Australian Government
Department of Infrastructure and Regional Development
Bureau of Infrastructure, Transport and Regional Economics

New passenger vehicle fuel consumption trends, 1979 to 2013

At a glance

The Bureau of Infrastructure, Transport and Regional Economics (BITRE) has examined long-term trends in the fuel consumption of new passenger vehicles[1] sold in Australia. Up to 2005, advances in engine technology, which improved fuel efficiency, were somewhat offset by increases in power, weight and the popularity of four wheel drive (4WD) vehicles. Since 2005 the overall trend in decreased fuel consumption has accelerated, with the average rated fuel consumption of new light vehicles (measured over a standard vehicle approval test)[2] down around 17 per cent to about 7.2 litres per 100 kilometres (L/100 km) for 2013. This information sheet is an update of BITRE (2009) Information Sheet 30 (*Fuel consumption by new passenger vehicles in Australia, 1979-2008*), which was itself an update of the earlier Information Sheet 18 (BTRE 2002, *Fuel consumption by new passenger vehicles in Australia*). Annual values provided in this Information Sheet relate to averages or totals over financial years (years ending June 30).

BITRE New Passenger Vehicle Database

BITRE has recently updated its New Passenger Vehicle Database which includes attributes of all new light vehicle sales, by make and model, back to 1979. While average fuel consumption is the main focus of the database, it also includes time series data on other vehicle characteristics such as engine power, vehicle weight and engine size/performance.

Time series were collated using three main sources:

- data on sales by model, reported by the VFACTS unit of the Federal Chamber of Automotive Industries (FCAI)
- vehicle specifications or characteristics data by model from Glass's Guide (Glass's Research Data, GRD)
- fuel consumption rate data by model from the Australian Government's *Fuel Consumption Guide Database* (http://www.environment.gov.au/settlements/transport/fuelguide/search.html) and Green Vehicle Guide (www.greenvehicleguide.gov.au, hosted by the Department of Infrastructure and Regional Development).

New vehicle sales volumes

Since 2001 annual new light vehicle sales have grown by about 40 per cent, surpassing 1.1 million vehicles sold for the 2013 financial year.

The new vehicle mix has continued some trends that had already become evident by the time of the first Bureau Information Sheet using the New Passenger Vehicle Database (Information Sheet 18, BTRE 2002), namely a decrease in the proportion of passenger cars, with an increase in the all-terrain wagon or sports

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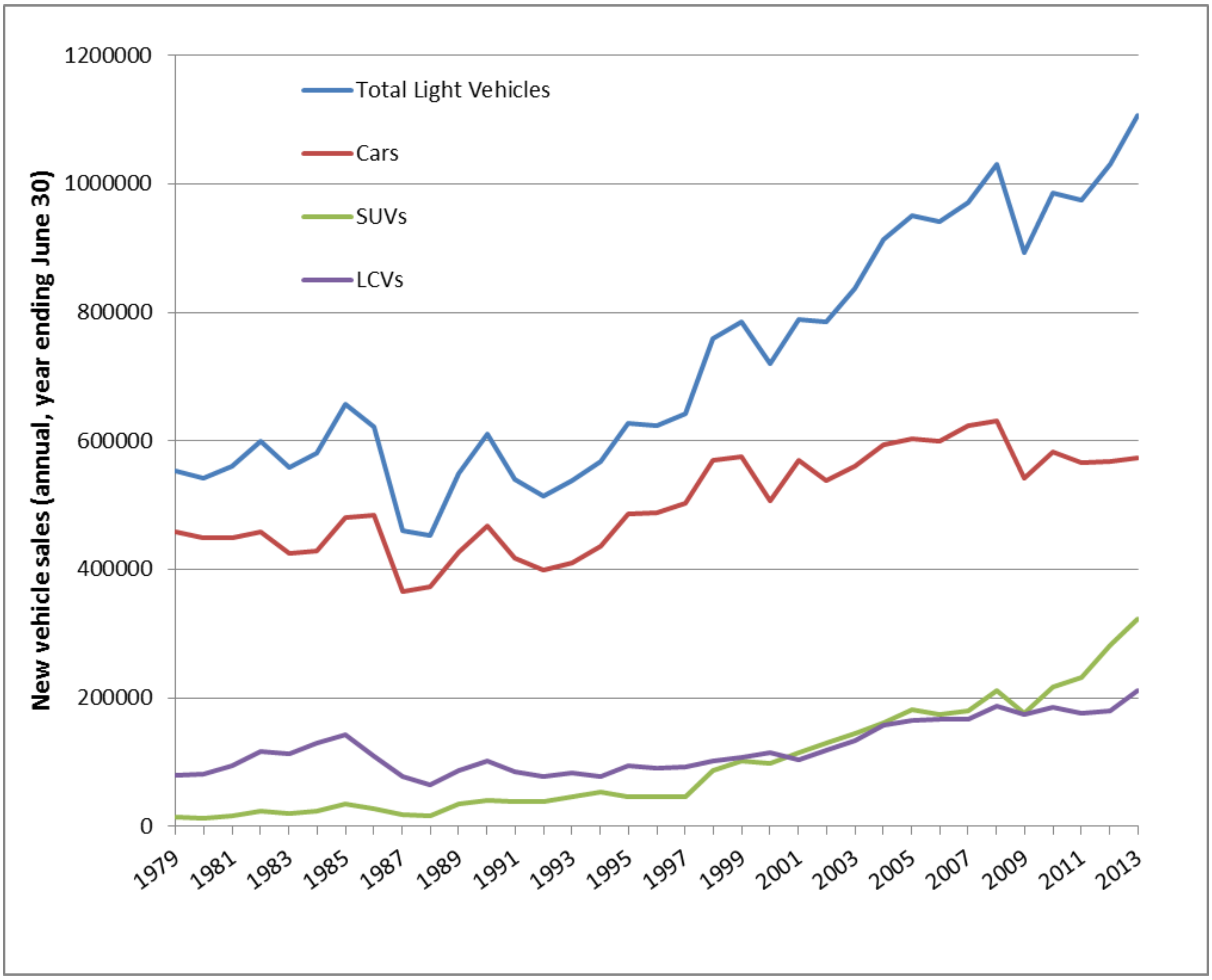
[1] This information sheet deals with sales of all 'light' motor vehicles (all 4-wheeled road vehicles with a gross vehicle mass under 3.5 tonnes); encompassing the categories of cars, all-terrain wagons (ATWs) or sports utility vehicles (SUVs) and light commercial vehicles (LCVs). The sum of the 'cars' and 'SUVs' categories is equivalent to the standard Australian Bureau of Statistics (ABS) category of 'Passenger vehicles'.

[2] Note that the *rated* or *cycle test* fuel consumption values given herein are mostly based on standard laboratory or dynamometer cycle results over the United States Federal Test Procedure (USFTP), which are typically at least 20 per cent lower than actual on-road fuel consumption.

utility vehicle (SUV) category. Between 2001 and 2013, passenger cars have decreased their share from 72 to 52 per cent, SUVs have increased from 15 to 29 per cent and the light commercial vehicle (LCV) share has grown from 13 to 19 per cent.

Figure 1 illustrates the new light vehicle sales in Australia since 1979, showing total sales and subtotals for the various light vehicle categories.

Figure 1: New light vehicle sales in Australia, 1979–2013



Notes: Includes sales of all light motor vehicles (all 4-wheeled road vehicles with a gross vehicle mass under 3.5 tonnes); divided here into subtotals for the categories of Cars, All-Terrain Wagons or Sports Utility Vehicles (SUVs), and Light Commercial Vehicles (LCVs) such as utilities and panel vans.

Sources: Federal Chamber of Automotive Industries (FCAI) VFACTS (various issues), BTRE 2002, BITRE 2009 and BITRE estimates.

