THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

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Vehicle Emissions Working Group
Department of Infrastructure and Regional Development
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Via email: vemissions@infrastructure.gov.au

**Subject: Comments on the draft Regulation Impact Statement for improving the efficiency of new light vehicles**

To Whom It May Concern:

The International Council on Clean Transportation (ICCT) would like to thank the Department of Infrastructure and Regional Development for the opportunity to provide comments on your "Improving the efficiency of new light vehicles" draft Regulation Impact Statement (RIS).

The ICCT is an independent research organization that provides unbiased technical research and analysis to regulators focused on improving the environmental performance and energy efficiency of the transport sector. The ICCT promotes best practices and comprehensive solutions to improve vehicle emissions and efficiency, increase fuel quality and sustainability of alternative fuels, reduce pollution from the in-use fleet, and curtail emissions of local air pollutants and greenhouse gases (GHG) from international goods movement.

We commend the Department of Infrastructure and Regional Development for the thoughtful work towards establishing Australia's first light vehicle $CO_2$ standards. The options considered in the RIS are consistent with the levels of stringency in other major vehicle markets. A reduction in new light vehicle $CO_2$ emissions from 184g$CO_2$/km in 2015 to 105g$CO_2$/km in 2025 (Target A) would be achievable with known and cost-effective technologies that are already being implemented in the US, Europe, Japan, and other markets around the world. As a result, the Department of Infrastructure and Regional Development should seek to establish mandatory $CO_2$ standards consistent with Target A.

We would be glad to clarify or elaborate on any points made in the attached comments. If there are any questions, please let us know.

Best regards,

[redacted]

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**Summary of comments supporting Australia's fuel efficiency standards**

In 2015, Australia was the 11th largest vehicle market in the world. Of the top 10 vehicle markets[1], only Russia (9th) has not yet adopted a mandatory fuel efficiency/$CO_2$ emission standard for light-duty vehicles (LDVs) or passenger cars. This draft RIS proposes a huge leap towards catching up with vehicle efficiency standards in the US, EU, Japan, Mexico, Saudi Arabia, and other markets. As expanded upon below, the RIS explores Australia's opportunity to reduce emissions from light-duty vehicles in the coming years. Continuing this progress into the future is essential in meting Australia's commitments under the Paris climate agreement.

The ICCT strongly supports the proposed Target A stringency of 105 $gCO_2$/km in 2025. A summary of our key comments and recommendations is as follows:

1. Costs of efficiency technologies have decreased, and a greater variety of technologies have become available, since the studies used in BITRE's cost-benefit analysis were completed. Consequently, the overall costs of the proposed standards will be lower than estimated in the RIS. As a result, the net benefits of the standards and the benefit-cost ratio will be higher. (See response to Question 9)

2. Footprint-based standards preserve consumer choice and safety better than mass-based, or flat, standards. Footprint as the utility parameter also accounts for vehicle load reduction more equitably than mass, and evidence suggests that footprint has lower overall compliance costs. (See response to Question 4)

3. The present fuel quality in Australia is not a hindrance to lowering $CO_2$ emissions from new light vehicles. While gasoline sulfur content in Australia should be brought down to 10ppm over time in view of reducing noxious emissions, lack of availability of ultra low sulfur or extra high octane gasoline should not become an excuse for delaying action on light vehicle $CO_2$ standards. (See Comment on fuel quality)

4. The technologies to comply with the proposed standard already exist in the global marketplace. Thus, the proposed standard simply requires manufacturers use these technologies for vehicles sold in Australia as well. As a result, the standard, if finalized in 2017, provides sufficient lead-time to get the Australian market ready for a phase-in from 2020 onwards. (See response to Question 8)

5. Appropriate credits for technologies whose benefits are not counted under test conditions can enhance the standard, but must be used cautiously and judiciously to avoid double-counting and to properly reflect real world conditions. (See response to Questions 10 and 11)

