Motor Vehicle Engine Idling in Australia

– a critical review and initial assessment

Transport Emission Energy Research

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1. Introduction

Idling is defined as running the engine when the vehicle is stationary.

Engine idling is ubiquitous and done for various reasons.

Idling:

- happens in normal traffic,
- provides power to accessories (e.g. heater, air conditioning),
- keeps batteries charged,
- enables easier engine re-start in cold temperatures, and
- prevents cold-weather gelling of diesel fuel.

Two types of idling may be distinguished. The first is idling while driving and waiting for short periods during, before or immediately after a journey. The second is the practice of leaving the engine on while stopped either out of habit or to provide services unrelated to driving, such as cooling or heating the cabin. Some idling is unavoidable, but other idling can be reduced. Engine idling is increasingly recognized as an aesthetic and environmental problem. It appears generally accepted that idling increases emissions, fuel use, maintenance costs and noise, and impacts on local air quality.

This report provides a critical review of overseas research into idling. The report examines idling behaviour, idling impacts, mitigation measures and reported effectiveness of these measures. Finally, an initial assessment is made regarding idling emissions for the Australian situation.

2. Objective

The objective of this study is to provide an initial assessment of the relevance of idling and its impacts on fuel consumption, emissions and local air quality in Australia.

3. Idling Behaviour

In practice, the actual extent of idling varies substantially with the type of vehicle, the driver, climate and type of operation. Places where idling usually occurs include intersections (e.g. queuing for traffic lights, roundabouts, stop signs), bus terminals, truck stops and rest areas, restaurant drive-throughs, tourist attractions, and schools, among others.

Survey data in Europe and North America show that idling typically accounts for 13% - 23% of vehicle travel time.[1] However, it is unclear what types of idling is reflected in these numbers. It is likely that idling observed in driving behaviour data mainly reflects interactions between a vehicle, other vehicles (level of congestion, fleet mix), traffic control (traffic lights, roundabouts, speed limits, number of lanes, lane width) and land use characteristics (urban, residential, intersection density, etc.).

A term, often used, but not well defined is 'excessive idling'. Excessive idling reflects a long and unnecessary idling period when the vehicle is parked. In this report, excessive idling is arbitrarily defined as idling periods of 5 minutes or longer while parked. This value is in line with e.g. California's anti-idling regulations, as will be discussed later. However, a shorter period may be more appropriate. For instance, it has been assumed that stationary durations longer than two minutes are events when the vehicle is parked.[2]

A substantial amount of idling research in the USA has been directed at long-haul trucks. Extended idle occurs when 'Class 8' long haul diesel truck drivers rest in the sleeper/cab compartment during rest periods (hoteling).[1] Long-haul truck drivers primarily idle their engines to heat or cool sleeper cab compartments, to maintain vehicle battery charge while electrical appliances such as televisions and microwaves are in use, or to keep air brakes working and fully charged.[e.g. 3,4] The relevance of long-haul truck idling (sleeper cabs) in Australia may be significant given the long distances between major cities. However, further investigation is required.

Estimates for long-distance, freight-hauling, heavy-duty truck idling in the USA vary from 6-16 hours per day.[5] Interviews[2] with truck operators and fleet owners showed a wide variation in actual behaviour.[6,7] A typical long-haul truck idles an estimated 1,800 hours/year when parked overnight at truck stops, although a significant range of 1,000 – 2,500 hours/year has been reported.[6,8-13] This translates in an average annual fuel used by long haul truck idling of about 6,000 litres of diesel fuel per year[9,14], or approximately 5 – 8% of the total fuel used.[13,15]

Other trucks and vehicles can also be idled for long periods. For instance, school bus drivers idle their buses in the morning to defrost the windshield and heat the bus (cold climates), and transit bus drivers idle their buses to heat or cool the bus while waiting to pick up passengers at terminals.[e.g. 6] Perhaps another source of idling in Australia is hoteling of campervans to keep the vehicle cool for tourists at night.

Company or government vehicles might idle for extended amounts of time during the work day. Idling may occur during the delivery process, queuing at loading docks, to power on-board systems, or to provide comfort during the work day.[2,4] While drivers of passenger vehicles may have the option of simply not idling, fleet and emergency vehicle operators may need to keep the vehicle operating to supply power to critical on-board equipment. For example, police and emergency vehicles can spend up to 70-80% of their in-service time simply idling to provide electrical power for on-board systems[3] as well as heating and cooling for the passenger compartment.[16,17]

[1] Nearly 500,000 long-haul trucks drivers in the USA are required to take mandatory rest stops for specific periods prescribed by the U.S. Department of Transportation's Hours of Service regulation.

[2] At one extreme, one owner-operator of an older truck reported that he leaves his truck running all the time, even at home over the weekend, to make absolutely sure that it will start. On an annual basis, he idles his truck for more than 5,000 h. At the other extreme is another owner-operator only runs his truck when he is in it. He plugs in a small electric heater to keep the engine warm at home in the winter, but he still does occasionally have trouble starting the truck. He idles his truck for fewer than 1,000 h/yr.

[3] For instance, roof top light bar, take down lights, communication equipment and laptop computer.

Nevertheless, some idling can be due to driver habits, forgetfulness, excessive cooling or heating, and other unnecessary engine operation that does not provide any benefit and is not required for the vehicle's intended operation.[2] For instance, some drivers idle for significant time periods at beginning or end of trips in the belief that this ensures engine health. However, modern diesel engines do not normally require significant idle time to warm up. In fact, most diesel engine manufacturers recommend an optimum warm-up and cool-down time of between 3-5 minutes. Idling for longer periods of time can harm an engine by causing carbon build-up and decreasing oil life.[15]

4. Adverse Impacts of Idling

Idling behaviour and associated environmental impacts have been examined for quite some time, and particularly in the USA. This section provides a brief overview of the adverse impacts of idling.

4.1 Emissions and fuel consumption

Idling vehicles emit air pollutants and greenhouse gases. To a large extent this is simply due to the fact that a running internal combustion engine (ICE) uses fuel and emits air pollutants. So idling emissions simply add to the total accumulated emissions during a journey because the vehicle is not moving (zero kilometre per litre of fuel). In addition, idle engine operation is inefficient[4] and can suffer from incomplete combustion, leading to increased fuel consumption and elevated emissions.[e.g. 18] According to NACFE, a 10% annual reduction in idling is worth about 1% in fuel economy.[13]

Idle fuel consumption and emissions are a function of engine type, engine size and engine speed (revolutions per minute or RPM).[5] The idle RPM setting depends on the accessory load (e.g. air conditioning, cooling fan[6]). Other factors such as ambient temperature, humidity and accessory loads will also impact. In general, the larger the engine and/or the higher the engine speed, the higher the fuel rate and CO_2 emission rate. The effect of these factors on air pollutant emissions is harder to predict with confidence, as emission rates are the result of complex interactions between engine out emissions and the emission control system, as will be discussed shortly.