Average fuel consumption rates for new vehicle sales

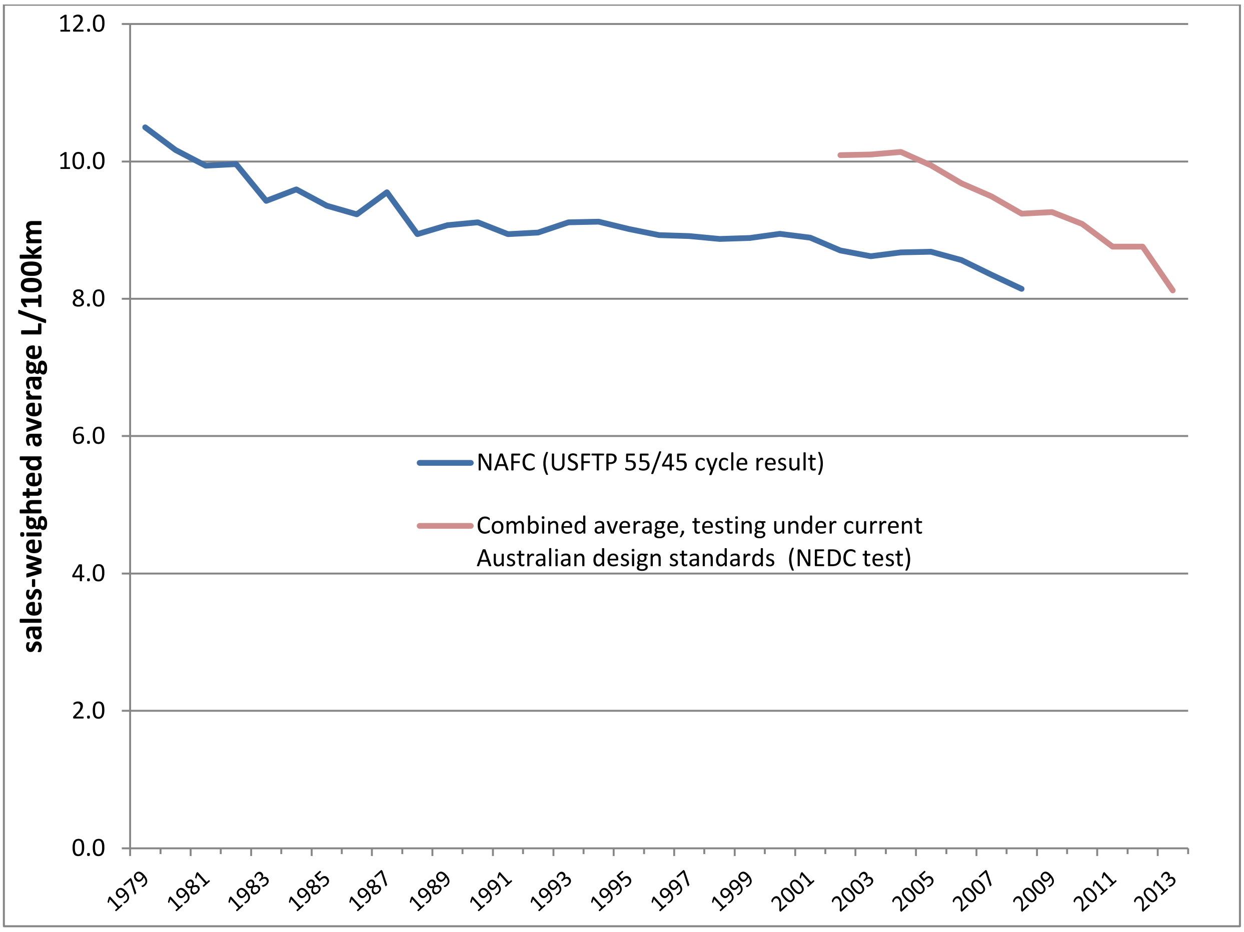
The BITRE New Passenger Vehicle Database records fuel consumption rates over various 'city' and 'highway' laboratory test cycles, as reported over time by the Green Vehicle Guide or Glass's Research Data. Historically, National Average Fuel Consumption (NAFC) values were calculated for new vehicle sales using combined city-highway fuel and emission test cycle results over the standard United States Federal Test Procedure (USFTP), weighted by sales volumes. These test cycle results (which applied to Australian vehicle design standards up until around 2002) were combined by a weighting of 55 per cent 'city' and 45 per cent 'highway' fuel consumption rate values.

Note that these weighted test cycle values (standard laboratory or dynamometer test results over the specified USFTP cycles, with NAFC weighted at the 55/45 ratio for the city/highway tests) tend to be at least 20 per cent lower than actual average on-road fuel consumption.

After 2002, regulatory test values for fuel economy (and CO_2 emissions) of new passenger vehicles in Australia generally involve 'combined' test results over the New European Driving Cycle (NEDC)[3]. This more recently adopted test consists of an 'urban' phase or cycle (lasting 13 minutes, which attempts to represent conditions found in stop-start traffic) and an 'extra-urban' driving cycle (lasting 6 minutes 40 seconds, which involves the vehicle accelerating to a high peak speed)[4]. The weighting of the urban and extra-urban results, to determine the full 'combined' test result, is based on the simulated distances for these two phases of the overall cycle.

The Green Vehicle Guide currently reports fuel consumption values (in litres of fuel consumed per 100 kilometres driven, L/100km) tested over the NEDC. See Figure 2a for a demonstration of how average fuel consumption rates calculated using the more recent combined cycle results (over the NEDC test) are considerably higher than for the previous NAFC trend (with tests performed over the older USFTP combined cycle).

Figure 2a: Rated National Average Fuel Consumption by Australian new light vehicles, over different test cycles



Note: Values relate to average *rated* fuel consumption, sales-weighted – tested over a) USFTP cycle (with NAFC value equal to 55% urban result and 45% highway result), where average on-road consumption is typically at least 20% higher; and b) over NEDC test, which generally gives results more comparable to actual on-road performance.

Sources: BITRE estimates, Green Vehicle Guide, Glass's Research Data.

[3] The NEDC test is specified in United Nations Economic Commission for Europe (UNECE) regulations setting out procedures for determining fuel consumption and CO_2 emissions from light vehicles. The NEDC is a driving cycle that attempts to better represent typical on-road driving conditions than previous regulatory test cycles. Though tests over the NEDC are generally closer to real world results than for the USFTP cycle, they will still typically underestimate on-road levels; and research into test cycles that give even more realistic representations of actual average driving conditions are on-going.