6. A single target curve for M1 and N1 vehicles is best as many of the same technologies to improve efficiency are available for M1 and N1 vehicles alike. However, if two target curves are used, one encompassing M1 (cars and SUVs) and the other N1 (LCVs) makes the most sense. Such standards would be consistent with Australia's current regulatory categories, as well as global practice. (See response to Question 6)

[1] *The top 10 vehicle markets in 2015 were: China, U.S., EU, Japan, India, Brazil, Canada, South Korea, Russia, and Mexico.*

## ICCT responses to key questions raised in Appendix A of the RIS

### Question 1. What parameter ($CO_2$ emissions or fuel consumption) should be used for an Australian fuel efficiency standard and why?

Since the Government primarily seeks to reduce $CO_2$ emissions through improved vehicle efficiency, a $CO_2$ emissions-based standard is preferable. In contrast to a fuel consumption-based standard, a $CO_2$ emissions parameter is independent of type of fuel burned. Thus, alternative, low carbon fuels are equally encouraged.

Furthermore, Australia's Green Vehicle Guide already uses $CO_2$ as a metric for vehicle efficiency. As evidenced by Australia's fuel consumption labeling program, measuring efficiency in terms of $CO_2$ emissions easily translates into fuel consumption. Thus, using $CO_2$ as the efficiency parameter is both administratively easier and more straightforward, as well as more technology neutral than using fuel consumption to measure efficiency.

### Question 2. How should a vehicle's efficiency for the purposes of an Australian fuel efficiency standard be assessed and why?

Australian Design Rule (ADR) 81/02 currently uses the test cycle consistent with UN Economic Commission for Europe (UNECE) Regulation No. 83 as the standardized laboratory test applied to all new light duty vehicles. The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) has formally adopted the Worldwide harmonized Light vehicles Test Procedure (WLTP) (Mock 2013b). The test cycle does more than simply harmonize global testing procedures: it improves the test procedure and closes loopholes, thus providing more realistic results that are closer to real world emissions (Mock et al. 2014). The more realistic emissions data delivered by the WLTP leads to the adjustment of the EU target of 95 $gCO_2$/km (based upon the New European Driving Cycle or NEDC) in 2020 to 100-102 $gCO_2$/km on the WLTP (Mock et al. 2014). Thus, adoption of WLTP in ADR 81/02 will not greatly affect the necessary targets under the proposed fuel efficiency standard. Several markets are already preparing to adopt the WLTP: the EU is set to adopt WLTP in 2017-18, Japan will adopt in 2018-19, and China will add WLTP along with the China 6 emission standards in 2020.

### Question 3. How should a sales weighted average target be applied in Australia and why?

As acknowledged in the RIS, attribute-based standards equitably spread the regulatory burden across all manufacturers while respecting consumer choice. Attribute-based standards provide a variety of ways for manufacturers to comply by linking the target to the fleet mix, which may change over time.

In contrast, flat standards, while administratively simple, are not nearly as equitable as attribute-based standards, as they disproportionately disadvantage manufacturers at both ends of the emissions spectrum. As acknowledged in the RIS, absolute limits/caps could reduce consumer choice by forcing manufacturers to stop offering larger vehicle models (CCA 2014). Uniform percentage improvements penalize manufacturers that have already improved vehicle efficiency and reward technology laggards with a less stringent standard.

**Question 4. If an attribute based standard is adopted, which attribute should be adopted in Australia and why?**

Footprint-indexed standards more directly and efficiently encourage mass reduction (lightweighting), which is the primary means for reducing vehicle load, than mass-indexed standards. Since lightweighting promises to be one of the least expensive ways to increase efficiency (EPA 2016a, ICCT 2016) and thereby comply with the standards, footprint-based standards reduce compliance costs. Furthermore, footprint-based standards encourage better safety design than mass-based standards (NHTSA 2006). Weight-based standards can encourage smaller vehicles, which has negative safety impacts for the vehicle fleet. Size-based standards encourage lighter vehicles while maintaining vehicle size. As long as size is maintained, safety impacts are negligible, or even positive (ICCT 2009).