[4] For instance, truck engine idling has a net efficiency of 11-15%[6], meaning that about 85-90% of fuel energy is wasted as heat and not used.

[5] For instance, mean fuel consumption rates at idle for different engine speeds reported by a truck engine manufacturer are: 2 l/h at 650 RPM, 4 l/h at 1,000 RPM and 6 l/h at 1,200 RPM.[13] To avoid engine wear due to low-speed idling, most truckers idle their engines at 1,000 rpm with some load.[6]

[6] During idling the engine temperature can increase and with high ambient temperatures the cooling fan may be activated leading to higher fuel use.[20]

The Australian passenger vehicle fleet has a relatively high proportion of large engines.[19] This is shown in Figure 1. The majority (about 75%) of the Australian car fleet has an engine capacity of more than 2 litres. This contrasts with the UK and Dutch car fleets where these vehicles only make up about 10% of the fleet because smaller engines are dominant. This means that the Australian fleet can potentially achieve larger fuel and associated CO_2 emissions savings with idle reduction initiatives, as compared with EU countries.

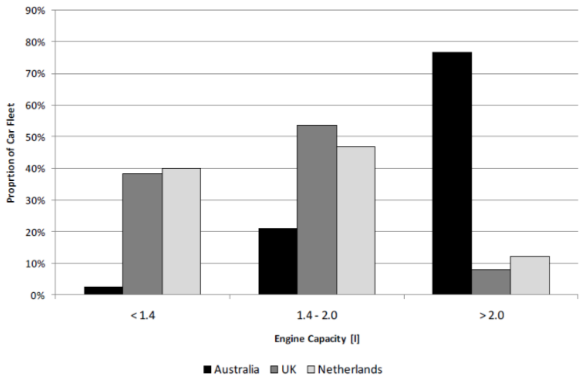

Figure 1 – Australian, UK and Dutch Car Fleet Composition in terms of engine capacity.[19]

The argument to reduce idling to save fuel and reduce greenhouse gas emissions is sound. However, the grounds for minimizing idling to reduce air pollutant emissions is less straightforward.

With progressive strengthening of vehicle emission standards, emission control systems have become increasingly sophisticated over time, often combining different types of emission control. Vehicle emission control today is a complex, computer-controlled and optimised system with a high efficiency for pollutant removal. Factors such as the age of the vehicle, vehicle maintenance, the type of engine (diesel or petrol), catalyst type and formulation, and ambient conditions (e.g. temperature, humidity) all affect air pollution emissions at idling.

One objection to idle reduction is that air pollutant emissions from an engine re-starts is significantly larger than accumulated idling emissions, due to progressive cooling of the emission control system including catalysts.[1] However, the catalyst system can also cool down during idling due to low exhaust flow rates, although it is unlikely light-off temperatures will be reached.[20] Others reported that a petrol engine in cold weather that is shut off for a short period (under 10 minutes) does not cool down enough to reduce the effectiveness of the catalytic converter.[21] However, in extreme cold a vehicle shut down for a longer period (over 30 minutes) would have increased pollutant emissions when re-started.

Limited research has been published on the net emission effect for modern vehicles, i.e. excess start emissions[7] versus avoided emissions due to engine shutdown. For older technology vehicles the benefits of idle reduction on air pollutant emissions were clearer. For instance, cold start emissions have been shown to be significantly lower than emissions from extended idling for diesel trucks.[22]

[7] A re-start after engine shutdown always show a small peak in emissions and fuel consumption due to fuel-rich conditions.[20]

For newer technology vehicles, there is a general lack of data, although cold start emission levels have generally dropped with progressive emission standards.[e.g. 23] As a consequence, assessing the impacts of idling on air pollutant emissions is challenging. A research study in the Netherlands measured idling emissions from diesel and petrol cars (Euro 3 and 4) after 1, 2 and 5 minute engine stop intervals.[20] The measurements show that an engine shut down reduces emissions already for short stops for CO_2, (all cars), NO_x and PM (diesel cars), but that idling may be beneficial for NO_x, CO and VOC emissions (petrol cars) due to catalyst cooling. For long stops (more than one hour) engine shut down is always beneficial.

4.2 Vehicle maintenance

It is also generally reported that excessive idling has a negative effect on the engine and exhaust system and increases maintenance costs.[e.g. 24] For instance, extended idle operation may lead to reduced efficiency of engine lubricants (increased frequency of oil change), engine or spark plug wear/fouling and accumulation of fuel residue in the exhaust system.[e.g. 1,18]

This negative impact appears to have worsened with the introduction of modern emission control such as the diesel particulate filter (DPF) and selective catalytic reduction (SCR).[13,25] These components are expensive to replace, and it is no secret that they have caused an increase in maintenance costs for fleets since their introduction. However, it has proved challenging to obtain data that definitively shows the connection between reduced idle time and reduced maintenance costs.[13]

4.3 Local air quality

The impacts of traffic-related air pollution on public health have been researched intensively. For instance, diesel exhaust is classified as a carcinogen by the International Agency for Research on Cancer (IARC). This was based on sufficient evidence that exposure to diesel exhaust[8] causes lung cancer.[26] Exacerbation of existing asthma and new-onset asthma has been demonstrated to be associated with traffic-related air pollution exposure overseas [27,28], as well as in Australia [29]. Exposure of school-age children to traffic emissions is of particular concern. They are especially vulnerable considering the effect of air pollution on the growth of lung function and the fact that immunological systems undergo major developments.[28,30] An important finding in these studies is that health impacts are observed at low levels, and that exposure reduction by emission reduction measures, such as engine idle reduction, will potentially generate measurable benefits.

The contribution of motor vehicle emissions to population exposure and associated health effects is substantially greater than one would expect on the basis of their emissions alone. International studies have found that motor vehicles are the largest single contributor to human health effects (PM, ozone), and that emission levels are leveraged by about a factor of three to four when population exposure is considered.[e.g. 31]

[8] People are exposed not only to motor vehicle exhausts (cars, trucks) but also to exhausts from other diesel engines, including from other modes of transport (e.g. diesel trains and ships) and from power generators.