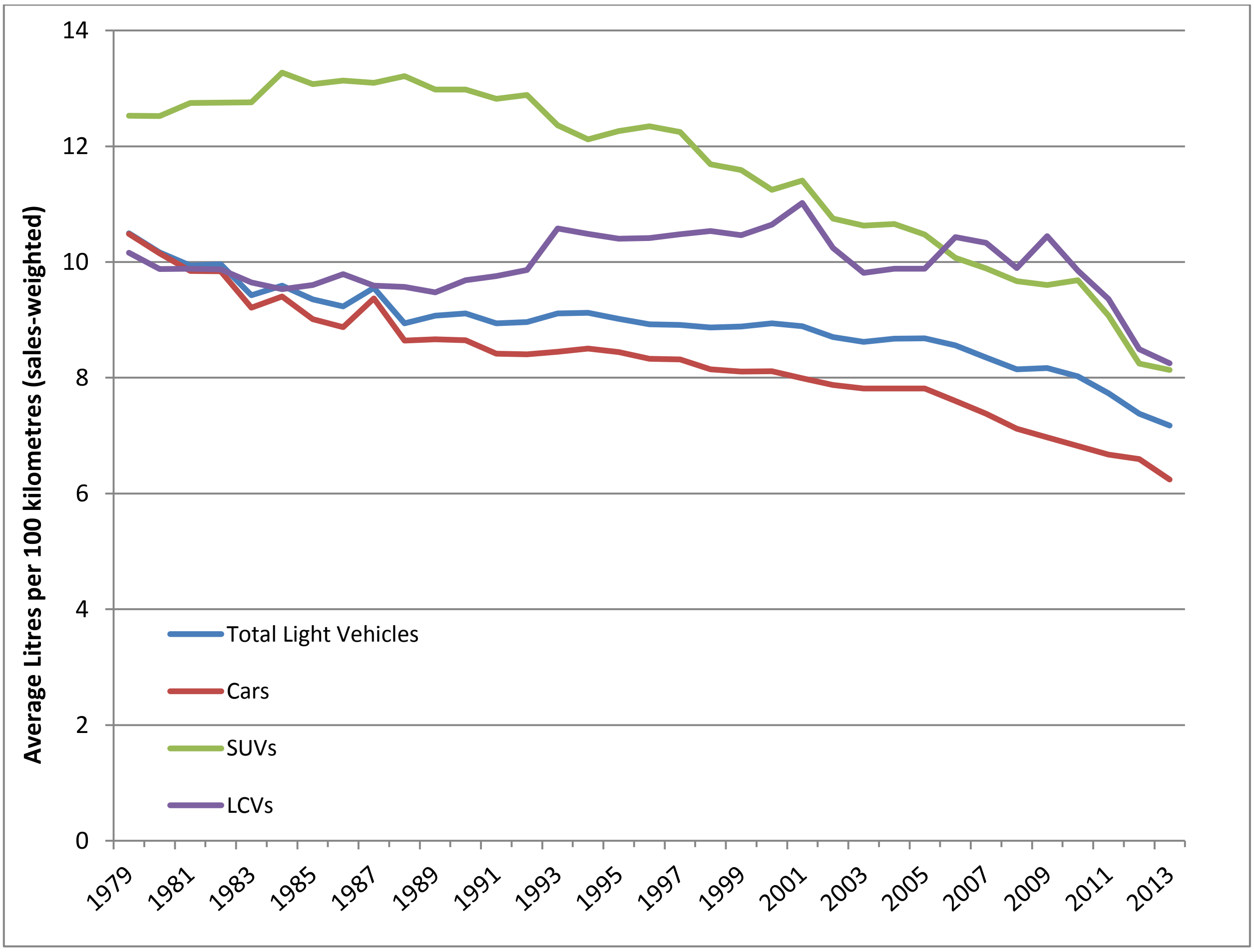
[4] Vehicles generally have considerably higher fuel consumption over the 'urban' phase of the test cycle, which features a low average speed (19 km/hr), substantial idle periods and frequent stop-start events; compared to the 'extra-urban' component, which has a relatively high average speed (63 km/hr) and a peak speed of 120 km/hr (even though it is not a typical 'highway' cycle since it does not maintain a relatively constant speed over an extended period of time).

Note that even though these higher NEDC combined test values are considerably closer to achieving 'real world' driving results, they are still typically lower than the average L/100km levels most drivers will get in actual traffic. It appears that up until recent years, most cars would be expected to average around 2-4 per cent higher on-road than their rated (NEDC) test result (or about 19-22 per cent higher than a corresponding rated result over the USFTP 55/45 cycle test result). There is some evidence that this gap has widened over time (particularly amongst recent European models/makes – see ICCT 2012, 2014), with the divergence between fuel consumption for combined (NEDC) test results and actual average Australian driving possibly more like 5-10 per cent for some newer models (with an equivalent widening for any derived NAFC/USFTP L/100km estimates based on such NEDC *type-approval* results).

For some summary values of typical variations, between fuel consumption results, over the two tests/procedures (for different phases of the combined USFTP cycle and the combined NEDC/UNECE standard) see Figure 9 of Information Sheet 30 (BITRE 2009). This comparison chart demonstrates that the newer combined test (NEDC/UNECE) tends to give results approximately equal to the older (USFTP) test's 'city' component.

In order to present on-going time-series for average fuel intensity across the new fleet, the NAFC L/100km values, derived for previous years from the BITRE New Passenger Vehicle Database (lower curve in Figure 2a, using test results over the USFTP 55/45 city/highway cycles), have been continued over recent years using a proportional scaling of the Database's averaged NEDC values (combined cycle results, upper curve in Figure 2a).

Figure 2b: Rated National Average Fuel Consumption by Australian new light vehicles, by type of vehicle, 1979–2013



Note: Values relate to average *rated* fuel consumption, sales-weighted – i.e. up to about 2002 tested over USFTP cycle (with NAFC value equal to 55% urban result and 45% highway result), where average on-road consumption is typically at least 20% higher; and scaled since then using trend results over the NEDC test.

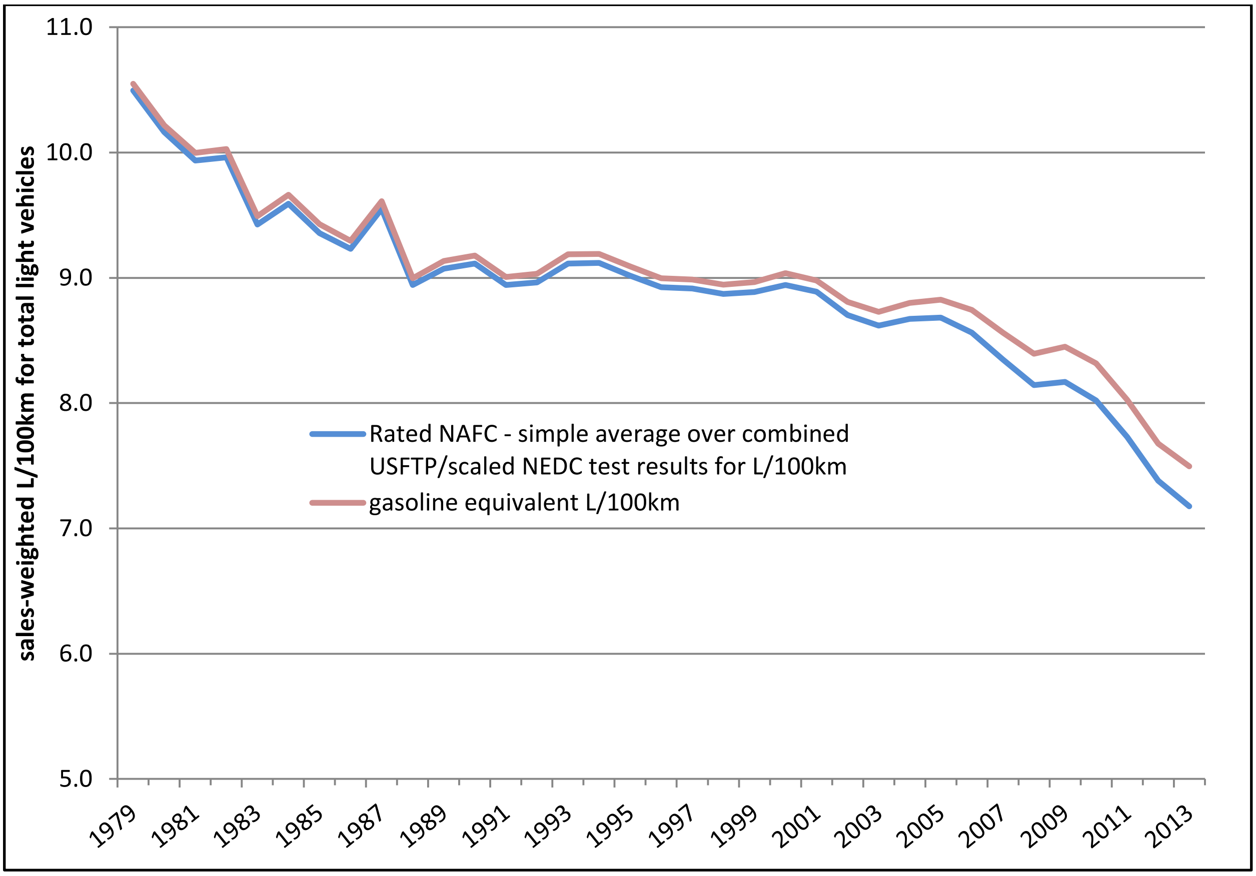
Sources: BITRE estimates, Green Vehicle Guide, Glass's Research Data.

