Monitoring black carbon

12 month summary
July 2024 - June 2025

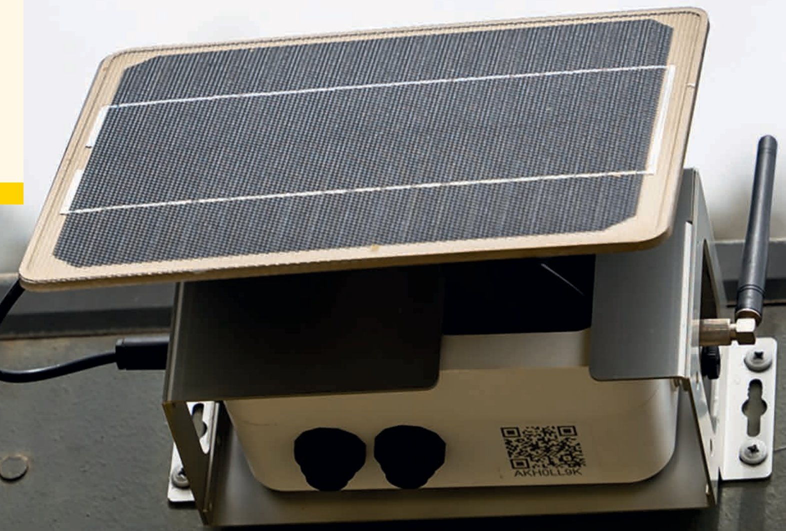
For the better

Background

RAC's Vision is for a safer, more sustainable, and better-connected future for all Western Australians. To create a more sustainable future, it is very important we reduce transport emissions so that current and future generations can enjoy cleaner and healthier air.

To support efforts in understanding the impacts of vehicle emissions, the idea of the RAC Air Health Monitor (AHM) was formed. Launched in November 2022, the AHM is intended to empower members and the community with access to air quality information that is easy to understand and interpret to support positive change whilst providing localised air quality insights.

RAC has partnered with Clarity Movement, a world leading air sensing technology organisation, which has deployed highly accurate sensors globally. In addition to sensor technology, using a highly advanced model developed by global engineering firm Ramboll Shair, the monitor blends air quality data from the network of sensors with other sources, including data from traffic monitoring services, meteorology and industrial activity.



Clarity Node-S sensor

Understanding black carbon – a super pollutant

Black carbon, often referred to as "soot," is a component of fine particulate matter ($PM_{2.5}$) resulting from the incomplete combustion of fossil fuel (i.e. sooty black material emitted from gas and diesel engines), biofuel and biomass[1,2].

Black carbon is a potent pollutant with significant implications for both climate change and human health[1,3].

Unlike other airborne particles, black carbon absorbs solar radiation, contributing directly to atmospheric warming, accelerating the melting of snow and ice, sea level rising and overall local climate alteration[1,4]. Presence of black carbon in urban environments is primarily linked to traffic emissions such as diesel vehicles, industrial activities, bushfires, coal-burning, and wood stoves[1,2].

Black carbon particles penetrate deep into the lungs and have been linked to increasing the risk of respiratory diseases and cardiovascular diseases, particularly in vulnerable population groups such as children, the elderly and those with pre-existing health conditions[3,4].

[1] Climate & Clean Air Coalition. (n.d.). Black carbon. CCAC. https://www.ccacoalition.org/short-lived-climate-pollutants/black-carbon

[2] Carbon Containment Lab. (2022). Black Carbon: An introduction to a high-impact super pollutant. Yale University. https://carboncontainmentlab.org/updates/posts/black-carbon-an-introduction-to-a-high-impact-super-pollutant

[3] World Health Organization. (2012). Health effects of black carbon. WHO Regional Office for Europe. https://www.who.int/europe/publications/i/item/9789289002653

[4] World Economic Forum. (2024, September). Protecting the Arctic and human health: The hidden potential of black carbon. WEF. https://www.weforum.org/stories/2024/09/protecting-the-arctic-and-human-health-the-hidden-potential-of-black-carbon/

Diesel vehicle exhaust

The Black Carbon Module – measuring the truth

Clarity Movement Co. have developed a modular, solar-powered sensor platform that enables real-time monitoring of black carbon in ambient air.

