Enacting policies for an (even) cleaner local environment

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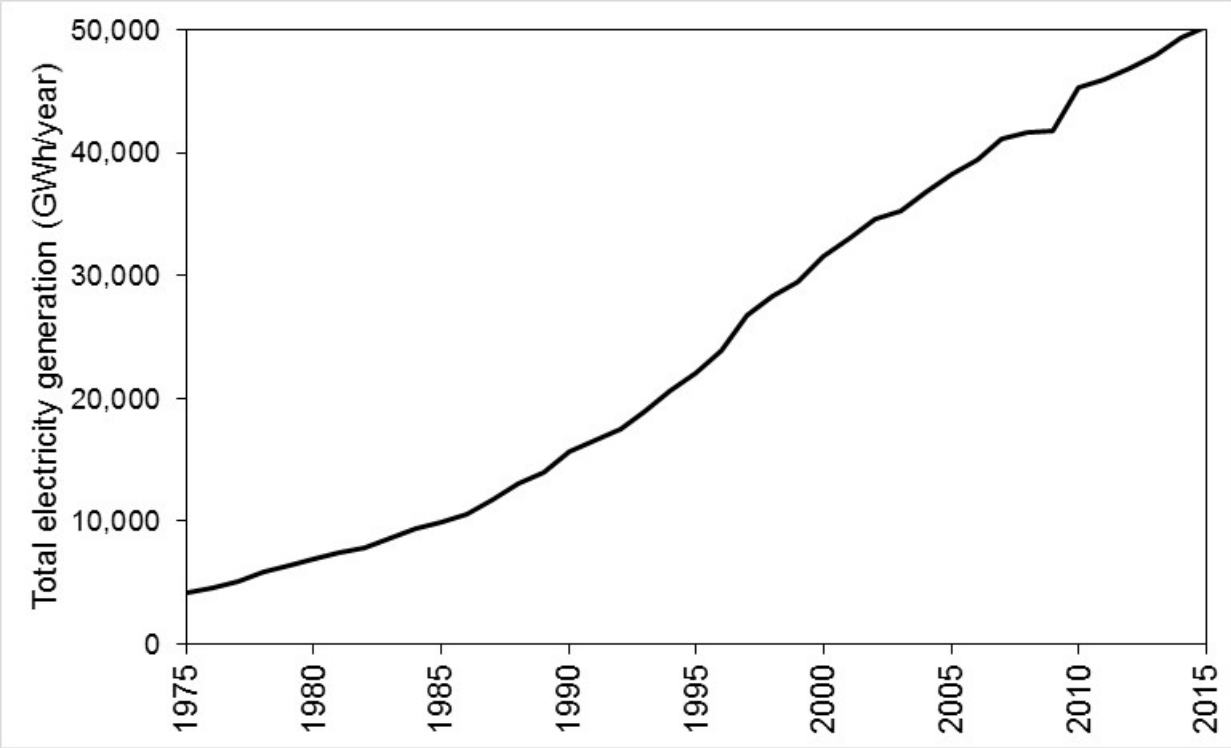
Introduction and caveats

- Title of talk is rather grand
- Stick to:
  - A current research domain: Local air quality
  - Emissions (burning) that we have more control over: Onshore, not transboundary
  - PM2.5 as a proxy for air quality (particulate matter of diameter up to one millionth of a meter in diameter)
  - PM2.5 dominates Singapore's PSI
- Keywords:
  - Vehicle emissions, demand for driving, commercial fleet, diesel exhaust, idling, school buses, land use, emission permits, atmospheric ventilation, hotspots

Singapore has come a long way 1

- Nation has deftly managed economic growth, a rising population, and environmental protection
  - For example, electricity generation is powered by natural gas