Powertrain efficiency improvements generate the same benefit under mass- and footprint-based standards. Under a footprint-based standard, the same efficiency improvement derived from weight reduction moves a manufacturer closer to the target emission level by the same amount. In contrast, a mass-based standard does not reduce the distance to compliance given the same efficiency benefit due solely to weight reduction (see figure 1 below). Thus, weight-reducing technologies are not treated equally under the two standards (German and Lutsey, 2011).

In 2014, Ricardo-AEA completed a study for the European Commission comparing footprint- and mass-based standards (Kollamthodi 2014). It was found that overall compliance costs are 16% lower under a footprint standard than a mass standard. All but one manufacturer showed reduced costs using footprint as the utility parameter. The study also found that mass as the utility parameter may result in other, rival manufacturers benefitting from weight reduction efforts by an individual manufacturer, providing a competitive disincentive to reduce weight. Finally, the study reinforces independent findings that weight reduction can be achieved at lower costs than originally anticipated, due to improved materials and design options.

Although the evidence supports more cost-effective footprint-indexed standards, suddenly switching from the design of EU $CO_2$ standards to a footprint-based standard may provide some manufacturers with a competitive advantage. Utilizing footprint as an index in Australia from the beginning provides uniform accounting for all methods of improving vehicle efficiency, costs less overall for the vast majority of manufacturers, and avoids possible administrative and competitive problems later. Finally, the objective of attribute-based standards is to preserve consumer choice. Size is a utility desired by consumers, while weight is invisible to customers and is not directly valued.

Footprint as the utility parameter preserves size and more efficiently encourages lightweighting, which improves vehicle handling and performance. As explained above, footprint also results in lower overall costs of compliance, and technology costs continue to fall while new advancements routinely come to market. Thus consumer choice is not limited, and efficiency improvements could be accompanied by improved performance as well.

