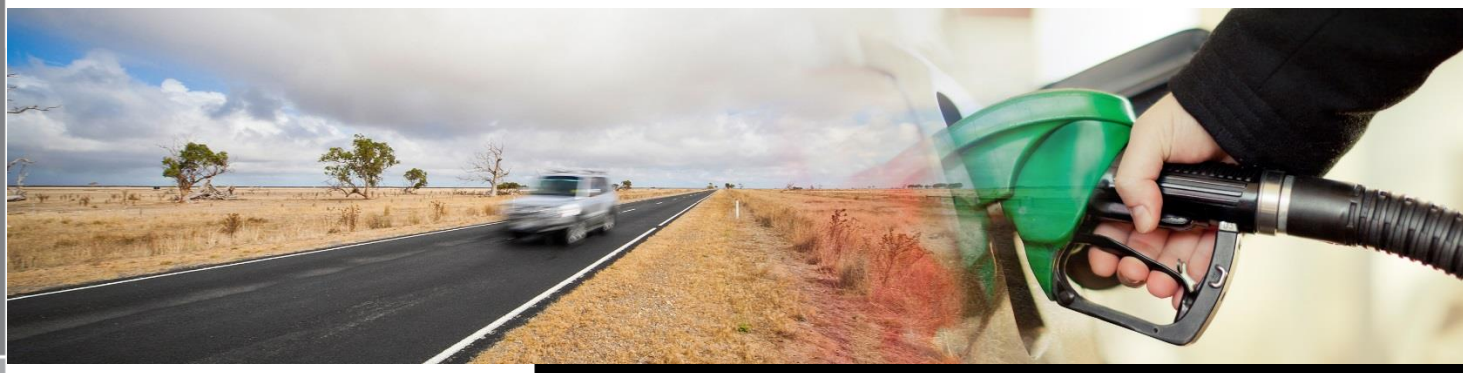
Australian Government
Department of Infrastructure and Regional Development
Bureau of Infrastructure, Transport and Regional Economics



Fuel economy of Australian passenger vehicles – a regional perspective

At a glance

- According to the ABS *Survey of Motor Vehicle Use* (SMVU), the average rate of fuel consumption of passenger vehicles was 11.9 litres per 100 kilometres (l/100km) in 2000 and has trended downwards since then to reach 10.6 l/100km in 2016. Motorcycles are more fuel efficient, using 5.6 l/100km in 2016, down from a peak of 6.5 l/100km in 2007.
- Based on the ABS 2016 *Census of Motor Vehicles*, petrol vehicles comprise about 87 per cent of the stock of passenger vehicles, compared to 11 per cent for diesel vehicles and 2 per cent for LPG/dual fuel vehicles. The diesel-fuelled passenger vehicle fleet is relatively new, with 52 per cent of diesel vehicles manufactured after 2010, compared to 29 per cent of petrol-fuelled passenger vehicles and 14 per cent of LPG/dual fuel passenger vehicles. The great majority of LPG and dual fuel passenger vehicles have six or more cylinder engines (91 per cent), while four cylinder engines are the major category for both petrol and diesel passenger vehicles (69 per cent each).
- Average rates of fuel consumption rise steadily with the number of cylinders for passenger vehicles. Vehicles with 1 to 3 cylinders had relatively low rates of fuel consumption (7.7 l/100km) in 2016, compared to 10.0 l/100km for 4 cylinder vehicles, 11.7 l/100km for 6 cylinder vehicles, and 12.9 l/100km for vehicles with 8 or more cylinders.
- Older model vehicles tend to have higher rates of fuel consumption, with passenger vehicles made in 2000 or earlier averaging 11.4 l/100km, compared to 10.3 l/100km for vehicles made in 2011 or later. While post-2000 model diesel vehicles tend to be more fuel efficient than post-2000 model petrol vehicles, for older passenger vehicles, average rates of fuel consumption are significantly higher for diesel vehicles than for petrol vehicles (12.2 l/100km versus 10.9 l/100km). Average rates of fuel consumption are relatively high for 'LPG, CNG, dual fuel, hybrid and other' passenger vehicles (11.1 l/100km).
- There is minimal variation in the fuel economy of passenger vehicles by state of registration, with the six states and the Northern Territory all having average rates of fuel consumption of between 10.0 and 11.0 l/100km. The Australian Capital Territory has the least fuel-intensive passenger vehicles (averaging 9.7 l/100km), reflecting a higher than average proportion of smaller vehicles (with 4 or less cylinders) and recent model vehicles in its vehicle fleet.
- The literature identifies significant discrepancies between official test results and real-world fuel consumption, and the discrepancies appear to be increasing over time. Real-world fuel consumption is affected by many factors that have little to do with the vehicle, including weather, driving behaviour (e.g. average speed, speed change), road environment (e.g. quality of road surface, congestion) and driver demographics (e.g. gender, age).

- BITRE's small area estimates of the average rate of fuel consumption are based on the characteristics of the passenger vehicle and motorcycle fleet in each region (i.e. vehicle type, fuel type, number of cylinders, year of manufacture). This approach is consistent with the literature (e.g. Li et al. 2013, Lindsey et al. 2011, Oregon Department of Transportation 2013), except that BITRE's estimates reflect actual rates of fuel consumption for each type of vehicle, rather than official test results. The small area estimates were produced at both the Statistical Area 3 and 4 (SA3 and SA4) scale.
- The small area estimates of the average rate of fuel consumption range between 10.3 and 10.8 l/100km across the 87 SA4s. This limited variation across regions is consistent with previous studies. Regional residents drive vehicles that are slightly (0.7 per cent) less fuel-efficient, on average, than their urban counterparts, reflecting the greater prevalence of large passenger vehicles (with 6 or more cylinders) and older model vehicles in regional Australia.
- BITRE's small area estimates show that the SA4s with the least fuel-efficient vehicles are SA Outback, WA Wheatbelt, North West VIC, Barossa-Yorke-Mid North SA and Shepparton VIC. The SA4s with the most fuel-efficient vehicles are Brisbane Inner City QLD, Brisbane West QLD, Sydney City and Inner South NSW, Sydney Eastern Suburbs NSW and Brisbane South QLD. Inner city residents tend to have lower average rates of fuel consumption than middle and outer suburban residents, due to the greater prevalence of small vehicles in inner city areas.

Background

This information sheet presents Australian data on how realised rates of fuel consumption vary over time, and how the rates depend on key vehicle characteristics such as number of cylinders, fuel type and vehicle age. It includes a review of the literature on key drivers of the average rate of fuel consumption.

The measures presented in this information sheet relate to those vehicle types that are largely owned and operated by households (i.e. passenger vehicles, motorcycles). The key data sources are the Australian Bureau of Statistics (ABS) *Survey of Motor Vehicle Use* (SMVU) 2016 and the ABS *Census of Motor Vehicles* 2016.

This information sheet also investigates state/territory differences in fuel economy[1] and presents new small area estimates of the average rate of fuel consumption for Australia's regions. These small area estimates are based on the composition of the passenger vehicle and motorcycle fleet in the region, and are derived at both the Statistical Area Level 3 (SA3) and Statistical Area Level 4 (SA4) scale.

BITRE Information Sheet 86 (*Spending by Australian households on owning and operating vehicles*) explored how household spending on motor vehicle fuel (and other vehicle-related expenditure) varies across different types of regions. It revealed, for example, that average weekly household expenditure on motor vehicle fuel is much higher in rural areas ($65), than it is for the average Australian household ($47) (BITRE 2017a). Potential contributors to this higher spend include rural households facing higher fuel prices, travelling greater distances and/or achieving worse fuel economy. The current information sheet builds on the previous research by quantifying spatial differences in average rates of fuel consumption across 332 Australian regions.

In the Australian context, rates of fuel consumption are typically measured in litres of fuel per 100 kilometres travelled (l/100km).

Australian data on average rates of fuel consumption

This section is based on the ABS *Survey of Motor Vehicle Use* for the 12 months ended 31 October 2016, including both the published data from ABS Cat. 9208.0 and customised tabulations purchased from ABS. Some time-series comparisons are made between the results of this survey and its predecessors.

The SMVU is a vehicle-based survey (not a household survey). The survey's scope comprises all vehicles that were registered with a state or territory motor vehicle authority for road use during the 12 month period

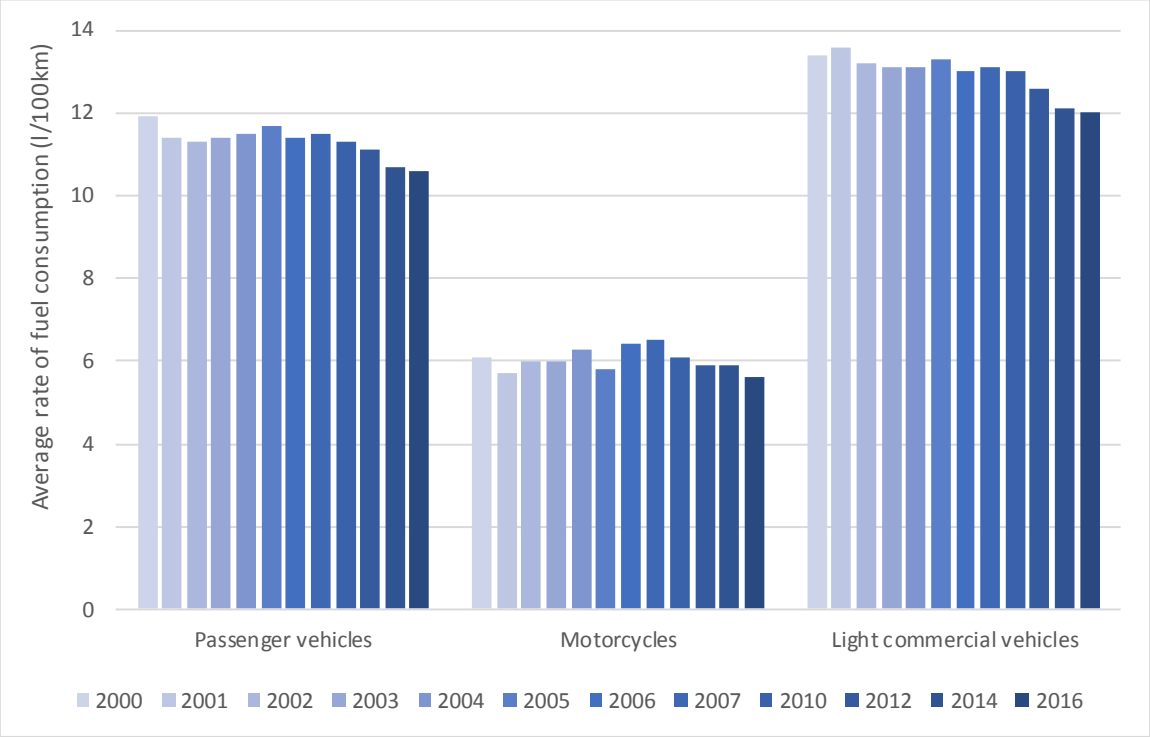
[1] The terms 'fuel economy' and 'fuel efficiency' are commonly used to refer to the average rate of fuel consumption.

(excluding vehicles belonging to the defence services and vehicles with diplomatic or consular plates, and vehicles registered as vintage or veteran cars). The ABS *Census of Motor Vehicles* as at 31 January 2015 provides the survey frame. A total of 16 000 vehicles were selected for inclusion in the SMVU 2016, of which 22.7 per cent were passenger vehicles or motorcycles.

The average rate of fuel consumption across all Australian vehicles in 2016 was 13.1 l/100km. However, this includes buses and trucks which are overwhelmingly used for business purposes.[2] Given that this study is focused on the vehicle costs of Australian households (and not businesses), Figure 1 presents the average rate of fuel consumption for the three types of vehicles which have significant private use, namely passenger vehicles, motorcycles and light commercial vehicles. Motorcycles are relatively fuel efficient using 5.6 litres of fuel per 100 km travelled in 2016, compared to 10.6 l/100km for passenger vehicles and 12.0 l/100 km for light commercial vehicles.

Figure 1 reveals that the average rate of fuel consumption of passenger vehicles was 11.9 l/100km in 2000 and has shown a trend decline since then to reach 10.6 l/100km in 2016. The average rate of fuel consumption of light commercial vehicles has displayed a similar pattern of gradual decline over the 2000 to 2016 period, while the average rate of fuel consumption of motorcycles declined between 2007 and 2016.

Figure 1 Average rate of fuel consumption by vehicle type, Australia, 2000 to 2016



Source: BITRE analysis of ABS Cat. 9208.0 *Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016* and earlier issues of this publication.

BITRE's research relates to the spending of Australian households on owning and operating private vehicles, including their fuel spending (see BITRE 2017a). The SMVU captured 13.71 million passenger vehicles, 825 000 motorcycles and 2.98 million light commercial vehicles in 2016. The SMVU does not provide information on whether these vehicles are owned by a household or business, but it does report how kilometres travelled are split between business use, travel to and from work, and personal/other use for each type of vehicle. Business use comprises only a small proportion of the total use of motorcycles (7 per cent) and passenger vehicles (19 per cent), but represents the majority of light commercial vehicle use (59 per cent). With light commercial vehicles being primarily used for business purposes, the operating costs are likely to be borne mainly by

[2] Business use comprises 94-100 per cent of total kilometres travelled by buses, rigid trucks, articulated trucks and non-freight carrying trucks.

businesses rather than households. Consequently, light commercial vehicles have been excluded from the remainder of BITRE's fuel consumption analysis, which covers just two types of vehicles: motorcycles and passenger vehicles.