This is because motor vehicle emissions are ubiquitous and are typically emitted in close proximity to where people live and work. In contrast, other sources may be more localised and have different dispersion characteristics. For instance, industry emissions are typically emitted through vents and stacks, and are generally located some distance from populated areas.

Diesel idling has been identified as a significant factor in elevated concentrations of elemental carbon and PM near schools.[27] Children spend a significant amount of their time at schools where exposure to traffic-related air pollutants may be elevated due to idling buses. Air quality measurements show that anti-idling campaigns are effective in significantly reducing $PM_{2.5}$, EC and particle number concentrations at schools with significant amounts of buses and passenger cars.[32] Another study found that changes in outdoor air quality associated with an anti-idling campaign are also capable of reducing children exposure to traffic air pollution *inside* the schools.[28]

However, the impacts of idling on local air quality may not always be significant. For instance, overseas research has estimated that removing idling emissions on busy roads would result in insignificant improvements in ambient concentration levels.[20] The maximum contribution of idling to these concentrations varying from 0.5% (CO), 1% (PM, benzene) to 2% (NO_2). The main reasons are elevated background concentration levels combined with a high contribution from moving vehicles.

4.4 Noise

The sound of idle combustion is considered an unwelcome source of noise pollution to some people.[e.g. 18]

5. Idle Reduction Measures

Although there are various ways to reduce emissions and fuel consumption, one of the most direct and easy methods is to reduce fuel consumption by limiting unnecessary idling. Idle reduction measures have traditionally focussed on diesel buses and trucks, where idling is common practice and most visible. A number of benefits can be obtained in limiting idling time, as discussed before. These benefits may include savings in fuel use and maintenance costs, vehicle life extension, and reduction in exhaust emissions.

Several options are available to reduce idling:

- Driver behaviour change
- Idle reduction technologies
- Idle reduction regulation

5.1 Driver behaviour change

Idling can be prevented by simply shutting down the engine thereby eliminating unnecessary engine idling and fuel consumption. So the driver may manually turn of the engine when he/she expects to experience a long stop. For long-haul trucks, drivers could use a hotel room, if possible, rather than spending the night inside an idling truck.[13]

A commonly reported idle reduction guideline is that more than 10 seconds of idling burns more fuel, and hence creates more CO_2 emissions, than re-starting the engine.[1,2,18,21,33] When also accounting for the costs of additional engine wear (starter, battery) due to re-start, waiting for a little less than a minute before turning off the engine has been recommended.[1,18]

Fleet operators have actively sought to reduce idling emissions, particularly in the USA.[e.g. 2] This is not surprising as fuel costs are a significant part of the expense to operate a fleet. For instance, fuel costs typically account for 22% of a trucking fleet total operating costs in the USA, the second-largest expense for fleets behind only driver wages.[13] Many fleets in the USA therefore have incentive systems to encourage drivers to be involved in reducing the fleet's fuel expenses by sharing the savings between the truck owners and the drivers.[13] Although some national truck programs in the EU were identified, e.g. Freight Best Practice in the UK [24], there appears to be limited interest in the anti-idling measures in the EU.

In the USA most truck operators are aware of the cost of fuel consumed while idling, and importantly, the wear on the engine due to idling. Engine manufacturers caution owners to monitor the extent of idling that occurs for each truck and to reduce the oil change interval if the idle time exceeds ten percent of the work day. Accordingly, many utility truck operators track their oil change intervals in engine hours rather than in miles.[12]

Anti-idling initiatives appear to have a measurable impact.

For instance, studies show that when truck drivers are educated about the harm of excessive idling, they tend to reduce their level of idling.[15] For instance, it was common for US trucking companies to report idle time in excess of 50 percent.[34] Fleets with good operations would often report 35 percent idle time, and a benchmark number was below 20 percent. Today, it is more common for these same fleets to report worst case numbers around 35 percent, and averages 10 – 20 percent, with benchmark numbers suggesting as low as 5 percent.[13,34]

A public health initiative in the USA aimed at reducing traffic-related air pollution exposure of the school community at four public schools.[27] Anti-idling campaign materials were developed and education and training were provided to school bus drivers, students, parents, and school staff. After completing the educational component of the public health initiative, bus drivers, community members, and staff demonstrated significantly increased knowledge about the health effects of idling. More than 30% of parents signed a pledge to reduce idling after the public health intervention.

> A successful anti-idling or idle-reduction campaign can serve as a catalyst for public involvement in the improvement of air quality and reduction of greenhouse gas emissions. Its prevalence provides an opportunity to engage many people in an activity that has a direct relationship to climate change and air quality.[e.g. 33]

Another initiative in Canada called “Turn it Off” aimed to encourage members of the public to avoid idling their engines while waiting in their vehicles using e.g. no idling signs, stickers and information cards. The “Turn it Off” initiative reduced idling by 32% and idling duration by 73%.[33] Community-driven public health initiatives can be effective in: [27]

1) enhancing community awareness about the benefits of reducing idling vehicles, and
2) increasing active participation in idling reduction.

5.2 Idle reduction technology

There are various technologies available to reduce idling.

- Engine control – nearly all aspects of engine operation in a modern vehicle are controlled by an Engine Control Unit (ECU), an embedded system creating a closed control loop between engine sensors and actuators. This allows manufacturers to precisely control all aspects of engine operation and thus drive improvements in performance, reliability, and fuel economy. The ECU also controls idle speed and other idle settings (e.g. engine shut-off). A low RPM setting reduces fuel use, but also creates additional wear on the engine’s internal parts. It is therefore unlikely that idling settings in the ECU are fully optimised for minimum fuel use.[e.g. 13]
- Stop-start system[9] – a simple and non-invasive solution to reduce idling, but may not provide as much savings as more extensive idle reduction systems. They are a key feature of hybrid electric vehicles (HEVs). The use of stop-start systems is rapidly growing and are likely to be universal by 2030.[35] For light-duty vehicles or LDVs (cars, light-commercial vehicles), anti-idling technology is already widely adopted in the EU. Most LDVs currently sold in the EU come with a stop-start system.[10] In the USA, adoption of stop-start technology is slower. In model year 2012 adoption was less than one percent, but the use of stop-start systems was projected to increase to almost 30% projected for model year 2018.[36] The number of stop-start systems sold in Australia is unclear, but there are a number of European and Japanese manufacturers (e.g. BMW, VW, Mercedes, Mazda, Honda and Subaru) that offer idle stop-start technology on the models sold in Australia.
- HDV anti-idling devices – a variety of anti-idling devices are available for heavy-duty vehicles (HDVs), either installed in the factory, or aftermarket.[4] They generally prevent unnecessary main engine idling by the provision of an alternative and more efficient source of power to

