

Understanding the sources and trends of roadside air particulate matter pollution

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Mission

GNS Science has been researching the composition and sources of air particulate matter in NZ (and overseas) for over 20 years.

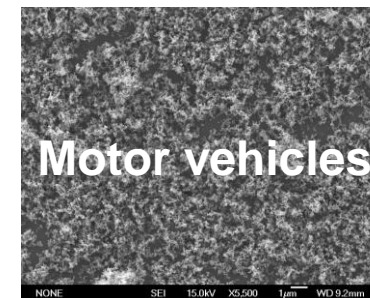
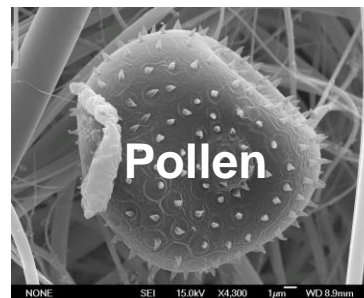
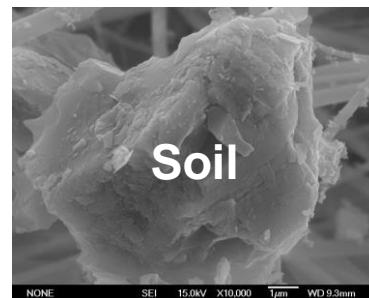
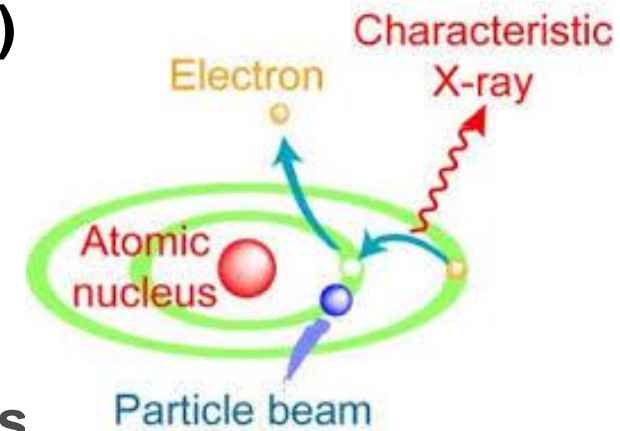
Drivers for this research include:

- **Understanding human health effects (particle size and composition)**
- **Air quality management (sources and source contributions to total PM)**
- **Changes over time (trends and step changes)**
 - **policy evaluation**
 - **effectiveness of regulation**
 - **impact of technology**



Air particulate matter composition and derivation of sources

- A complex mix of elements and compounds from multiple emission sources and atmospheric chemistry (gas↔particle)
- Compositional analysis by nuclear analytical techniques (elements Na to U), black carbon (BC) by light reflectance
- Each source or source type of particulate matter has a distinctive particle size range and chemical composition
- Multivariate and other data analytics across multiple samples to identify sources



Air particulate matter speciation monitoring sites

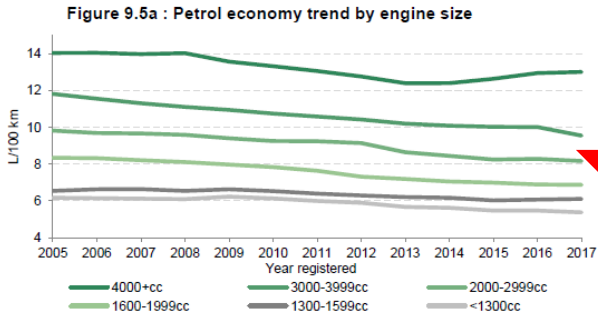
- Data from 1997 onwards (> 50,000 time integrated (24-hour) samples \approx 1.25 M datapoints)
- Majority have been short duration (1-2 years) as part of source apportionment studies for air quality management (NES driven)
- Auckland dataset across 5 sites (mostly) continuous since 1998 \rightarrow trend information



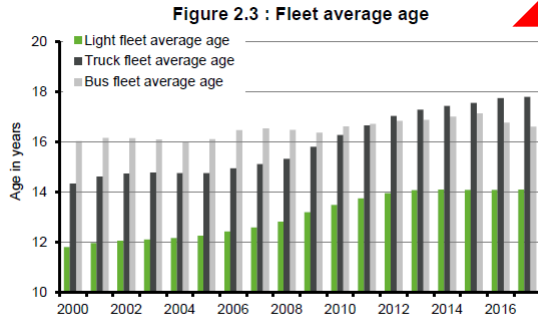
Transport metrics that impact on air quality?

Source: Annual Fleet Statistics 2017, Ministry of Transport

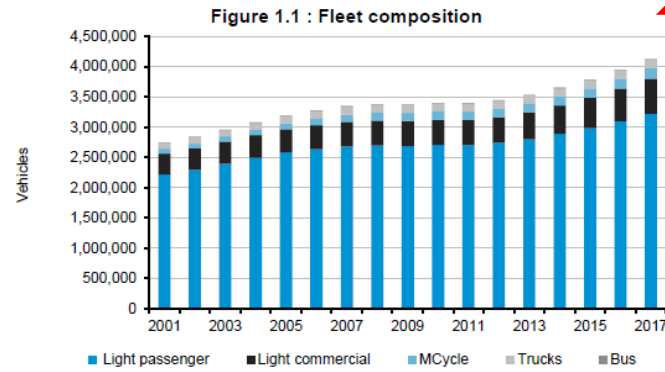
Fuel economy/efficiency (L/100km)?



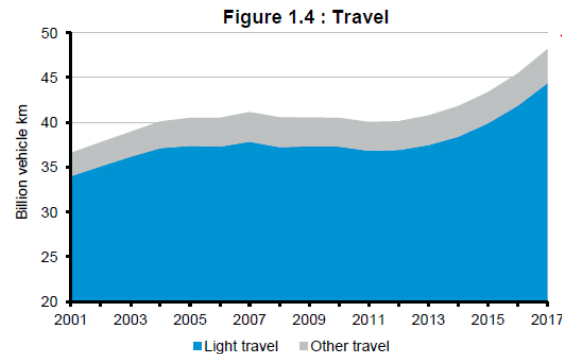
Fleet age?



Fleet size and composition (diesel/petrol)?

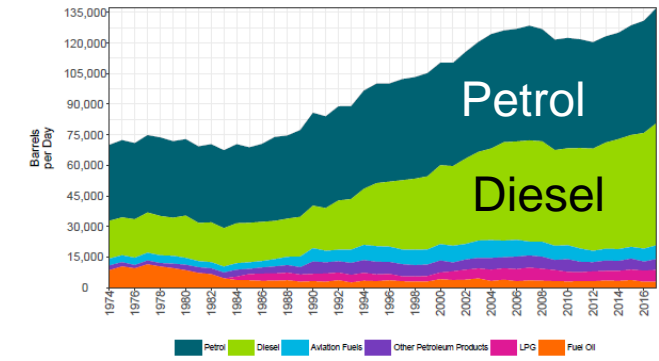


Vehicle kilometres travelled?



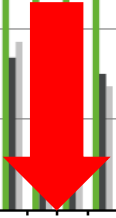
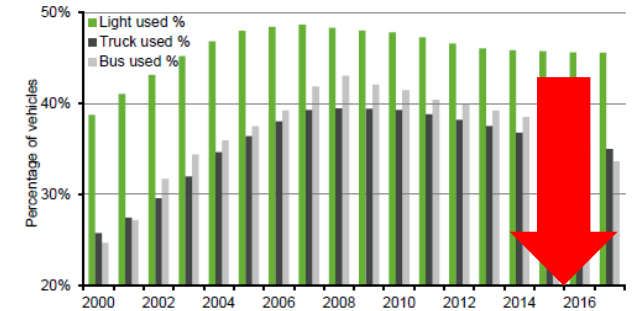
Fuel consumption?

Figure 14: Observed Oil Products Consumption



NZ new or used import?