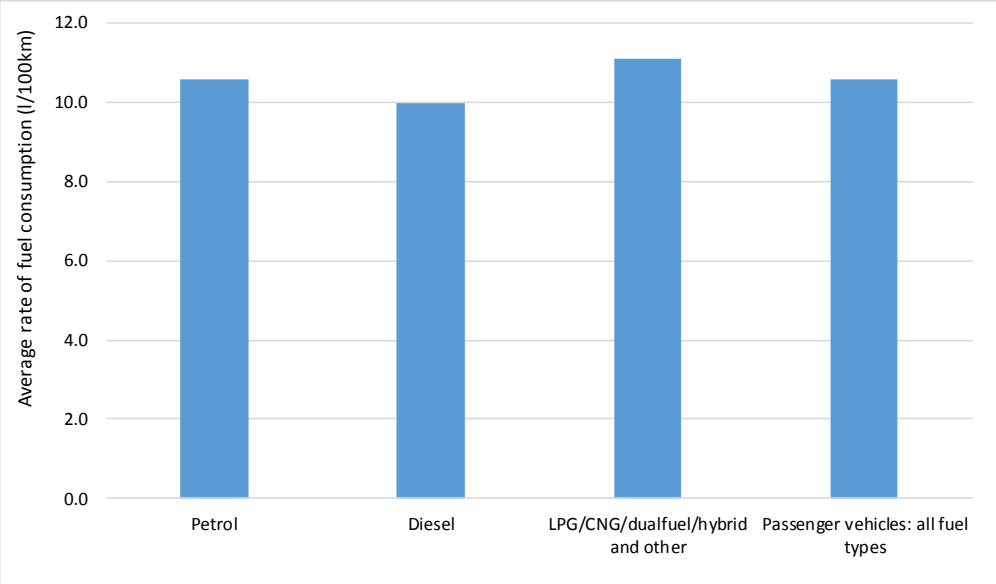
Of course, some households will own light commercial vehicles (e.g. utes, panel vans) and use them for private travel, while some passenger vehicles will be owned by businesses and used principally for business travel. For this reason, BITRE's estimates of the average rate of fuel consumption across the total stock of passenger vehicles and motorcycles can only provide a guide to the average rate of fuel consumption of the household-owned vehicle stock.

Across the total stock of passenger vehicles and motorcycles, the average rate of fuel consumption was 10.5 l/100 km in 2016. This compares to 10.8 l/100 km across the total stock of passenger vehicles, motorcycles and light commercial vehicles.

Fuel economy and key vehicle characteristics

Figure 2 shows the average rate of fuel consumption of passenger vehicles by fuel type. Petrol vehicles have higher average rates of fuel consumption (10.6 l/100km) than diesel vehicles (10.0 l/100km). However, average rates of fuel consumption are highest for the combined category of 'LPG, CNG, dual fuel, hybrid and other' passenger vehicles (11.1 l/100km).

Figure 2 Average rate of fuel consumption of passenger vehicles by fuel type, Australia, 2016



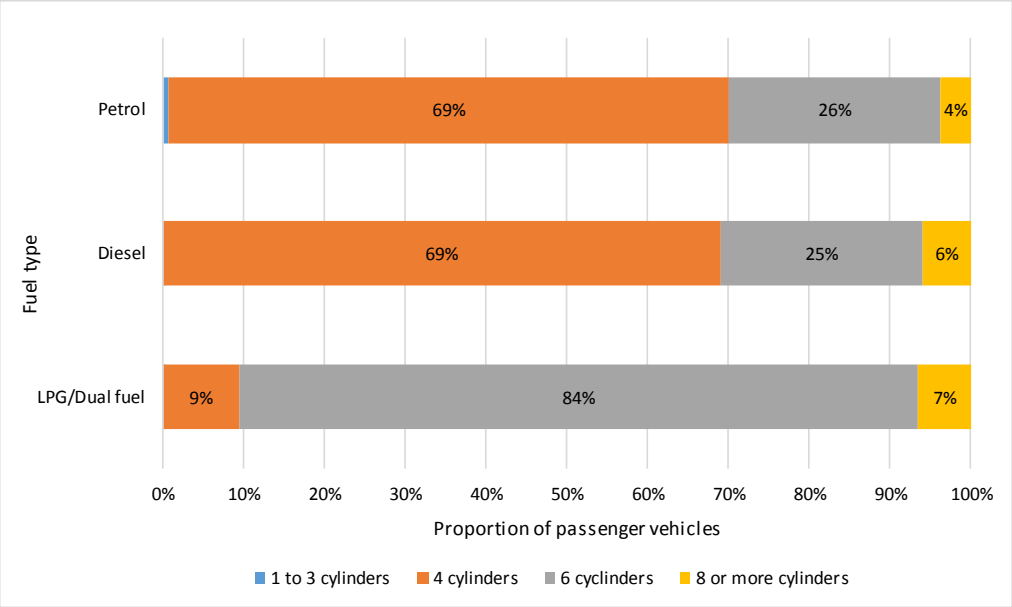
Note: Motorcycles could not be disaggregated by fuel type, as they overwhelmingly used petrol.
Source: BITRE analysis of ABS Cat. 9208.0 *Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016.*

Based on the 2016 *Census of Motor Vehicles*, petrol vehicles comprise about 87 per cent of the stock of passenger vehicles, compared to 11 per cent for diesel vehicles and 2 per cent for LPG/dual fuel vehicles.[3] The results in Figure 2 are influenced by the different characteristics of petrol, diesel and LPG/dual fuel vehicles. Figure 3 shows passenger vehicles disaggregated by the number of cylinders and fuel type, and reveals that the great majority of LPG and dual fuel vehicles have six of more cylinder engines (91 per cent). In contrast, four cylinder vehicles are the major category for both petrol vehicles and diesel vehicles (69 per cent each). Figure 4 shows passenger vehicles disaggregated by year of manufacture and fuel type, and reveals that the diesel vehicle fleet is relatively new, with 52 per cent of diesel vehicles manufactured in 2011 or after, compared to

[3] There were around 5000 electric passenger vehicles, comprising 0.04 per cent of the total passenger vehicle fleet. About 38000 passenger vehicles (0.28 per cent of the passenger vehicle fleet) were classified as having an 'other' or 'unknown' fuel type.

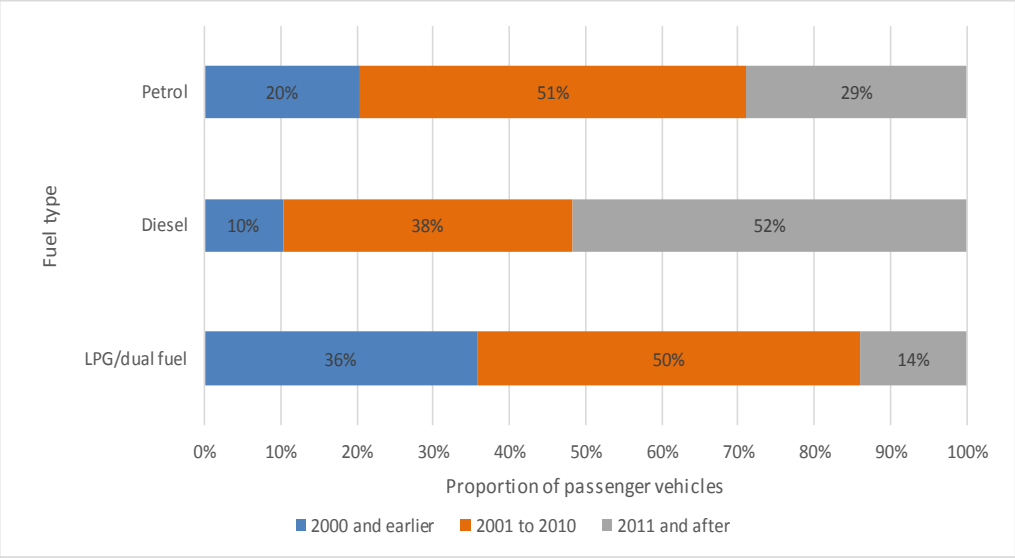
29 per cent of petrol vehicles. The LPG/dual fuel vehicle fleet is relatively old, with 36 per cent of vehicles manufactured in 2000 or earlier, compared to 20 per cent of petrol vehicles and 10 per cent of diesel vehicles.

Figure 3 Proportion of passenger vehicle stock by number of cylinders and fuel type, Australia, 2016



Notes: Excludes electric and other fuelled vehicles. Excludes vehicles with rotary-powered engines and non-responses/other responses to the number of cylinders question.
Source: BITRE analysis of ABS *Census of Motor Vehicles, 2016* (using Tablebuilder).

Figure 4 Proportion of passenger vehicle stock by year of manufacture and fuel type, Australia, 2016

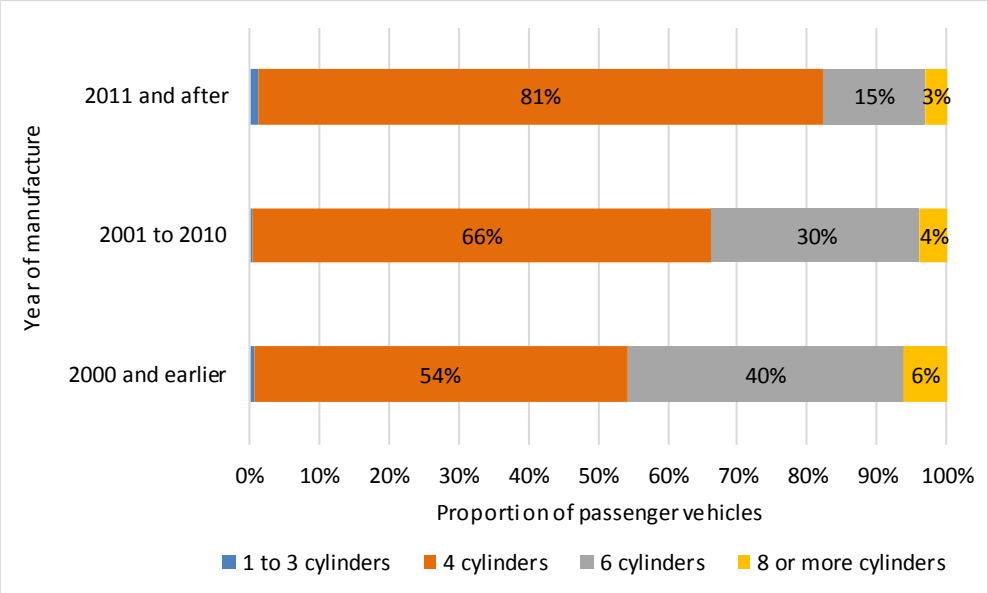


Notes: Excludes year of manufacture not stated.
Source: BITRE analysis of ABS *Census of Motor Vehicles, 2016* (using Tablebuilder).

Additional customised SMVU data purchased from ABS (see Table 1) shows that while post-2000 model diesel vehicles tend to be more fuel efficient than post-2000 model petrol vehicles, for older passenger vehicles, average rates of fuel consumption are significantly higher for diesel vehicles than for petrol vehicles (12.2 l/100km versus 10.9 l/100km).

Figure 5 shows passenger vehicles disaggregated by year of manufacture and the number of cylinders. While 54 per cent of the 2000 and earlier model passenger vehicle fleet had 4 cylinders, this proportion increased to 81 per cent for post-2010 model vehicles. Six cylinder vehicles represented a much larger proportion of the pre-2001 fleet (40 per cent), than of the post-2010 fleet (15 per cent). In recent years, smaller (i.e. more fuel-efficient) passenger vehicles have gained popularity due to high petrol and diesel prices, particularly between 2007 and 2013 (for details, see BITRE 2017b).

Figure 5 Proportion of passenger vehicle stock by year of manufacture and the number of cylinders, Australia, 2016



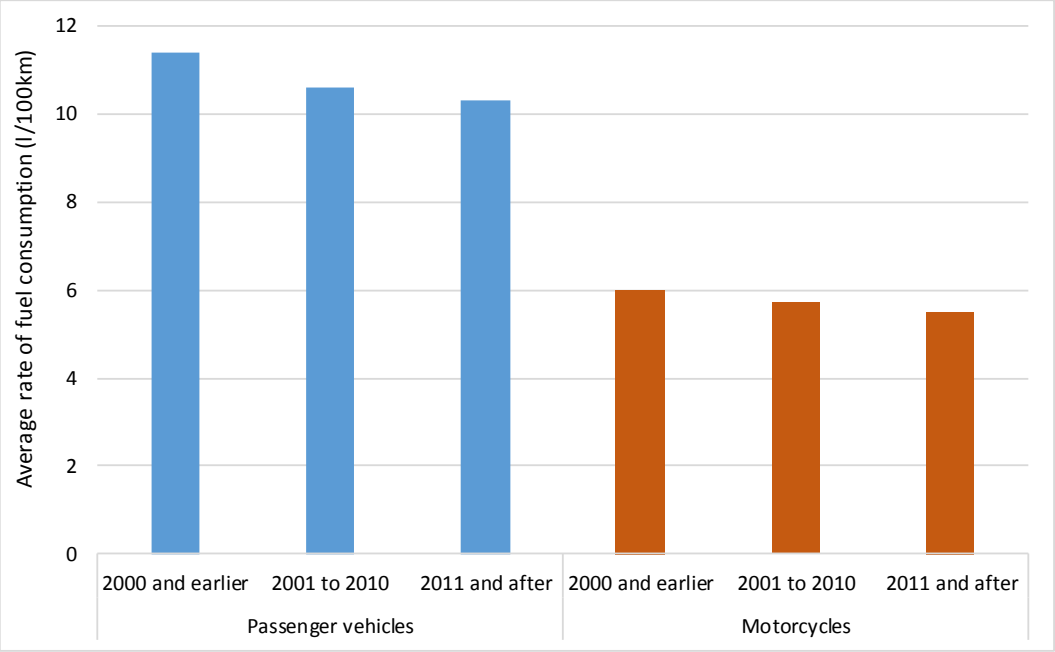
Notes: Excludes 'Other, not stated and rotary powered vehicles' from cylinder category. Excludes year of manufacture not stated.
Source: BITRE analysis of ABS Motor Vehicles Census, 2016 (using TableBuilder).

Figure 6 shows the influence of the year the vehicle was manufactured on the average rate of fuel consumption. Older passenger vehicles have the highest rates of fuel consumption (11.4 l/100km for 2000 and earlier model vehicles) and there is a significant improvement in fuel economy across the three vehicle age categories, with vehicles made in 2011 or later consuming 10.3 l/100km on average. A similar pattern is evident for motorcycles, with the oldest motorcycles having the highest rates of fuel consumption (6.0 l/100km) and the newest motorcycles having the lowest rates of fuel consumption (5.5 l/100km).