Clarity's solution allows for widespread deployment across urban and rural environments.

The Black Carbon Module uses optical techniques to detect and quantify black carbon particles, distinguishing between emissions from **fossil fuels** and **biomass burning**.

The device is designed to operate autonomously, powered by solar energy and connected via cellular networks, making it ideal for continuous monitoring in diverse settings[5].

Data is collected by the sensors and transmitted to a dashboard, where it can be visualised and analysed in real time.

The Black Carbon Module data provides RAC additional visibility into black carbon emissions. This information complements the $PM_{2.5}$ data by providing a more detailed picture of vehicle-related pollution, supporting RAC's advocacy, air-quality insights, and understanding of emissions impacts.

[5] Clarity. (n.d.). Black Carbon Module Air Quality Monitor. https://www.clarity.io/products/black-carbon-module

Clarity's Black Carbon Module

Black Carbon Module installed in Bassendean

Opportunity for deployment in the Perth and Peel region

In RAC's continued pursuit for greater information and detail of Perth's air quality, the deployment of ten Black Carbon Modules was completed, and installed across multiple locations in the Perth and Peel region.

The deployed Black Carbon Modules were integrated with the existing Node-S sensors already operating within the AHM network. This integration enables the modules to measure black carbon levels alongside nitrogen dioxide (NO_2), fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}). To ensure the trial was focused on the most relevant sites, locations were selected based on daily exceedances recorded during 2022 and 2023 monitoring years for NO_2 and $PM_{2.5}$.

These locations were verified and appropriately geo-mapped to ensure they were near to major highways, busy roads, and peak traffic areas. The hypothesis was to assess whether the black carbon patterns followed the trends of traffic related pollution.

The modules were installed in partnership with our sensor hosts comprising of six local governments, three RAC sites, and one industry partner.

Black Carbon Module installed in Victoria Park

Key analysis

The first 12 months of black carbon monitoring **(July 2024–June 2025)**, using ten deployed modules, has delivered important insights into localised air-pollution sources.

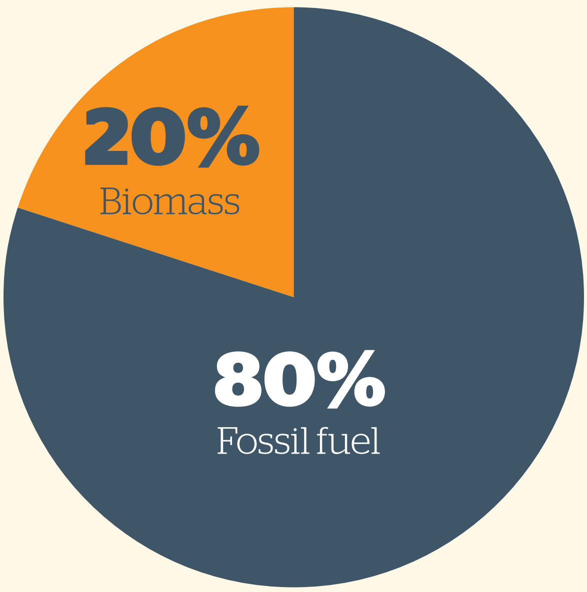
- **67,337 hourly** averages were analysed.
- Across the entire network, fossil fuels revealed a predominant average pollutant source distribution compared to biomass.

Black Carbon Module at RAC West Perth Head Office

Hourly concentration peak events were evaluated during the first 12 months of monitoring:

- The peaks represented 2.11% of all data points.
- 68.49% of hourly peak events were primarily attributed to fossil fuel emissions.
- 4.43% of hourly peak events were primarily attributed to biomass sources, such as bushfires and prescribed burns.
- 27.08% of hourly peak events were the result of a combination of fossil fuel and biomass sources.