[9] A start-stop, stop-start or micro-hybrid system automatically turns off the engine when a vehicle pauses in traffic, as long as critical vehicle parameters are at acceptable thresholds[2], re-starting quickly when the vehicle needs to move again. This is done to minimize the amount of time the engine spends idling, thereby reducing fuel consumption and emissions. This technology requires a higher capacity battery and starter motor. Fuel economy gains from this technology are typically in the order of 5 percent.[37]

[10] This is largely the result of the large idle portion in the current EU emission test (New European Drive Cycle or NEDC, 23% idle). The NEDC will be replaced in 2021 by the Worldwide Harmonized Light-duty Test Procedure or WLTC, which is closer to the Australian CUEDCs. In 2020 the CO_2 emissions of all new vehicles will be determined with both NEDC and WLTP, in order to set the specific WLTP emission target for 2021. It is noted that the smaller contribution of idle in the WLTP (13.4%) means that the impact of start-stop systems on achieving low CO_2 emissions will fade out when the WLTP is introduced, with a yet unclear impact on the penetration of stop-start technology.

provide heat, air conditioning and/or electricity.[e.g. 2,18] An average truck fleet, employing a suite of idle-reduction technologies along with the proper engine parameter settings, driver training and processes, will likely reduce idle percent on a fleet-wide, annualized basis by about 20% (from 30% to 10%).[13] Almost all long haul trucks sold today in the USA have stop-start technology, referred to as tamper-proof automatic engine shutoff system (AESS), in combination with hoteling support technology.[12,13] Regarding the latter, popular options include diesel- or battery-powered auxiliary power units (APUs) and diesel direct-fired heaters (DFHs) [4,13,16,34], or even fuel-cell APUs[7]. Many truck OEMs offer battery APUs—typically called battery HVAC (Heating, Ventilation & Air Conditioning) systems as factory options.[13] Truck Stop Electrification (TSE) is another approach to reduce heavy truck idling at truck stops and rest areas. TSE systems can be classified as on-board or off-board, the latter often referred to as shore power or electrified parking space.[e.g. 3,4] These devices can achieve significant reductions in idling emissions (e.g. 70-99% NO_x) and fuel consumption/CO_2 emissions (e.g. 50-96%), although in some cases (PM) emissions reportedly increase.[11] There may also be some downsides to these technologies. For instance, the reduction in fuel economy caused by the increase in weight is commonly assumed negligible, but it will have an effect.[14] In the EU, fuel and emission reduction technologies other than anti-idling technology are expected to be more relevant for HDVs.[e.g. 38]


Figure 2 – Service area with a shore power system.[3]

- **EVs** – Finally, electric vehicles or hybrid electric vehicles will eliminate or reduce idling emissions, local air quality impacts and noise.

As a final note, overseas government and industry have actively worked together to reduce idling, particularly in North America [16,40], which may serve as an example in Australia. The SuperTruck project is an example of a collaborative US government-industry initiative. The project aimed to develop a truck that could meet or exceed 10 miles per gallon fuel use, and included the use of a battery APU to reduce idling emissions.[4]

5.3 Idle reduction regulation

In the USA and Canada, local and state governments have enacted voluntary or mandatory anti-idling legislation driven by a need to address complaints and reduce fuel use, emissions and noise.[e.g. 3,9,21,34] Other countries like Taiwan have also adopted anti-idling laws.[41]

The idling regulations in North America vary widely. Anti-idling laws generally focus on commercial vehicles (trucks, buses), locomotives, and school buses.

[11] Detailed assessment and discussion of these anti-idling technologies can be found elsewhere. [2,4,5,6,8,10,11,13,14,18,34,56,61,62]

Some idling laws are broad enough in scope to also cover passenger vehicles, but idling laws have not generally been enforced against cars.[15] Permitted idle times range from zero to 20 minutes, with first-time fines ranging from $25 up to $500, and maximum penalties up to $25,000.

Anti-idling laws do not ban idling completely. In fact, several exceptions are made, e.g. for certain traffic (e.g. queuing) or weather conditions[12], in the event of mechanical difficulties, and for safety reasons.[6,13] These exemptions have led to doubts about the real-world effectiveness of anti-idling laws, especially when it matters, for instance on high temperature smog days.[21]

California is regarded as a leader in anti-idling regulations. Since 1 January 2008, operators of diesel-fuelled trucks (> MY 2006) with a gross vehicle weight rating greater than 4,500 kg are not to idle for more than 5 minutes when stopped within California's borders, unless strict emission standards are met.[14,34]

CARB also introduced “Clean Idle” stickers, which signified that a given engine system met the CARB requirements for extended idling. This has since grown to include a separate sticker that indicates a diesel APU has a Diesel Particulate Filter (DPF) and meets more stringent requirements for California. These stickers allow drivers to idle the certified component beyond the 5-minute limit in California.[13]

6. Idling in Australia

6.1 Many unknowns

In Australia almost no idle reduction initiatives or anti-idling legislation were identified. Eco-driving has received some attention and includes the recommendation to reduce idling while parked.[e.g. 42]

The use of idle reduction technology in Australian on-road vehicles is also unclear. For instance, the use of stop-start or other anti-idling technology in Australian vehicle needs further investigation. What is clear is that Australia does not have fuel efficiency or CO_2 emission standards, in contrast to other developed countries such as the EU and USA.[43] This means that vehicle manufacturers do not have an incentive to include idle reduction technologies (or other fuel-saving technologies) in vehicles sold in Australia. Indeed, Australia, is the worst performing country in relation to LDV CO_2 emission rates in comparison with e.g. the EU, USA and Japan.[44] Since extra costs are associated with the use emission reduction technologies, it appears likely that idle reduction technologies are not commonly used in Australian vehicles, and that this situation will not change unless mandatory emission standards are implemented.