At the time of the 2016 *Census of Motor Vehicles*, about 20 per cent of passenger vehicles were manufactured in 2000 or earlier, while 49 per cent were manufactured between 2001 and 2010 and 31 per cent were manufactured during or after 2011.[4] The year of manufacture split for motorcycles was very similar, with 19 per cent manufactured in 2000 or earlier, 48 per cent manufactured between 2001 and 2010 and 32 per cent manufactured during or after 2011.[5]

[4] Year of manufacture information was missing for only 0.1 per cent of the passenger vehicle fleet (16 100 vehicles).
[5] Year of manufacture information was missing for 0.9 per cent of the motorcycle fleet (7600 motorcycles).

Figure 6 Average rate of fuel consumption by year of manufacture and vehicle type, Australia, 2016



Source: BITRE analysis of ABS Cat. 9208.0 *Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016*.

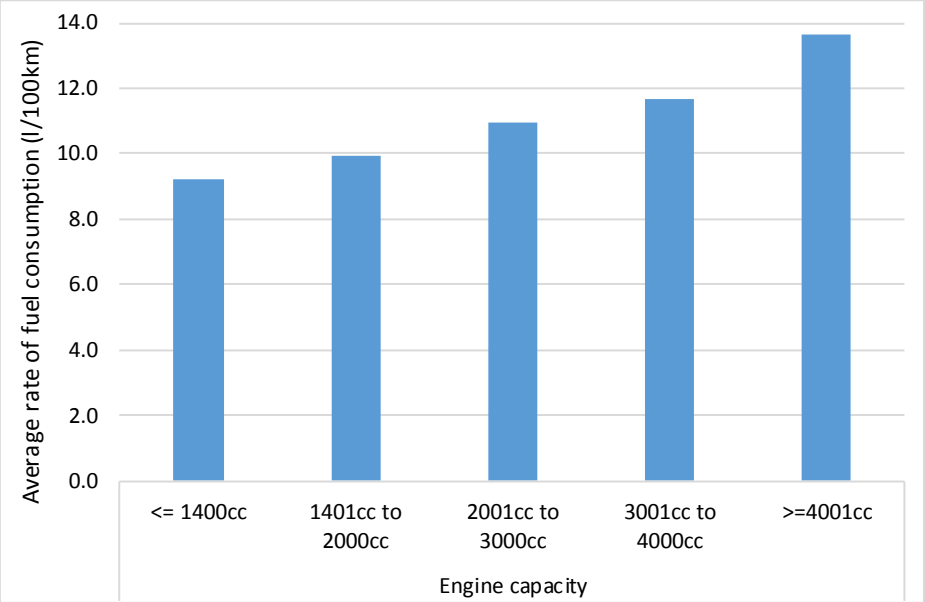
Engine capacity is an important influence on a vehicle's average rate of fuel consumption (Wang at al 2015). The number of cylinders is a proxy for engine capacity that has a similar influence on the average rate of fuel consumption. Figure 7 shows how the average rate of fuel consumption of passenger vehicles depends on engine capacity in 2014, while Figure 8 shows the relationship between the average rate of fuel consumption of passenger vehicles and the number of cylinders in 2016.

As of 2014, vehicles with an engine capacity of less than 1.4 litres had the lowest rates of fuel consumption (9.2 l/100km), with rates of fuel consumption rising steadily as engine capacity increases, with vehicles with an engine capacity of more than 4 litres having very high rates of fuel consumption (13.7 l/100km) (Figure 7). According to the 2016 *Census of Motor Vehicles*, most Australian passenger vehicles for which engine capacity information was available[6] have an engine capacity of 1401 to 2000cc (44 per cent) or 2001 to 3000cc (27 per cent), with only 5 per cent of passenger vehicles having an engine capacity of 4001cc or more.

In 2016, vehicles with 1 to 3 cylinders have relatively low rates of fuel consumption (7.7 l/100km), and rates of fuel consumption rise steadily with the number of cylinders, reaching a maximum of 12.9 l/100km for vehicles with eight or more cylinders (Figure 8). According to the 2016 *Census of Motor Vehicles*, the majority (67 per cent) of Australian passenger vehicles have 4 cylinders, with 27 per cent having 6 cylinders, and only 4 per cent of passenger vehicles having 8 or more cylinders.[7]

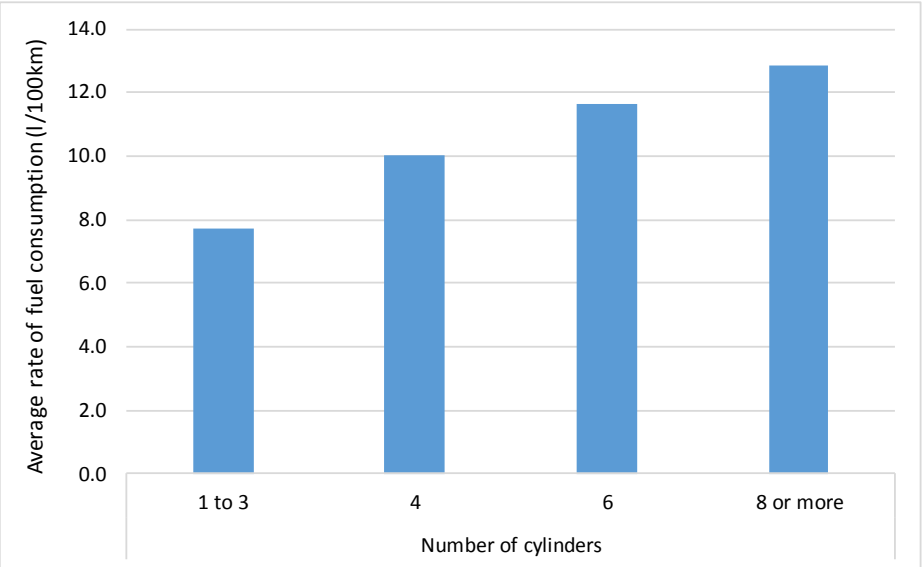
[6] The *Census of Motor Vehicles* dataset only contains engine size data for about one-third of passenger vehicles, due to it only being routinely collected in NSW, ACT and NT (and for recent model Tasmanian vehicles).
[7] About 3000 passenger vehicles have rotary powered engines (0.02 per cent of the passenger vehicle fleet). About 228 000 passenger vehicles, representing 1.65 per cent of the passenger vehicle fleet, reported an 'other' or 'not stated' response to the number of cylinders question, and this category would include 5 cylinder vehicles.

Figure 7 Average rate of fuel consumption of passenger vehicles by engine capacity, Australia, 2014



Note: BITRE purchased a customised tabulation for 2014, but did not repurchase for 2016.
Source: BITRE analysis of ABS customised tabulation of *Survey of Motor Vehicle Use,* 2014 data.

Figure 8 Average rate of fuel consumption of passenger vehicles by number of cylinders, Australia, 2016



Note: Excludes rotary powered engines, 5 cylinder vehicles and other/not elsewhere specified responses.
Source: BITRE analysis of ABS customised tabulation of *Survey of Motor Vehicle Use,* 2016 data.

BITRE purchased customised SMVU 2016 cross-tabulations from ABS which disaggregate average rates of fuel consumption by fuel type, year of manufacture and number of cylinders (see Table 1). The lowest rates of fuel consumption are for motorcycles (5.6 l/100km), particularly the recent model motorcycles (5.5 l/100km). The recent model four cylinder passenger vehicles also have relatively low rates of fuel consumption (10.0 l/100km), particularly LPG, CNG, dual fuel, hybrid and other vehicles (8.7 l/100km). The older, larger passenger vehicles have relatively high rates of fuel consumption, such as the pre-2001 passenger vehicles with eight or more cylinders (15.4 l/100km). Recent model six-cylinder LPG/CNG/dual fuel/hybrid/other vehicles also have a high rate of fuel consumption (16.0l/100km).

While some of the older, larger passenger vehicles have very high rates of fuel consumption, they represent a small proportion of the overall stock of passenger vehicles. In 2016, over 93 per cent of the total stock of passenger vehicles (according to the ABS *Census of Motor Vehicles*) related to Table 1 categories that had an average rate of fuel consumption of between 8 and 12 l/100km.

Table 1 Average rate of fuel consumption by vehicle type, fuel type, year of manufacture, and number of cylinders, Australia, 2016

	Average rate of fuel consumption (l/100km)			
	Year of manufacture			
	2000 and earlier	2001 to 2010	2011 and after	All years
PASSENGER VEHICLES				
1 to 3 cylinders	n.p.	n.p.	n.p.	7.7
4 cylinders				
Petrol	10.3	10.1	10.1	10.1
Diesel	12.3	8.6	9.9	9.5
LPG/CNG/dual fuel/hybrid/other	n.p.	7.0	8.0	8.7
Total	10.5	9.9	10.0	10.0
6 cylinders				
Petrol	11.4	11.8	12.0	11.8
Diesel	11.9	10.4	10.0	10.5
LPG/CNG/dual fuel/hybrid/other	n.p.	10.6	16.0	12.1
Total	12.0	11.6	11.5	11.7
8 or more cylinders				
Petrol	15.2	11.3	12.2	12.7
Diesel	n.p.	14.5	12.2	13.3
Total[1]	15.4	12.0	12.2	12.9
Other - not elsewhere specified	n.p.	n.p.	n.p.	13.6
All cylinders				
Petrol	10.9	10.7	10.4	10.6
Diesel	12.2	9.4	10.1	10.0
LPG/CNG/dual fuel/hybrid/other	n.p.	9.8	10.0	11.1
Total	11.4	10.6	10.3	10.6
MOTORCYCLES	6.0	5.7	5.5	5.6

Notes: n.p. = not available for publication. Other cylinders includes 5 cylinder vehicles and rotary engines.
1 Total includes LPG/CNG/dual fuel/hybrid/other vehicles.
Source: BITRE analysis of ABS customised tabulations of *Survey of Motor Vehicle Use,* 2016 data.

Table 2 presents information on the number of vehicles in each of these categories in 2016, and separates out LPG and dual fuel vehicles from electric, other and unknown fuel type vehicles. As previous noted, 4 cylinder passenger vehicles dominate. The single most important detailed vehicle category in Table 2 is the 4.04 million petrol-fuelled 4 cylinder passenger vehicles that were manufactured between 2001 and 2010, and represent 29 per cent of the total Australian passenger vehicle fleet.

Table 2 Number of passenger vehicles and motorcycles, disaggregated by year of manufacture, number of cylinders and fuel type, Australia, 2016

	Year of manufacture			
	2000 and earlier	2001 to 2010	2011 and after	All years[1]
PASSENGER VEHICLES				
1 to 3 cylinders				
Petrol	13 675	19 657	51 917	85 359
Diesel	151	128	308	586
LPG/dual fuel	87	16	27	130
Electric, other and unknown	9	64	182	249
Total	13 922	19 865	52 434	86 324
4 cylinders				
Petrol	1 343 392	4 035 000	2 860 782	8 243 600
Diesel	41 488	392 933	540 100	974 623
LPG/dual fuel	8 022	11 021	4 686	23 739
Electric, other and unknown	153	13 223	22 056	35 434
Total	1 393 055	4 452 177	3 427 624	9 277 396
6 cylinders				
Petrol	852 124	1 782 962	457 773	3 097 069
Diesel	94 834	110 304	148 002	353 192
LPG/dual fuel	82 776	116 178	12 424	211 439
Electric, other and unknown	204	1 924	1 652	3 786
Total	1 029 938	2 011 368	619 851	3 665 486
8 or more cylinders				
Petrol	148 589	219 090	78 658	453 364
Diesel	1 513	29 181	53 977	84 682
LPG/dual fuel	10 987	5 123	198	16 431
Electric, other and unknown	108	96	45	249
Total	161 197	253 490	132 878	554 726
Other - Not elsewhere specified[2]				
Petrol	104 008	42 589	26 720	173 337
Diesel	12 379	24 462	14 507	51 350
LPG/dual fuel	2 979	155	17	3 148
Electric, other and unknown	160	1 110	2 065	3 339
Total	119 526	68 316	43 309	231 174
All cylinders				
Petrol	2 461 788	6 099 298	3 475 850	12 052 729
Diesel	150 365	557 008	756 894	1 464 433
LPG/dual fuel	104 851	132 493	17 352	254 887
Electric, other and unknown	634	16 417	26 000	43 057
Total	2 717 638	6 805 216	4 276 096	13 815 106
MOTOR CYCLES	145 114	368 670	250 361	770 141

Notes: Cells have been randomly adjusted to avoid the release of confidential data. Discrepancies may occur between sums of the component items and totals.

[1] Total includes year of manufacture not stated.

[2] Includes 5 cylinder vehicles, rotary engines and not stated.

Source: BITRE analysis of ABS *Census of Motor Vehicles, 2016* (using Tablebuilder).

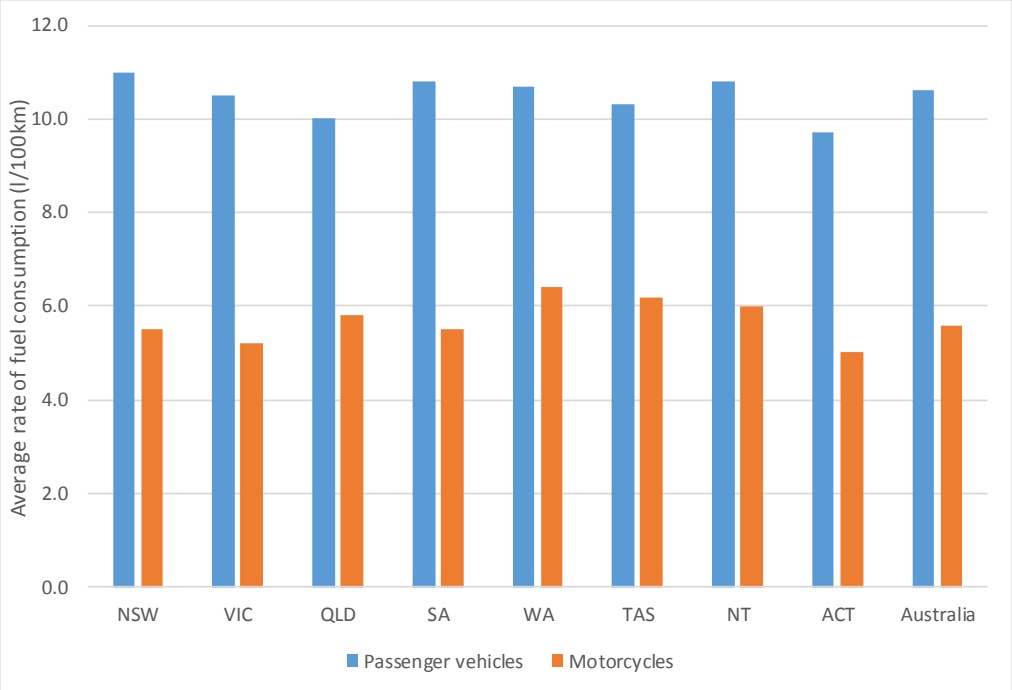
Relationship between fuel economy and place

The SMVU publishes average rates of fuel consumption at the state and territory scale, based on the registration address of the vehicle. The ABS advised that it was not possible to generate sub-state estimates based on registration address as the survey was not designed to be representative at that scale.[8] Figure 9 presents the average rate of fuel consumption for passenger vehicles and motorcycles that are registered in each state and territory.