Figure 2.2 : Fleet used import percentage

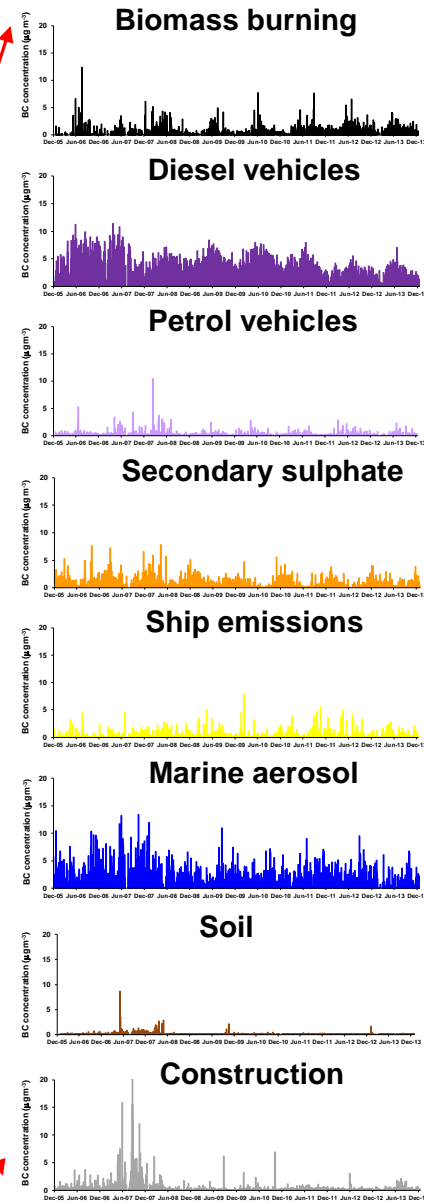
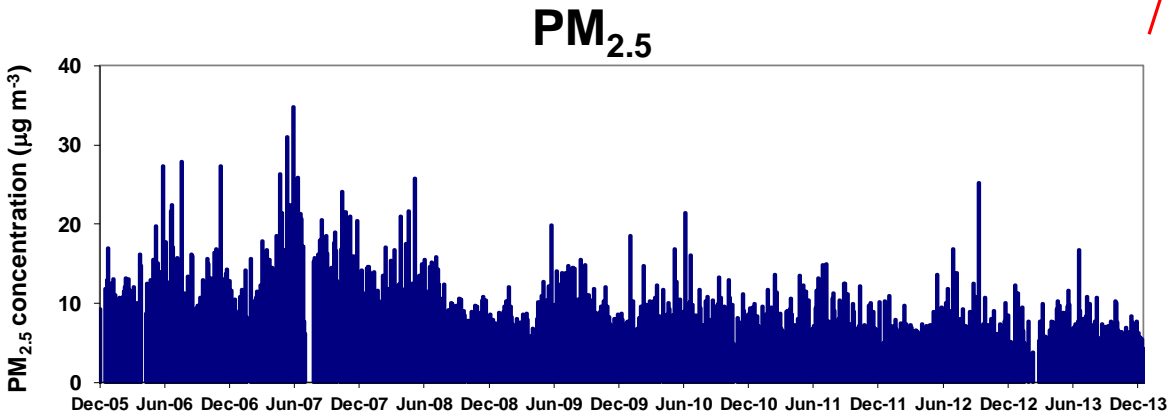


**Land Transport Rule
Vehicle Exhaust
Emissions 2007**

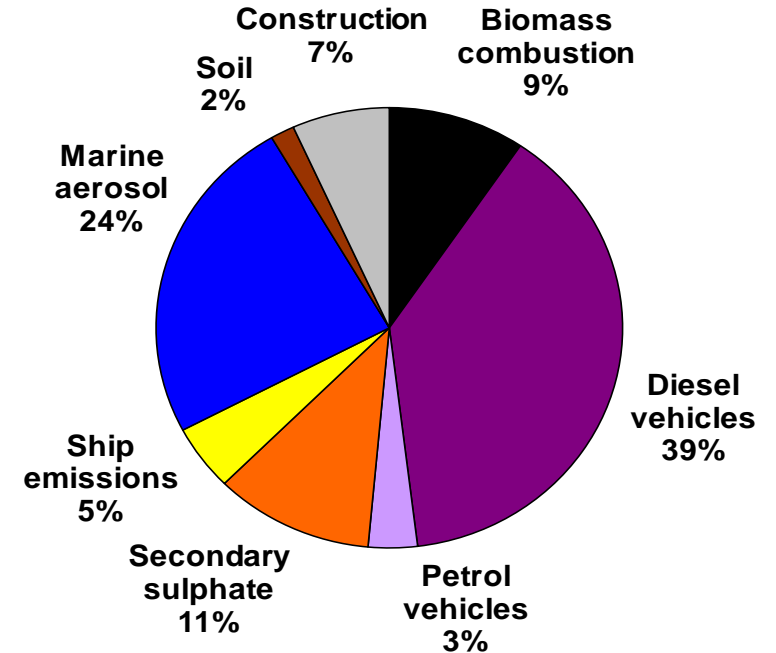


What are the main sources and their contributions to PM?

Queen Street PM_{2.5}, Auckland example (no particular reason for picking this site)



Queen Street average PM_{2.5} = 9.3 µg m⁻³



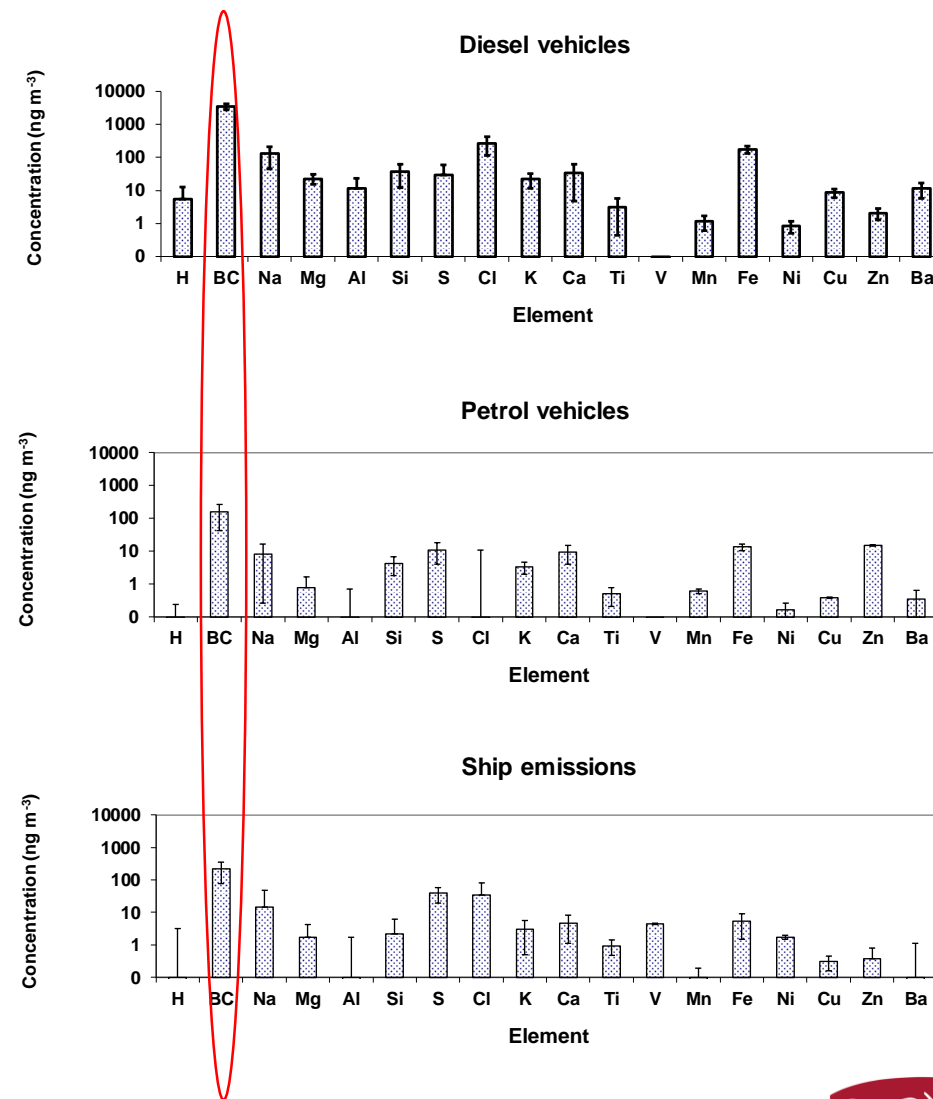
Composition of transport source PM

Motor vehicle related emissions of particulate matter include:

- Tailpipe emissions (BC dominant, Fe, Ca, Zn)
- Wear of brakes and mechanical parts (Cu, Fe, Ba, Sb)
- Tyre wear (Zn, S, BC)
- Road surface abrasion (Al, Si)
- Re-entrainment of any dusts that end up on the road surface

R
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Ship emissions characterised by S, V and Ni content



BC (log scale)