Average pollutant source distribution



Seasonal trends

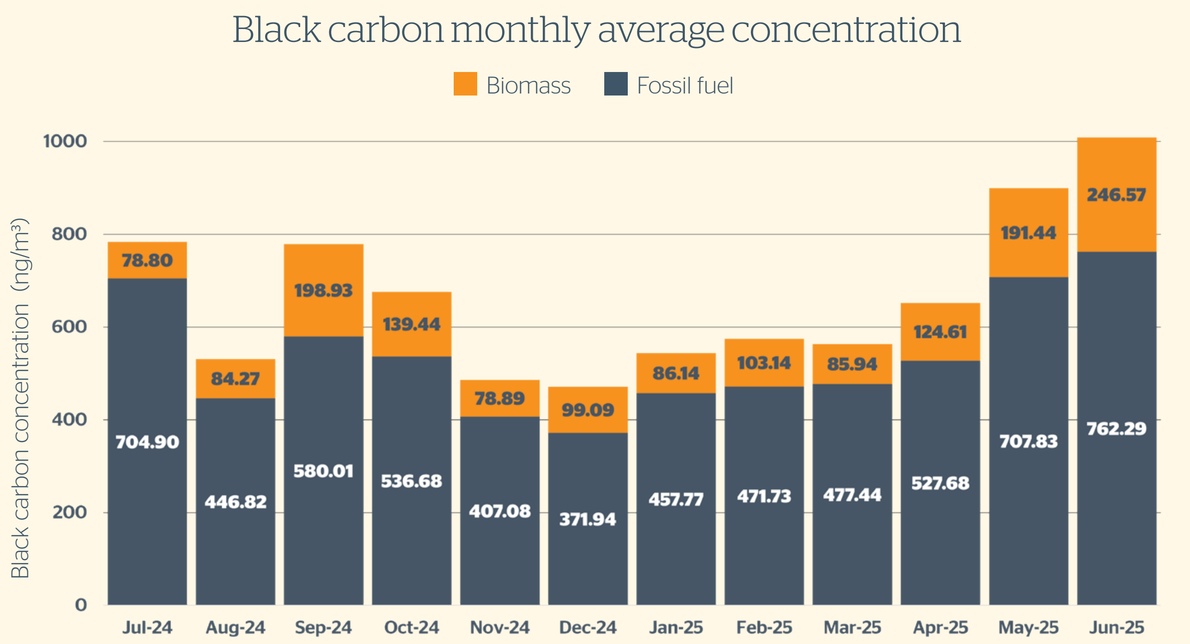
The pattern of black carbon through 2024–25 reflects the combined influence of human behaviour, seasonal biomass burning, and the weather's ability to disperse pollution. Fossil fuel-derived black carbon, driven largely by traffic in urban areas, followed the rhythm of daily life.

From July 2024 to November 2024, dispersion and meteorological conditions alternated between favouring and not favouring pollutant accumulation near the surface. Periods of lower wind speed allowed concentrations to build, while intervals of stronger winds promoted their dispersal, shaping the pattern observed in November 2024.

Concentrations eased in December 2024, in particular during the summer holiday period when commuting slowed, then began to climb again as activity resumed in the new year. Biomass-derived black carbon followed a different seasonal rhythm, beginning its rise in autumn as emissions from bushfires, prescribed burns, and residential wood heating increased, reaching its highest levels in June 2025.

May 2025 and June 2025 brought conditions for concentration to spike. Cooler temperatures, reduced atmospheric mixing, and stable air masses trapped pollutants close to the ground, allowing traffic emissions and biomass smoke to build up day after day.

In urban areas, where the fossil fuel baseline was already high, the seasonal lift in biomass smoke caused concentration spikes to occur more frequently. Rural areas, with lower background levels, saw high concentration mainly when biomass smoke from fires or heating lingered in the stagnant air. This pattern shows that black carbon is shaped not only by the amount of pollution emitted, but also by the timing, source mix, and prevailing weather conditions.