There is minimal variation in the average rate of fuel consumption of passenger vehicles across the six states and the Northern Territory (NT), which all have average rates of fuel consumption of between 10.0 and 11.0 l/100km. New South Wales (NSW) has the most fuel-intensive passenger vehicles (11.0 l/100km). The Australian Capital Territory (ACT) has the least fuel-intensive passenger vehicles (9.7 l/100km), reflecting its high proportion of smaller vehicles (4 or less cylinders) and a higher than average proportion of recent model vehicles in its vehicle stock.

Overall, these estimates of the average rate of fuel consumption of passenger vehicles show limited variation across the states and territories, with only the Queensland and ACT estimates showing a statistically significant difference from the national estimate.[9] In the 2014 survey, the estimates of the average rate of fuel consumption of Queensland and the ACT passenger vehicles (10.5 l/100km and 10.3 l/100km, respectively) were again lower than the national average of 10.7 l/100km, but the gap was less pronounced and not statistically significant. The NT passenger vehicle estimate showed a statistically significant difference from the national estimate in the 2014 survey (12.0 l/100km *versus* 10.7 l/100km), but not in the 2016 survey (10.8 l/100km *versus* 10.6 l/100km).

Figure 9 Average rate of fuel consumption of passenger vehicles and motorcycles, by state/territory of registration, Australia, 2016



Source: BITRE analysis of ABS Cat. 9208.0 *Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016*.

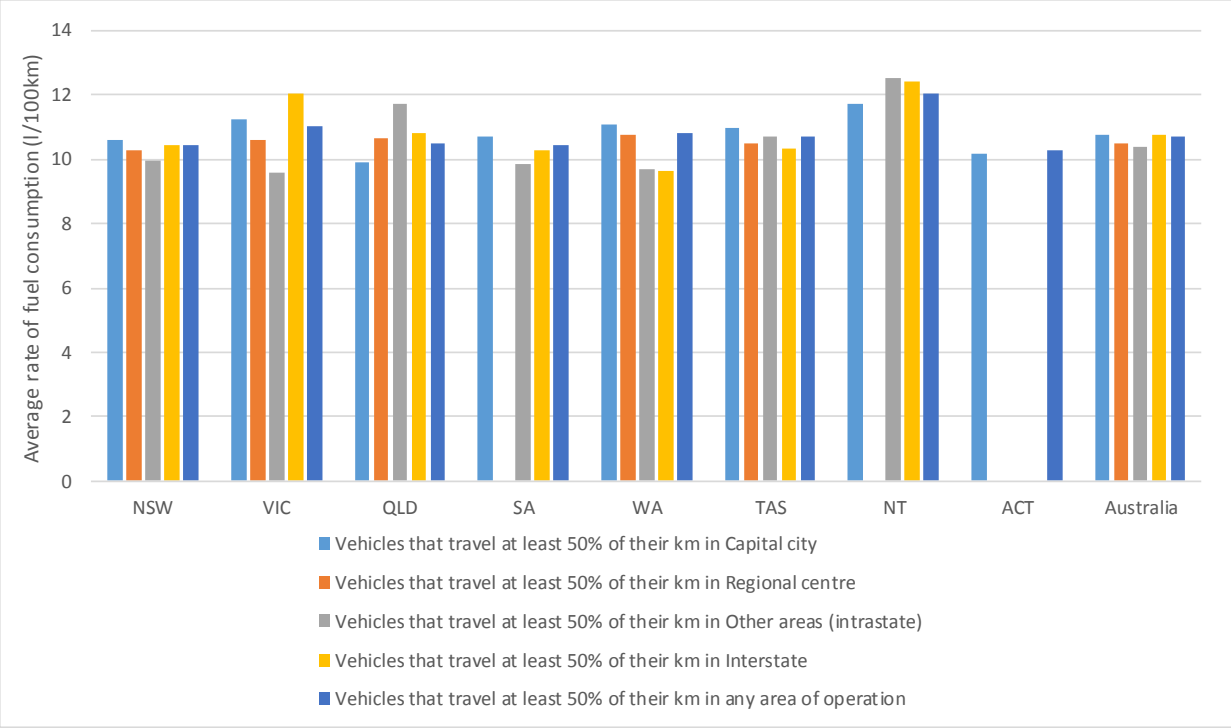
[8] Note that the SMVU does publish VKT data that shows the split in kilometres travelled across different 'areas of operation' within a state/territory (i.e. within capital city, within major towns, other intrastate, between capital cities etc).
[9] The ACT estimate is significantly different from the national estimate at the 99 per cent confidence level, while the Queensland estimate is significantly different from the national estimate at the 95 per cent confidence level, but not the 99 per cent confidence level.

The average rate of fuel consumption of motorcycles ranges from 5.0 l/100km for the ACT to 6.4 l/100km for Western Australia (WA), but none of these estimates are significantly different from the national average at the 95 per cent confidence level. Similarly, in the preceding survey conducted in 2014, none of the state/territory estimates were significantly different from the national motorcycle average.

There is no obvious relationship evident between the proportion of city driving (vs open-road driving) in a jurisdiction and average rates of fuel consumption. Holding other factors constant, it is expected that a more urbanised jurisdiction with a higher proportion of travel within cities would have higher rates of fuel consumption due to more stop-start driving. The ACT is the most urbanised jurisdiction and has the highest proportion of km driven within the capital city (73 per cent), but has the lowest average rate of fuel consumption for passenger vehicles (9.7 l/100km). WA also has a high proportion of km driven within the capital city (71 per cent), but it has a slightly above-average rate of fuel consumption for passenger vehicles (10.7 l/100km). The overall correlation between the proportion of capital city driving and the rate of fuel consumption at the state/territory scale is low at 0.12. The lack of any obvious relationship between fuel economy and driving conditions at the state/territory scale probably reflects the influence of other factors, such as differences in the vehicle stock, across jurisdictions.

Figure 10 shows that the average rate of fuel consumption displays only minor variations for passenger vehicles that are predominantly driven in different areas of operation. At the national scale, in 2014, the average rate of fuel consumption was a little higher for vehicles with 50 per cent or more of their distance driven within capital cities (10.8 l/100km), compared to vehicles with at least 50 per cent of their distance driven within other urban areas (10.5 l/100km) or non-urban intrastate areas (10.4 l/100km). The pattern is in line with expectations that capital cities would have higher rates of fuel consumption due to lower travel speeds and more stop-start driving. However, at the national scale, these differences are not statistically significant.

Figure 10 Average rate of fuel consumption of passenger vehicles, by area of operation, Australia, 2014



Note: BITRE purchased a customised tabulation for 2014, but did not repurchase for 2016.
Source: BITRE analysis of ABS customised tabulations of *Survey of Motor Vehicle Use,* 2014 data.

A few of the sub-state estimates are significantly different from the national average rate of fuel consumption, with the estimates for vehicles driven mainly in Brisbane or regional SA being significantly below the national

average, and the estimates for vehicles driven mainly in Darwin and the regional NT being significantly above the national average.[10]

The data in Figure 10 provide the best guide we have to how rates of fuel consumption differ locationally within a state. The within-state variation in this customised data is modest, and generally lies within the survey's margin of error. For example in NSW, the average rate of fuel consumption varies little between vehicles that are mainly driven in capital cities, regional centres, other intrastate areas, or interstate. The only statistically significant sub-state difference (relative to the state average) is observed for Victoria. Victorian registered vehicles for which at least 50 per cent of VKT are travelled in other intrastate areas have a significantly lower rate of fuel consumption than Victorian-registered vehicles as a whole.[11] This suggests that vehicles from rural Victoria may achieve a significantly lower rate of fuel consumption than vehicles from urban Victoria (i.e. Melbourne and the nominated regional centres). This would reflect local driving conditions being more conducive to achieving better fuel economy (e.g. less stop-start driving), as the fleet of vehicles in rural Victoria is not particularly fuel-efficient.[12]

Literature review

The literature shows that there are significant discrepancies between official claimed (from vehicle manufacturers) and real-world fuel consumption statistics, and such discrepancies appear to be increasing over time (Schipper and Tax 1994, Wang et al. 2015, McKinnon 2016, Global Fuel Economy Initiative 2016). Schipper and Tax (1994) compared data from the United States of America (USA), Canada and four European countries and found that automobile fuel economy tests tended to underestimate fuel use by between 15 and 25 per cent. In a recent report published by the Global Fuel Economy Initiative (2016), it was found that real-world fuel consumption of new European passenger cars exceeded official-type-approval values by around 40 per cent. In Australia, Melbourne-based Engineering Consultant ABMARC, which conducted research for the Australian Automobile Association on emissions and fuel consumption on Melbourne roads (incorporating urban, rural and freeway driving conditions), found that the real-world fuel consumption of vehicles tested was on average 20 per cent higher than the New European Driving Cycle (NEDC) results, with the highest measurement being 35 per cent greater (ABMARC 2016).

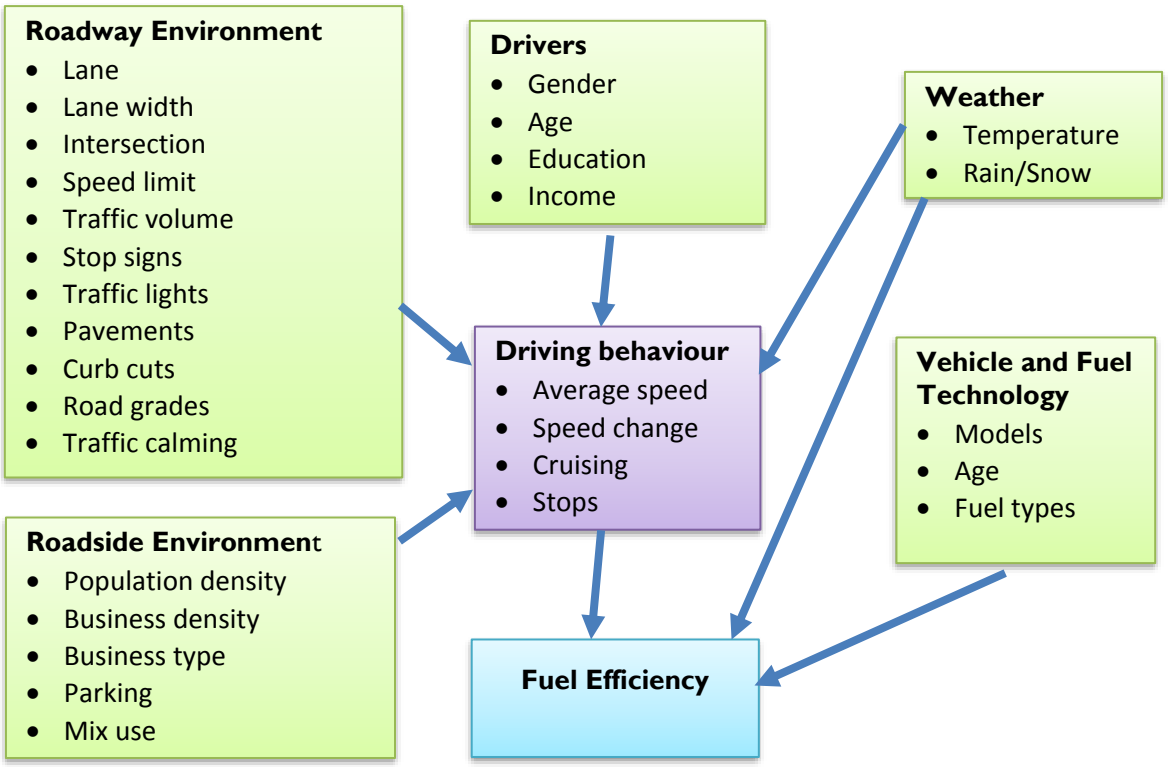
Wang et al. (2014) summarised four major categories of influential factors that affect fuel efficiency, as shown in Figure 11. These categories are: built environment (both roadway and roadside environment), driver characteristics, weather and vehicle/fuel type. Each of these categories has several possible sub-categories or variables. Wang et al. (2014) noted that speed and speed change directly affect fuel efficiency, while other factors including street environments affect fuel efficiency indirectly through driving behaviour.

Real-world fuel consumption can vary greatly as it can be affected by many factors that have little to do with the vehicle. These include: driving conditions (i.e. weather, traffic, temperature etc.), driving style or driver behaviour (i.e. hard braking, sudden acceleration and speeding), road conditions (i.e. paved and gravel, smooth and potholes), and other things, such as carrying excess weight, roof racks, and fuel quality. The combination of these factors can increase fuel consumption rates well beyond the official fuel consumption figures that are published on the Green Vehicle Guide (GVG) website by the Department of Infrastructure and Regional Development and available on the windscreen stickers of all new cars. In addition, the discrepancy between the official figures and the real-world fuel consumption figures has been increasing over time (ABMARC 2016). For example, the Global Fuel Economy Initiative (2016) found that during the last 15 years (since 2001), the gap between official measurements of vehicle efficiency and actual performance in everyday driving increased by more than 25 per cent. This increase is most likely as a result of manufacturers optimising technologies to ensure compliance with their carbon-dioxide obligations (ABMARC 2016).

[10] Each of these estimates are significantly different from the national average at the 95 per cent confidence level, but there are no statistically significant differences at the 99 per cent confidence level.
[11] This estimate is significantly different from the Victorian average at the 95 per cent confidence level, but not at the 99 per cent confidence level.
[12] For example, LPG and dual fuel passenger vehicles are relatively prominent in regional Victoria, and are not a very fuel-efficient vehicle type (see Table 1 and Figure 2).