It is clear that there is a lack of data regarding idling behaviour, idle reduction technology and idling impacts in Australia. Further research is required to shed more light on these factors. For instance, surveys into idling behaviour and the use of anti-idling technology in Australian vehicles would be very helpful.

[12] For instance, outside 0 – 24 °C temperature range, so that drivers can operate air conditioners or heaters to maintain passenger comfort in the vehicle.

It is likely that vehicle movement, including idling, is tracked and recorded in the truck industry and by fleet operators. Further discussions with these entities can shed further light on what idling data are collected and what could be made available. Modern cars may also track total idling time spent, which could be useful if these data can somehow be accessed.

Although overseas research is relevant for this study, the main issue is that the impacts are quantified for overseas on-road fleets with unique characteristics in terms of vehicle age, fuel type, engine and emission control technology, engine calibration, level of maintenance, local fuel quality, emission standards, etc. In addition, driving behaviour in Australia may differ from those observed overseas. It is therefore challenging to extract robust conclusions regarding the impact of idling in Australia from just published overseas studies.

Two primary objections to idling are made on the grounds of fuel consumption (and thus CO_2 emissions) and air pollution emissions. It is therefore of interest to examine to what extent idling contributes to fuel use and emission loads in Australia.

Previous research has shown that detailed and high resolution (1 Hz) emissions simulation using a power-based model is an appropriate and defensible approach to quantify the impacts of driving behaviour on fleet emissions.[e.g. 45,46,47]

A cost-effective and feasible way to estimate the impacts of idling on on-road vehicle emissions is to use a comprehensive vehicle emission model that:

- is representative of the Australian fleet, and
- is able to explicitly simulate the impacts of idling.

The PΔP model complies with these criteria, and is discussed in the next section.

6.2 How relevant are idling emissions in Australia?

This section provides an initial assessment of the relevance of idling behaviour on fuel use and emissions from the Australian on-road fleet. Transport Energy/Emission Research (TER) has developed an Australian power-based model. The model is based on millions of seconds of empirical emissions data that were collected from various (Australian) test programs. Before the data were used in model development, they were verified using data quality protocols.[48]

The power-delta-power or PΔP model predicts emissions, energy use and fuel consumption for 115 Australian vehicle classes, and has been used in various studies.[46,49-53] The input to the model is second-by-second speed-time data and information on second-by-second air speed (e.g. tunnel assessment), road gradient, vehicle load and use of air-conditioning (on/off). The model is designed to simulate the impacts of changing traffic and operational conditions (including road gradient), as well as a wide range or traffic measures. It can also be used to assess the impact of idling on emissions from Australian vehicles.

PΔP simulates fuel consumption (FC) rates and hot running emissions (NO_x, CO_2) second-by-second for all major vehicle classes, including cars, SUVs, light-commercial vehicles, rigid trucks and articulated trucks. PΔP uses simulated instantaneous engine power (P) and the change in engine power (ΔP), both expressed as kW. Hence the name "PΔP". Although a Hong Kong version of PΔP predicts a range air pollutant emissions, such as CO, PM, HC, NO and NO_2 [54], the current Australian version of PΔP predicts fuel consumption and NO_x and CO_2 emissions, but not CO, HC, NO_2 and PM (exhaust).

The first step in the simulation is to prepare an input file. The input file quantifies an operational drive pattern, which includes second-by-second speed, road gradient, vehicle load, air speed and air conditioning on/off values. For this study, real-world Australian drive cycles were used: [55]

- CUEDC-P (passenger vehicle)
- CUEDC-D/ME (bus)
- CUEDC-D/NCH (large truck)

CUEDC stands for 'Composite Urban Emission Drive Cycles' and '-P' or '-D' denotes petrol or diesel. The cycles were constructed from Australian driving pattern data collected in the field. The real–world driving cycles were developed for four distinct traffic situations (congested, residential, arterial and freeway) and different vehicle classes to properly reflect speed-acceleration characteristics due to different power-to-mass ratios. The cycles are meant to reflect representative driving behaviour of Australian drivers for different vehicle categories.

Other simulation settings are 1) air speed was set to zero, 2) air conditioning use was set to 'on', 3) vehicle load was set to 30% (passenger vehicle) and 50% (bus, large truck), and 4) road gradient was set to zero. The drive cycles are shown in Figure 3 and 4. Cycle statistics are presented in Table 1. It can be seen that a significant amount of idling (12-21%) is present in contemporary Australian driving. This compares well with internationally reported values.[e.g. 1]

Table 1 – Statistics for Australian real-world drive cycles.

Cycle	Cycle time (s)	Idle time (s)	Percentage idle time (%)	Distance (km)	Maximum speed (km/h)	Average speed (km/h)
CUEDC-P	1,797	380	21	19.4	94	39
CUEDC-D-ME	1,678	253	15	14.4	85	31
CUEDC-D-NCH	1,676	206	12	15.5	96	33

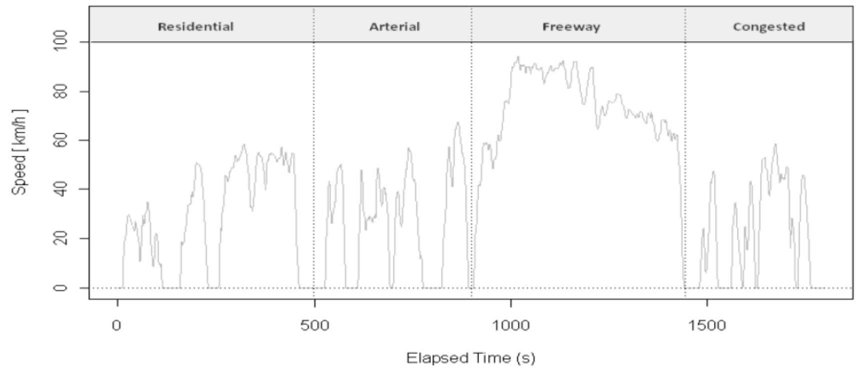

Figure 3 – CUEDC-P drive cycle [55]