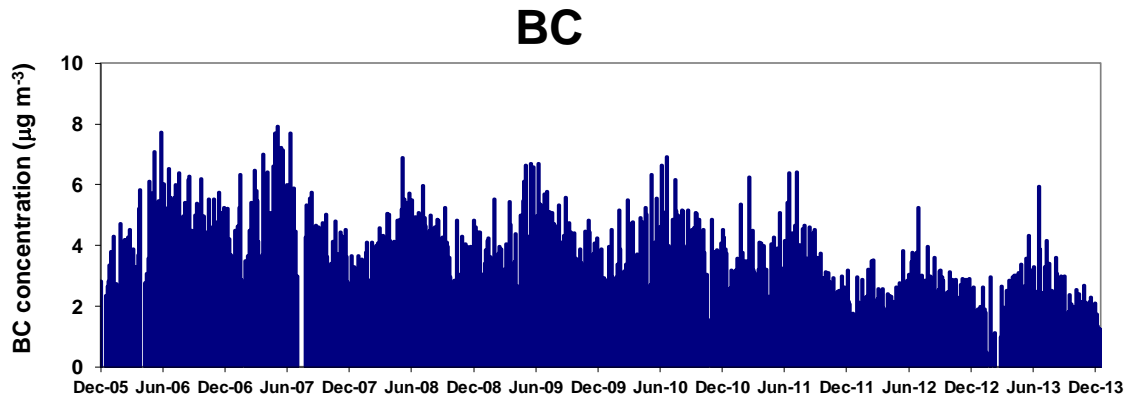
Davy PK, Ancelet T, Trompetter WJ, Markwitz A. 2017. Source apportionment and trend analysis of air particulate matter in the Auckland region. GNS Science. 80 p. (GNS Science consultancy report; 2014/194)



Black carbon is a combustion source emission

Queen Street BC, Auckland example (represents the ultrafine PM component)

- BC from incomplete combustion
- BC consistently 40% PM_{2.5} concentration in Auckland

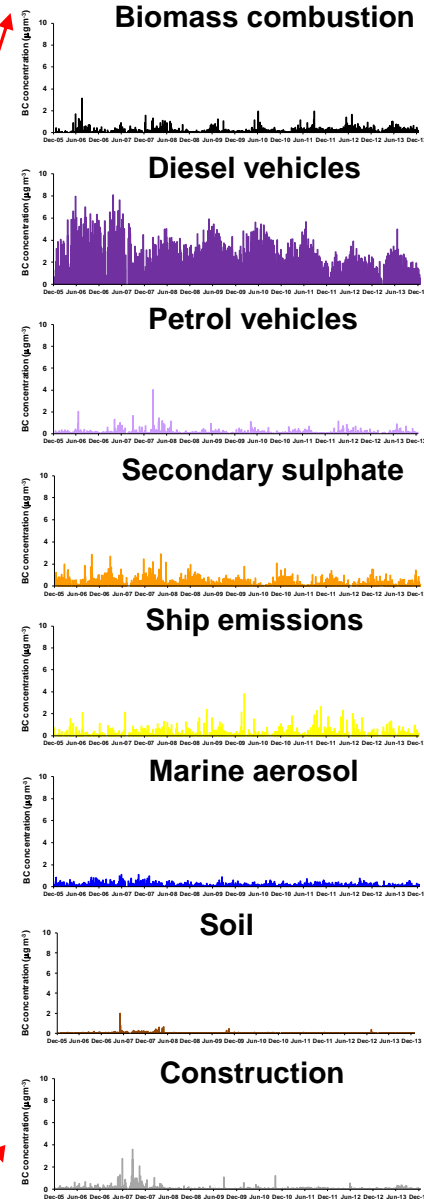


Rising levels of 'black carbon' in Queen St heighten health risk for Aucklanders

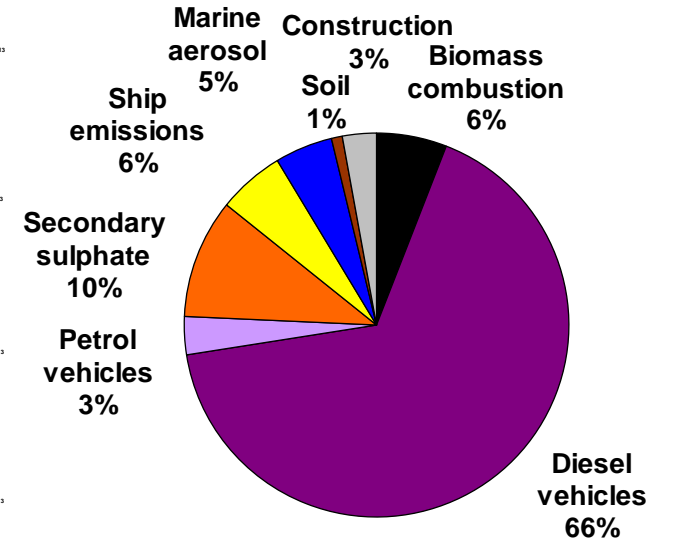
7 Nov, 2018 11:05am © 3 minutes to read



Soot or 'black carbon' is something to be aware of in Auckland's Queen St. It's emitted from diesel vehicles and is on the rise again. Photo / Brett Phibbs



Queen Street average PM_{2.5} Black carbon = 3.5 µg m⁻³



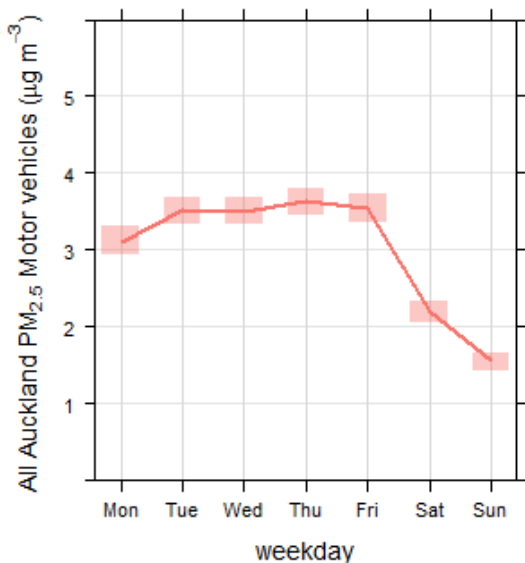
BC is also a measure of fuel efficiency



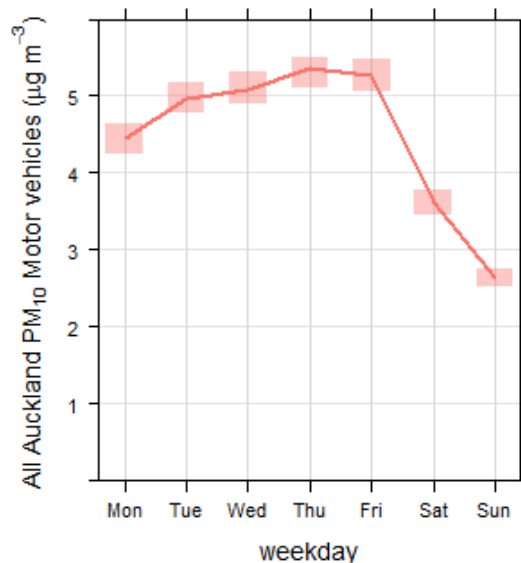
Motor vehicle source activity

- Difference in weekday/weekend PM concentrations due to vehicle activity
- Less HCV (diesel) activity during weekends
- Mondays affected by public holidays ($\approx 15\%$)
- Difference between $PM_{2.5}$ and PM_{10} contributions is road dust component