The weight of a vehicle is a critical factor impacting on fuel economy. For example, Knittel (2009) finds that a ten per cent decrease in a passenger vehicle's weight is associated with more than a 4 per cent improvement in fuel economy. Vehicle engine size and fuel type also play an important role in determining fuel efficiency (Biggs and Akcelik 1987, Wang et al. 2015). Knittel (2009) also reports that a ten per cent decrease in an engine's horsepower is associated with a 2.6 per cent improvement in fuel economy. Wang et al. (2015), who studied the effects of engine size and the year of manufacture on light petrol vehicles real-world fuel efficiency in New Zealand, found that fuel efficiency increased linearly with engine size between 1350cc and 4000cc. However, they found that vehicles with a small engine size (less than 1350cc) were somewhat less fuel efficient than those with a slightly larger engine (1350cc to less than 1650cc), which they attributed to the fact that vehicles with a small engine needed to be driven harder than larger vehicles to keep up with the traffic in the real world. They also found that for a given engine size, newer vehicles were generally more fuel efficient than their older counterparts. In addition, Wang et al. (2015) also found that, on average, the fleet travel-weighted fuel efficiency was better for the light petrol vehicles compared to the light diesel vehicles (9.2 l/100km versus 10.2 l/100km).

Figure 11 Diagram showing factors that affect vehicle fuel efficiency



Source: Redrawn from Wang et al. (2014).

Vehicle speed is another factor that influences fuel efficiency. Vehicle fuel efficiency decreases as the speed increases beyond a certain speed threshold, which is around 55 miles per hour (mph) (or 89 km per hour) (FuelEconomy.gov 2012). In the USA, *FuelEconomy.gov*[13] showed that each 5 mph more speed could reduce fuel economy by 7 to 8 per cent (ibid). Similarly, in another study in the USA, Jenness et al. (2009) showed that 'a vehicle maintaining a constant speed reaches peak freeway fuel economy near 50 mph, and fuel economy decreases substantially above 60 mph'. This may be due to two factors: increasing air resistance, particularly in the highway, and engines being designed for specific speed, temperature and round per minute ranges.

[13] *FuelEconomy.gov* is an Internet resource that helps consumers make informed fuel economy choices and provides accurate miles per gallon (mpg) information. This is maintained by the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy with data provided by the U.S. Environmental Protection Agency (EPA).

Motor vehicle fuel consumption is highly dependent on trip length and trip frequency. Bureau of Transport Economics (1978) investigated the implications of trip length, trip frequency and distance travelled by different types of vehicles, noting that emissions and fuel consumption rates were strongly dependent on the frequency of trips, and fuel consumption was also a function of the average length of trips. These effects were caused by the different engine operating conditions that apply to cold and warm engines.

Motor vehicle fuel consumption differs by road type, with fuel economy at its best on freeways (Wang et al. 2012), where vehicles can travel close to the optimal speed. The quality of the road surface, and particularly surface roughness (as measured by the International Roughness Index), has been shown to have a significant effect on fuel consumption (Zaabar and Chatti 2010).

Street environment can also influence fuel economy. Wang et al. (2014) applied structural equation modelling to examine how driving behaviour and fuel efficiency respond to different street environments in Southeast Michigan. The study showed that some features of compact streets (such as lower speed limits, higher intersection density, and higher employment density) were associated with lower driving speeds, more speed changes, and lower fuel efficiency. Other features such as higher population density and higher density of pedestrian-scale retail were associated with improved fuel efficiency (ibid).

Wang et al. (2014) also examined the effects of weather conditions on fuel economy, specifically the effects of outside temperature and wiper usage (a proxy for rainy or snowy conditions). Controlling for other factors, fuel economy deteriorated when the outside temperature dropped.

Driver's demographic characteristics, especially gender and age, can also influence fuel efficiency. For example, Wang et al. (2014) using simple multiple linear regression found that women drivers were less fuel efficient than male drivers, due to lower driving speed and more speed changes. Compared to old-age drivers (60-70 years), young drivers (20-30 years) and middle-aged drivers (40-50 years) had better fuel efficiency, due to higher travel speeds. The young drivers had worse fuel efficiency than the middle-aged drivers, due to more aggressive accelerations and frequent stops.

Li et al. (2013) investigated the spatial patterns of vehicle energy consumption in urban areas through an analysis of private vehicle trip distances (journey-to-work) and of vehicle fleet efficiency in Brisbane. This study applied the official fuel efficiency data from the GVG to motor vehicle registration record counts for the different vehicle models to generate average fuel consumption rates for small areas. The authors found that private vehicle fuel efficiency tended to be higher in the inner urban areas surrounding the Brisbane CBD. Areas to the far north, far west and southeast exhibited the lowest fuel efficiencies. They also found that rates of fuel consumption tended to increase with increasing distance from the city centre. They also commented on some results for particular areas of interest:

> *"the average vehicle efficiency in Kenmore Hills appears to be slightly lower than nearby suburbs. This can be explained by the higher proportion of large- (e.g. sport utility vehicles) and/or high performance vehicles found in some high-income suburbs that reduced overall vehicle fuel efficiency. The lower efficiencies observed in some blue-collar suburbs (e.g. Rocklea and Kingston) suggest that the occupation and employment sector may affect vehicle choice (e.g. a higher proportion of light trucks, utes and minivans)." (ibid, p.6)*

It is worth noting that the average rate of fuel consumption shows only limited variation across the 224 Brisbane Statistical Local Areas, ranging from a low of 9.06 l/100km to a maximum of 9.45 l/100km.[14]

In the USA, the Oregon Department of Transportation (2013) found that rural residents tend to drive less fuel-efficient vehicles than their urban counterparts (with average fleet fuel efficiency of 20.7 miles per gallon or mpg vs 22.3 mpg), but they also tend to drive in conditions conducive to better fuel efficiency. A similar study by the Washington State Transportation Commission (2015) found that rural vehicles are about 3 per cent less fuel efficient on average. Another similar Californian study found that rural vehicles were marginally more fuel efficient than urban vehicles (Mineta Transportation Institute 2012).

[14] Note that these average rates of fuel consumption are considerably lower than the rates in the ABS' *Survey of Motor Vehicle Use* as they are based on the official GVG rates of fuel consumption (based on test results), rather than on real-world rates of fuel consumption.

Based on US Department of Agriculture data, Cooper (2007) reported that households living outside of metropolitan areas got 6 per cent fewer mpg than households living in metropolitan areas (19.70 versus 20.91 mpg, which is equivalent to 11.94 l/100 km and 11.25 l/100km). The author also reported that households living outside of metropolitan areas consumed 21 per cent more transport fuel (i.e. gasoline) per year than the households in metropolitan areas, reflecting higher miles travelled as well as the higher rate of fuel consumption.

Implications for differences in fuel economy by place of residence

From the available literature, it is evident that many factors affect passenger vehicle fuel economy, including vehicle characteristics (e.g. engine size, vehicle age, fuel type), weather, driving behaviour (average speed, speed change, trip length), road environment (e.g. quality of road surface, congestion, intersection density) and driver demographics (e.g. gender, age).

Some of these factors will vary systematically across regions, and create spatial differences in average rates of fuel consumption. For example, ABS *Census of Motor Vehicles* data shows that the passenger vehicle stock tends to be older in regional Australia than in the capital cities, while small vehicles are most prominent in inner city areas, and large passenger vehicles are most prominent in rural and outback locations. These characteristics of the Australian vehicle stock are likely to mean that on average, regional residents drive less fuel-efficient vehicles than their urban counterparts (as occurs in the US state of Oregon, see Oregon Department of Transportation 2013) and that inner city residents drive more fuel-efficient vehicles than middle and outer suburban residents (as found by Li et al. 2013 for Brisbane).

While regional residents may have less fuel-efficient vehicles, they are potentially driving their vehicles in conditions conducive to achieving better fuel efficiency (e.g. closer to the optimal speed of around 89 km/hour, with less stop-start driving). The standard testing regime for fuel economy contains an urban cycle (intended to reflect city traffic conditions) and an extra-urban driving cycle (intended to provide a better indication of freeway or highway driving) (Australian Government 2017). The GVG website notes that most vehicles have much higher rates of fuel consumption on the urban part of the test cycle, which features a low average speed, substantial idle periods and frequent stop/start events (ibid). Of course, real-world driving conditions may differ significantly from these test cycles. Regional residents will drive in a wide range of driving conditions (including not just highway driving, but also driving in capital cities and regional cities and towns, and on potentially poor quality local roads), just as capital city residents will not drive all of their annual kilometres in congested city traffic conditions.

The potentially counteracting effects of the vehicle fleet and driving conditions mean that a-priori, it is not clear whether real-world fuel economy will be better or worse for regional residents than capital city residents, on average. The literature review identified only a few studies that directly compared realised rates of fuel consumption across regions using survey data collected from regional residents (as opposed to modelled estimates based on the vehicle fleet in a region):

- Based on the 2001 *National Household Transportation Survey*, Cooper (2007) reported that US households living outside of metropolitan areas got 6 per cent worse fuel economy than households in metropolitan areas.
- A survey conducted in Washington State directly asked residents to report fuel economy, with little variation in average mpg across urban (24.8), suburban (24.7) and rural (24.4) households (Washington State Transportation Commission 2015).
- Based on the 2016 ABS *Survey of Motor Vehicle Use*, there was no statistically significant variation in the average rate of fuel consumption of motorcycles across Australia's states and territories, and for passenger vehicles, only the ACT and Queensland estimates differed significantly from the national average rate of fuel consumption.[15]

[15] The ACT had an average rate of fuel consumption 8 per cent below the national average, while Queensland's estimate was 6 per cent below the national average. The estimates for the remaining five states and the NT were all within 4 per cent of the national average rate of fuel consumption of passenger vehicles.

- The customised data we obtained from the 2014 SMVU suggests there are few statistically meaningful differences in average rates of fuel consumption across different types of regions of residence (if it is assumed that vehicles that are predominantly driven in a particular area of operation will typically be based in that area of operation). The SMVU finds that the average rate of fuel consumption for passenger vehicles and motorcycles which mainly travel within capital cities is 10.7 l/100km, compared to 10.6 l/100km for all other main journey types. It also finds that the average rate of fuel consumption is 10.8 l/100km for passenger vehicles that travel at least 50 per cent of their vehicle kilometres travelled (VKT) in capital cities, compared to 10.5 l/100km for vehicles that travel at least 50 per cent of their VKT in other urban areas and 10.4 l/100km for vehicles that travel at least 50 per cent of their VKT in the rest of the state. None of these differences were statistically significant at the national level.
- The customised SMVU data also provided little evidence of statistically meaningful differences in the average rate of fuel consumption within states and territories. The sole exception was that Victorian passenger vehicles that travelled at least 50 per cent of their VKT in non-urban areas had a significantly lower rate of fuel consumption (9.6 l/100km) than the Victorian average (11.0 l/100km) in 2014.

Given that Li et al. (2013) found the average fuel economy of the vehicle fleet varied by less than 5 per cent across Brisbane Statistical Local Areas[16], the limited available evidence suggests that spatial differences in average rates of fuel consumption are not likely to be large.

Small area estimates of the average rate of fuel consumption

The aim of this section is to generate estimates of the average rate of fuel consumption of the passenger vehicle and motorcycle fleet in different Australian regions.

Direct survey-based estimates of rates of fuel consumption are only available at the national and state/territory scale from the ABS *Survey of Motor Vehicle Use*. There is a policy need for information on how rates of fuel consumption vary between sub-state locations—such information can help build an improved understanding of the locational impact of different policy options.

Methodology

The standard methodology for generating small area estimates of average rates of fuel consumption involves obtaining motor vehicle registration data for each region on the number of vehicles of different makes and models. Official data on the average rate of fuel consumption for that type of vehicle is then applied to the vehicle count data, and used to generate a weighted average for the region as a whole.[17] This methodology was applied by Li et al. (2013) for Brisbane, Lindsey et al. (2011) for Chicago, Mineta Transportation Institute (2012) for California, as well as in Oregon Department of Transportation (2013) and Washington State Transportation Commission (2015). It provides an estimate of the average rate of fuel consumption of the vehicle fleet in a region, based on the results of government testing, rather than on real-world fuel consumption.

In this study, BITRE has applied a variant of this methodology. Rather than using the official fuel consumption figures that are published on the GVG website, BITRE used the realised average rates of fuel consumption collected in the ABS SMVU for 2016. These realised rates of fuel consumption tend to be higher than the figures on the GVG website, and averaged 10.6 l/100km for passenger vehicles in 2016. This approach was

[16] Based on official GVG fuel-economy figures for each vehicle model.

[17] In the small area estimation literature more broadly, regression methods are the standard methodology, but to our knowledge have not been applied to generate estimates of fuel consumption rates. The small sample size (8 regions) was a factor in opting not to use regression methods to develop the small area estimates of average rates of fuel consumption. Further, as noted in the discussion around Figure 5, there is no statistically significant variation in the state/territory estimates of average rates of fuel consumption for motorcycles, and only the ACT and Queensland estimates differ significantly from the national average for passenger vehicles. As it is therefore likely the observed variation in fuel consumption rates across jurisdictions is largely random in nature, no attempt was made to attempt to explain variation in the state/territory estimates by reference to potential correlates using regression methods.

preferred over the standard methodology as it provides a more realistic guide to the actual rates of fuel consumption achieved by the Australian passenger vehicle and motorcycle fleet. The SMVU data on rates of fuel consumption was collected from vehicle owners who were asked to complete two questionnaires (at the beginning and end of the four month survey period), including provision of odometer readings and of data on the number of litres of fuel consumed.

SMVU estimates of the average rate of fuel consumption are not available at the detailed level of vehicle make and model. However, the SMVU estimates of rates of fuel consumption can be disaggregated by key vehicle characteristics, such as vehicle type, number of cylinders, engine size, year of manufacture and fuel type.