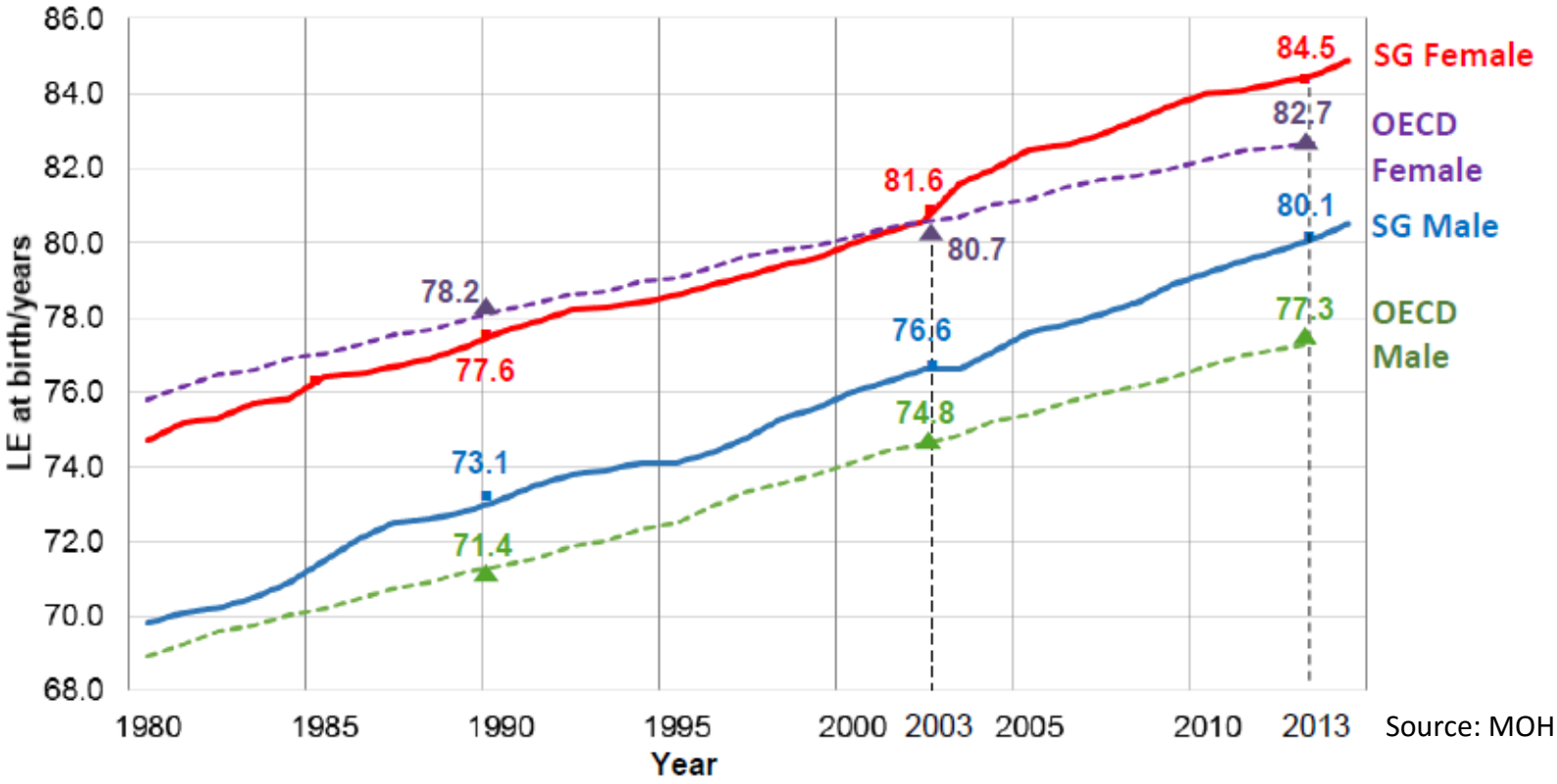


Source: EMA

Singapore has come a long way 2

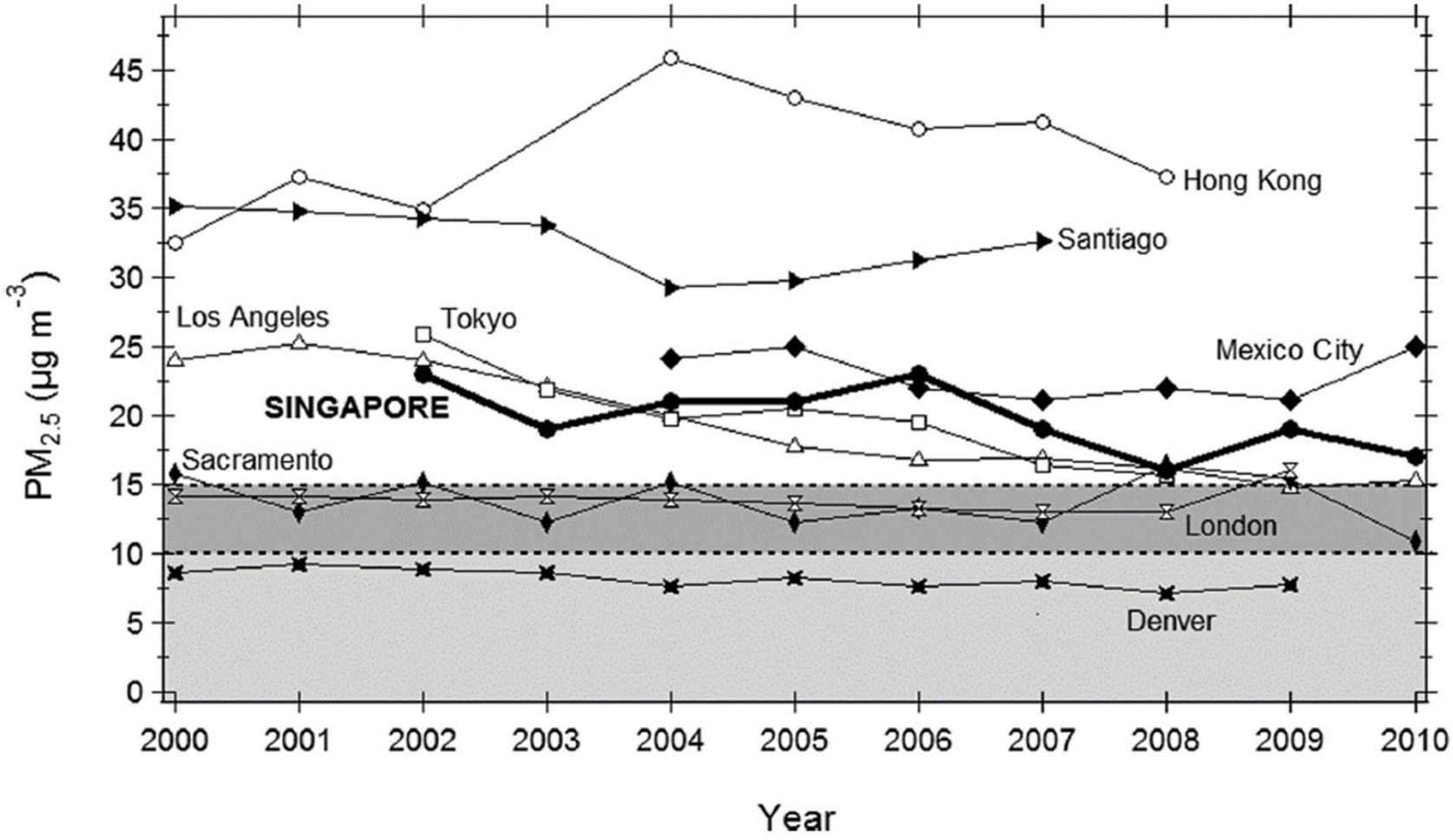
- Ranks world's 3rd for life expectancy

Figure 1: Resident Life Expectancy at birth in Singapore by Gender compared to OECD Aggregate



Source: MOH

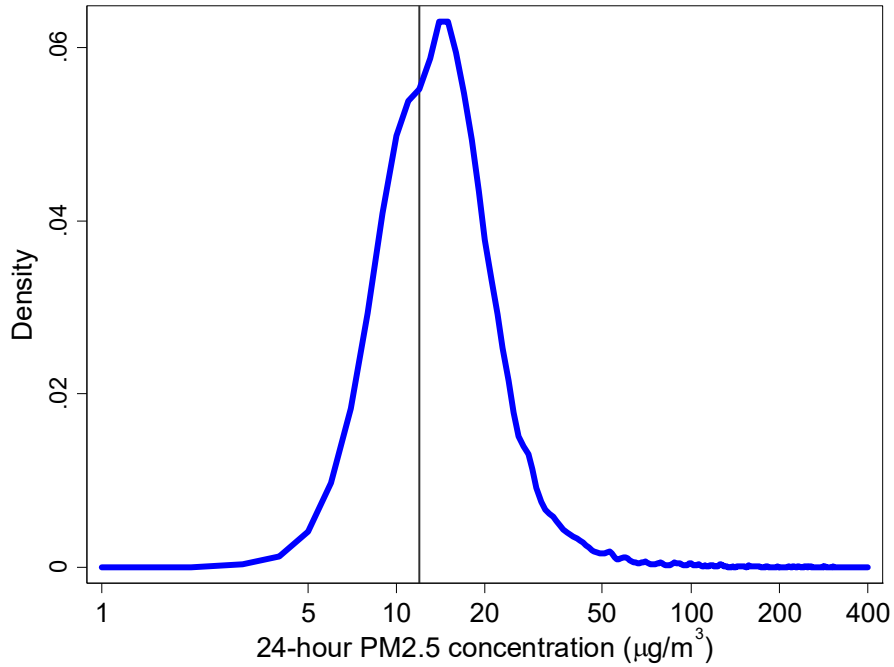
Singapore has come a long way 3



Source: Velasco and Roth (2012)

Singapore's goal for particle (PM2.5) pollution

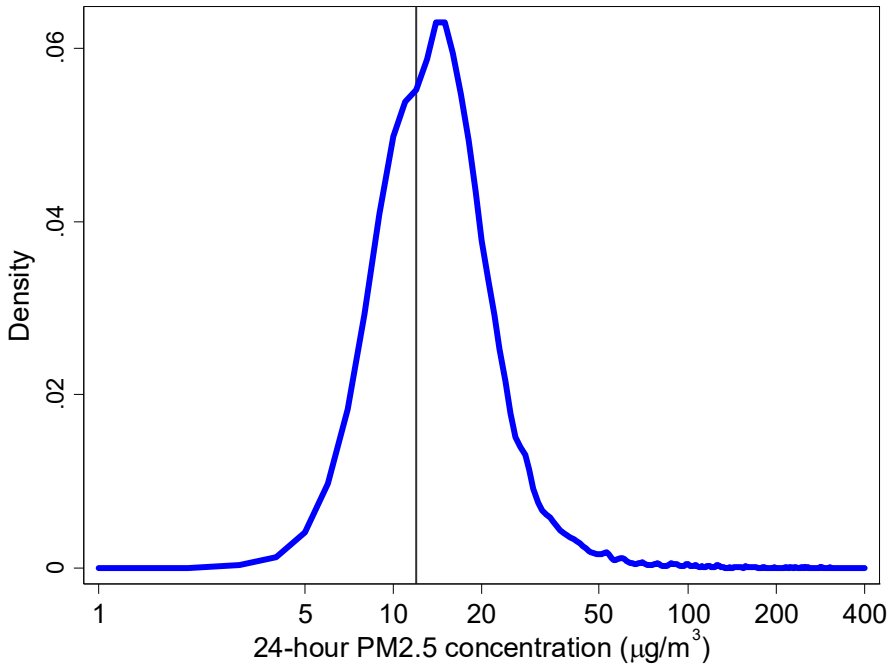
- Reach 12 µg/m^3 (same as US primary NAAQS)
- Actual distribution for 24-hour mean, August 2012 to December 2015:



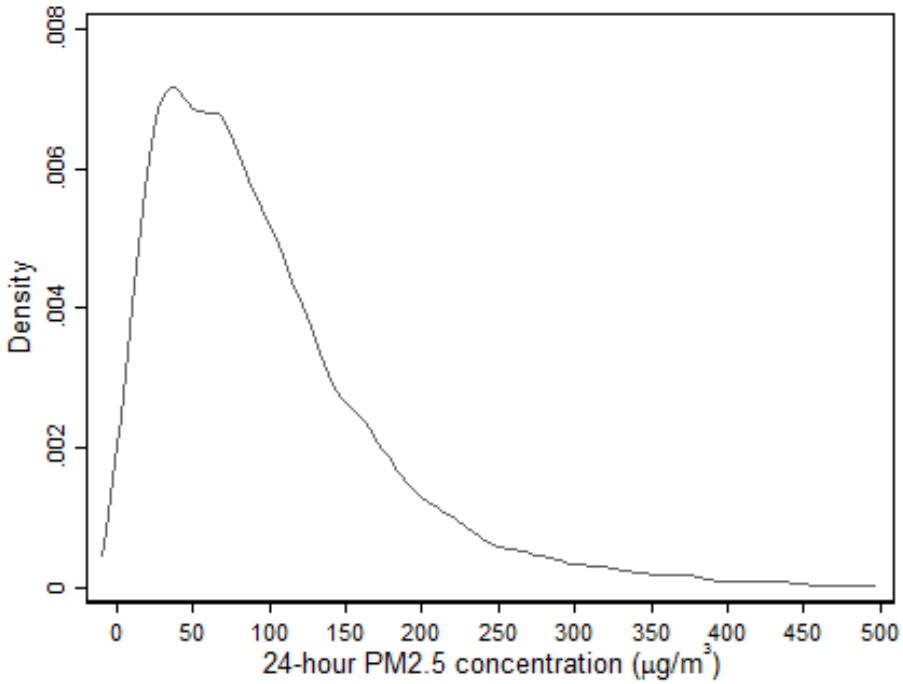
Source: NEA, author's calculations

Singapore versus Beijing

Singapore: Mean ≈ 20 µg/m^3



Beijing: Mean ≈ 100 µg/m^3



Source: US Department of State

Singapore versus other cities, rich & developing

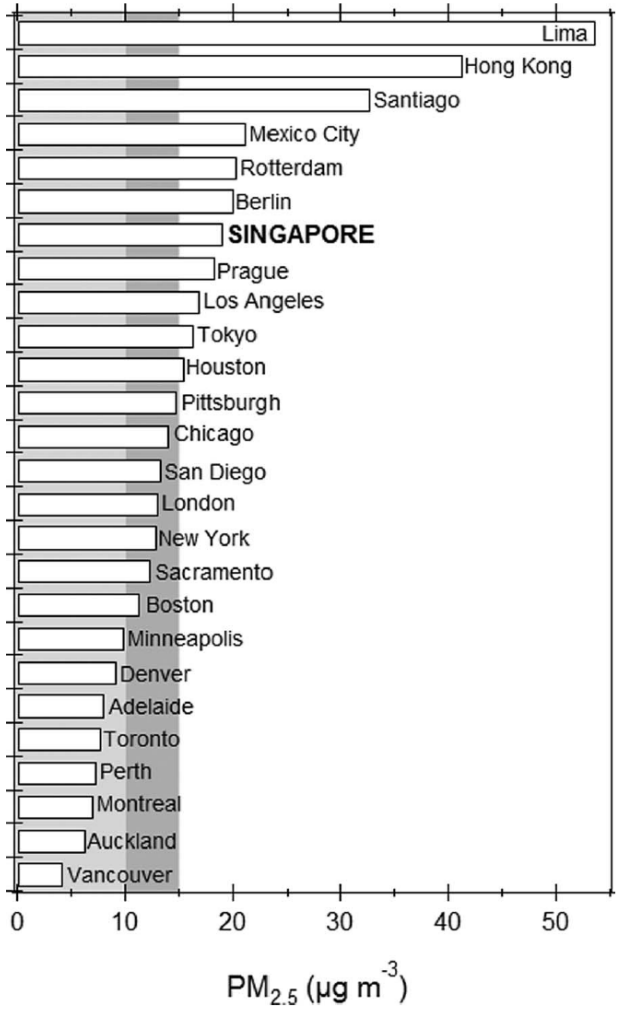
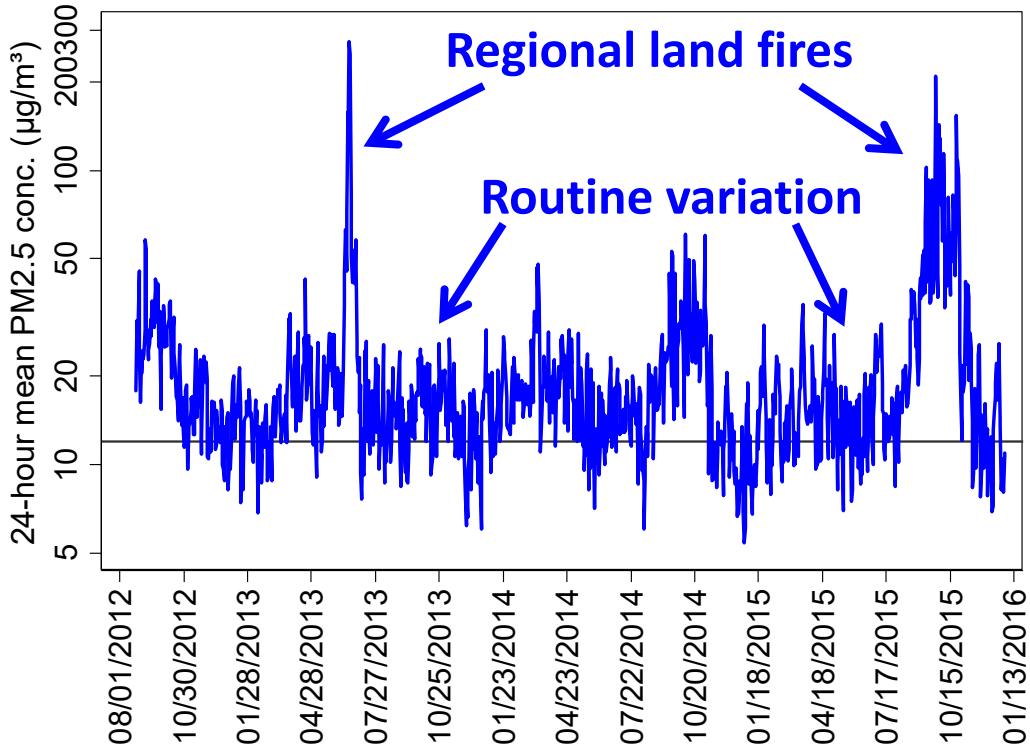


Figure 9. Annual average concentrations of $PM_{2.5}$ in 2007 for selected cities. Vertical light and dark shaded areas indicate $PM_{2.5}$ levels below the WHO guidelines and EPA standards, respectively. Data cities included in Figure 8

Source: Velasco and Roth (2012)

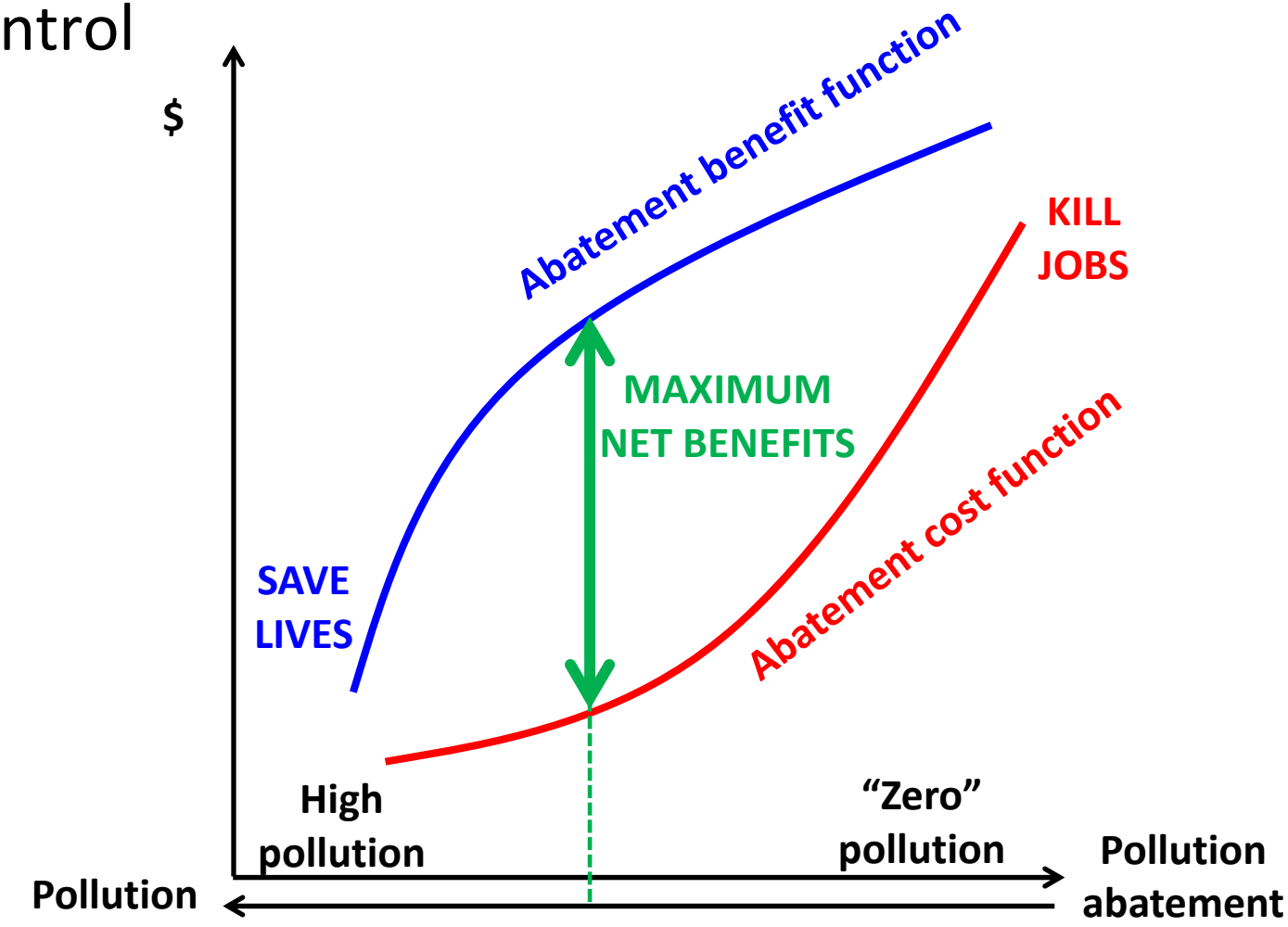
Routine versus extreme variation in PM2.5