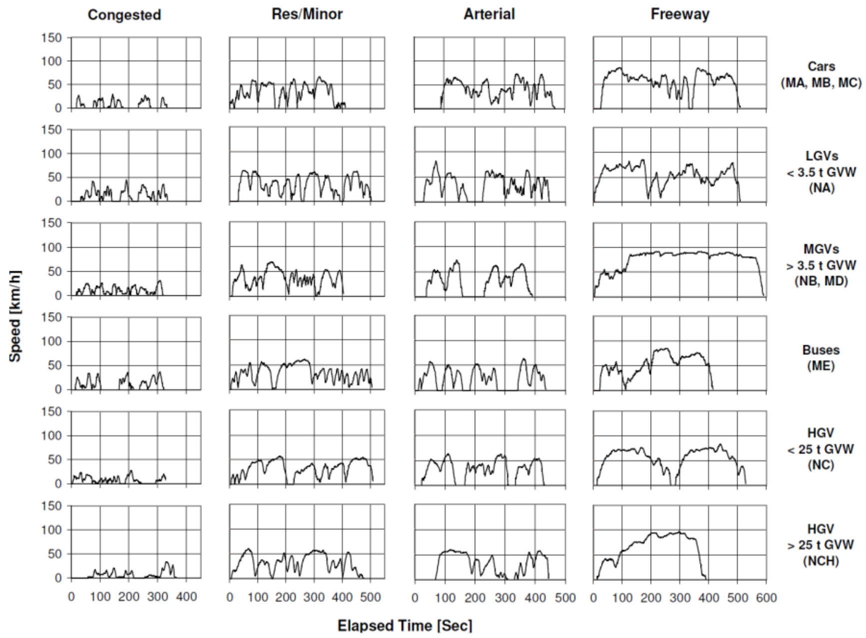

Figure 4 – CUEDC-D drive cycles [55]

PΔP provides second-by-second fuel consumption and NO_x and CO_2 emission rates (g/s), as well as an output summary table with average fuel consumption and emission factors (g/km) for 14 main vehicle classes. The fuel use and emission rates/factors are weighted averaged values, also called composite emission rate or factors. This means that they are weighted according to the proportion of travel (vehicle kilometres travelled or VKT) in the on-road fleet.

For instance, composite emission factors are provided for large petrol passenger cars using detailed emission factors and VKT weighting factors for 8 technology classes for base year 2020 that reflect different emission standards (ADRs, Australian Design Rules). Further aggregation to the three vehicle classes considered in this study is then carried out in a similar fashion, i.e. by combining detailed emission rates or emission factors with VKT weighting factors for the relevant vehicle/fuel type and ADR classes for base year 2020.

Figure 5 (next page) shows examples of graphical output from PΔP. The speed-time and composite CO_2 emission profiles are shown for three vehicle classes. The idling periods can clearly be seen, combined with relatively low emission rates (g/s).

Analysis of the emission simulation data shows that idling in the drive cycles represents a small but not insignificant portion of total (journey) emissions. This is in line with overseas research.[16,20]

- Passenger vehicle:
    - 21% idle time (CUEDC-P)
    - 2% of total NO_x emissions
    - 8% of total fuel consumption and CO_2 emissions
- Bus
    - 15% idle time (CUEDC-D/ME)
    - 6% of total NO_x emissions
    - 3% of total fuel consumption and CO_2 emissions
- Truck
    - 12% idle time (CUEDC-D/NCH)
    - 2% of total NO_x emissions
    - 1% of total fuel consumption and CO_2 emissions

From the perspective of management and mitigation of total emission loads from motor vehicles, reducing idling may not expected to make a large difference, and other measures may be more effective.

However, these percentages still equate to a significant amounts of emissions. For instance, CO_2 emissions due to idling equate to a little over 1.5 million cars on the road, a significant number.

This is computed as follows. The Australian Greenhouse Emissions Information System (AGEIS) [56], reports a total CO_2 emission load of 44,170, 15,456 and 22,233 ktonne in 2017 for cars, light-commercial vehicles and heavy-duty vehicles (trucks and buses), respectively. Assuming idling accounts for 8%, 8% and 1% of these total emissions, total CO_2 emissions due to idling for all vehicle classes combined are about 5,000 ktonne per year. Australian cars are estimated to have driven 185 billion kilometres in 2017 [57], resulting in an estimated average CO_2 emission rate of 240 g/km. ABS reported an average annual mileage for passenger vehicles of 13,100 km/year in 2016. [58] This means that the average Australian passenger vehicle emits about 3.1 tonnes of CO_2 per year. Dividing 5 million tonne per year (5,000 ktonne/year) by 3.1 tonne per car per year gives 1.6 million cars.

Importantly, idling reflected in the drive cycles is considered representative of typical driving behaviour in Australian cities. It therefore mainly reflects the impacts of traffic control, land use and congestion (e.g. traffic lights, queuing, roundabouts, speed limits) on driving conditions. As such, excessive idling is not sufficiently captured in the drive cycles. Idling impacts (nuisance, emissions, air quality) can be highly localised, for instance, at pick up areas in school and airports, parking lots, etc.