BITRE used the motor vehicle registration data available from the ABS *Census of Motor Vehicles* 2016 to extract detailed vehicle count information for each Australian postcode. The initial preference was to base the methodology on vehicle type (i.e. passenger vehicle, motorcycle), engine size and year of manufacture (as well as fuel type, where SMVU data was sufficiently reliable). This preference was based on the SMVU results that showed that these factors were key determinants of fuel consumption, and the literature. For example, Wang et al. (2015) argued that engine size and the year of vehicle manufacture are two of the most important factors influencing real-world fuel economy. Unfortunately, the *Census of Motor Vehicles* dataset only contains engine size data for about one-third of passenger vehicles, due to it only being routinely collected in NSW, ACT and NT (and for recent model Tasmanian vehicles). In contrast, the *Census of Motor Vehicles* contains data on the number of cylinders for 98 per cent of passenger vehicles, and this data was routinely collected in all jurisdictions. Consequently, BITRE elected to use the number of cylinders (along with year of manufacture and fuel type) as the basis of its small area estimation for passenger vehicles, rather than engine size.

The postcode-level passenger vehicle counts from the ABS *Census of Motor Vehicles* were disaggregated by number of cylinders, year of manufacture, and fuel type. The postcode-level motorcycle counts were disaggregated by year of manufacture only. As a result, the estimates reflect the passenger vehicle and motorcycle fleet that had a registration address in each region in 2016.

The postcode-level vehicle counts were concorded to the ABS' Australian Statistical Geography Standard (ASGS) Statistical Area Level 3 (SA3) scale using the ABS population-weighted concordance made available online.[18] There are more than 2600 postcodes, and aggregating to the scale of SA3s (of which there are 351) generally produced good quality estimates for those SA3s. The ABS assessed the overall quality of this concordance as 'good'. The quality of this concordance was good for 68 per cent of SA3s, acceptable for 22 per cent, and poor for 10 per cent of SA3s. It was decided not to attempt to concord the postcode-level vehicle counts to the Statistical Area Level 2 (SA2) scale, which contains 2214 regions, due to the ABS' overall assessment of the concordance quality as 'poor', and its assessment that the majority (64 per cent) of the SA2 estimates would be of poor quality. By generating estimates at the SA3 scale, this also provides the flexibility to present and analyse the estimates at either the SA4 or SA3 scale.

The national average rates of fuel consumption for each vehicle category that are presented in Table 1 were then applied to the vehicle count data for each SA3 to produce an average rate of fuel consumption for the passenger vehicle fleet and for the motorcycle fleet in each SA3. The rates of fuel consumption for passenger vehicles and motorcycles were then combined into a single weighted average rate of fuel consumption for the SA3 based on the number of vehicles of each type and the SMVU 2016 average vehicle kilometres travelled for each vehicle type (i.e. 12800km for passenger vehicles and 2600km for motorcycles).

The methodology for estimating average rates of fuel consumption is simply based on the composition of the vehicle fleet in each region. It does not take into account potential differences in driving conditions that could result in the same type of vehicle tending to achieve much better rates of fuel consumption in one region than it does in another (e.g. due to more optimal driving speeds, less stop-start driving, good quality roads, more optimal weather conditions).

[18] Note that about 0.5 per cent of vehicles had a missing postcode in the ABS *Census of Motor Vehicles* data and were omitted from the analysis. Furthermore, some of the postcodes did not relate to a valid geographic area (e.g. post box postcodes), were not included in the ABS concordance, and were therefore omitted from the analysis (amounting to about 0.7 per cent of vehicles).

BITRE trialled two different means of incorporating locational differences in driving conditions into the small area estimation methodology:

a) Incorporate state/territory differences in driving conditions into the methodology by benchmarking the SA3 estimates to the SMVU average rates of fuel consumption for passenger vehicles and motorcycles in each state and territory (as provided in Figure 9).

b) Incorporate capital city/regional city/non-urban differences in driving conditions into the methodology by benchmarking the SA3 estimates to sub-state estimates of the average rate of fuel consumption (extrapolated from the customised SMVU data in Figure 10 using a modelling approach).

BITRE did not benchmark the small area estimates to sub-state estimates, as the evidence from the SMVU data is that there is little meaningful variation in rates of fuel consumption across the different areas of operation within each state/territory (with the exception of Victoria). Similarly, benchmarking of the fleet-based small area estimates to the SMVU state/territory estimates of the average rate of fuel consumption could not be justified as the SMVU estimates for most states/territories do not differ significantly from the national average rate of fuel consumption (for passenger vehicles or motorcycles).[19] Such benchmarks would not be meaningful, with differences from the national average likely to simply reflect random sampling variation.

Consequently, BITRE's small area estimates of the average rate of fuel consumption are based on the characteristics of the vehicle fleet in each region, and do not adjust for differences in driving conditions across regions. This approach is consistent with the approach to generating small area estimates of fuel consumption in the literature (e.g. Li et al. 2013, Lindsey et al. 2011, Oregon Department of Transportation 2013), except that BITRE's estimates reflect actual realised rates of fuel consumption for each type of vehicle, rather than official test results. While several means of controlling for spatial differences in driving conditions were explored, the available evidence on state/territory and sub-state differences in realised rates of fuel consumption was not considered sufficiently statistically robust to anchor the small area estimates.

Input variables

The ABS *Census of Motor Vehicles* provides information on the characteristics of the local passenger vehicle and motorcycle fleet, as of 2016. This section provides an overview of small area variation in each of the input variables for BITRE's small area estimation methodology (i.e. vehicle type, number of cylinders, fuel type, year of manufacture). These patterns of variation provide some context for the small area estimates that follow, and can help to explain why particular locations will have relatively high or low rates of fuel consumption.

Table 3 lists the SA3s with the highest and lowest proportion of motorcycles in their combined passenger vehicle and motorcycle fleet. Nationally, motorcycles comprise 5.6 per cent of the total passenger vehicle and motorcycle fleet. Relatively remote regions tend to have the highest proportion of motorcycles. Lord Howe Island has by far the highest proportion of motorcycles (23 per cent), but this is out of a fleet of just 117 vehicles. Regional and remote WA locations have a very high proportion of motorcycles, including Kimberley, Goldfields and Esperance, but also Gascoyne, Mundaring, Manjimup, Pilbara, Mid West, Serpentine-Jarrahdale, Wheatbelt North and Albany, which all have motorcycles making up at least 10 per cent of their vehicle fleet. Apart from Lord Howe Island, the only SA3 outside WA that surpasses the 10 per cent share is Gladstone-Biloela in Queensland.

It is generally metropolitan regions that have the lowest proportion of motorcycles in their vehicle fleet, including Dandenong, Monash and Stonnington East in Melbourne, and Fairfield and Merrylands-Guildford in Sydney.

[19] Note that ACT and Queensland passenger vehicles do have a significantly lower rate of fuel consumption than Australian passenger vehicles in the 2016 survey. However, in the 2014 survey, the ACT and Queensland estimates did not differ significantly from the national estimate.

Table 3 SA3s with a particularly high or low proportion of motorcycles, 2016

High proportion		Low proportion	
SA3 name	Proportion of motorcycles in motorcycle and passenger vehicle fleet (per cent)	SA3 name	Proportion of motorcycles in motorcycle and passenger vehicle fleet (per cent)
Lord Howe Island NSW	23.1	Dandenong VIC	2.2
Kimberley WA	13.8	Monash VIC	2.3
Goldfields WA	12.7	Merrylands-Guildford NSW	2.4
Esperance WA	12.4	Fairfield NSW	2.4
Gladstone-Biloela QLD	11.6	Stonnington East VIC	2.4

Note: External territories are excluded.
Source: BITRE analysis of ABS *Census of Motor Vehicles* 2016 data, extracted using Tablebuilder, and concorded from postcode to SA3 using the ABS population-weighted concordance.

Table 4 provides information on the proportion of the passenger vehicle fleet that is comprised of vehicles with 6 or more cylinder engines. Nationally, 31 per cent of the passenger vehicle fleet has six or more cylinders. There are several regions where six or more cylinder vehicles comprise more than half of the passenger vehicle fleet, including Wheat Belt South, Wheat Belt North and Gascoyne in WA, Murray River-Swan Hill in Victoria, and Bourke-Cobar-Coonamble in NSW. More generally, the pattern is for agriculturally-based regions to have a high proportion of six or more cylinder vehicles, presumably reflecting a high proportion of 4WD vehicles used in these locations.[20] Examples that lie outside the top five include Mid North, Yorke Peninsula and Murray-Mallee SA, Loddon-Elmore VIC and Lower Murray NSW.

Lord Howe Island is again an outlier, having by far the smallest proportion of passenger vehicles with six or more cylinders (7 per cent), albeit with a very small vehicle fleet. More generally, it is inner and middle suburban SA3s within our capital cities that have the lowest proportion of six or more cylinder vehicles. Examples with less than 22 per cent of six plus cylinder vehicles include Hobart Inner; North Canberra; Leichhardt and Marrickville-Sydenham-Petersham in Sydney; and Holland Park-Yeronga, Sherwood-Indooroopilly and Nundah in Brisbane.

Table 4 SA3s with a particularly high or low proportion of six or more cylinder passenger vehicles, 2016

High proportion		Low proportion	
SA3 name	Proportion of passenger vehicles with six or more cylinders (per cent)	SA3 name	Proportion of passenger vehicles with six or more cylinders (per cent)
Wheat Belt South WA	55	Lord Howe Island NSW	7
Gascoyne WA	53	Hobart Inner TAS	19
Bourke-Cobar-Coonamble NSW	52	Marrickville-Sydenham-Petersham NSW	20
Murray River-Swan Hill VIC	51	Holland Park-Yeronga QLD	20
Wheat Belt North WA	51	Leichhardt NSW	20

Note: External territories are excluded.
Source: BITRE analysis of ABS *Census of Motor Vehicles* 2016 data, extracted using Tablebuilder, and concorded from postcode to SA3 using the ABS population-weighted concordance.

Table 5 provides information on the proportion of the passenger vehicle fleet that was manufactured in 2000 or earlier. Nationally, 20 per cent of the passenger vehicle fleet comprised older model vehicles. Tasmanian locations dominate the list of SA3s with the highest proportion of older model passenger vehicles. In addition to Central Highlands, South East Coast and Huon-Bruny Island, several other Tasmanian SA3s also have more

[20] Note that utilities are classed as light commercial vehicles, rather than passenger vehicles, in the SMVU and so are excluded from this analysis.

than 34 per cent of their passenger vehicle stock manufactured in 2000 or earlier, including Meander Valley-West Tamar, North East, Brighton, West Coast and Sorell-Dodges Ferry. Outside of Tasmania, it is regional and often remote locations that have the highest proportion of older model vehicles, including Lord Howe Island in NSW, Gascoyne in WA , Murray and Mallee in SA and Far North in QLD. The locations with the lowest proportion of older model vehicles are from several different capital cities, with inner city SA3s being prominent. All 22 SA3s where older model vehicles represent 12 per cent or less of the vehicle fleet are located in the capital cities, rather than in regional Australia.

Table 5 SA3s with a particularly high or low proportion of passenger vehicles manufactured in 2000 or earlier, 2016

High proportion		Low proportion	
SA3 name	Proportion of older model vehicles (per cent)	SA3 name	Proportion of older model vehicles (per cent)
Central Highlands TAS	39.3	Melbourne City VIC	9.1
South East Coast TAS	38.9	Brisbane Inner QLD	9.2
Huon - Bruny Island TAS	37.6	Adelaide City SA	9.3
Lord Howe Island NSW	37.4	Nundah QLD	9.9
Gascoyne WA	35.6	Ku-ring-gai NSW	10.0

Note: External territories are excluded.
Source: BITRE analysis of ABS *Census of Motor Vehicles* 2016 data, extracted using Tablebuilder, and concorded from postcode to SA3 using the ABS population-weighted concordance.

Table 6 provides information on the proportion of the passenger vehicle fleet that is comprised of diesel fuelled vehicles. Nationally, 11 per cent of the passenger vehicle fleet is fuelled by diesel. The locations with the highest proportion of diesel fuelled passenger vehicles are remote outback locations, such as East Arnhem, Daly-Tiwi-West Arnhem, Katherine and Barkly in the NT, Kimberley and Pilbara in WA, and Outback South, Outback North and Far North in Queensland. The locations with less than 6 per cent of diesel passenger vehicles are suburban SA3s in Sydney (e.g. Mount Druitt, Canterbury, Merrylands-Guildford, Fairfield, St Marys), Adelaide (Playford, Salisbury, Port Adelaide East) and Melbourne (Brimbank, Moreland North, Dandenong). This list contains many of the more socio-economically disadvantaged locations in these capital cities.

Table 6 SA3s with a particularly high or low proportion of diesel passenger vehicles, 2016

High proportion		Low proportion	
SA3 name	Proportion of diesel vehicles (per cent)	SA3 name	Proportion of diesel vehicles (per cent)
East Arnhem NT	40	Mount Druitt NSW	4
Daly-Tiwi-West Arnhem NT	32	Canterbury NSW	4
Kimberley WA	31	Merrylands-Guildford NSW	5
Pilbara WA	30	Fairfield NSW	5
Outback South QLD	30	Salisbury SA	5

Note: External territories are excluded.
Source: BITRE analysis of ABS *Census of Motor Vehicles* 2016 data, extracted using Tablebuilder, and concorded from postcode to SA3 using the ABS population-weighted concordance.

Table 7 provides information on the proportion of the passenger vehicle fleet that is comprised of vehicles that use a fuel other than diesel or petrol (e.g. LPG, CNG, dual fuel, hybrid). Nationally, 2.1 per cent of the passenger vehicle fleet uses other fuel. With the sole exception of Fyshwick-Pialligo-Hume in the ACT, the top-35 SA3s are all located in Victoria, with regional Victorian SA3s tending to have a higher proportion of vehicles using other fuels than Melbourne SA3s. The strong representation of Victorian SA3s reflects the much higher use of LPG fuel in Victoria, compared to the other states. Given that Figure 2 showed that other fuel vehicles have a higher average rate of fuel consumption than diesel and petrol vehicles, this has implications for the small area estimates for Victorian SA3s.

Not surprisingly, given the region's small vehicle fleet, there are zero other fuel passenger vehicles on Lord Howe Island. It is generally capital city locations that have the lowest proportion of other fuel passenger vehicles, principally in Hobart and Adelaide, although several NT SA3s also have a low proportion of other fuel vehicles.