- August 2012 to December 2015:



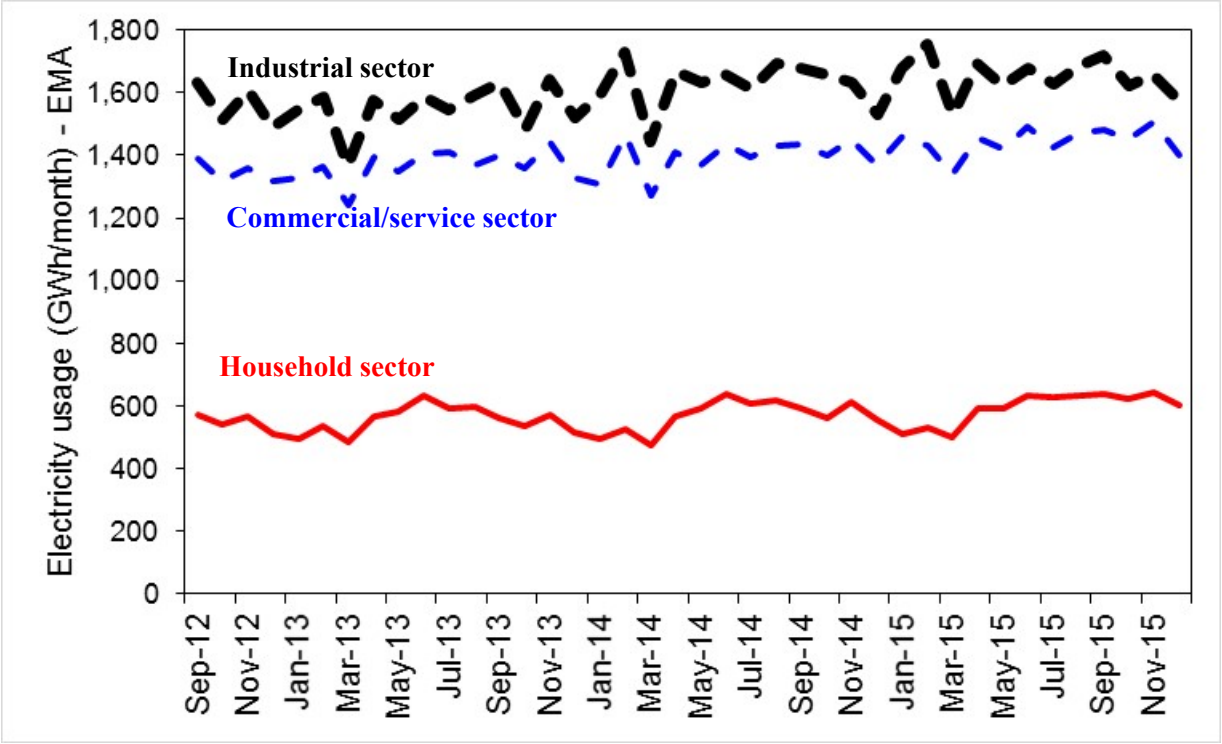
The socially optimal level of pollution is not zero

- There are benefits but also costs from pollution control



Singapore remains an industrial nation

- Electricity usage by sector



Onshore emissions: Transport, industry, ships

- Sample period: August 2012 to December 2015
- PSI adjusted to include PM2.5

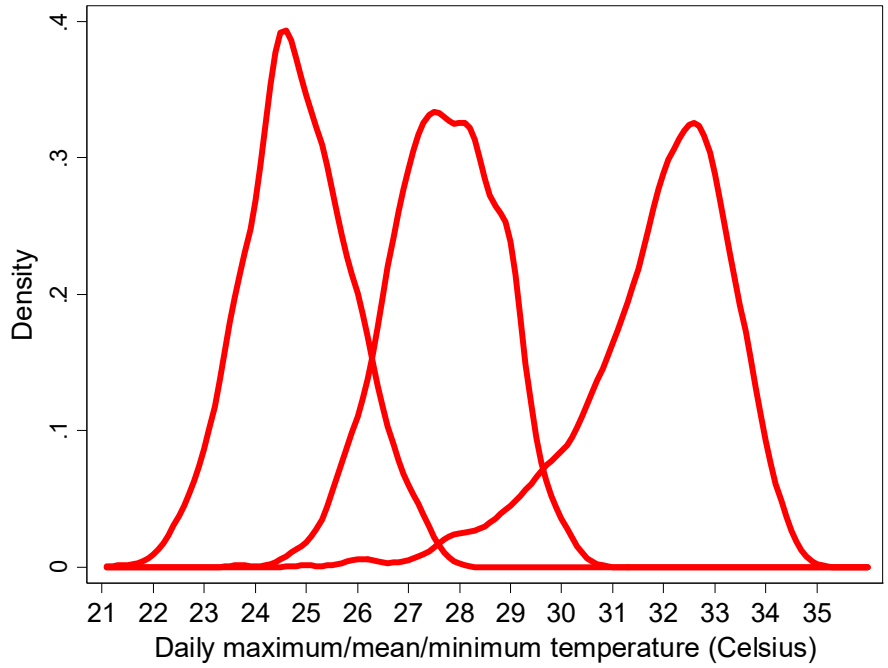
Variable	N	Mean	Min	Max
Air pollution				
PM2.5, East, 24-hour mean (µg/m^3)	1,225	20.9	5.8	282
PM2.5, **West**, 24-hour mean (µg/m^3)	1,225	**22.0**	4.0	256
PM2.5, **Center**, 24-hour mean (µg/m^3)	1,225	**19.2**	4.6	247
PM2.5, South, 24-hour mean (µg/m^3)	1,225	20.9	4.8	304
PM2.5, **North**, 24-hour mean (µg/m^3)	1,225	**22.2**	5.5	286
PSI, East, 24-hour (points)	1,225	58.6	24	332
PSI, **West**, 24-hour (points)	1,225	**59.7**	16.7	306
PSI, **Center**, 24-hour (points)	1,225	**55.9**	19	297
PSI, South, 24-hour (points)	1,225	58.3	20	354
PSI, **North**, 24-hour (points)	1,225	**60.6**	23	336

Exposure in daily microenvironments

- Low-hanging fruit, if agents can be better informed?
- Vehicle idling is widespread, right where people transit (despite now being an offence)
- Economics of idling
  - Hot weather: Demand for in-cabin air-conditioning
  - Fuel is probably not too expensive to vehicle owner
  - Fuel is probably cheap to vehicle driver
  - We feel heat, we do not see small particles
  - Lack of information
  - New technologies: Engine is turned off when vehicle halts

Demand for air conditioning

- Distribution of daily minimum, mean and maximum temperatures:



Exposure to diesel exhaust

- School bus departures can be optimized
- Children are particularly vulnerable
- US school districts:
  - No idling policy
  - Staggered departures
  - Prioritize exit road space over light vehicles

SWITCH OFF VEHICLE ENGINE WHEN STATIONARY

It is an offence for any driver to leave the engine of a motor vehicle running when it is stationary.