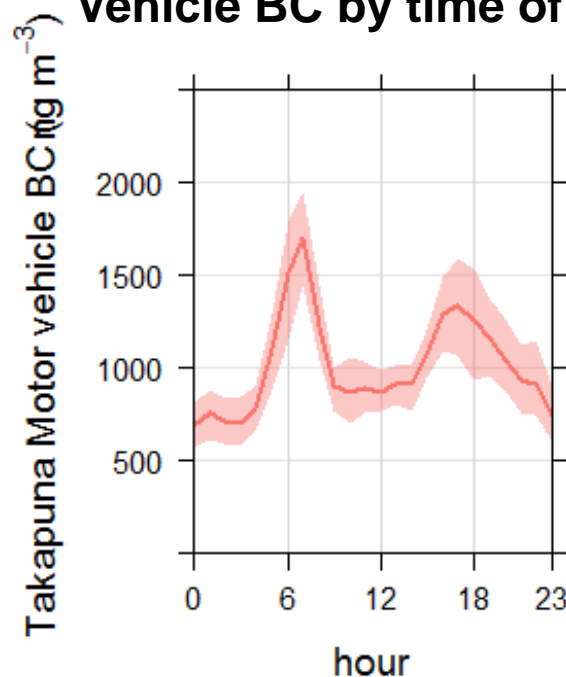
$PM_{2.5}$



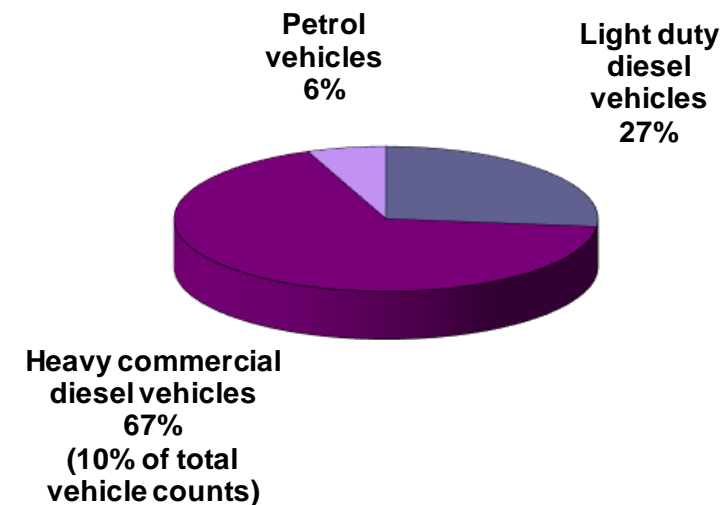
PM_{10}



Vehicle BC by time of day

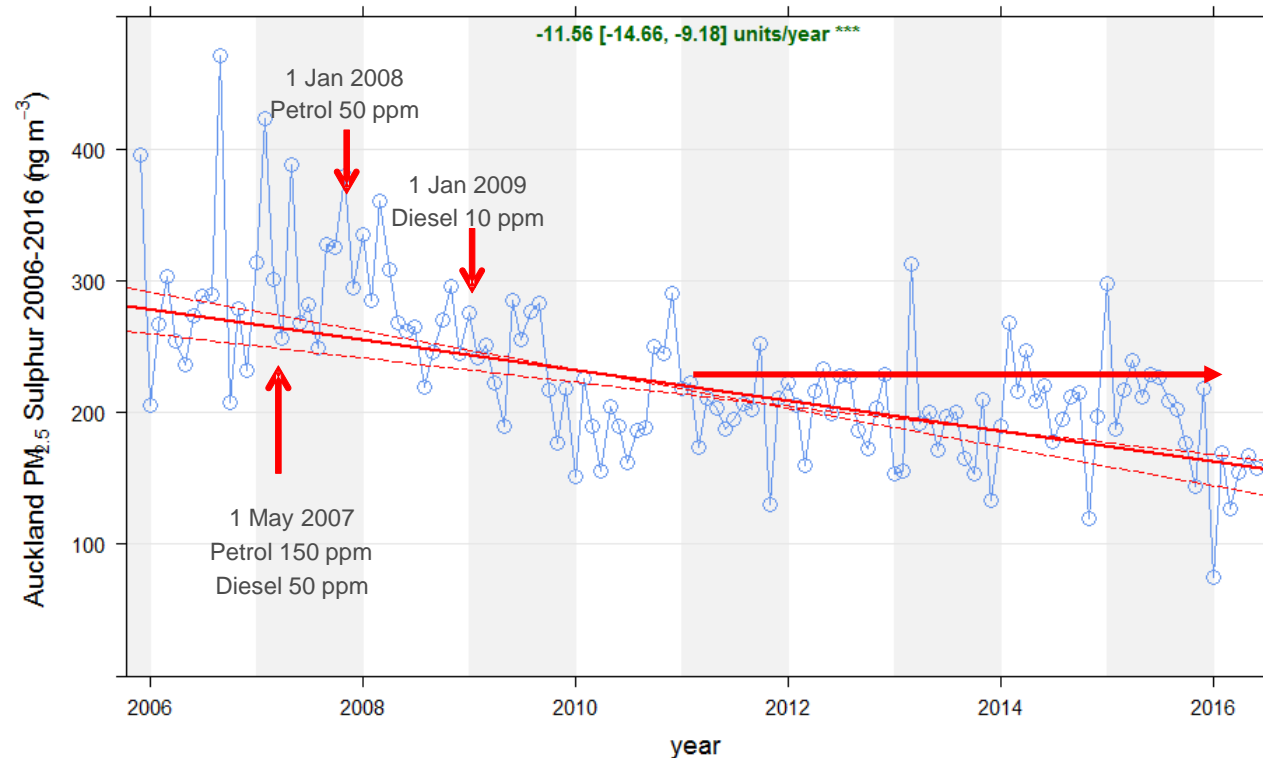


BC by vehicle class



Evaluation of regulatory effectiveness

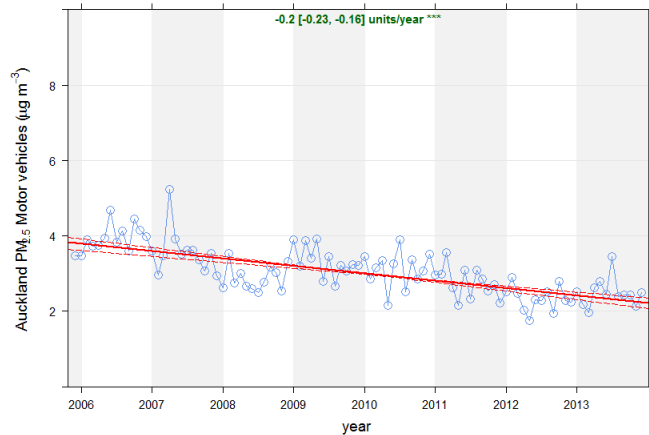
- **Reduction in urban PM sulphur concentrations in Auckland as a consequence of removal of S in fuels**
 - Petroleum Products Specification Regulations 2002
 - No real change in urban S concentrations since 2012



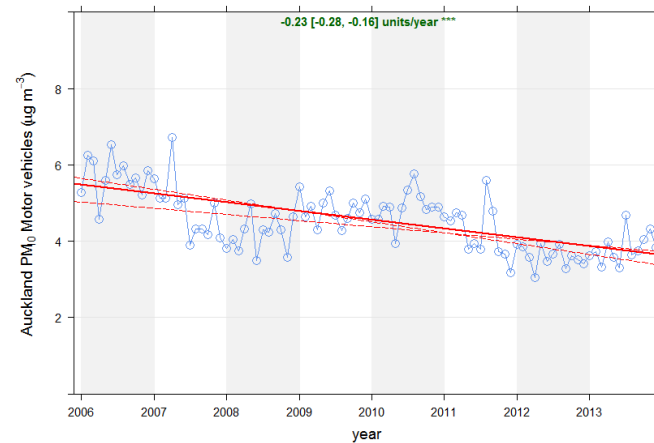
Trends in motor vehicle contributions (all of Auckland)

- **Decrease due to tailpipe emissions improvements (trend is all PM_{2.5})**
 - Better engine design/technology
 - Reduction of sulphur in fuels and other fuel improvements
- **Difference between PM_{2.5} and PM₁₀ is road dust component**
- **Motor vehicle tailpipe emissions account for ~75% PM_{2.5} trend across Auckland**

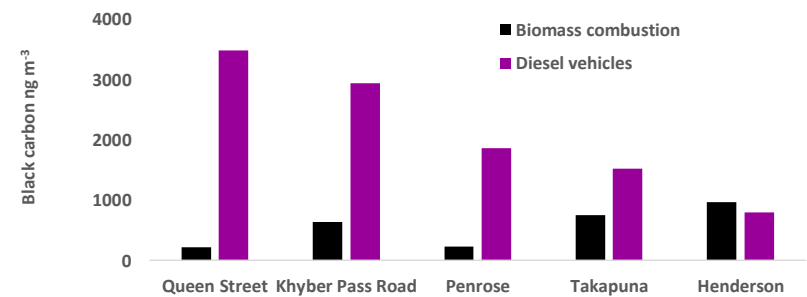
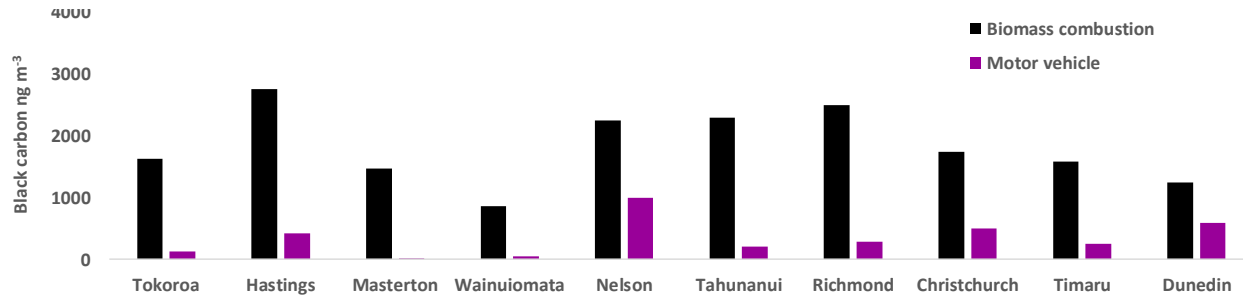
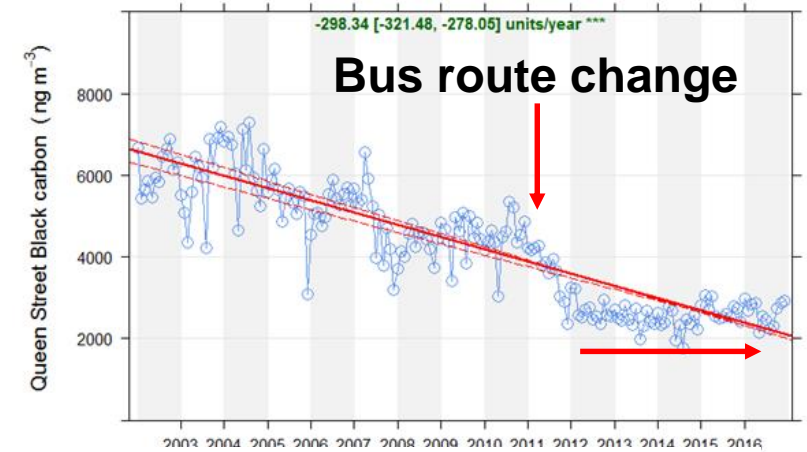
PM_{2.5}