Table 7 SA3s with a particularly high or low proportion of passenger vehicles that use a fuel other than petrol or diesel, 2016

High proportion		Low proportion	
SA3 name	Proportion of other fuel vehicles (per cent)	SA3 name	Proportion of other fuel vehicles (per cent)
Maryborough-Pyrenees VIC	7.2	Lord Howe Island NSW	0.0
Fyshwick-Pialligo-Hume ACT	6.6	Burnside SA	0.3
Creswick-Daylesford-Ballan VIC	6.5	Hobart Inner TAS	0.3
Barwon West VIC	6.5	Hobart North East TAS	0.4
Loddon-Elmore VIC	6.3	Norwood-Payneham-St Peters SA	0.4

Note: Other fuel includes LPG, CNG, dual fuel, hybrid etc. External territories are excluded.
Source: BITRE analysis of ABS *Census of Motor Vehicles* 2016 data, extracted using Tablebuilder, and concorded from postcode to SA3 using the ABS population-weighted concordance.

BITRE's small area estimates

BITRE's small area estimates of the average rate of fuel consumption of the vehicle fleet were initially constructed at the SA3 scale, and were then aggregated to the SA4 scale. They are suitable for use at either the SA3 or SA4 scale. However, there is a data quality issue that impacts 10 per cent of the SA3 estimates, which have a poor quality postcode to SA3 concordance. This means that the *Census of Motor Vehicles* count is not particularly reliable for this 10 per cent of SA3s and the small area estimates of the average rate of fuel consumption should therefore be treated with caution for these SA3s (which are flagged when listed in the tables below). This concordance issue does not impact on the SA4 estimates.

Small area estimates for SA3s of vehicle registration

The small area estimates of the average rate of fuel consumption range between 10.0 and 11.0 l/100km across the 332 SA3s, compared to the national figure of 10.5 l/100km across the motorcycle and passenger vehicle fleet. This limited variation across regions is consistent with previous studies, which have identified relatively little variation in average rates of fuel consumption across regions (e.g. Li et al. 2013, Washington State Transportation Commission 2015, ABS 2015).

When the SA3 estimates were aggregated, there was found to be only a very minor gap between the average rate of fuel consumption of vehicles registered in capital cities and regional Australia. The average rate of fuel consumption was 0.7 per cent higher for passenger vehicles and motorcycles registered in regional Australia. This reflects the greater prevalence of large passenger vehicles (with 6 or more cylinders) and older model vehicles in regional Australia.

Table 8 presents the highest and lowest SA3 estimates of the average rate of fuel consumption. BITRE's small area estimates show that the SA4s with the least fuel-efficient vehicles are in remote areas and rural agricultural areas, mainly in WA, Victoria and SA.

- The three highest estimates are all in Western Australia, with the Wheat Belt South SA3 having the most extreme estimate (11.0 l/100km), followed by the Wheat Belt North and Gascoyne SA3s (each having the same average rate of fuel consumption of 10.9 l/100km). In addition, the Serpentine – Jarrahdale SA3 has an estimated rate of fuel consumption of 10.8 l/100km. The high rates of fuel consumption in these WA SA3s reflects the prevalence of vehicles with six or more cylinders and older model diesel vehicles in many of these locations, although the high proportion of motorcycles is an offsetting factor in some SA3s.

- In Victoria, the regions with the highest average rates of fuel consumption are predominantly rural SA3s (e.g. Moira, Murray River-Swan Hill, Grampians, Loddon-Elmore and Maryborough-Pyrenees), with Victoria's regional cities and Melbourne having much lower estimated rates of fuel consumption. Note that the poor quality of the postcode concordance is another potential influence on the estimates for the Loddon-Elmore SA3, which should be treated with caution. The high rates of fuel consumption in these regional Victorian SA3s reflects the prevalence of LPG-fuelled vehicles and vehicles with six or more cylinders in many of these locations (both of which have a high rate of fuel consumption).
- In NSW, two rural and regional SA3s (i.e. Bourke-Cobar-Coonamble and Lower Murray) are among the top 20 SA3s. These regions had a high estimated rate of fuel consumption due to the characteristics of the local vehicle fleet (e.g. many older model diesel vehicles as well as many vehicles with six or more cylinders).
- In SA, Murray and Mallee, Outback - North and East, Eyre Peninsula and South West, Yorke Peninsula, Mid North, Lower North and Playford are among the top 20 SA3 in terms of average fuel consumption. The Playford SA3 in Adelaide's northern suburbs is the only capital city suburban location within the top 20.[21]
- In the NT, the Barkly and Katherine SA3s have a vehicle fleet with a relatively high rate of fuel consumption. These regions had a high estimated rate of fuel consumption due to the characteristics of the local vehicle fleet (e.g. many older model diesel vehicles, many vehicles with six or more cylinders). The poor quality of the postcode concordance is another potential influence on the estimates for the Barkly SA3, which should be treated with caution.

Table 8 SA3s with a particularly high or low small area estimate of the average rate of fuel consumption

High estimates		**Low estimates**	
SA3 name	Average rate of fuel consumption (l/100km)	SA3 name	Average rate of fuel consumption (l/100km)
Wheat Belt - South WA	11.0	Lord Howe Island NSW#	10.0
Wheat Belt - North WA	10.9	Christmas Island#	10.1
Gascoyne WA	10.9	Leichhardt NSW	10.3
Loddon - Elmore VIC^	10.9	Sherwood - Indooroopilly QLD	10.3
Murray River - Swan Hill VIC	10.8	Brisbane Inner - West QLD	10.3
Maryborough - Pyrenees VIC	10.8	Holland Park - Yeronga QLD	10.3
Bourke - Cobar - Coonamble NSW	10.8	Marrickville - Sydenham - Petersham NSW	10.3
Murray and Mallee SA	10.8	Sydney Inner City NSW	10.3
Outback - North and East SA	10.8	Brisbane Inner QLD	10.3
Eyre Peninsula and South West SA	10.8	Brisbane Inner - North QLD	10.3
Mid North SA	10.8	The Gap - Enoggera QLD^	10.3
Grampians VIC	10.8	Hobart Inner TAS	10.3
Barkly NT^	10.8	Eastern Suburbs - North NSW	10.3
Moira VIC	10.8	Centenary QLD	10.3
Yorke Peninsula SA	10.8	Kenmore - Brookfield - Moggill QLD	10.3
Playford SA	10.8	Brisbane Inner - East QLD	10.3
Lower North SA	10.8	Nundah QLD	10.3
Serpentine - Jarrahdale WA	10.8	Eastern Suburbs - South NSW	10.3
Katherine NT	10.8	Carindale QLD	10.3
Lower Murray NSW	10.8	North Canberra ACT	10.3

Note: External territories are excluded.

^ The concordance quality (from postcode to SA3) is 'poor' for this SA3, and so estimates should be treated with caution.

Based on a low vehicle count of less than 500 vehicles.

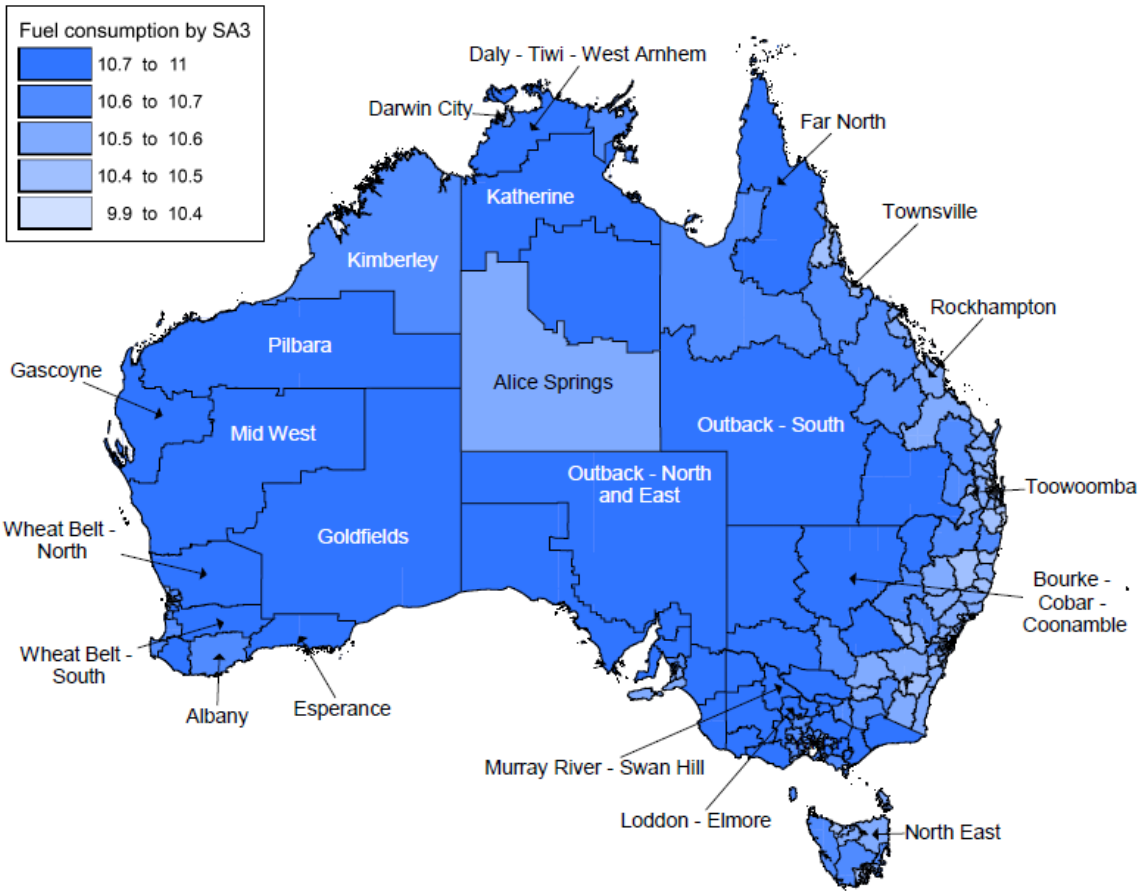
Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 average rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

[21] The Serpentine-Jarrahdale SA3 is located within the Perth Greater Capital City Statistical Area, but is predominantly rural in character.

The SA3s with the lowest estimated rates of fuel consumption are mainly from Sydney and Brisbane. The lowest estimated rate of fuel consumption is for Lord Howe Island (10.0 l/100km), which has a small vehicle fleet, dominated by relatively fuel-efficient motorcycles and passenger vehicles with 4 or less cylinders (as well as no LPG vehicles). Christmas Island has the second lowest estimated rate of fuel consumption (10.1 l/100km). Like Lord Howe Island, Christmas Island also has a small vehicle fleet, dominated by relatively fuel-efficient motorcycles and passenger vehicles with 4 or less cylinders (as well as no LPG vehicles). Inner city locations are particularly prevalent amongst the bottom 20 SA3s, including Leichhardt, Sydney Inner City, Brisbane Inner, Brisbane Inner East, Brisbane Inner West, Brisbane Inner North, North Canberra and Hobart Inner. These inner city locations typically have a vehicle fleet consisting largely of smaller vehicles and recent model vehicles, which tend to be relatively fuel-efficient. Some middle and outer suburban SA3s also have a relatively low rate of fuel consumption, such as Ku-ring-gai in Sydney, reflecting the prevalence of recent model vehicles in this location.

Map 1 illustrates the average rate of fuel consumption at the SA3 scale across Australia. It reveals that the highest rates of fuel consumption are concentrated in regional and remote Australia. Victoria, WA, SA, NT, NSW and Queensland all have a number of regional SA3s with an estimated average rate of fuel consumption of 10.7 l/100km or more. Note that while the Alice Springs SA3 stands out in Map 1 because it has a lower rate of fuel consumption than the SA3s that surround it, the estimated rate of fuel consumption of this SA3 is actually slightly above the national average of 10.5 l/100km. There are some regional SA3s that are visible on Map 1 and have an average rate of fuel consumption of less than 10.5 l/100km, including Townsville in Queensland and Coffs Harbour and Southern Highlands in NSW. However, the lowest rates of fuel consumption are concentrated in Sydney (see Map 2) and Brisbane (see Map 4) and are not generally visible on Map 1.

Map 1 Average rate of fuel consumption by SA3, Australia



Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 average rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

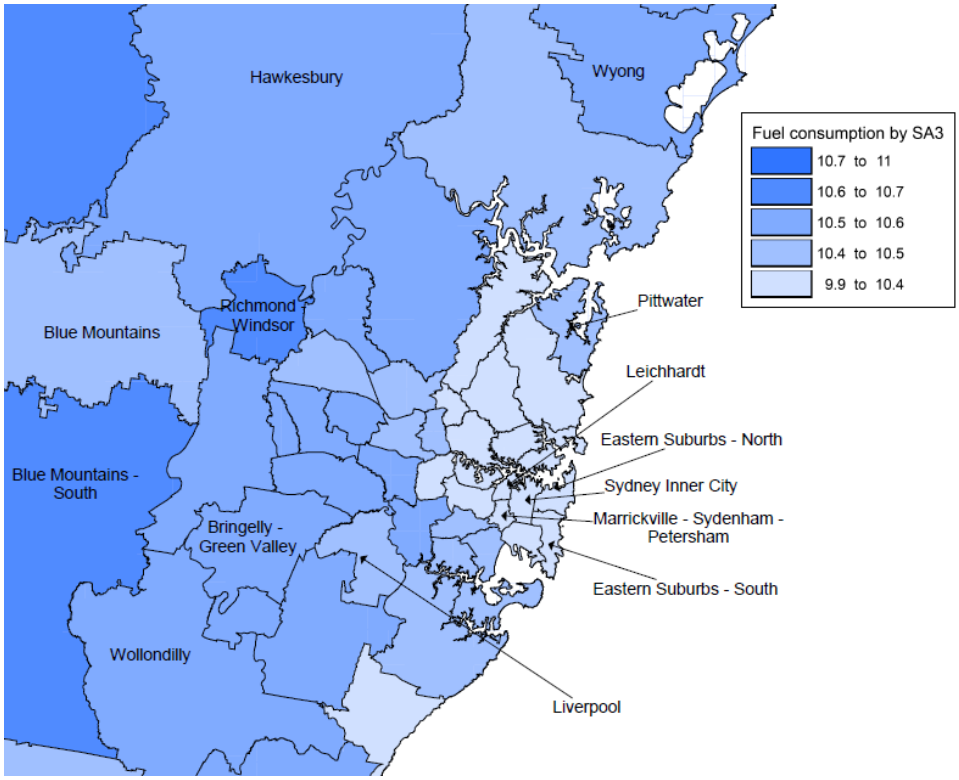
Maps 2 to 4 illustrate the average rate of fuel consumption by SA3 for Sydney and surrounds, Melbourne and surrounds, and Brisbane and surrounds, respectively. All three cities show a pattern of lower rates of fuel consumption in the inner and middle suburbs, and higher rates of fuel consumption in fringe areas. However, the low rates of fuel consumption are far more extensive in Sydney and Brisbane, than they are in Melbourne.