Problems caused by idling engine

A stationary motor vehicle with engine running (idling) wastes fuel and also causes air pollution. It also causes smell and noise nuisance to the public.

A vehicle parked with engine running can damage the engine in the long term as the engine is not operating at optimum temperature for complete combustion of the fuel. This leaves fuel residues that may contaminate engine oil and make the spark plug dirty.

A vehicle parked with prolonged idling of the engine also allows water to condense in the vehicle exhaust, contributing to corrosion of the exhaust system.

Frequently asked questions on idling engines

What is the law against stationary motor vehicles with engine running (idling)?

- Environmental Protection and Management (Vehicular Emissions) Regulations

What is the purpose of the law?

- To minimise the emission of exhaust gases from vehicles
- To help conserve energy by minimising fuel wastage
- To minimise smell and noise nuisance to the public.

What is the penalty for this offence?

- A composition sum of $70 or
- A court fine not exceeding $5000

Are there any exemptions to the law?

No enforcement action will be taken under any of the following circumstances:

a) Due to traffic conditions;

b) For working of on-board machinery for some ancillary purpose, such as for controlling cargo temperature, operating a lift, crane, pump, hoist, mixer;

c) Taxis/buses in a moving queue at their designated stops, stands or terminals waiting to pick up passengers;

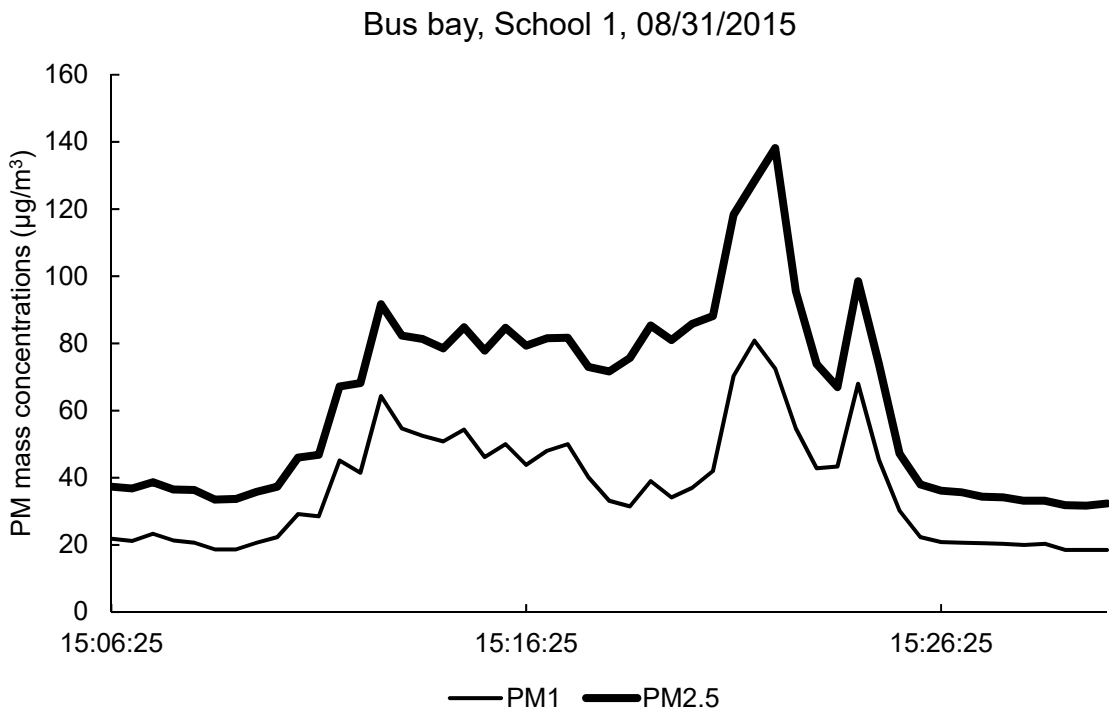
d) For law enforcement or emergency purposes, such as ambulances; or

e) Vehicles under inspection, maintenance or diagnostics at inspection/repair facility.

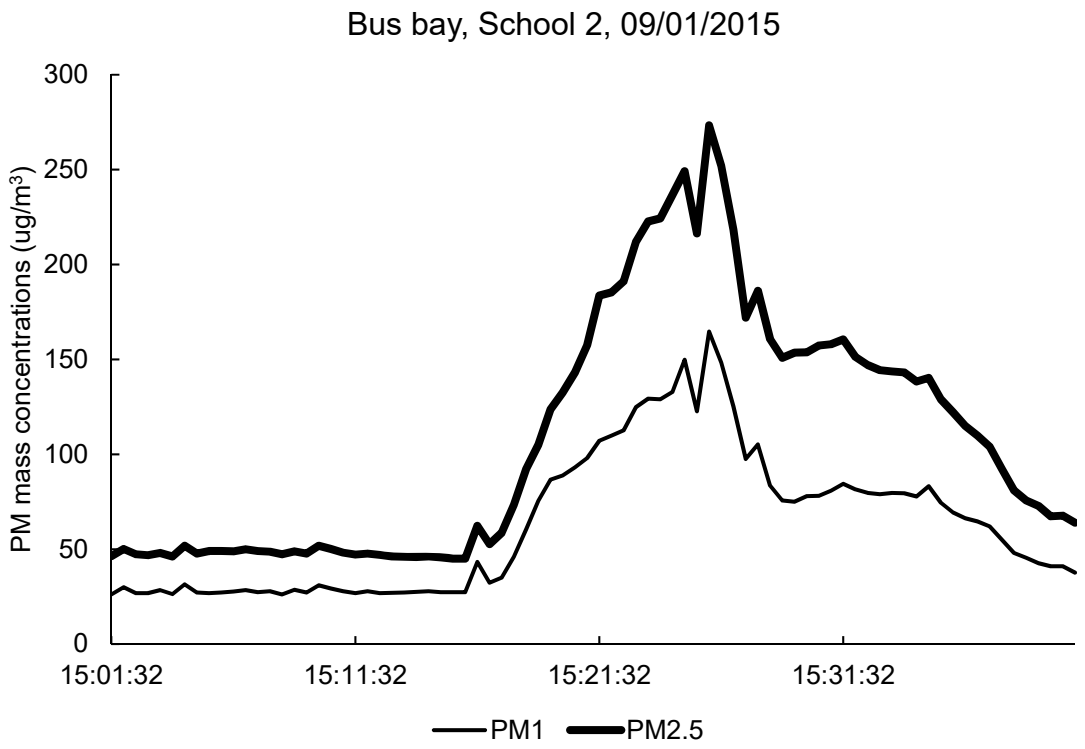
How to obtain further information on idling engines?

If you need any further information on idling engines, please contact NEA Call Centre on 1800-CALL NEA (1800 2255 632) or email to: Contact_NEA@nea.gov.sg or visit www.nea.gov.sg

Bus bay, School 1, Singapore, 08/31/2015



Bus bay, School 2, Singapore, 09/01/2015



Some views about idling

- Source: TODAYonline
- Video producer Jeremy, 27, said he often waits for his friends in his car with the engine running. "*Sometimes they take a long time to leave (their houses) — up to 15 minutes — so I wait for them in my car with the air-conditioning on because it is comfortable*"
- Taxi driver David said that, while he was aware of the regulations and had tried to adhere to them, he felt they were an inconvenience... "*Sometimes, passengers enter my taxi and complain that it is too warm inside. But I have no choice, because I have to turn off my engine while waiting for them.*"

Diesel exhaust and health

- Heavy vehicles bring many benefits to Singapore
- Negative externalities need to be managed
- Environmental economics research
- 3 examples, briefly
  - Washington state, US: School bus emissions
  - Sao Paulo, Brazil: Truck emissions
  - Singapore: School bus idling

Beatty and Shimshack (2011, JHealthEcon)

"School buses, diesel emissions, and respiratory health"

- Clean school bus program in WA state
- Staggered retrofitting of school buses with pollution control equipment
  - Diesel oxidation catalyst (DOC)
  - Crankcase ventilation filter (CCV)
- Difference-in-difference approach
- Find significant health gains
  - "Adopter districts experienced 23 percent fewer children's bronchitis and asthma cases… relative to a control group… (and) 37 percent fewer children's pneumonia cases"