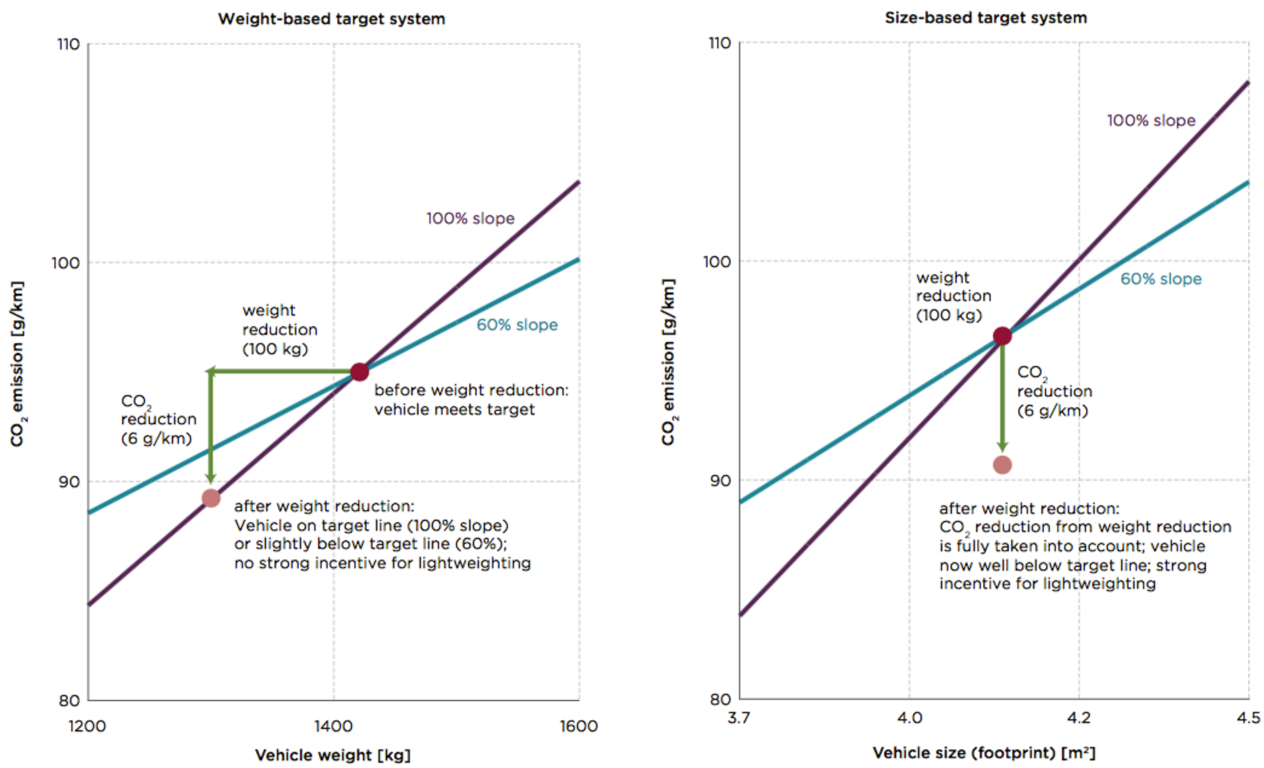


*Figure 1: Two different incentives for vehicle load reduction via lightweighting under standards based on mass or footprint as utility parameter (Mock 2011).*

**Questions**

**5. How should a fuel efficiency standard be applied to each light vehicle category and why?**

**6. If SUVs are subject to a different target to passenger cars, how should SUVs be defined, and why?**

The technologies available to improve efficiency of both M1 vehicles (cars & SUVs) and N1 vehicles (light-commercial vehicles or LCVs, comprising light trucks such as pickups and vans) are largely similar. Hence, the best practice is to regulate all vehicles (M1 and N1) together, under the same target curve. However, no country or region regulates all M1 and N1 vehicles under the same standard at present.

While some people use LCVs as a personal transport vehicle just like a car or an SUV, there are many legitimate users of LCVs who need the fundamental load carrying/towing capacity provided by LCVs, and which affects overall $CO_2$ emissions of those vehicles. Combining the standards into one may put some of these vehicles at a disadvantage, if the standard is not attribute based. Under an attribute-based standard, however, consideration can be given to the larger size/mass of the LCVs while maintaining one set of standards for all light vehicles. Indeed, LCVs generally have a lot of empty space inside, and do not carry the extra seats and other consumer features of cars/SUVs. Therefore, LCVs are typically much lighter for their size than a similar sized passenger vehicle, and consequently have better fuel efficiency. In this way, a single footprint-based standard can apply to all light vehicles, whereas a mass-based standard (which penalizes LCVs for their light weight relative to their size) will likely require a separate standard for cars & SUVs and another for LCVs (as is the case in Europe, the split standards in the US is explained below).

If two curves are deemed necessary, they should be separated into M1 (again, cars and SUVs) and N1 (LCVs). Since M1 vehicles are based on car platforms, having a curve for cars & SUVs, rather than cars only, would provide a consistent target for vehicles based on car platforms and for which similar methods of improving efficiency apply. However, the following explains some of the historical drawbacks of separate target curves.

Separate car/SUV standards and LCV standards creates an incentive for manufacturers to reclassify some of the larger/heavier/less efficient cars and SUVs as LCVs through simple design changes, without affecting the underlying engine/transmission or overall utility of the vehicle – or its purchase by customers for non-commercial use.