Figure 2b shows the resulting estimates of sales-weighted NAFC trends, for the various light vehicle categories, since 1979. Average rated fuel intensity, across total light vehicle sales, has declined by close to 1 per cent per annum over the last three decades[5].

Overall, new passenger cars have continued a downward trend in rated fuel consumption, with a somewhat steeper downward trend after about 2004. Similarly, SUV rated fuel intensities have declined noticeably, possibly due to the emergence and popularity of the 'compact' and 'medium' SUVs. The LCV category, although somewhat volatile, was relatively flat to 2007 but since 2008 has joined in the downward trend. Note that a possible widening, over recent years, of the gap between rated L/100km (measured by test cycles) and average on-road consumption levels means that perhaps not the full extent of the displayed *rated* decreases will be obtained during actual real-world driving.

Part of the derived NAFC L/100km levels, and their overall declines shown in Figure 2b, are in fact due to how these particular values are calculated – that is, by purely summing across all vehicle makes, without separating vehicle models by fuel type. Relatively few new vehicles are currently fuelled by other than petrol (automotive gasoline) or diesel (automotive diesel oil) – with less than half a per cent of 2013 new light vehicle sales due to LPG or electric vehicles. Yet the substantial numbers of new light diesel vehicles sold annually – which have grown from a share of about 8 per cent of 2002 sales to about 31 per cent by 2013 – can have a significant impact on averages across fuel consumption values, particularly for the SUV and LCV categories.

Figure 2c: Rated National Average Fuel Consumption by Australian new light vehicles, with adjustments for fuel energy content, 1979–2013



Note: Values relate to average *rated* fuel consumption, sales-weighted across all fuel types – i.e. up to about 2002 tested over USFTP cycle (with NAFC value equal to 55% urban result and 45% highway result) and scaled since then using trend results over the NEDC test. 'Gasoline equivalent L/100km' averages have been adjusted to allow for the higher energy content per litre of diesel over petrol.

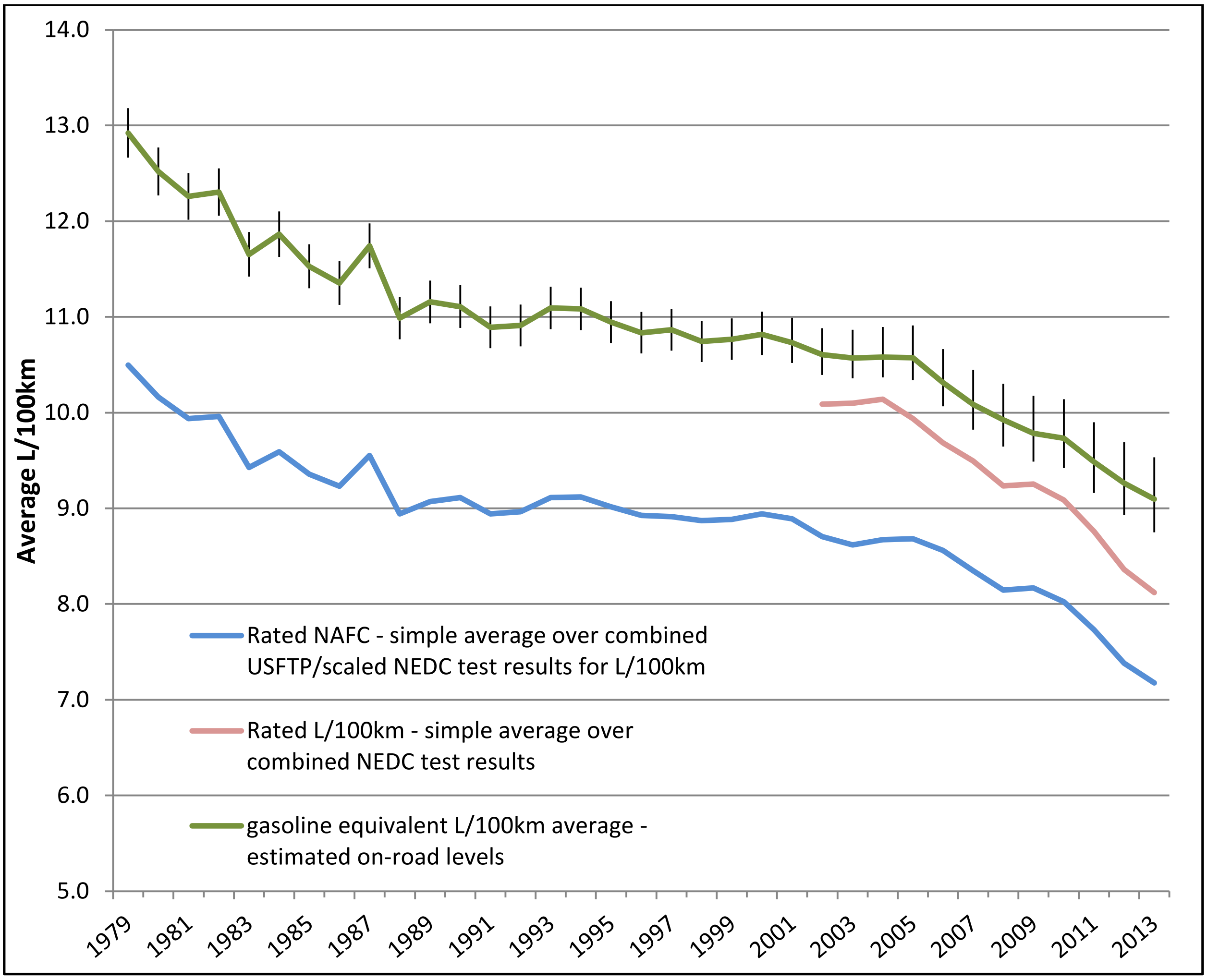
Sources: BITRE estimates, FCAI VFACTS, Green Vehicle Guide, Glass's Research Data.

[5] Note that even though the curves in Figure 2b are useful for exhibiting rough overall trends, the changes to the regulatory cycle tests – along with other fleet characteristics altering over time (such as the increasing penetration of light diesel vehicle sales, where diesel has a higher energy content per litre than gasoline) and the afore-mentioned possibility of the gap between test results and on-road consumption widening over recent years – complicate making precise comparisons of new vehicle fuel efficiency over the decades.

Diesel has a higher energy density (Joules per litre) than petrol, so – in energy consumption terms – L/100km for a diesel vehicle is not directly comparable with L/100km for a petrol vehicle (where estimation of CO_2 emission rates is also impacted by this issue, since the carbon content of diesel is also higher than petrol). Figure 2c shows how values calculated for average fleet fuel consumption rates can alter if this energy content difference is taken into account, where the 'Total light vehicles' trend from Figure 2b (calculated by a simple average of tested L/100km across all makes, irrespective of fuel type) is contrasted with estimated 'gasoline equivalent L/100km' of the new light fleet (i.e. where the tested L/100km values for diesel vehicles, in the USFTP sales-weighted summation, have been scaled by the proportional difference in the unit energy contents of diesel and petrol). In such gasoline equivalent terms, the fuel consumption average across the new light fleet is noticeably higher, especially from about 2002 onwards.

Besides fuel type variations, the other main factor complicating trend analyses over time (in fleet fuel consumption performance) is the difference between test results (as plotted in Figures 2a-2c) and actual on-road L/100km. The typical size of this gap is only roughly quantified and, as mentioned above, the size of the divergence has possibly been growing over recent years (see ICCT 2012, 2014)[6].

Figure 2d: Average fuel consumption of Australian new light vehicles, comparison of test cycle results with on-road estimates, 1979–2013



Notes: Sales-weighted values for rated fuel consumption refer to dynamometer tests over USFTP cycle (55% urban and 45% highway results) and over NEDC test (combined urban and extra-urban cycle results).
Estimates of actual on-road fuel performance (in terms of gasoline equivalent L/100km) are based on BITRE vehicle fleet modelling, where error bars provide an indication of possible uncertainty in the level determination.