He, Gouveia, Salvo (Resubmitted)

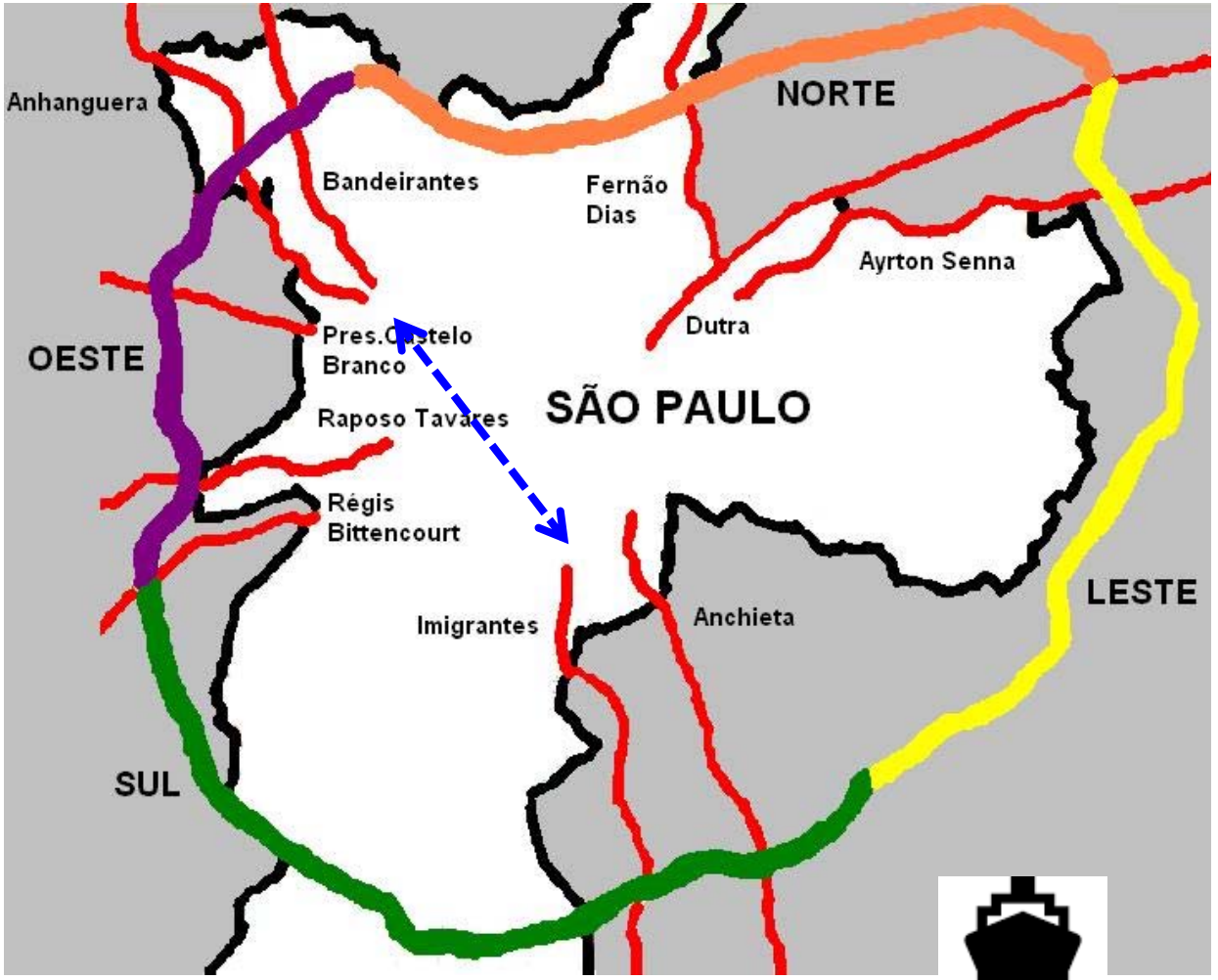
"External Effects of Diesel Trucks Circulating Inside the São Paulo Megacity"

- Sao Paulo's beltway abruptly removed 20,000 trucks from inner-city roads
- Transient effect on traffic congestion, sustained effect on diesel pollution and cardiorespiratory health
- Instrumental variables & difference-in-difference
- Find significant health gains
  - "…quantify about one annual hospitalization for every 10 to 20 trucks – and one annual death for every 100 to 200 trucks – using inner-city roads. "

The São Paulo beltway: Displaced truck traffic

To northwest SP state

To west and south SP state



State of São Paulo: One-third of Brazil's GDP

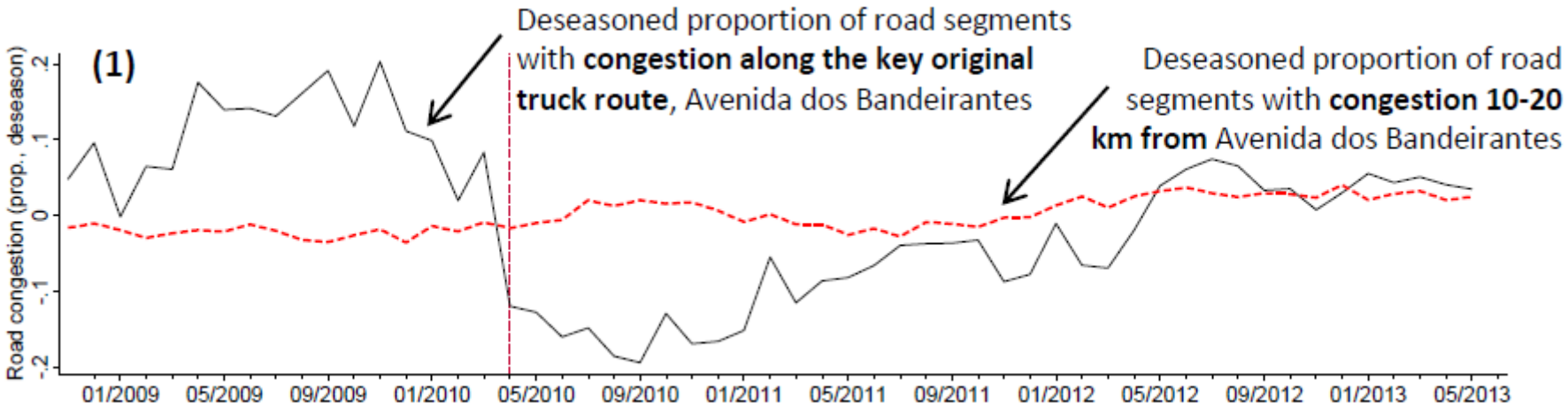
Open in Mar 2010

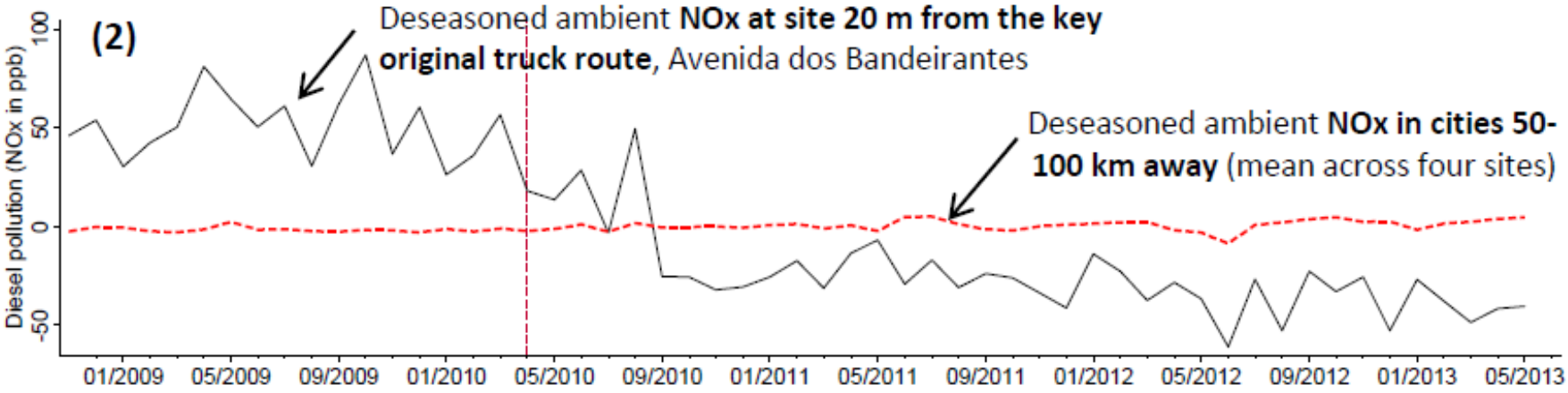
To the major port of Santos

Gridlocked roads in a developing-country megacity

The new beltway displaced 20,000 cargo trucks from inner-city roads on a daily basis. Inner-city roads have high human exposure.