Globally, light-commercial vehicles are typically restricted to vehicles designed to carry cargo, such as pickups and boxed vans (e.g. Ford Transit). SUVs and minivans under 3500kg are classified as passenger vehicles. Only in the US are minivans and SUVs under 3863kg (8500 lbs) considered as light-trucks. Since some manufacturers sell more light-commercial vehicles than passenger cars and SUVs, a split standard may impact relative competitiveness among manufacturers. Additionally, LCVs tend to have less efficiency technology applied (although there is no technical reason why the same amount of efficiency technology cannot be applied). As the LCV standards in Europe reflect the lower level of technology on the baseline vehicles, the EU standards for LCVs are relatively lenient, resulting in manufacturers meeting their future targets well in advance (Mock 2013a).

When US fuel economy standards were initially formulated under the 1975 Energy Policy and Conservation Act, light trucks were only 20% of the market and minivans and car-based SUVs did not exist. Thus, the initial focus of the Congress was on car standards, with the establishment of light-truck standards delegated to the National Highway Traffic Safety Administration (NHTSA). When the larger car-based minivans and SUVs began developing, NHTSA included them along with the pickup trucks. As sales of minivans and SUVs increased, this classification became increasingly problematic. Acknowledging some of the issues with this classification, EPA and NHTSA subsequently reclassified all 2wd SUVs less than 6,000 lbs GVWR as cars, but left 4wd SUVs, larger 2wd SUVs, and minivans as light trucks.

Unfortunately, the less stringent standard for trucks strongly incentivizes manufacturers to reclassify cars as trucks in the US, by increasing the ground clearance of cars so that they can be classified as SUVs and eliminating 2wd versions of small SUVs. Less efficient 4wd versions remain, along with the addition of vehicles with higher ground clearance, which directly increase fleet fuel consumption. Additionally, this eases manufacturer compliance, so that they need not install available technology on other vehicles. Most light trucks (except for certain SUVs and pickups) are based on car platforms; and pickups are much lighter than truck-based SUVs of the same size (due to empty bed). These two facts, plus the applicability of similar technologies to all vehicles regardless of platform, indicate that there is no technical reason to have separate curves for M1 and N1 vehicles.

It is time to end the artificial distinction between M1 and N1 vehicles for fuel efficiency and greenhouse gas emissions. A single footprint function will still give larger trucks a less stringent target to meet, while avoiding vehicle classification games and helping to ensure fuel consumption and GHG emission goals are actually met. Australia can lead the world in this respect.

**Question 7. How should targets for a fuel efficiency standard be phased in and why?**

Annual targets encourage annual rates of efficiency improvements, which have greater environmental benefits than a periodic phase-in. Annual targets also set interim goals for manufacturers, ensuring they do not wait until the last minute to comply. Two other important benefits are that some of the flexibility mechanisms are not implementable without annual targets and adoption of annual targets would harmonize with other international standards. The combination of interim goals and flexibility mechanisms allows regulators to judge whether manufacturers are putting forth their best efforts, and, if falling short of the standards in spite of the best efforts, provides the capacity to relax the mandates.

**Question 8. If annual targets are adopted, what targets should apply in each year for each segment and why?**

After setting the initial fleetwide goal under Target A (105 $gCO_2$/km in 2025, NEDC), the calculated percentage reduction in emissions can be applied each year to each yearly fleet. With a starting fleet efficiency of 184 $gCO_2$/km (NEDC) in 2015, Target A corresponds to a 5.5% annual reduction. While this might appear to be an aggressive standard, it is important to understand that Australia is starting from a different baseline than other major markets such as EU and US. Australia is a “technology taker”, meaning that the new mandatory standards would bring technology to Australia that is already in widespread use in much of the regulated world. This is much easier, requires much less lead time than technology forcing standards, and allows for larger annual reductions. Given the comparable standards in other vehicle markets and the availability of existing technology to comply with those standards, a 5.5% annual reduction for a technology taker is quite feasible. Using a percentage based target also allows for flexibility in the standard based on changing fleet mix.