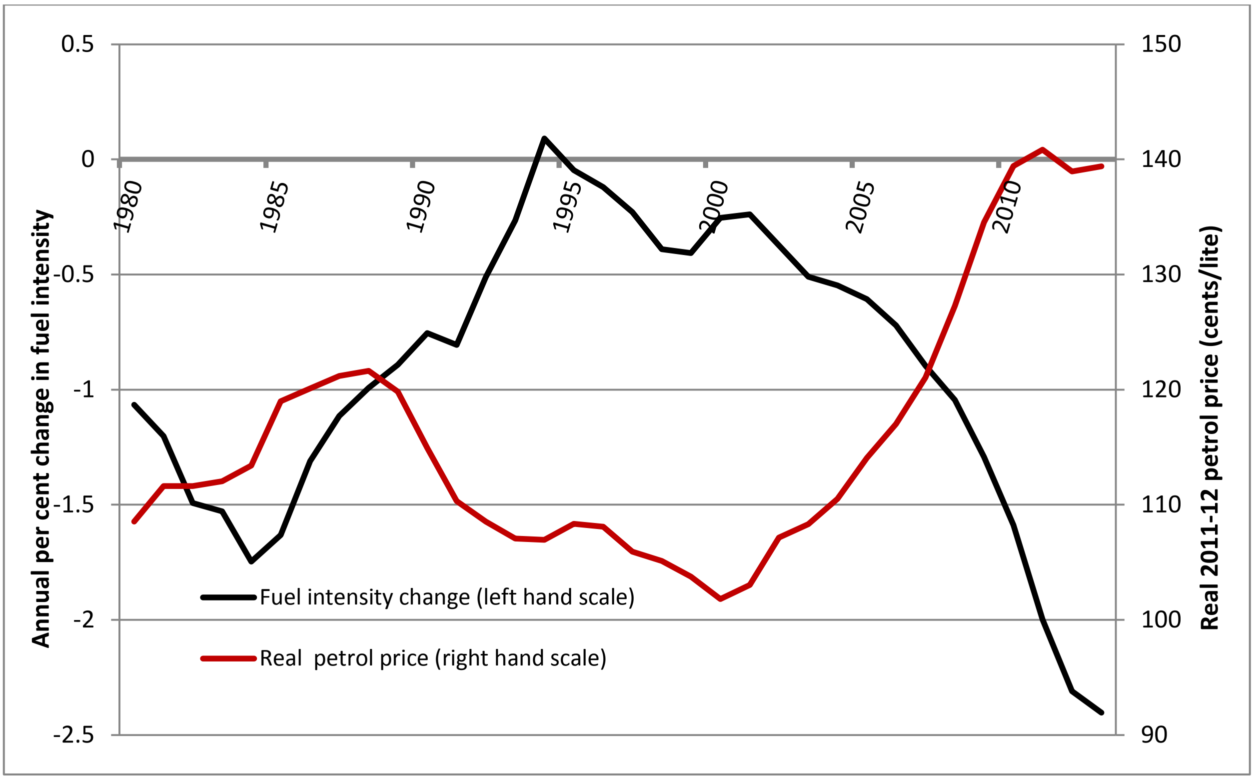
Sources: BITRE estimates, BITRE 2010, Green Vehicle Guide, Glass's Research Data.

[6] For some discussion around various factors that can contribute to this possibly expanding gap between standard ('type approval') cycle test results and actual on-road fleet performance – and the probable magnitude of such divergences experienced for European vehicle sales over the last decade or so – see TNO 2012.

Figure 2d displays a comparison of the rated L/100km estimates for new light vehicle sales – for the NAFC (USFTP-based) series (i.e. blue trend-line from Figures 2c and 2b) and the higher NEDC test results (pink trend-line from Figure 2a) – with values derived from BITRE fleet modelling (using the trend series in new sales volumes and their rated fuel intensity, coupled with data on total fuel sales) for probable on-road consumption levels. The upper (green) trend-line gives average gasoline equivalent L/100km estimates for the on-road performance of new light vehicles (cars, SUVs and LCVs) – where error bars on the estimated trend are provided to give an indication of the likely uncertainty in these values (noting that the spread of the error margin expands somewhat over recent years, due to various factors – discussed in ICCT 2014 and TNO 2012 – that can lead to the gap widening between type-approval cycle test results and actual on-road fuel consumption).

Figure 3 shows the degree, for the Australian light vehicle market, of a roughly inverse relationship between fuel consumption choices and fuel prices – by plotting smoothed annual percentage declines in the estimated rated fuel intensity of total light vehicle sales (using Figure 2b) and smoothed real petrol prices (moving average for years preceding the sales then chosen). In general, when real petrol prices are relatively high, as in the early 1980s and in the period since 2004, declines in the average fuel intensity of new vehicle sales accelerate, mainly through buyers shifting to smaller, more fuel-efficient vehicles.

Figure 3: Change in average fuel intensity of sales versus fuel price trend



Note: Percentage change values relate to those for average *rated* fuel consumption (type-approval cycle tested L/100km), sales-weighted across all fuel types – where annual changes in actual on-road fuel performance may not always be quite as significant.

Source: BITRE estimates.