PM₁₀



Queen Street BC

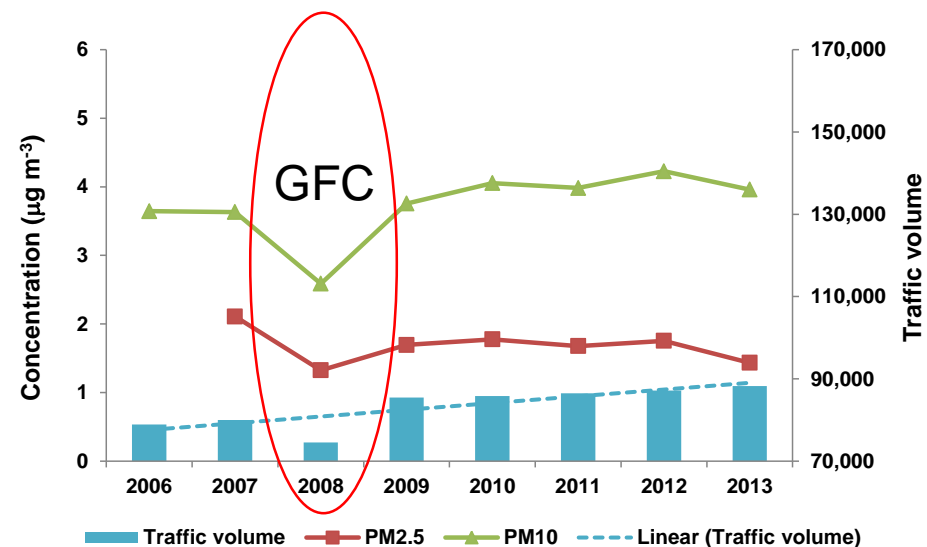


Trends in PM contributions and traffic volumes

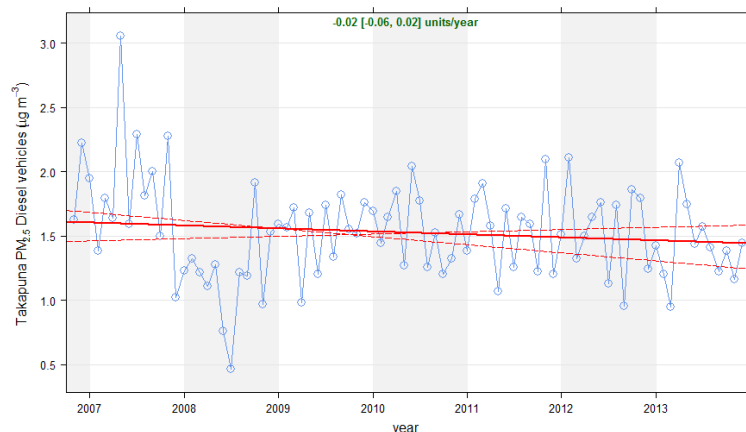
Takapuna

- No significant trend for diesel PM_{2.5}
- Upward trend for traffic volume and PM₁₀ → road dust increase
- Emissions improvements offset by local traffic volume increase (busway, Smales Farm hub)
- Road dust component will remain for EVs

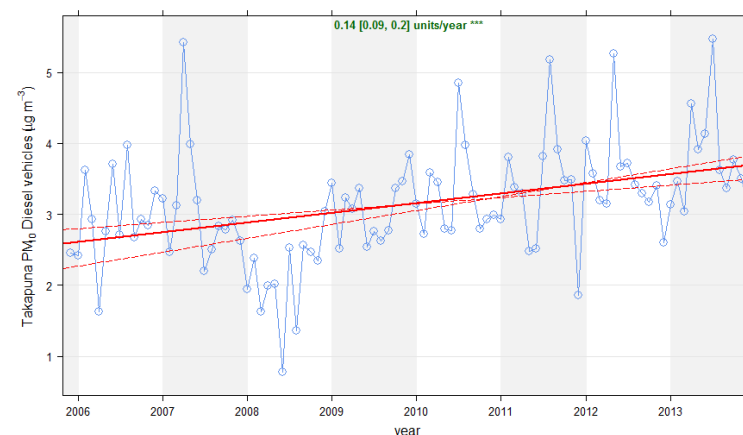
Takapuna: PM_{2.5} and PM₁₀ from vehicles and traffic volumes



Vehicle PM_{2.5} Thielsen trend (deseasonalised)



Vehicle PM₁₀ Thielsen trend (deseasonalised)



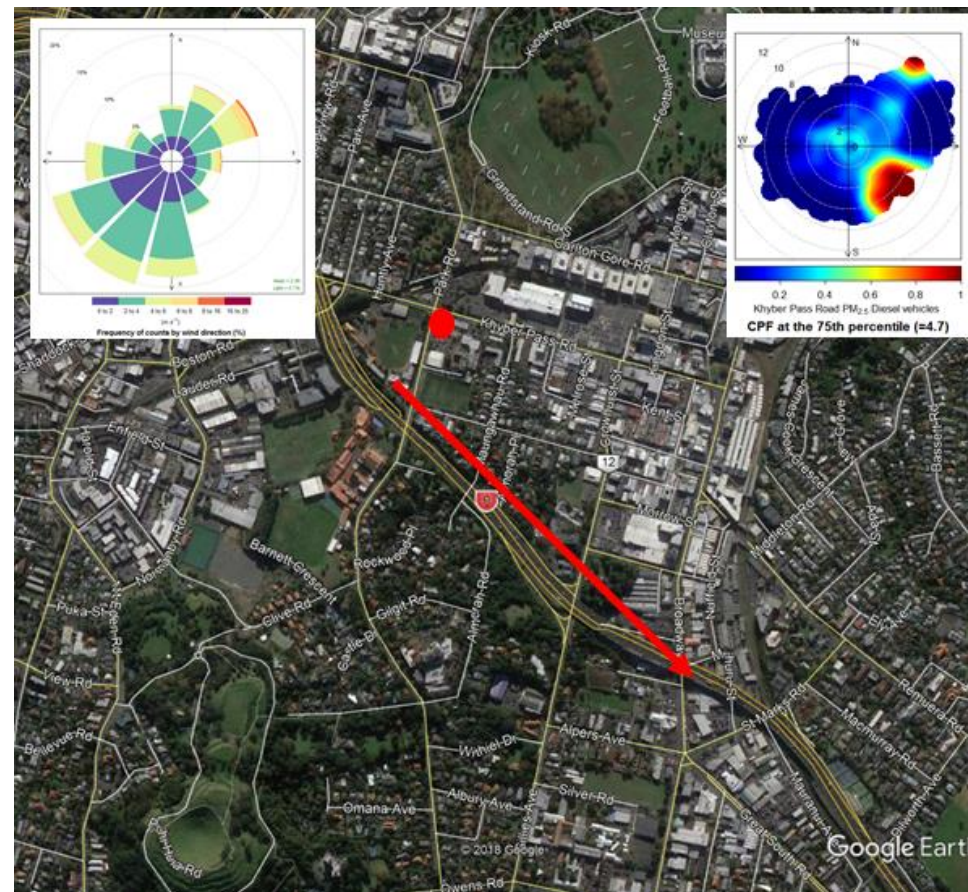
Xie, S., Davy, P., K., Sridhar, S. & Metcalfe, J. Quantifying trends of particulate matter emissions from motor vehicles in Auckland. Air Quality and Climate Change Volume 50 No.2. May 2016



Location relative to a roadway is important for PM impacts

- Roads are a line source and the highest receptor concentrations are experienced when wind direction is aligned with the road centreline

Khyber Pass Road AQMS, Auckland



Almost 10 million pedestrians were counted at lower Queen St / Customs street in 2017. Research shows this area to have highest the NO₂ concentrations in CBD



Shipping Emissions contribute 5% PM_{2.5} and 10% Black Carbon at Queen Street



Diesel emissions account for 40% PM_{2.5} and 66% Black Carbon in CBD



Key factors to consider for Auckland CBD air pollution

Parks have far lower air pollution levels than neighbouring Streets



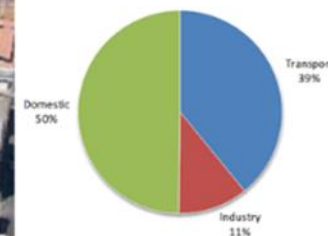
Over 38,000 private vehicle journeys into the CBD each month