The publication of the RIS and supporting documents come far in advance of 2020 (when the standards would be implemented). Thus, finalizing the standards this year (2017) provides ample lead-time for implementation in 2020. Furthermore, the sooner the standards are finalized, the greater stability and regulatory certainty they offer for the future. The stringency of the standard could be ramped up over time, as necessary, but this would delay implementation.

The U.S. CAFE standards in the past have been routinely announced 18 months prior to enforcement. Saudi Arabia, which has a vehicle fleet very similar to Australia’s and is also a technology taker, gave even less lead time (Bandivadekar and Posada 2014). Like Target A proposed in the RIS, Saudi Arabia’s target requires the same level of technology on vehicles as in the US (albeit lagging by 3 years), thereby harmonizing the standards and simplifying manufacturer compliance. Manufacturers are already anticipating efficiency standards globally, thus extended lead time is not as critical for technology takers.

**Question 9. If a percentage phase in is adopted, what percentage should apply in each year and each segment, and why?**

A 5.5% reduction per year would place Australia roughly in line with the US at the end of the phase-in in 2025, combining less stringent initial requirements with a faster rate of efficiency improvement. This ensures that the technologies put on vehicles sold in Australia will be on par with the technologies used in the US and EU by 2025 (CCA 2014). Since all vehicles to the Australian market will be imported beginning in 2018, little extra burden will be placed on manufacturers to meet these standards, as they only need to export the same vehicles to Australia that they are already planning to sell in the US, Europe, and Japan.

The relatively low burden is further supported by reduced technology costs and greater variety of available technologies. Although several new studies and publications regarding technology cost are referenced in the RIS, there is still newer information and data that should be taken into account, and which will reduce the costs of the fuel efficiency program. For example, the technical support document to US EPA's Proposed Determination (EPA 2016a) updates cost and efficiency values for numerous technologies compared to the draft Technical Assessment Report (EPA 2016b). In that report, costs/vehicle for bringing the MY2021 fleet to MY2025 standards is $986 for passenger cars ($749 US), and $1339 for light trucks ($1018 US) (see Table IV.4).

In the RIS, Table 10, the costs for bringing the Australian FY2021 fleet to FY2025 Target A standards is $1158 for passenger cars and $2344 for LCVs. (These numbers were determined by subtracting the 2021 costs from the 2025 costs.) The RIS predicted costs per vehicle are approximately 1.2x and 1.75x the costs estimated by the US EPA. The Australian and US baseline fleets are different in share of passenger cars and LCVs, as well as share of diesel and gasoline. However, diesel technology costs are expected to continue to decrease, below even the costs presented by the US EPA (ICCT 2016a, Martec 2016, and Meszler 2016). Lightweighting costs are expected to decrease as well, with a 15% reduction in light truck mass costing less than $733 ($557 US dollars) in 2025. Thus, despite the differences between the Australian and American baseline fleets, the technologies that show the greatest benefit for the Australian fleet have significantly decreased costs than those used in the BITRE benefit-cost analysis (BCA). Thus, based solely on updated technology costs, cost per vehicle will likely be 1.2x-1.75x less (that is 57%-85% of the costs in the RIS Table 10). This would increase the Target A net benefits to $16,330m-$20,870m and the benefit-cost ratio up from 1.86 to 2.18-3.26.

ICCT is even more optimistic about the technologies available for compliance (ICCT 2016a, Meszler 2016). Finally, ICCT's comments on US EPA's Proposed Determination (ICCT 2016b) demonstrate that even EPA's Proposed Determination did not consider or incorporate the latest available technology developments. For example, Atkinson and Miller cycle engines improve conventional gasoline vehicle efficiency, e-boosting and 48V mild hybrid systems greatly improve gasoline and diesel efficiency, electric vehicle battery costs have fallen dramatically, and lightweighting continues to advance. Updating BITRE's cost analysis with this data is important, as only the most recent technology studies can provide accurate starting points for future projections.