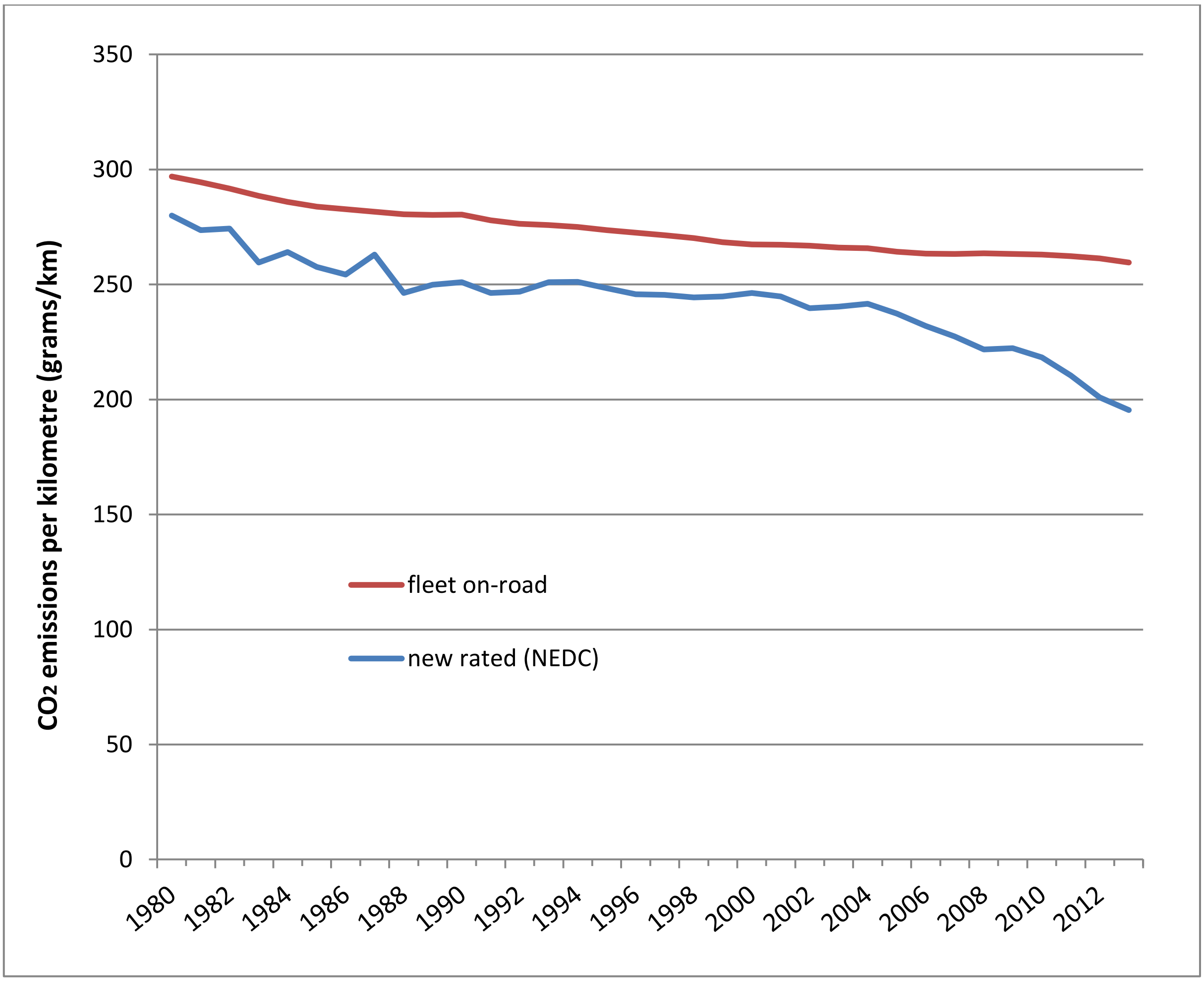
CO_2 emissions for light vehicles

BITRE estimates (based on sales-weighted combined NEDC carbon dioxide test results for recent years and by appropriately scaling the NAFC trends given in Figure 2b for previous years) indicate an overall drop in rated CO_2 emissions intensity of new light vehicles of about 30 per cent from 1980 to 2013, with CO_2 emissions for new light vehicles (over the NEDC test) falling to about 195 grams per kilometre (see Figure 4).

The rated CO_2 values derived for the last few years (right hand side of Figure 4's blue trend-line) can be compared with similar results, for new light vehicles, given in a recent National Transport Commission (NTC 2014) report and in the Federal Chamber of Automotive Industries' *Annual Report 2013* (FCAI 2014).

Figure 4 also displays values for the average on-road CO_2 emissions of the entire light vehicle fleet (estimated from BITRE fleet modelling) – which are higher than the new vehicles' rated values (partially due to on-road levels being higher than for dynamometer tests and since the majority of the fleet is composed of older vehicles).

Figure 4: Average carbon dioxide emissions for Australian light vehicles



Notes: The 'new rated' emission values are sales-weighted dynamometer results over the NEDC test (combined urban and extra-urban cycle), which will be relatively close to (though generally slightly understating) average on-road performance.

Estimates for the actual on-road CO_2 emission rate (g/km) of the entire light vehicle fleet are based on BITRE modelling and fuel sales data.

Sources: BITRE estimates, BITRE 2010, Green Vehicle Guide.

Light vehicle power and weight trends

Through the 1980s and 1990s, the passenger car category of new vehicle sales had (with some fluctuations at various times) a generally increasing trend in both power and gross vehicle mass (GVM)[7]. Over the last decade, these trends have plateaued and even shown slight declines (with some downsizing within new car choices, especially after 2006, following increases in fuel prices). Apart from a few fluctuations, the average

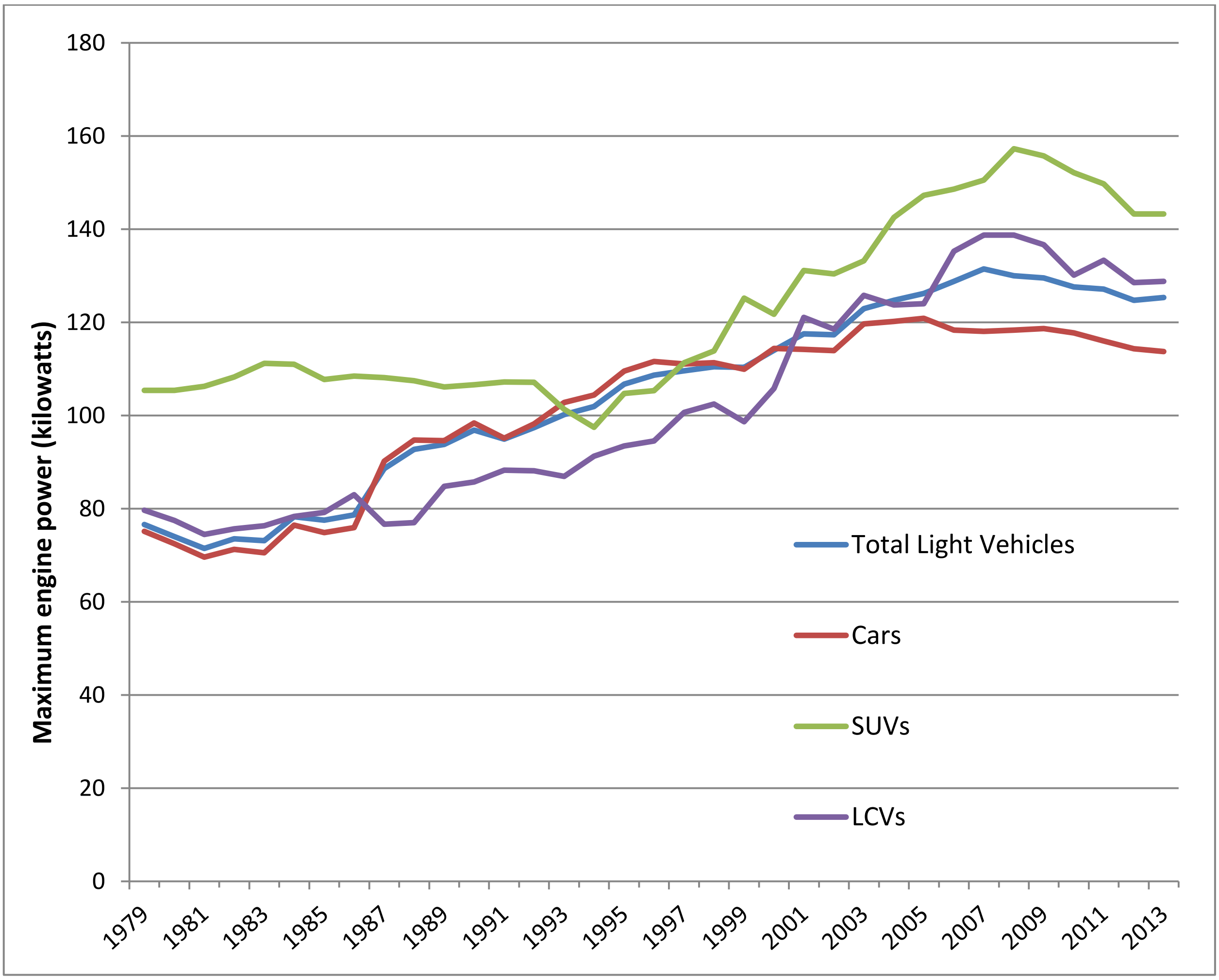
[7] Due to data consistency issues (especially around reporting of vehicle weight specifications over time for a representative sample of vehicle models), average GVM estimates are only very approximate (particularly so for the 'car' category) – making any trend analyses involving vehicle weights quite rough.

GVM of LCV sales has tended to gradually increase for most of the last 30 years; with sales-weighted averages for maximum engine power output generally increasing up to about 2008, but showing some declines thereafter. The SUV category also exhibited a mostly increasing trend in maximum power output, from the mid-1990s to about 2008, with a decline in the average power rating over the years since 2008. Average GVM for SUVs has had periods of both increase (such as from 2001 to 2008) and fall (such as from the mid-1990s to 2001 and following 2008), with current values not greatly different from averages for the 1980s.

Decreases in the sales-weighted power rating of new light vehicles, from about 2009 on, have accompanied some of the declines in rated fuel intensity evident in Figure 2b.