Transient v. long-lasting effects



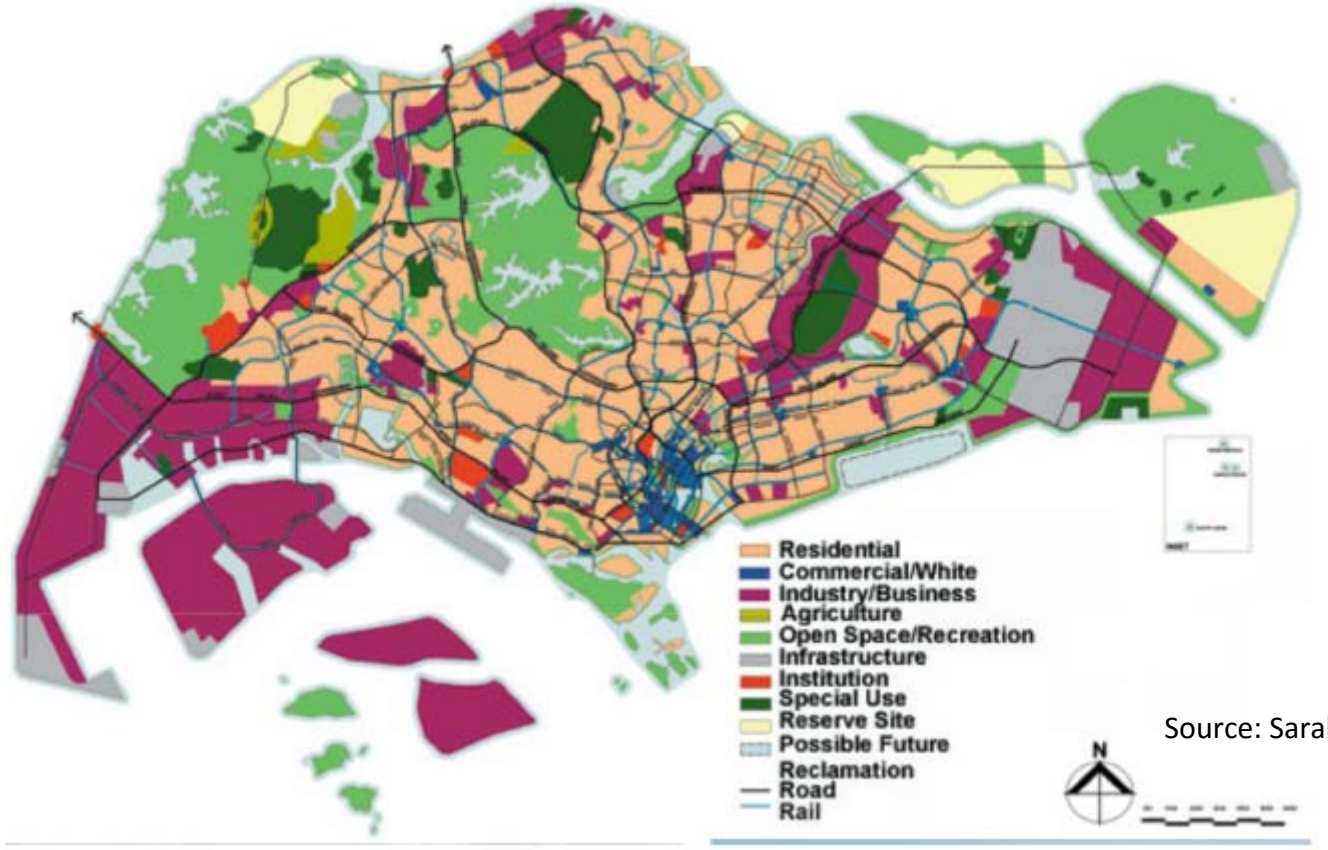


Research in progress

- Longitudinal student-level data for two large educational establishments in Singapore
- 6,000 students, multiple years
- Absences and commuting status
  - School bus/bay v. not school bus/bay
- Correlation:
  - Students who take the bus v. students who take the car
  - Exposure to diesel exhaust or to stay-home parent?
- Causation:
  - Within-student co-variation in absence rate and commuting status

Land use

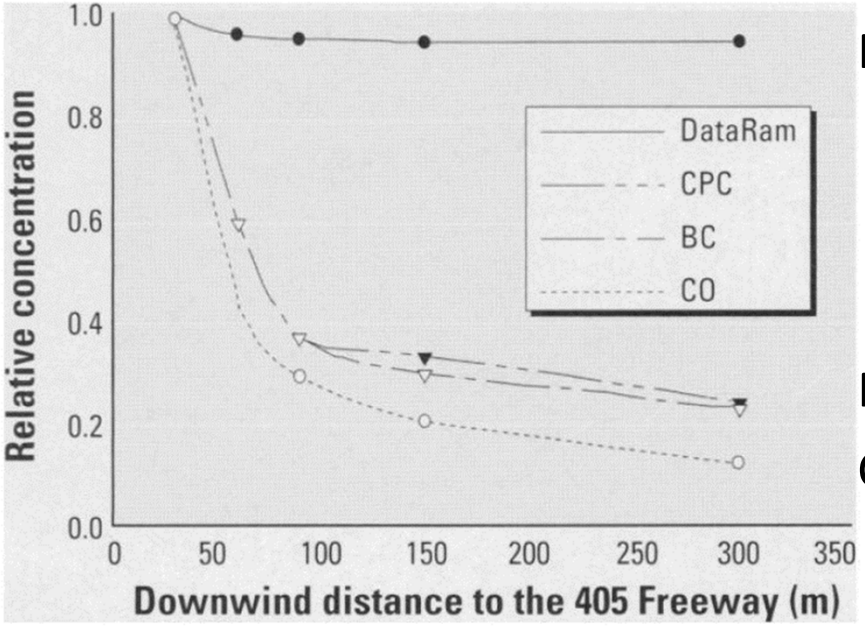
- Zoning of industry



Source: Sarahom (2013)

Land use

- Nanoparticles, black carbon, CO v. proximity to roads



PM2.5

Nanoparticles & BC

CO

Figure 11. Relative $PM_{2.5}$ mass [measured by DataRam nephelometer (MIE, Inc., Bedford, MA)], particle number (measured by CPC), black carbon (BC), and carbon monoxide (CO) concentrations versus downwind distance from the Los Angeles 405 freeway (Zhu et al. 2002).

Source: Lippmann (2003)

Land use

- Outdoor playgrounds and proximity to roads

Industrial emissions

- Industry brings many benefits to Singapore
  - Creates/forms job, wealth, skills, etc.
- Negative externalities need to be managed
- Environmental economics research
- 2 examples, briefly
  - Atmospheric ventilation and emission permits in Northeastern US
  - French refinery strikes

Mauzerall et al. (2005, AE), Fowlie (2010, AER)

"Emissions Trading, Electricity Restructuring, and Investment in Pollution Abatement"

- 11 t/d NOx emissions in Maryland upwind of NY

minus

- 11 t/d NOx emissions in North Carolina upwind of the Atlantic Ocean

=

- One human life every 10 days

Lavaine and Neidell (2017, JAERE)