We note here that, while regulatory design is crucial, stringency is equally important. The stringency of Target A effectively brings technology to Australia that is already in widespread use in much of the world, including in the world's most stringent economies. As discussed, these technologies are available at decreasing costs and wider applicability, thus making a more stringent 2025 target than Target A feasible and cost effective.

**Question 10. What flexibility arrangements should be allowed under an Australian fuel efficiency standard and why?**

In theory, we support all flexibility mechanisms, provided that they are properly implemented. Specific flexibility mechanisms we support include: credit trading among vehicle categories, credit trading between years, credit trading between companies (pooling), derogations (concessional arrangements, exemptions, or relaxations of the rule, see below), and fiscal and non-fiscal fines (see below).

Banking, borrowing and trading should be allowed within a compliance period, assuming the standards are phased in annually. There is no point in banking credits for a periodically phased in standard.

Carry-forward credits are given to over-compliant manufacturers for use in future model years. Carry-backward credits, on the other hand, would be applied to past model years.

Allowing manufacturers to bank, borrow, and trade carry-forward credits between annual compliance periods encourages over-compliance, which improves the energy security and global warming benefits of the standards and establishes a more efficient baseline, effectively allowing more stringent standards to be set in the next phase.

However, banking, borrowing and trading carry-backward credits between longer compliance periods (i.e. not annual) would compromise the effectiveness of the standard to reduce emissions. Furthermore, standards for each successive phase typically aren't known until only a few years in advance, thus manufacturers should not rely on borrowing and trading for these unknowns.

In summary, banking, trading, and borrowing both styles of credits within a compliance period, and banking, borrowing, and trading carry-forward credits between periods, incentivize manufacturers to over-perform within a compliance period, if the standards are relatively lenient. Conversely, disallowing inter-period banking would only encourage a minimum amount of improvement. Furthermore, banking between periods allows manufacturers to comply even if product development timelines do not match up with the start (or end) of a new compliance period.

Assuming annual targets, applying a 3-year expiration date for banked credits prevents excess credits from being carried forward.

**Question 11. What, if any, credits should an Australian fuel efficiency standard adopt to further encourage the supply of more efficient vehicles, and why?**

The RIS even-handedly considers the variety of credits available. ICCT supports off-cycle and air-conditioning credits, as long as they are verifiable and do not weaken the stringency of the standard by duplicating on-cycle benefits. Validation procedures, performed by the government, can serve as a means for verifying off-cycle benefits before granting credits. For examples of such procedures, see US EPA/NHTSA 2010 and the eco-innovations requirements in the EU 2020 standards (EC 2011).

The process granting off-cycle credits in the US does suffer some problems, which have an interesting solution. In the US, granting off-cycle credits is a contentious issue, primarily because real world data on nationwide travel behavior and conditions often does not exist. A possible solution to this issue is to conduct a joint program with manufacturers and other invested entities to gather comprehensive data on nationwide, year-around travel behavior and conditions. This will allow Australia to establish standardized procedures for granting off-cycle credits, streamlining the approval process and providing known credits equally to all manufacturers.

Multipliers/super-credits for zero- and low-tailpipe emission vehicles should be limited as much as possible; low credits and short duration helps maintain technology neutrality (ClimateWorks 2014). To further help neutrality, full electric vehicles could be required to account for upstream emissions from the grid, while being allowed to take off-cycle and air-conditioning credits. Upstream EV emissions can be calculated as follows (ICCT 2012):

> net upstream emissions = fuel carbon intensity*vehicle efficiency – off-cycle credits – displaced petroleum upstream emissions.

Alternatively, an intermediate option adopted in Japan and India estimates the $CO_2$ emission level of electric vehicles by converting known/test-cycle EV kWh/km into $gCO_2$/km using a gasoline-equivalent value for $gCO_2$/kWh.

Reducing the impact of multipliers and accounting for upstream emissions, in one way or another, encourages future improvements in EVs, as well as the application of off-cycle credits.