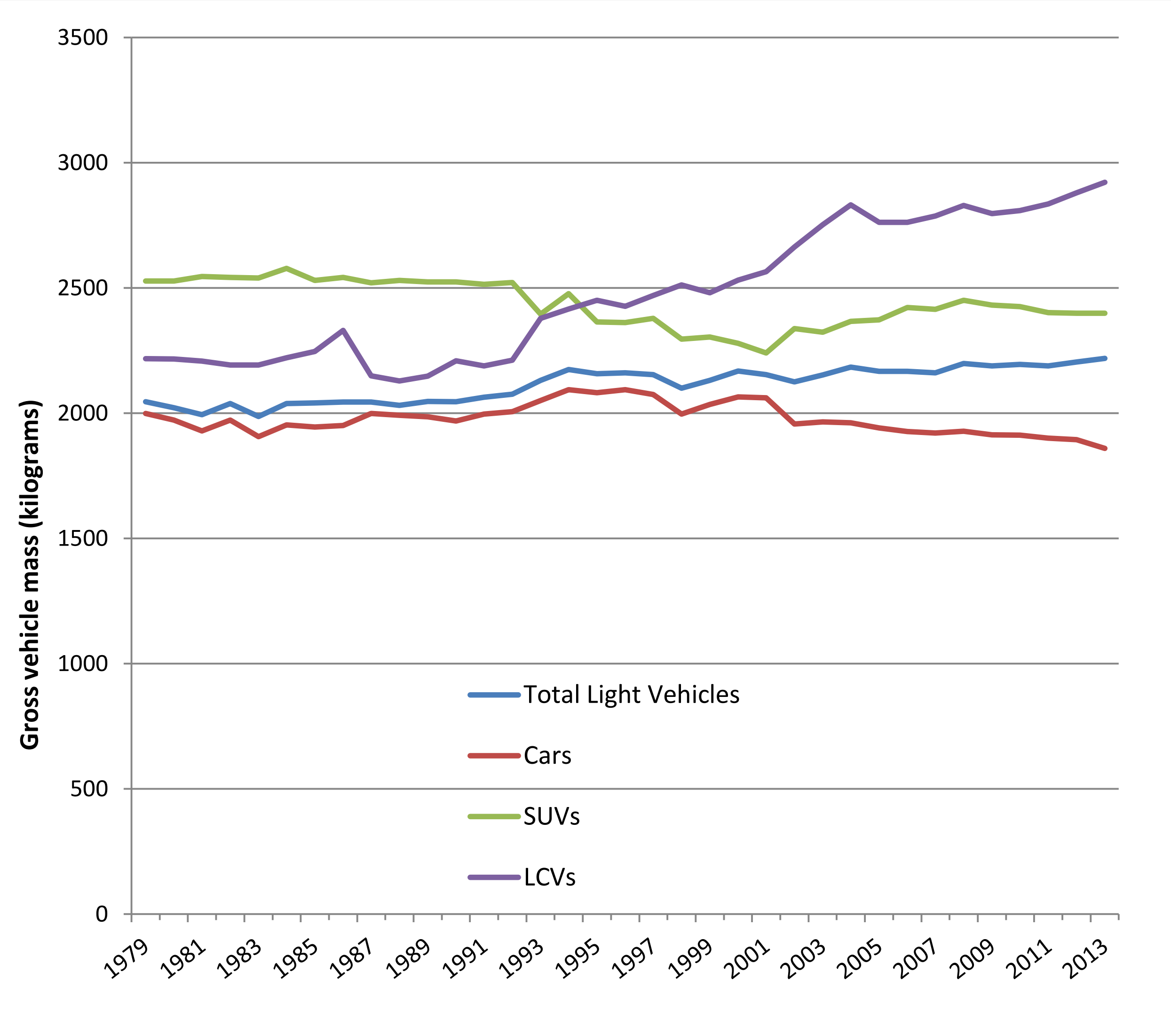
Figure 5 presents the movements over time in engine power rating for new light vehicle sales; and Figure 6 shows the estimated trends in average vehicle weight (GVM).

Figure 5: Maximum power output for new light vehicles in Australia



Sources: BITRE estimates, BITRE 2009, Glass's Research Data.

Figure 6: Average weight for new light vehicles in Australia



Note: Gross Vehicle Mass (GVM) values only very approximate, with possible breaks in series.

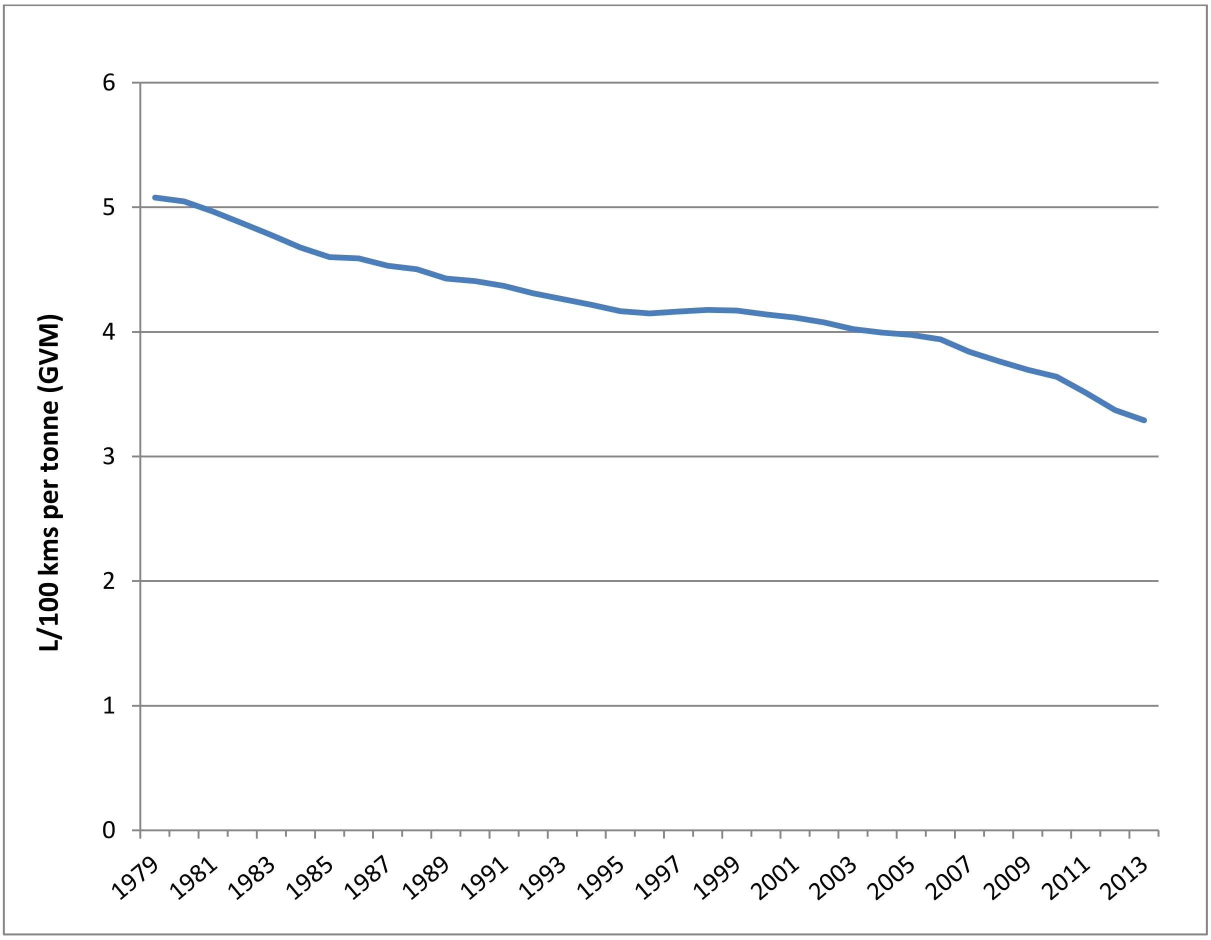
Source: BITRE estimates, BTRE 2002, BITRE 2009, Glass's Research Data.