The weekly commute

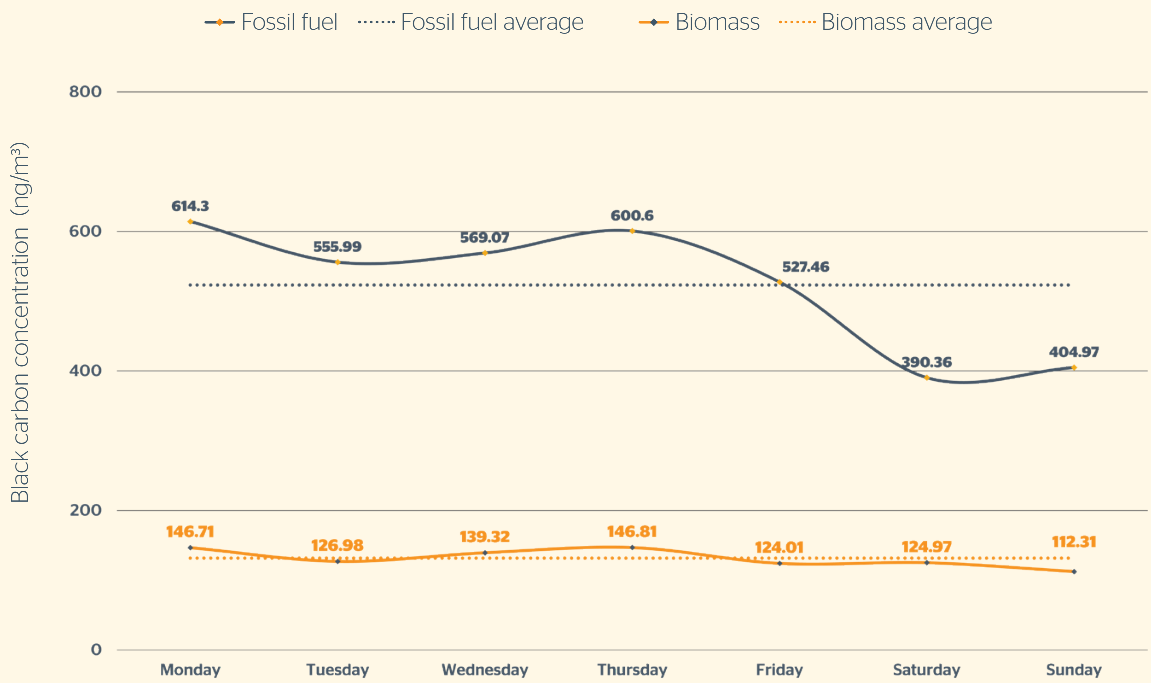
The weekday pattern of black carbon shows a strong human signature in fossil fuel emissions, and concentrations from fossil fuel sources are, on average, **30.6% lower on weekends**.

The reduction in weekends, reflects the slowdown in commuter traffic, freight movement, and other work related activity. This drop underscores how closely traffic-related pollution follows the weekly rhythm of urban life.

Biomass-derived black carbon, by contrast, remains comparatively stable across the week. The levels are influenced more by natural events such as bushfires and prescribed burns, and by domestic wood heating during cold months, which do not vary as sharply between weekdays and weekends. This stability highlights the different drivers behind each source, with fossil fuels tied to human schedules and biomass shaped by seasonal and environmental factors.

Australia does not currently have specific regulations for black carbon in ambient air quality. Existing air quality standards focus on particulate matter ($PM_{2.5}$ and PM_{10}), and black carbon is not explicitly included. The World Health Organization (WHO) does not set a guideline value for black carbon due to limited standardised evidence, but recognises it as a key component of particulate matter and encourages its measurement to reduce exposure and support health and climate outcomes.

Black carbon average concentration by weekday



The hourly profile of black carbon from fossil fuel sources reflects both human activity patterns and the atmosphere's ability to disperse pollution.