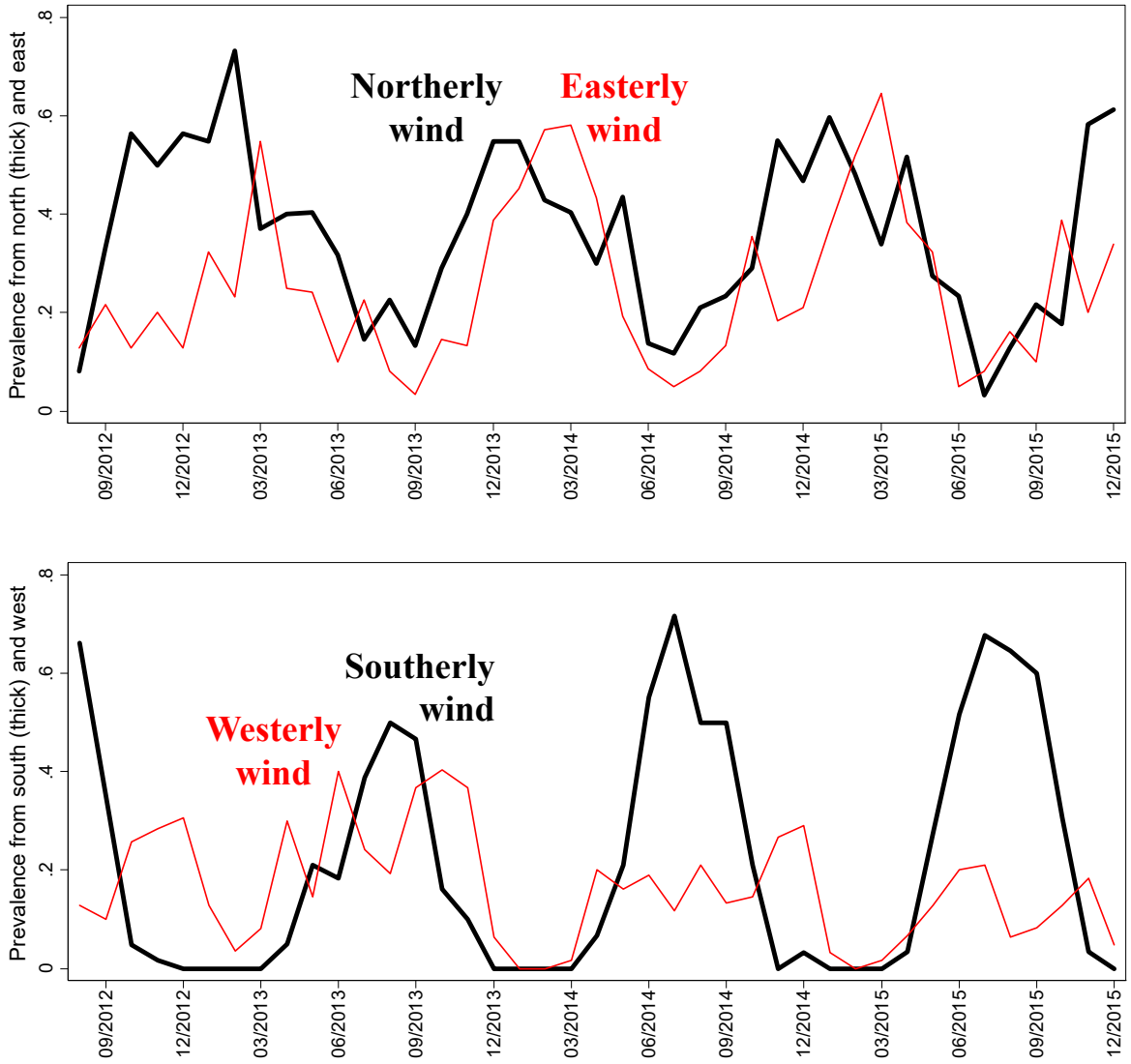
"Energy Production and Health Externalities: Evidence from Oil Refinery Strikes in France"

- Exploit year-long strike at oil refineries as a natural experiment
- Difference-in-difference approach
- Find significant health gains
  - Significant reduction in SO_2 concentrations
  - Higher birth weight and gestational age of newborns exposed to the strike during the 3rd trimester of pregnancy

Emissions and atmospheric ventilation

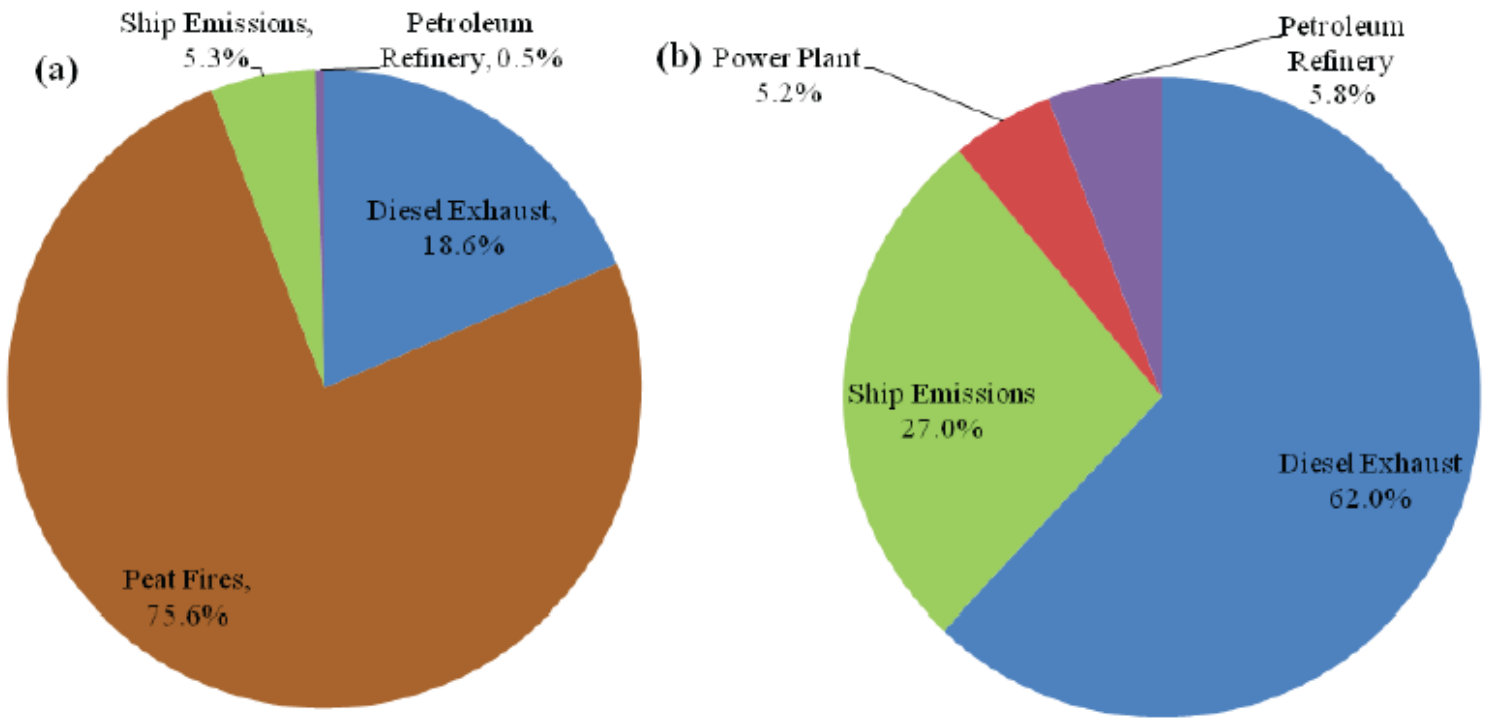
- Carrying capacity of the atmosphere varies
  - Wind speed, wind direction, atmospheric mixing layer, vertical thermal gradients, precipitation
  - Hotspots: High versus low damage locations/time
  - The atmosphere as a toilet: Frequency of flushing
- Night v. day: Less road emissions, people at home

Prevailing winds: Different monsoons



Parting thoughts on policy

- Willingness to pay for clean air likely going up
  - Richer citizens living longer
- Step up information & compliance on vehicle idling
  - Particularly at schools and stops
- Land use and future construction
  - Playgrounds, bus/taxi terminals/stops, e.g., mechanical ventilation
- Renovate the commercial vehicle fleet
  - Is natural gas an option?
- Industrial emission permits
  - Do these currently take advantage of variation in atmospheric ventilation?



($\mu g.m^{-3}$)	(a) Haze	(b) Clear days
Ship Emissions	4.46 ± 1.77	6.48 ± 1.4
Petroleum Refinery	0.42 ± 0.17	0.59 ± 0.3
Power Plant	-	0.55 ± 0.27
Diesel Exhaust	15.64 ± 6.21	14.88 ± 3.22
Peat Fires	63.58 ± 25.25	-

Figure 4. Source contributions to TSP during haze **(a)** and clear days **(b)** at St. John's Island in Singapore.