**Question 12. Which entities should be required to comply with a fuel efficiency standard, and why?**

All entities responsible for Australian certification of a vehicle under the *Motor Vehicle Standards Act 1989* should also be the entities required to comply with the fuel efficiency standard. From a practical view, this eliminates any disputes between entities of who is responsible for the different requirements and this is consistent with EU and US standards (under which domestic manufacturers or licensed importers are responsible for compliance).

**Question 13. What concessional arrangements should be offered to low volume suppliers under an Australian fuel efficiency standard and why?**

Special provisions for small volume manufacturers could be considered. However, an attribute-based standard does not put manufacturers of a limited product line at a competitive disadvantage, as the standard adjusts the stringency for each vehicle such that the amount of technology required for all vehicles is relatively consistent. In addition, any concessional arrangements need not rely on *volume in Australia*. Many low-volume manufacturers produce the same vehicles globally, which are subject to various standards world-wide. Thus, any small volume manufacturer provisions should be limited to manufacturers with limited engineering capacity, i.e. manufacturers with *worldwide* sales of less than 3,000 vehicles per year.

Another alternative is to allow a temporary lead time allowance. That is, low volume manufacturers are not subject to lower standards, but receive slightly more lead time. For example, a low volume manufacturer may be allowed to meet 2020 standards in 2021, but must meet 2025 standards in 2025.

**Question 14. What penalties should be applied to entities that failed to comply with a fuel efficiency standard and why?**

It is important to set financial penalties at a level high enough to provide a strong incentive to comply with the standard rather than simply pay the penalty. In other words, the penalties should be higher than the cost of technology required to reduce $CO_2$ emissions in order to make compliance the more cost-effective option.

Recent technology studies have found that most conventional technologies cost less than $50 per percent improvement, with full hybrids and diesels close to $100 per percent improvement (ICCT 2016a). Thus, the financial penalty should be at least $75 per percent improvement and, preferably, close to $100 per percent improvement.

The European Commission penalty of €95/g$CO_2$/km is acceptable, as it is almost exactly $100 per percent improvement, and will ensure widespread compliance. To put that figure into context, the expected cost of compliance with future 2025 standards of 70g$CO_2$/km (NEDC), is estimated to be between €1000 and €2150. Starting with a 2014 baseline fleet at around 120g$CO_2$/km (NEDC), this corresponds to a compliance cost of €20-€43/g$CO_2$/km, or less than $50 per percent improvement (Mock 2016 and Meszler et al. 2016). Thus the penalty of €95/g$CO_2$/km is more than two times the cost of compliance.

In the US, CAFE penalties have been low historically. Until MY2019, the penalty corresponds to $55/mpg shortfall, or less than $30 per percent improvement in 2025. But these penalties are increasing dramatically, to $145/mpg shortfall beginning in 2019, or close to $75 per percent improvement. Starting with a 2014 fleet at 31.5mpg, the costs to reach an estimated 51.4mpg is less than $1610 (EPA 2016c), or around $81/mpg reduction – more than the current CAFE penalties, but less than the increased penalties. In addition, it should be noted that since the US GHG standards are enforced under the Clean Air Act, the EPA is able to assess penalties of up to $37,500 per vehicle for each violation of the act.

**Comment on fuel quality**

Although Australia has a large share of LCVs, the present fuel quality is not a hindrance to emissions standards (Bandivadekar 2014). We support high-octane fuel, however it is not required for improved efficiency, as direct injection and cooled exhaust gas recirculation reduce in-cylinder temperatures and enable higher compression ratios. Furthermore, the impact of higher octane fuel is not large, especially compared to the multitude of technology pathways available (Bandivadekar 2014). For Australia to tighten pollutant emission standards beyond Euro 6, sulfur content of gasoline would require improvement. But lack of ultra-low sulfur gasoline does not affect viability of the proposed $CO_2$ emissions standards, since gasoline sulfur content does not hinder increased fuel economy.

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