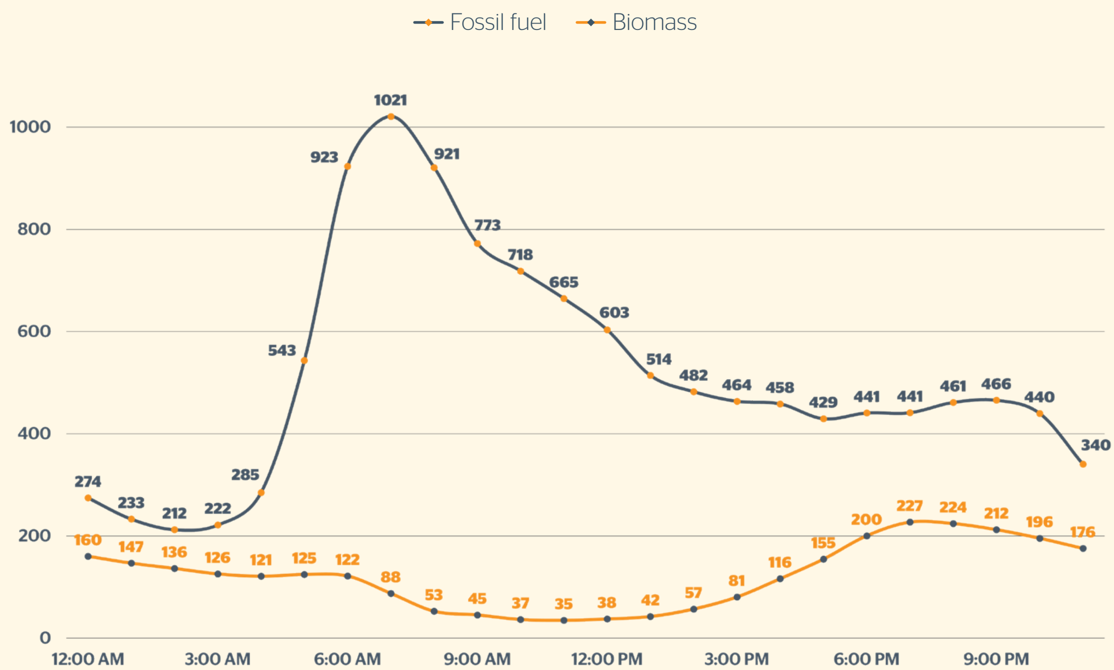
Concentrations rise sharply before sunrise as the first commuter wave moves through a shallow and stable boundary layer that traps emissions close to the ground.

Cars in traffic

This early morning surge is intensified by diesel-powered heavy trucks, buses and commercial vehicles, which tends to emit more black carbon per kilometre than petrol cars. Even though traffic remains heavy after this point, levels begin to fall as the sun warms the surface, the boundary layer deepens, and pollutants disperse more effectively.

In the afternoon, traffic activity increases again, yet black carbon does not show a similar spike. By this time of day, the atmosphere is well mixed, allowing fresh emissions, even from diesel vehicles, to disperse quickly. Unlike nitrogen dioxide, which can be formed secondarily through photochemical reactions and therefore build up later in the day, black carbon is purely a primary pollutant. Concentrations depend entirely on immediate emissions and dispersion conditions.

