicates the measurement was the result of combined emissions (Euro 5 bus also present at bus stop)



**Eliminate preventable particle pollution**  
from diesel vehicles during the transition to  
emissions-free transportation

# Long term efforts should support the transition to zero-emission transportation

## LIGHT-DUTY

(diesel passenger cars, taxis)



- new car registration tax
- filter tax
- city emissions tax



extend Euro 6 environmental zone to passenger vehicles

## HEAVY-DUTY

(diesel buses)



Funding for more electric buses in Movia's fleet

fossil fuel → biofuel → electric



# Short term efforts should address the imminent problems with diesel emissions

## LIGHT-DUTY

(diesel passenger cars, taxis)



Retrofit vehicles with Euro 6 emissions-equivalent filters



Regulate use of TSI PET emissions test

## HEAVY-DUTY

(diesel buses)



Retrofit vehicles with Euro 6 emissions-equivalent filters



Regulate use of P-Trak (UFP) measurement in emissions test

# Immediate efforts should engage citizens in the issue while the government passes legislation



Public Awareness Events

## Handkerchief Emissions Test



- 1 Attach white handkerchief or kitchen towel to tailpipe
- 2 Drive car or rev engine
- 3 Check towel; if dirty, the filter is malfunctioning and should be brought in for maintenance



Reporting Idling & Malfunctioning Public Buses via Municipality App



# Acknowledgements

We would like to give special thanks to:

*Miljøpunkt Indre By & Christianshavn*  
Marianne Spang Bech  
Sabine Sørensen

*All of our interviewees*

*And our professors*  
Professor Ault  
Professor Hanlan

Questions?



# Recommendations Summary

- **Prioritize shift to emission-free transportation**
  - Discourage diesel car ownership
  - Encourage electric vehicles
- **Enforce tighter regulation on diesel emissions**
  - Retrofit all vehicles with Euro 6 emission-equivalent DPFs
  - Extend environmental zone to all diesel vehicles
- **Standardize adequate emission testing to ensure DPF technology remains functional**
  - TSI PET tests for light-duty diesel vehicles
  - Particle number parameter for heavy-duty diesel vehicle tests