Active modes accounted for just 8% inbound traffic in 2017



Industrial sources account for just 11% of PM_{2.5} across Auckland



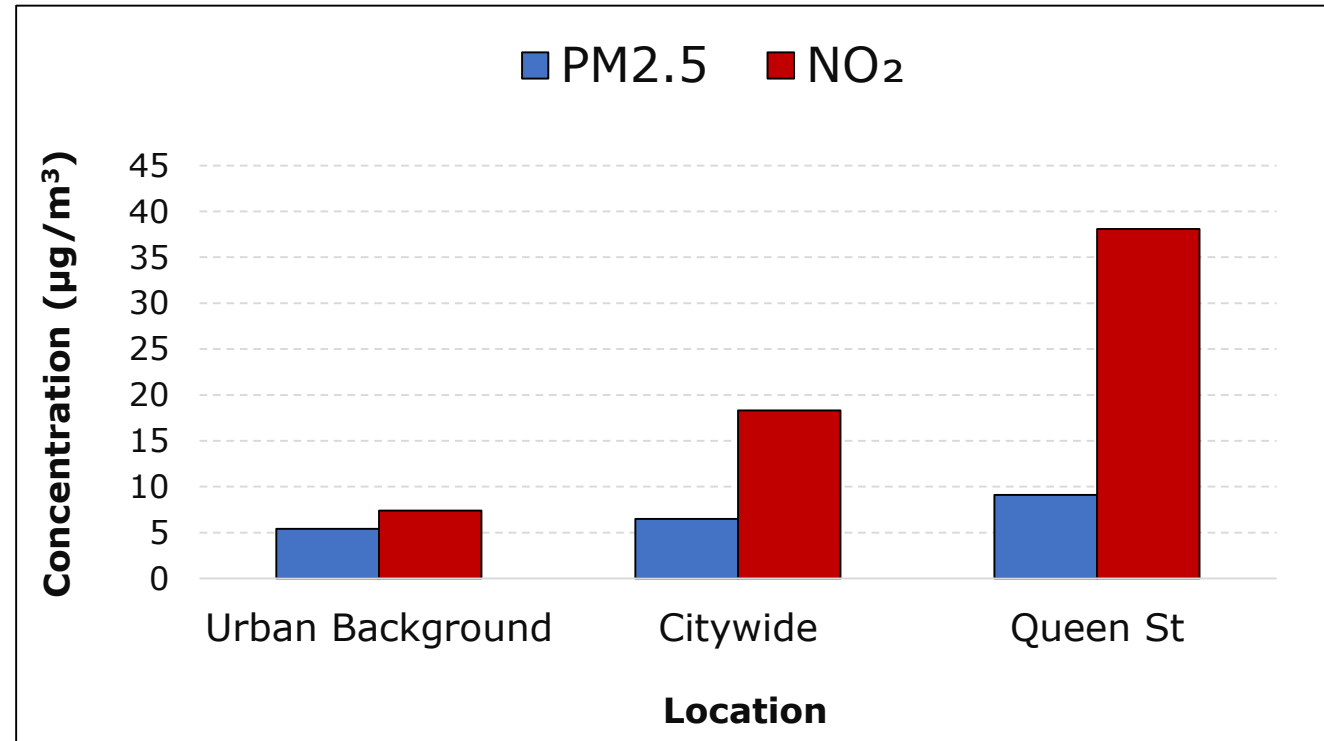
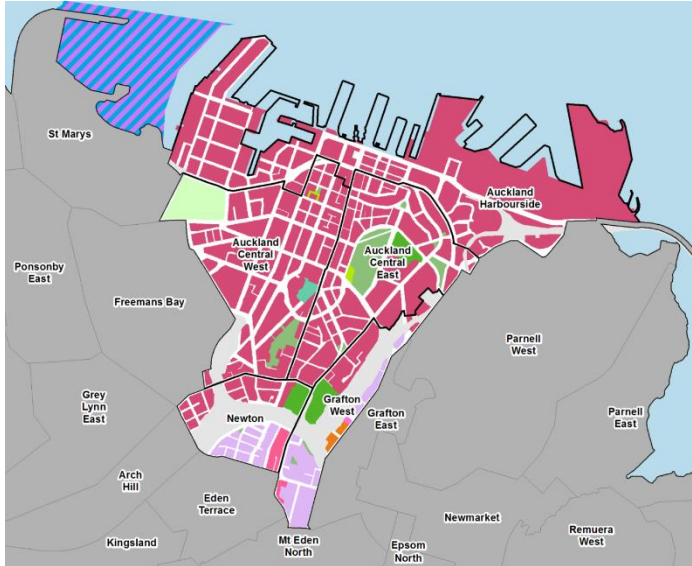
Relevance for AC policy decision-makers

- ❖ Auckland Council's Fossil Fuel Free Commitment (mayors office/ AT)
 - ❖ *Electric bus purchases by 2025 &*
 - ❖ *A designated Fossil Fuel Free area*
- ❖ The City Centre Masterplan refresh – *soon to go to committee*
- ❖ The Downtown Programme
- ❖ Auckland Transport Alignment Project (ATAP)
 - ❖ *Bringing back light rail*
 - ❖ *Extending cycleways*
 - ❖ *Smart road signalling*
- ❖ Auckland Transport safer streets approach
- ❖ Ports of Auckland Sustainability plan (Shore Power?).
- ❖ Construction of Auckland's city rail link.
 - ❖ *doubling rail capacity in the city*
 - ❖ *enabling 30,000 people an hour to move during peak time.*



Auckland's CBD: Context for considering a congestion charge of \$10

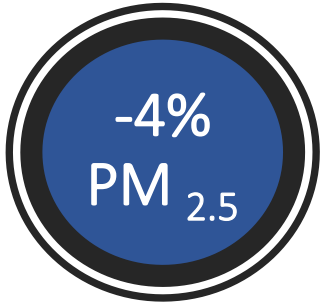
- The CBD area is the social and economic heart of Auckland
- Rapidly expanding resident population 53,000 in 2018
- About 75,000 people commute into the CBD every day



10-year annual averaged data for PM_{2.5} (blue) and NO₂ (red) at Auckland Council's urban background site (Glen Eden), Citywide (Penrose, Takapuna and Henderson) and Queen Street. The averaged data is to compensate for short term changes to emission sources such as traffic flow closer to monitoring sites.



C40 Modelled Social and Economic Impacts from car reduction (-11,000)



SOCIAL IMPACT

Number of deaths averted annually across the total population:
0 days per person

Life expectancy across the total population increased by:
0 days per person

ECONOMIC IMPACT

Approximate costs avoided due to reduced premature mortality from change in PM2.5 levels:
NZ \$40,291.15 Per Year