In Sydney, generally the inner SA3s have low rates of fuel consumption (e.g. Leichhardt, Sydney Inner City, Botany, Eastern Suburbs South, Eastern Suburbs North, Marrickville-Sydenham-Petersham), as do the northern suburbs (e.g. Manly, North Sydney-Mosman, Warringah), while outer SA3s have comparatively high rates of fuel consumption (e.g. Penrith, Bringelly-Green Valley, Richmond-Windsor, Wollondilly).

Melbourne has generally higher rates of fuel consumption than Sydney or Brisbane (see Map 3). A key contributor to the higher rates of fuel consumption in Melbourne (and Victoria, more generally) is the high rate of LPG fuel use. Based on the ABS *Household Expenditure Survey* 2009-10 expenditure data, BITRE (2017a)[22] pointed out that the LPG/other gas proportion of fuel expenditure was much higher in Melbourne (6.2 per cent) than for Sydney (1.2 per cent), Brisbane (1.3 per cent) and other capital cities. As shown earlier in Figure 2, LPG/other fuelled passenger vehicles have a higher average rate of fuel consumption than diesel or petrol passenger vehicles.

Map 4 for South East Queensland shows that the low rates of fuel consumption are concentrated within the City of Brisbane LGA, but that there are also some areas of the Gold Coast (e.g. Robina) and Sunshine Coast (e.g. Buderim and Maroochy) with relatively low rates of fuel consumption. Toowoomba also stands out with a lower rate of fuel consumption than the rural areas that surround it.

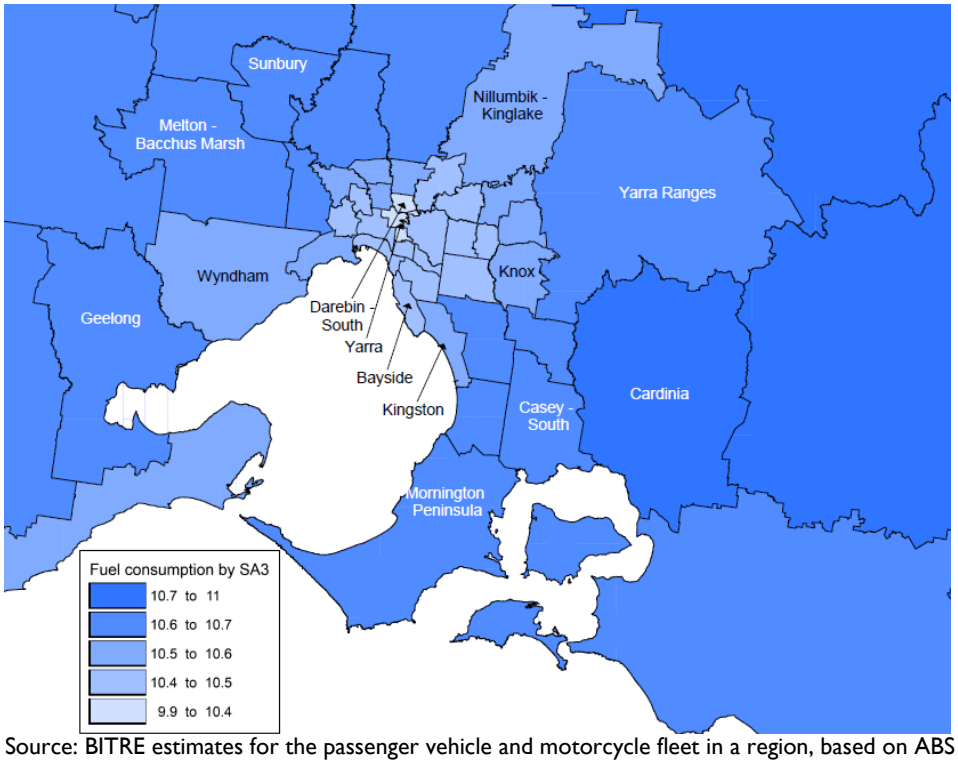
Map 2 Average rate of fuel consumption by SA3, Sydney and surrounds



Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

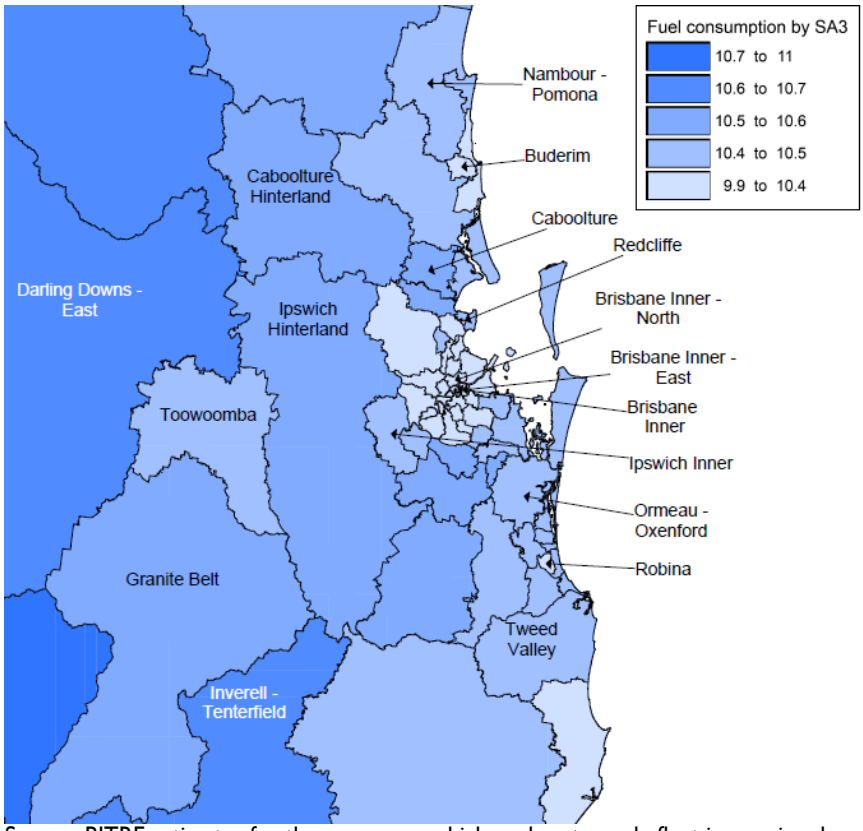
[22] See Box 2 of BITRE (2017a).

Map 3 Average rate of fuel consumption by SA3, Melbourne and surrounds



Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

Map 4 Average rate of fuel consumption by SA3, Brisbane and surrounds



Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 average rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

Small area estimates for SA4s of vehicle registration

The small area estimates of the average rate of fuel consumption range between 10.3 and 10.8 l/100km across the 87 SA4s, compared to the national figure of 10.5 l/100km across the motorcycle and passenger vehicle fleet. Thus, the range of the SA4 estimates is narrower than that of the SA3 estimates.

Table 9 presents the highest and lowest SA4 estimates of the average rate of fuel consumption. The SA4s with the highest rates of fuel consumption are in remote and regional locations, and the list contains SA4s from Victoria, South Australia and Western Australia. The SA Outback, the WA Wheat Belt and North West VIC SA4s have the highest estimates of the average rate of fuel consumption (10.8 l/100km).

The ten SA4s with the lowest estimated rates of fuel consumption are all located in two capital cities: Sydney and Brisbane. Inner city SA4s, such as Brisbane Inner City, Sydney City and Inner South, and Sydney Eastern Suburbs, tend to have lower rates of fuel consumption (10.3 l/100km) than middle and outer suburban areas of the same city.

Table 9 SA4s with a particularly high or low small area estimate of the average rate of fuel consumption

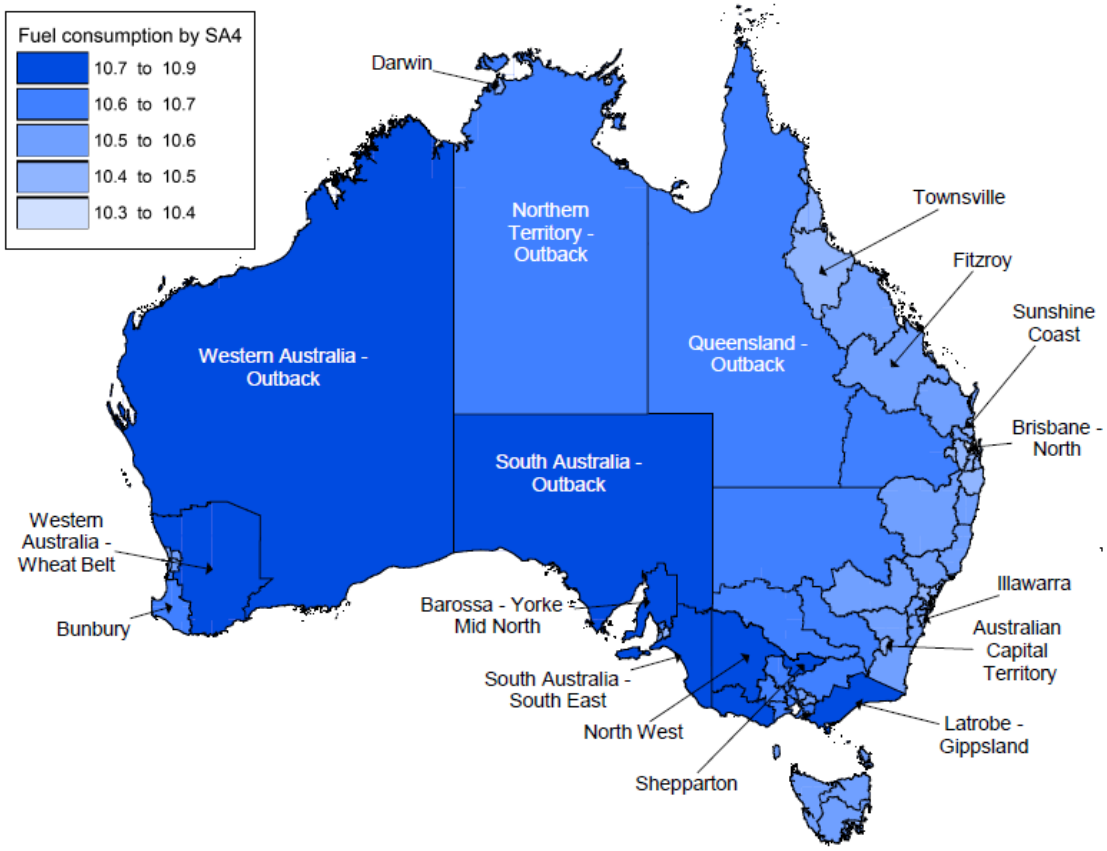
High estimates		Low estimates	
SA4 name	Average rate of fuel consumption (l/100km)	SA4 name	Average rate of fuel consumption (l/100km)
South Australia - Outback SA	10.8	Brisbane Inner City QLD	10.3
Western Australia - Wheat Belt WA	10.8	Brisbane - West QLD	10.3
North West VIC	10.8	Sydney - City and Inner South NSW	10.3
Barossa - Yorke - Mid North SA	10.7	Sydney - Eastern Suburbs NSW	10.3
Shepparton VIC	10.7	Brisbane - South QLD	10.3
Warrnambool and South West VIC	10.7	Brisbane - North QLD	10.3
South Australia - South East SA	10.7	Sydney - Inner West NSW	10.4
Western Australia - Outback WA	10.7	Sydney - Ryde NSW	10.4
Latrobe - Gippsland VIC	10.7	Sydney - North Sydney and Hornsby NSW	10.4
Ballarat VIC	10.7	Sydney - Northern Beaches NSW	10.4

Note: External territories are excluded.

Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 average rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

Map 5 illustrates the small area estimates of the average rate of fuel consumption at the SA4 scale, and reveals a very pronounced clustering of the high rates of fuel consumption in regional Victoria, regional WA, regional SA and outback regions more broadly. Low rates of fuel consumption are concentrated in the capital cities (particularly around Sydney and Brisbane).

Map 5 Average rate of fuel consumption by SA4, Australia



Source: BITRE estimates for the passenger vehicle and motorcycle fleet in a region, based on ABS *Census of Motor Vehicles* 2016 vehicle counts and SMVU 2016 average rates of fuel consumption, taking into account vehicle type, fuel type, number of cylinders and year of manufacture.

Conclusion

This study examined how realised rates of fuel consumption varied over time, and how the rates depended on key vehicle characteristics (e.g. number of cylinders, fuel type and vehicle age), using data from the ABS *Survey of Motor Vehicle Use* 2016 and the ABS *Census of Motor Vehicles* 2016. It also investigated how states and territories differed in fuel economy (or fuel efficiency) and estimated spatial differences in average rates of fuel consumption for Australia's regions (at both the SA3 and SA4 scale). In other words, this study has identified the locations where residents drive the least (or most) fuel-efficient vehicles.

BITRE recently published a related Information Sheet (BITRE 2017a) which summarised Australian household spending on owning and operating vehicles using the ABS *Household Expenditure Survey* 2009–10 data. Future research by BITRE will use the soon-to-be-released ABS *Household Expenditure Survey* 2015–16 data to identify any significant changes that have occurred in household transport spending since 2009-10, particularly with regard to regional differences in household transport spending and spending on motor vehicle fuel.

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Prepared by Leanne Johnson and Afzal Hossain.

For further information on this publication please contact bitre@infrastructure.gov.au.

Use of the Coat of Arms

Contact us

Department of Infrastructure and Regional Development
Bureau of Infrastructure, Transport and Regional Economics (BITRE)
GPO Box 501, Canberra ACT 2601, Australia

Phone: (international) +61 2 6274 7210
Fax: (international) +61 2 6274 6855
Email: bitre@infrastructure.gov.au
Website: www.bitre.gov.au