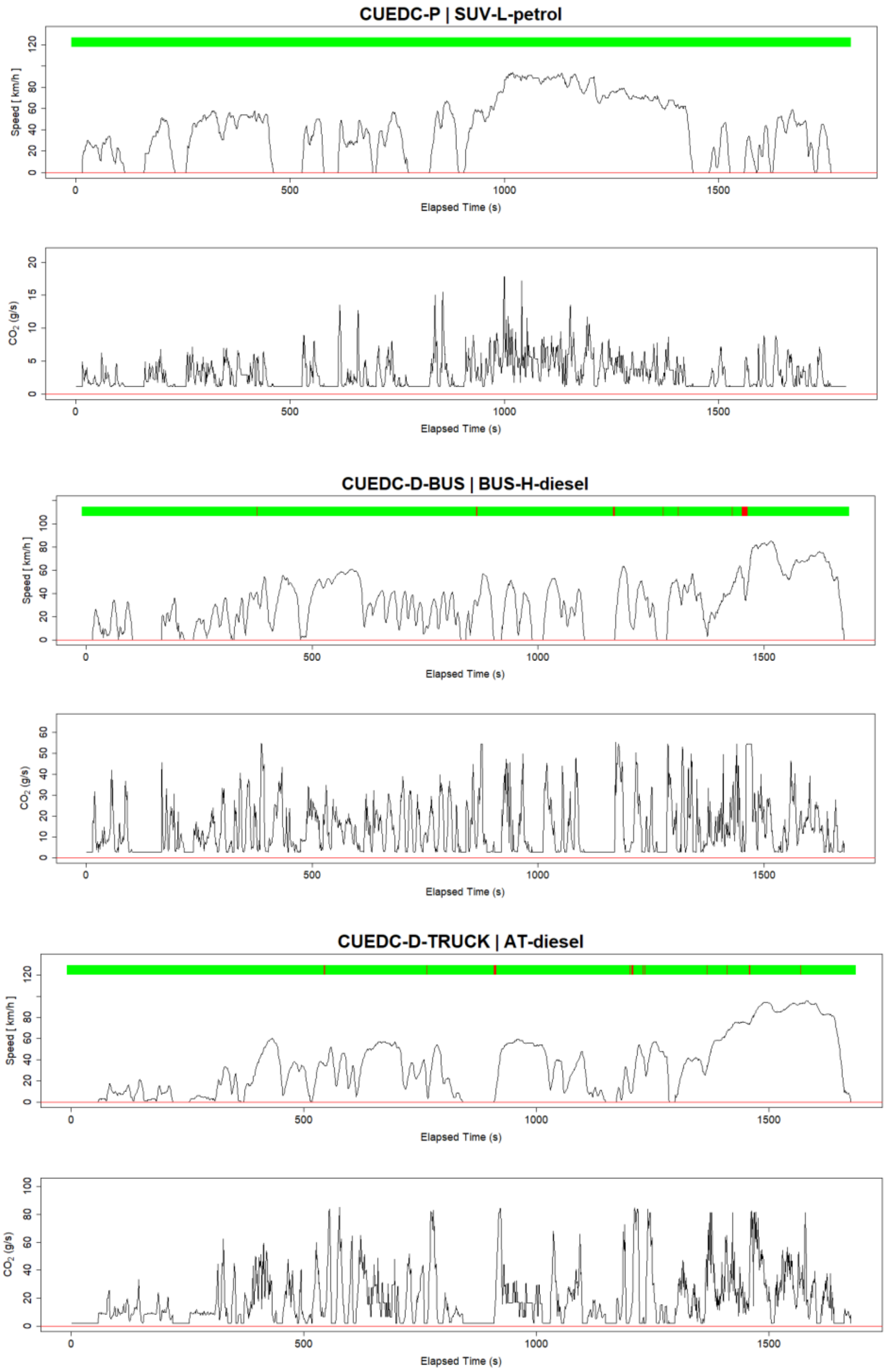

Figure 5 – Time-series plots showing examples of emission simulation of the Australian vehicles.

Although vehicle emissions are generally highly variable in real-world driving conditions, idling emissions have relatively good stability and have shown good repeatability in emission testing.[e.g. 59] It is therefore useful to examine fuel use and emission rates in idle conditions for Australian vehicles. Table 2 presents estimated fleet averaged numbers for the 2020 on-road fleet. These values can be used to estimate hourly idling emissions when the number and type of vehicles idling are known. These emission estimates can then be used in dispersion models to provide an initial assessment of local air quality impacts.

Table 2 – Typical fuel use and hot running emission rates at idle for Australian vehicles.

Cycle	Fuel Economy (l/h)	NO_x emission (g/h)	CO_2 emission (kg/h)
Small Petrol Car	1.0	0.1	2.4
Large Petrol Car	1.7	0.4	3.8
Large Petrol SUV	1.8	0.2	4.1
Large Diesel car	1.0	10.0	2.7
Large Diesel SUV	1.7	12.0	4.5
Large Diesel Truck	2.8	80.0	7.4
Large Diesel Bus	3.7	100.0	9.9

The emission rates presented in Table 2 are not fixed, and can vary due to local circumstances. They reflect the measured emissions data from a small vehicle sample and will change when new emissions data are examined and incorporated. Nevertheless, Table 2 appears to align with available overseas data. For instance, a diesel truck engine idling reportedly consumes about 2-6 litres of diesel fuel per hour in the USA when the truck's heating or air-conditioning system is operated.[4,6,14,24,34]

It is noted that Table 2 presents emission rates in hot running conditions, not starting conditions. This means that the emission rates are appropriate for situations where the majority of idling vehicles have been driving for some time before idling, at least for a few minutes. In cases where vehicles have been parked for a while (say more than an hour) before idling, excess cold start emissions need to be added using cold start emission factors (g/start) published elsewhere.[60] For an explanation of (cold) start versus hot running emissions, see the box below.

Cold start emissions

Vehicle (air pollutant) emissions are significantly elevated in (cold) start conditions. At initial start-up the vehicle engine and emission control systems are cold (ambient temperature), which means more fuel is required and emission control efficiency is reduced and often very low. In contrast, stabilised and low emission hot conditions occur when the vehicle engine, transmission and emission control technologies have reached their optimal operating temperatures (e.g. engine coolant 75-90 °C, catalysts > 200-250 °C).

For instance, in hot running and real-world conditions, three-way catalysts are highly effective in reducing engine-out emissions of CO, HC, (organic) PM and NO_x substantially (emission reduction efficiency > 90%). As a consequence, reduced catalyst efficiency due to cold starts has a large impact on vehicle emission levels.

The literature suggests that, at an ambient temperature of about 20°C, hot running conditions should generally be achieved for all relevant vehicle components (engine, transmission, catalyst) within 15 minutes of driving. However, “light-off” conditions for the catalyst and tight control of the air-to-fuel ratio, which together largely determine the magnitude of cold start emissions, will be achieved much faster than this, i.e. typically within a minute of engine start for modern vehicles and a maximum of a few minutes for older technology vehicles.[23]

After an engine start, a cold catalyst goes through two main stages. In stage 1 the converter gradually heats up by hot exhaust gases, but the reaction rate in the converter is generally low. After a short period of time, the temperature in the converter becomes sufficiently high for the reactions rate to increase and this generates additional heat (exothermic). The temperature and reactions rate then increase dramatically at this point and the converter “lights off”.

Light off is typically defined as the point in time where the catalyst achieves a 50% conversion efficiency. In stage 2, catalyst efficiency progressively improves after light-off conditions are reached as the so-called “light-off front” moves towards the converter outlet. Typically as the catalyst approaches optimal operating temperature, NO_x is the first to reach a high conversion efficiency, followed by CO and then HC. Light-off times have improved substantially with the advent of improved engine and catalyst technology. In comparison with older vehicles, which could take several minutes to achieve light-off conditions, modern vehicles achieve light-off conditions quickly within one to a few minutes.

The Australian on-road vehicle population is about 19 million vehicles.[58] About roughly 15 million are passenger vehicles, 250,000 are large trucks (articulated trucks) and 20,000 are buses (transit, coach). These approximate figures are used to make an initial estimation of total idling emissions for different excessive idling durations (Table 3).