Black carbon average hourly concentration by source



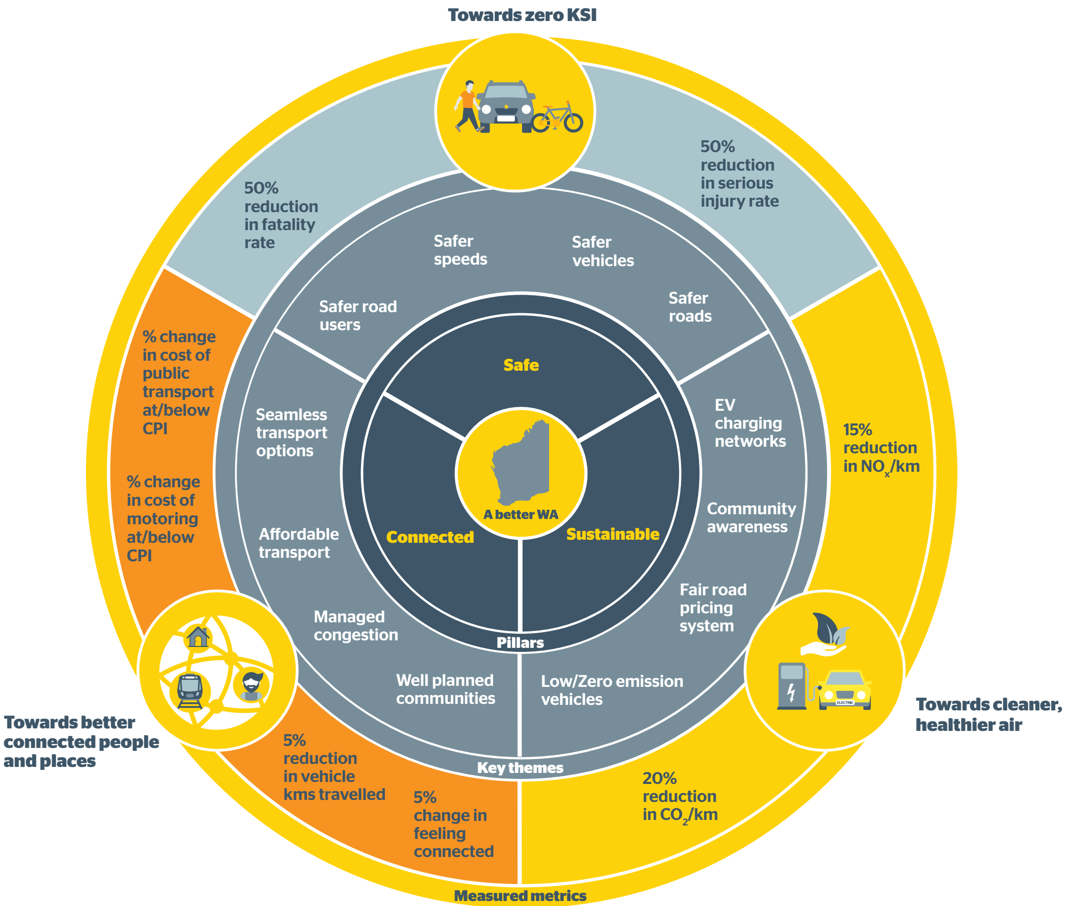
Future plans

> The deployment of Black Carbon Modules across the Perth and Peel region has enhanced RAC's understanding of localised air pollution, but more importantly, it has provided critical data to support the disproportionate impact of fossil fuel emissions on air quality.

The analysis of black carbon concentrations across varying time units, highlights the strong correlation between traffic emissions and levels of black carbon.

This reinforces the need to prioritise RAC's Vision 2030, and the set targets for a reduction in nitrogen oxides (NO_x) emissions and 20% reduction in carbon dioxide (CO_2) emissions per km travelled by car.

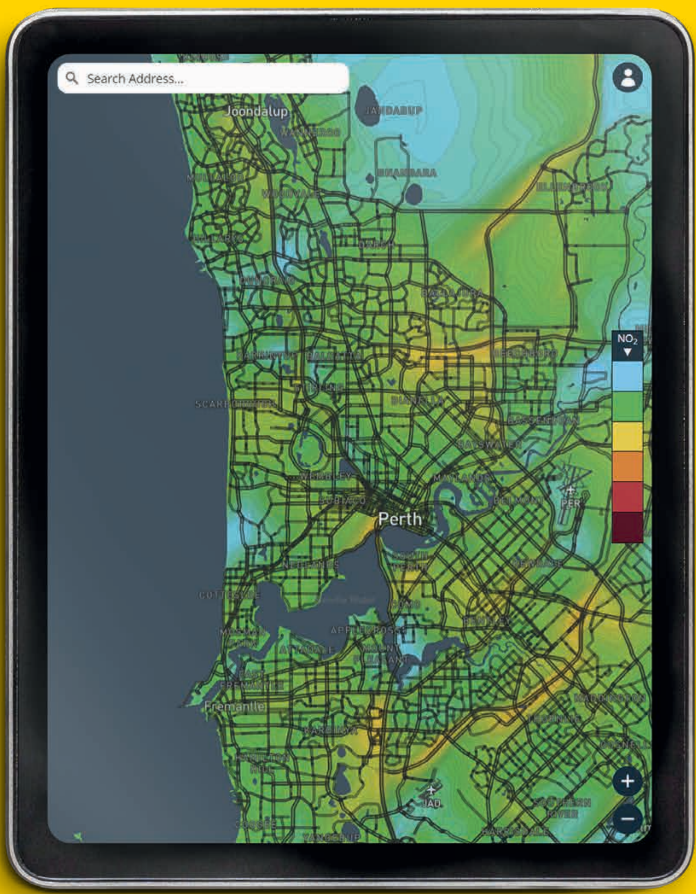
These trial findings will complement and work in association with our Air Health Monitor Annual Reports, in our continued advocacy efforts for cleaner and healthier air. This additional layer of data depth, enables more informed discussions with our members, key stakeholders and industry leaders.



Social and Community Impact Framework

Changing WA

one air health sensor at a time



RAC Air Health Monitor

For the better

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