NO₂ rather than PM_x is the best metric to assess vehicle impacts



SOCIAL IMPACT

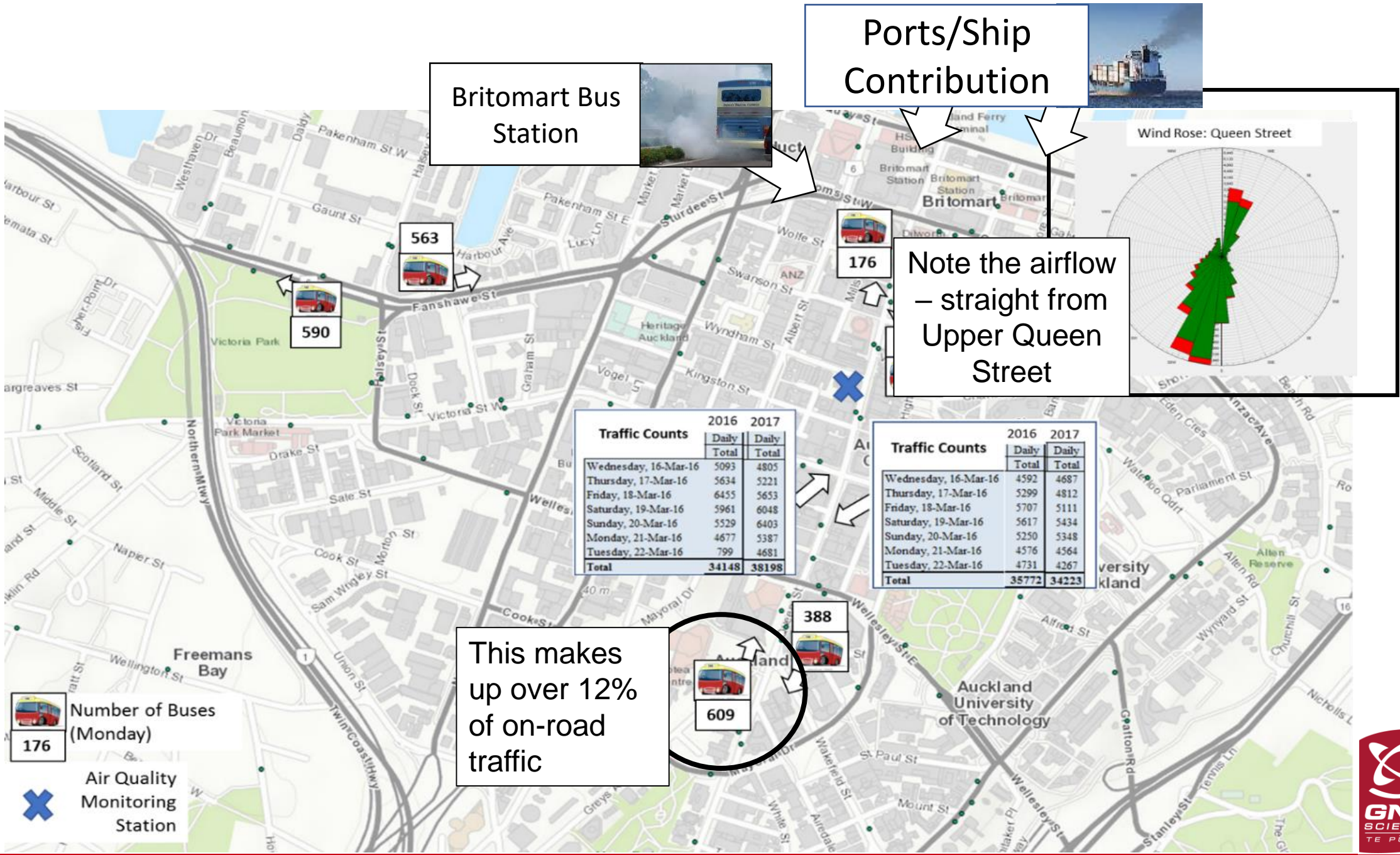
Number of deaths averted annually across the total population:
6

Life expectancy across the total population increased by:
31 days per person

ECONOMIC IMPACT

Approximate costs avoided due to reduced premature mortality from change in NO2 levels:
NZ \$1,051,099.51 year



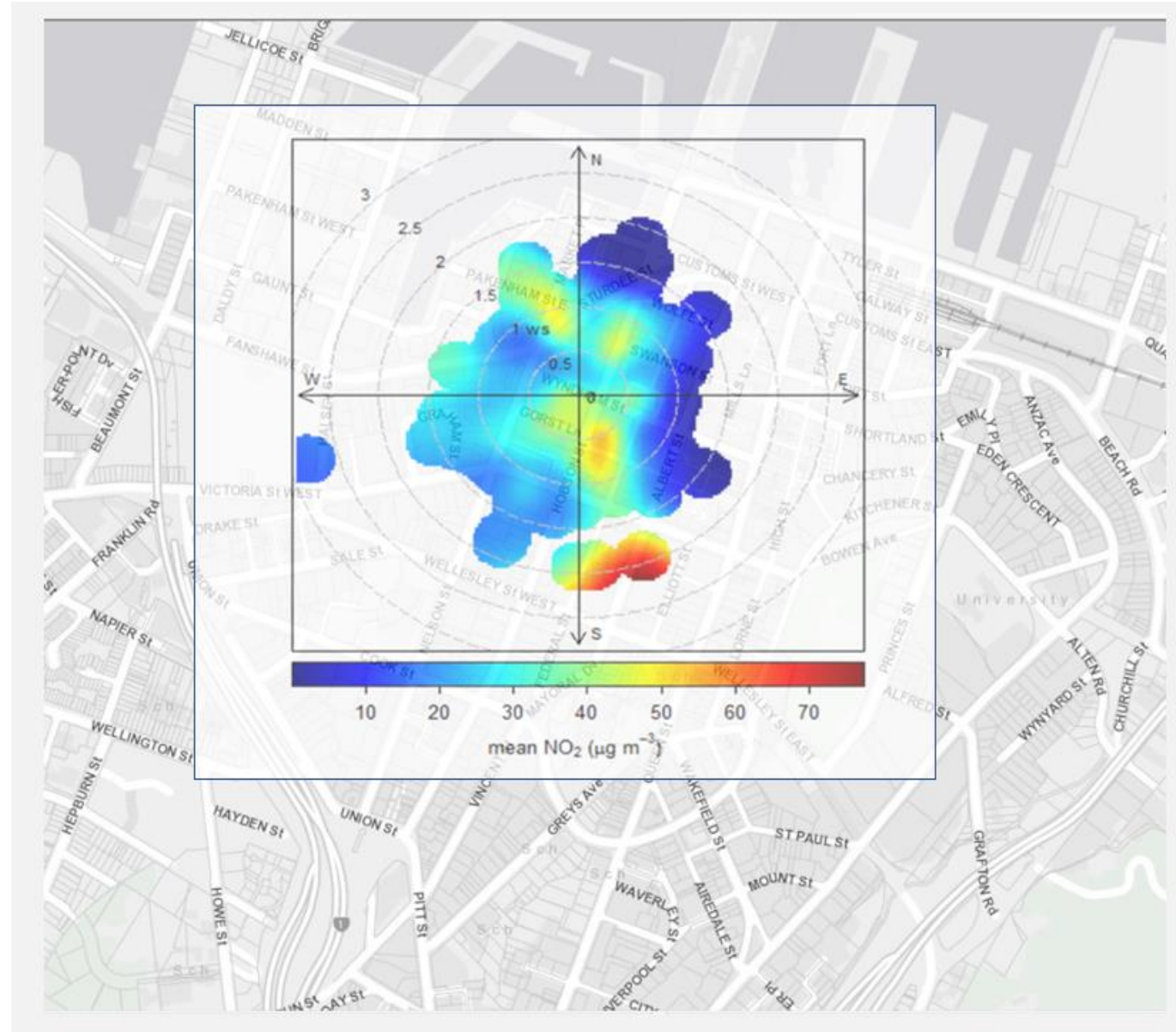


This makes up over 12% of on-road traffic

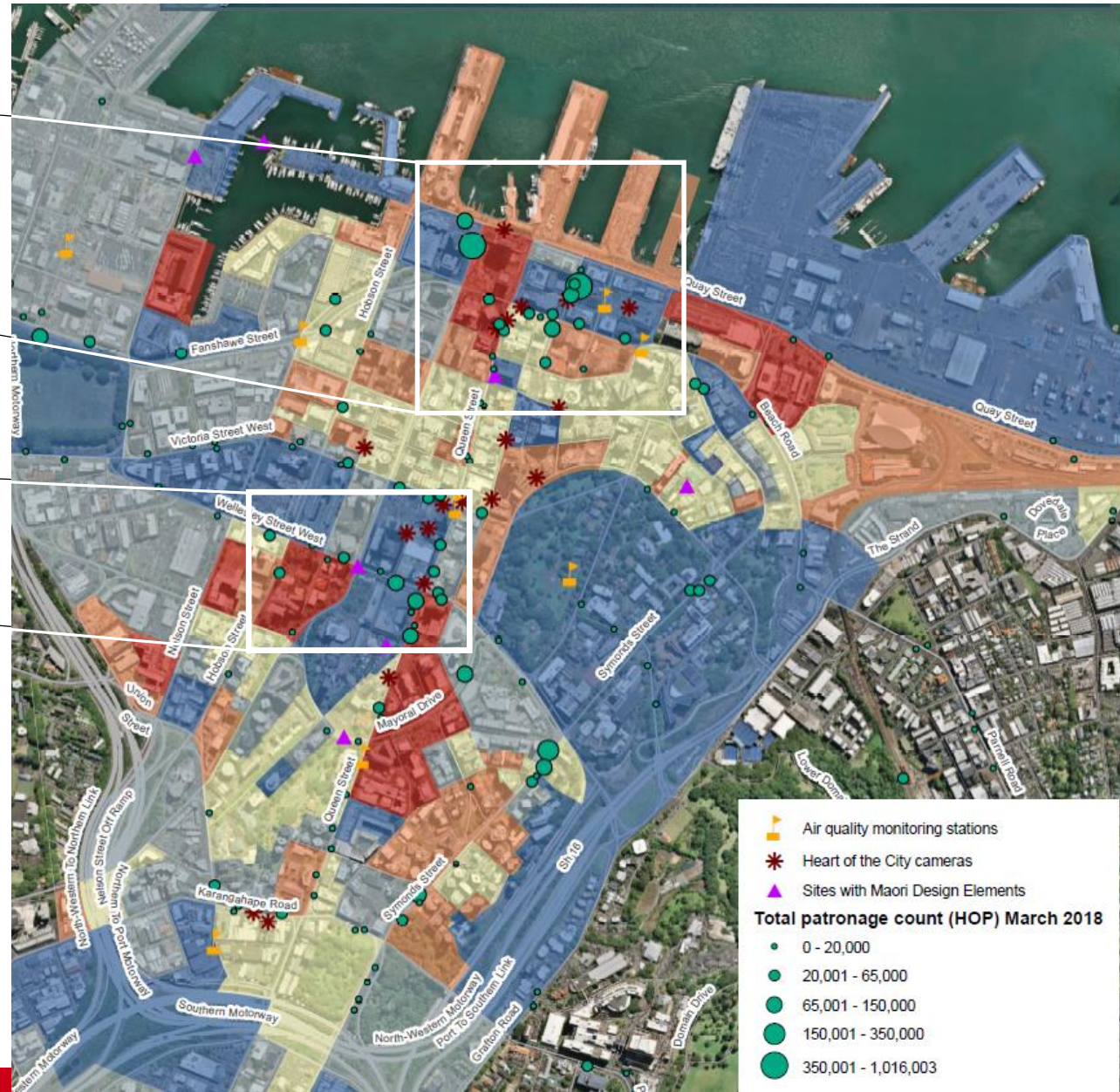
Looking at NO₂ concentrations in relation to wind speed and direction:
2017