Intrinsic engine performance

Engine technology has advanced considerably over time. Figure 7 illustrates an element of this trend, by plotting the average fuel consumption rate for total light vehicle sales (L/100 km) per unit of vehicle weight (GVM in tonnes).

The trend plotted in Figure 7 points to a significant increase in the underlying energy performance of vehicle engines over time, with the amount of fuel required to move a vehicle of a given size declining at about 1.3 per cent per year over the last three decades. Since this overall rate of decline is significantly faster than that for average L/100km across new light vehicle sales (as plotted in Figure 2c), it would appear that vehicle purchasers have often chosen to trade some of these intrinsic technology improvements for higher performance in other areas (such as acceleration, load/towing capacity, interior space or more auxiliary equipment) rather than it being fully utilised for fuel consumption reductions.

Figure 7: Engine performance trend for new light vehicles in Australia



Note: Smoothed values.

Source: BITRE estimates (using values from Figures 2b and 6), BITRE 2009.

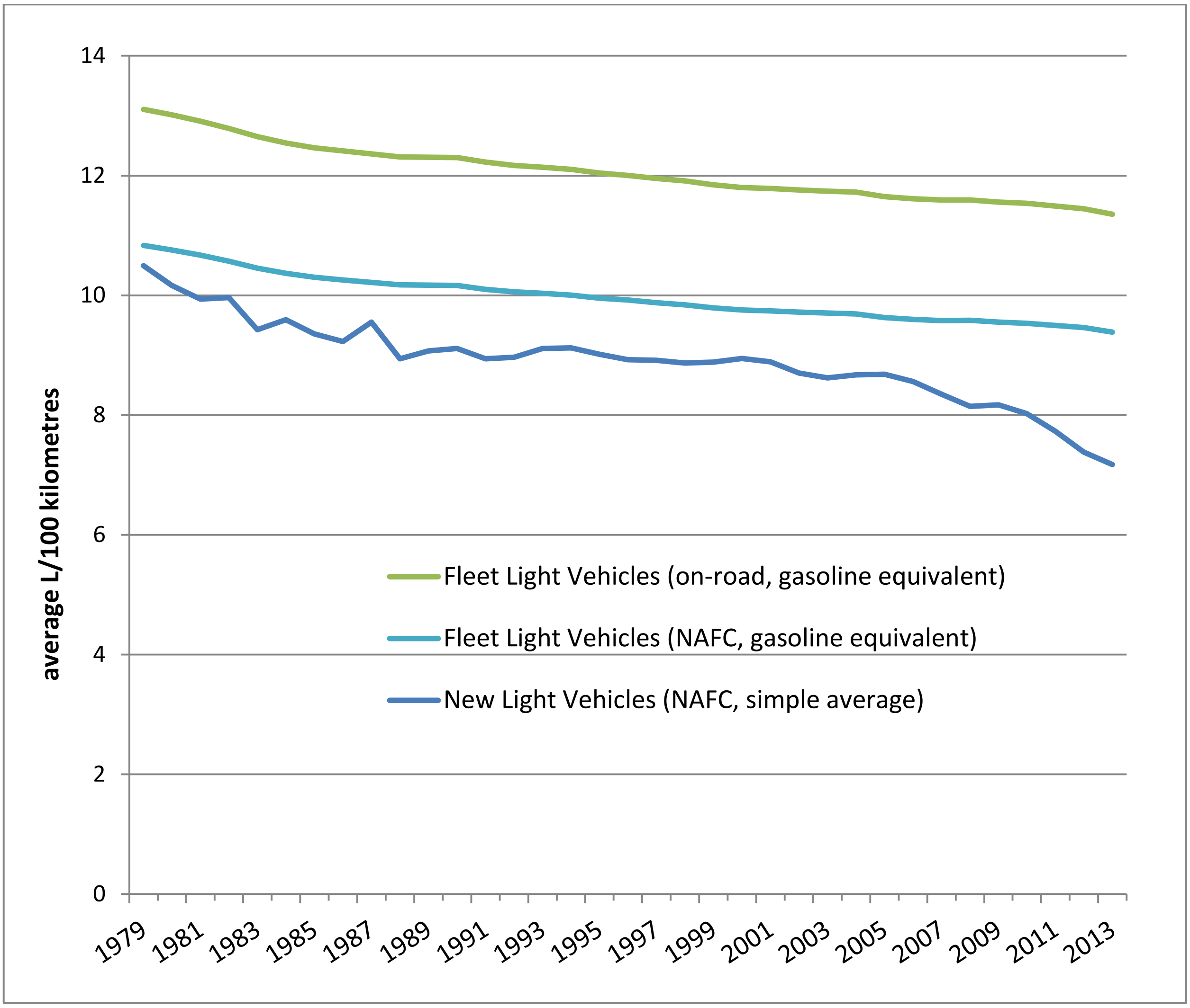
Performance of entire light vehicle fleet

The fuel intensity of the new light vehicle fleet obviously has consequences for the performance of the entire light vehicle fleet. Figure 8 presents new light vehicle average fuel consumption (rated L/100km values over the USFTP combined cycle, from Figure 2b) together with estimates of the entire light vehicle fleet average fuel intensity. Two series are given for comparison with the new vehicle NAFC results – the upper series, green trend-line, being estimates of actual on-road fuel intensity for the full light vehicle fleet, and below that, light blue trend-line, rough estimates for an equivalent 'rated' level (i.e. what that full fleet would probably attain if tested under NAFC conditions, using test results from the combined USFTP cycle).

The new light vehicle average rated fuel consumption has dropped a total 29 per cent since 1980 (slightly greater than 1 per cent per year decrease), whereas the fuel intensity of entire light vehicle fleet has decreased a total of about 12.8 per cent (about 0.4 per cent per year). The current rated value for the L/100km of the entire light vehicle fleet is similar to (though slightly higher than) the new light vehicle fleet rated value in 1993, indicating an approximately 20 year lag before then new vehicle levels are wholly reflected in overall fleet performance.

These 'rated' values for fleet intensity are based on the traditional 55/45 city/highway split for the USFTP cycle calculation, which typically underestimates actual on-road fuel performance by at least 20 per cent. Also, in the real world, vehicle engines tend to deteriorate with time, with some such defects leading to noticeable increases in fuel consumption rates. As well, average real world driving tends to involve stronger acceleration/deceleration patterns than the standard cycle specifications, more use of accessories (such as air conditioning) and higher on-board loads than during standard vehicle approval testing. The combination of such factors means that the actual on-road fuel intensity of the light vehicle fleet is considerably greater than for the new rated values (see Figure 8).

Figure 8: New and entire fleet light vehicle fuel consumption rates, Australia



Note: NAFC estimates based on levels returned by drive cycle test values (over combined USFTP) as opposed to actual on-road fuel use.

Sources: BITRE estimates, BTRE 2010, Green Vehicle Guide, Glass's Research Data.

Conclusion

The trends evident in BITRE's earlier Information Sheet (BITRE 2009) have continued since 2008. Vehicle sales have increased, with the SUV and LCV categories continuing to increase their shares. With the introduction of compact and more fuel-efficient 4WDs, the growing SUV category has shown a considerable reduction in rated fuel consumption. LCV sales have also been increasing, though not as strongly as SUVs, along with a similarly decreasing level (since about 2006) in rated fuel consumption.

In the past (before 2008), Australian consumers' preference for vehicle characteristics that typically increased fuel consumption (such as higher power, larger size, more accessories or 4WD capability), meant that potential reductions in fuel consumption made possible by technological advances were not fully realised (see Thoresen 2008). This has been a worldwide trend in the automobile sector. However, that said, the long-term downward trend in energy intensity has increased in recent years as the latest generation of more fuel efficient light vehicles (including hybrids) entered the market, and with some buyers moving to smaller vehicles as petrol prices rose. The result has been a marked acceleration, over recent years, of the downward trend in the rated fuel consumption (tested L/100km) of new vehicles sold.

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Use of the Coat of Arms

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