Table 3 – National annual emissions due to extended idling assuming different idle periods.

	PV	Truck	Bus	PV	Truck	Bus
Population	15,000,000	250,000	20,000	15,000,000	250,000	20,000
idle time	NO_x (tonne/annum)			CO_2 (ktonne/annum)		
5 min/day	968	608	62	1,568	56	6
10 min/day	1,936	1,216	124	3,136	112	12
30 min/day	5,807	3,648	372	9,409	337	36
1 h/day	11,615	7,295	743	18,819	674	73
2 h/day	23,230	14,591	1,487	37,637	1,348	145
5 h/day	58,074	36,477	3,717	94,093	3,370	363
10 h/day	116,148	72,955	7,435	188,185	6,740	725

Table 3 presents estimates of total NO_x and CO_2 emissions for each vehicle class assuming certain *extended* idle times. This information can be used to make an initial assessment of the relevance of extended idling on total national emissions:

- In reality, a distribution of extended idling behaviour would exist. For instance, some drivers may hardly idle, others may idle significantly (e.g. 30 minutes per day). A survey would be required to obtain more accurate information regarding extended idling behaviour by Australian drivers.
- For now, an average 5 minute extended idle assumption appears reasonable for passenger vehicles. If every passenger vehicle (PV) in the Australian on-road fleet would idle for 5 minutes per day, then this would result in an additional CO_2 emission load of approximately 1,600 ktonne per year. The Australian Greenhouse Emissions Information System (AGEIS) [56], reports a total CO_2 emission load for 'cars' of 44,170 ktonne in 2017. The average 5 minute extended idle per day assumption for cars would make up about 4% of total national CO_2 emission loads. This is a small contribution, but not insignificant. The contribution changes in a linear fashion with different assumptions on average excessive idling times. If a 10 minute extended idle assumption is used, cars would make up about 8% of total national CO_2 emission loads, etc.
- Assuming a plausible range of 1 to 5 hours extended idle for trucks and buses appears reasonable in the light of overseas data (discussed earlier). Extended idling generates an additional CO_2 emission load of approximately 700 to 4,000 ktonne per year, which equates to about 250,000 to 1,000,000 tonnes of fuel. For heavy-duty trucks and buses (combined), AGEIS reports a total CO_2 emission load of 22,233 ktonne in 2017. The average 1-5 hours extended idle per day assumption for trucks/buses combined makes up about 5-20% of total national CO_2 emission loads (and fuel use) for heavy vehicles. This initial calculation suggests that the contribution of extended idling by trucks and buses is potentially significant and warrants further examination.

7. Conclusions and Concluding Remarks

Idling is ubiquitous and done for various reasons. Some idling is unavoidable, but other idling can be reduced. Idling behaviour and associated environmental impacts have been examined overseas for quite some time, and particularly in North America. In general, Europe has been less interested in idle reduction, and instead has focussed on other measures to reduce fuel consumption and emissions.

The argument to reduce idling to save fuel and reduce greenhouse gas emissions is sound. However, minimizing idling to reduce air pollutant emissions is less convincing due to the importance and additional complexities with emission control technology. The main issue with idle reduction is progressive cooling of the emission control system (catalyst), and potentially increased emissions at re-start. There is only limited information regarding the impacts of catalyst cooling, but it appears that cooling issues may be restricted to certain pollutants (CO, HC, NO_x), vehicle technology (petrol cars), ambient conditions (temperature) and stop periods (approximately 5 to 60 minutes). However, more data are required, particularly because all modern vehicles now have advanced emission control systems.

It appears generally accepted that maintenance costs increase with excessive idling. The impacts of idling on local air quality may or may not be significant. It is logical to conclude that these impacts are in fact a function of idle duration, the number of vehicles, types of vehicles, weather conditions and local geography.

Idle reduction measures have traditionally focussed on diesel buses and trucks, where idling is common practice and most visible. Several options are available to reduce idling, namely driver behaviour change, idle reduction technologies and idle reduction regulation. The literature review suggests that anti-idling initiatives appear to have measurable impacts, at least on idling behaviour.

In Australia no idle reduction initiatives or anti-idling legislation were identified. The use of idle reduction technology in Australian on-road vehicles is also unclear.

An initial assessment of the relevance of idling behaviour on fuel use and emissions from the Australian on-road fleet suggests that the impact of idling emissions on total emission loads may be small, but not insignificant, i.e. 1-8% depending on the vehicle type and pollutant. However, excessive idling could increase this contribution, in particular for heavy-duty vehicles. Information on idling behaviour and use of idle reduction technology in Australia is necessary to make a better assessment.

Idling impacts on local air quality can also be substantially higher in local hot spots (e.g. schools, truck stops), and further analysis is recommended. This report offers relevant emissions input data for such studies.

While many activities contribute to emissions, idling reduction stands out for the potential ease with which it can be altered, at virtually no cost. Drivers simply have to turn their engines off while parked and wait in their vehicle (e.g. when picking children up from school), and perhaps open a window (or windows) to maintain comfortable conditions, if weather conditions allow (not too hot or cold, no rain). While other activities, such as commuting, clearly play a more critical role regarding emissions, engine idling behaviour is far more amenable to being altered.

Fleet operators and logistics companies are in a good position to roll-out idle reduction initiatives and save on operating (fuel) costs. Further, broad public participation in idle reduction initiatives can be used in future campaigns to leverage more meaningful and challenging changes in behaviour. Additionally, reducing engine idling has the added benefit of lowering greenhouse gas emissions, reduce fuel costs, and possibly air pollutant emissions and promoting the health of those individuals who are frequently exposed to emissions from idling engines.

The aim may be to make excessive and unnecessary idling socially unacceptable for all drivers as it is now to litter or drive drunk. Currently, it appears idling is still an accepted part of Australian driving culture and drivers may simply be oblivious about the issues with idling. Changing this culture can only be achieved by increasing public awareness.

8. Recommendations for further work

Since this work was unfunded, the scope was restricted. Below are suggestions for further work.

- A survey into idling behaviour of Australian behaviour (why, when, where, how long).
- An examination of the use of idle reduction technology in vehicles sold in Australia.
- Clarification of the costs and benefits to support action from e.g. government.
- Quantification of idling impacts using the outcomes from the previous recommendations.

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