NO₂ concentrations are highest with light- moderate winds from the South

The direction of upper Queen Street



Bus patronage in relation to peaks in NO₂ concentrations



Data collected in collaboration with NIWA, the University of Auckland and Auckland Council



A sneaky peak into the future structure of Auckland's CBD

Is this the future
of Auckland's
CBD?

Evidence can
make it happen!



ZERO EMISSIONS

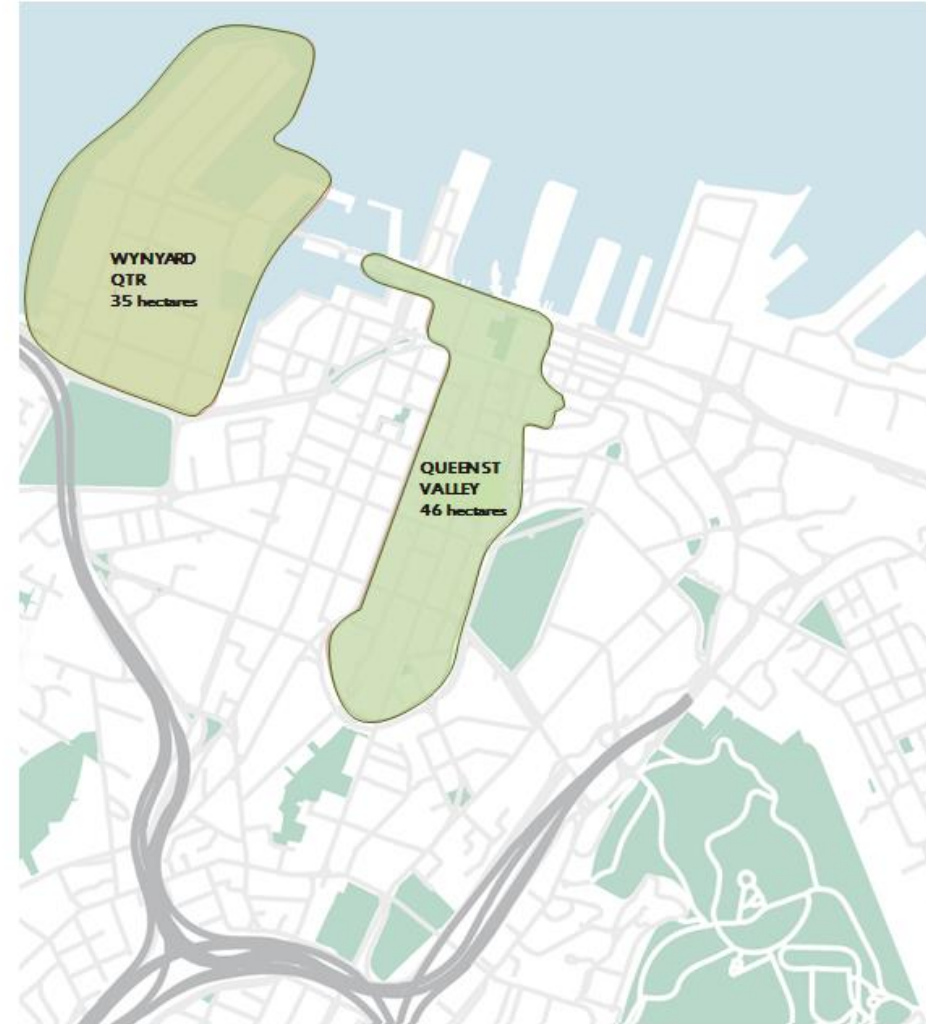
Two FFFS zones

1. Wynyard Quarter
2. Queen Street Valley

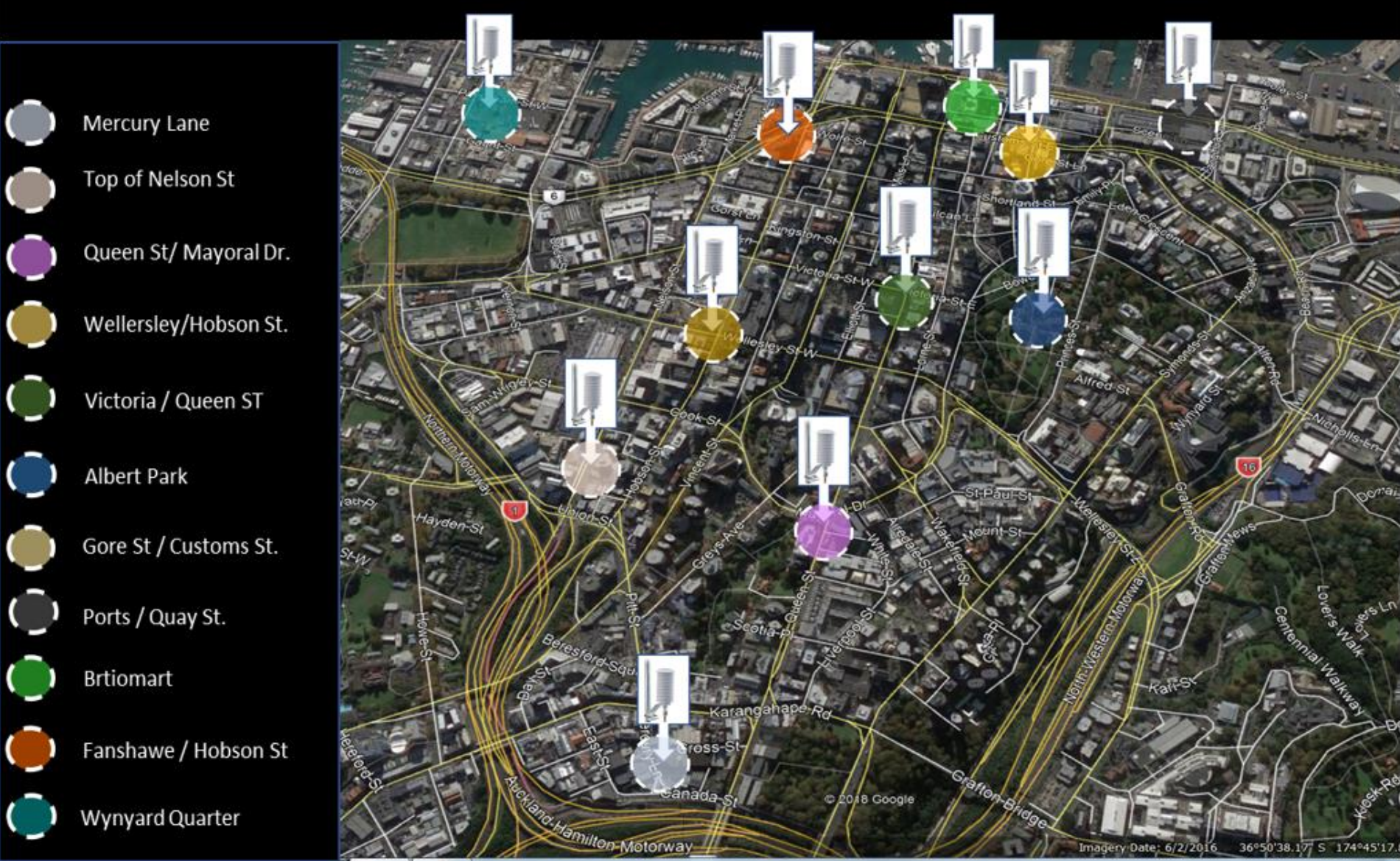
Whole city centre:

- Population 45,000;
- Area: 360 hectares

Total zero emissions area:
Approximately 1/4 of population
and area of whole city centre.



Developing a low-cost sensor network for Auckland's Central Business District to monitor changes



Thanks for your time!