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Survey of Tier 1 automotive suppliers with respect to the costs and performance of vehicle technologies

Report for CALSTART

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Survey of Tier 1 Suppliers with respect to the costs and performance of vehicle technologies needed to meet 2025 targets

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Executive summary

The National Program for greenhouse gas emissions (GHG) and fuel economy standards was developed jointly by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA). The EPA and NHTSA are required to conduct a review of the standards as part of the Final Rulemaking to extend the National Program of harmonized greenhouse gas and fuel economy standards for 2017-2025 period. The aim of this midterm evaluation (MTE) is to decide whether the standards for model years 2022-2025, established in 2012, are still appropriate given the latest available data and information.

The National Academies of Science (NAS) Report on Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles (NAS, 2015) was published in 2015, timed to inform the EPA midterm evaluation.

CALSTART has commissioned Ricardo Energy & Environment to conduct a Delphi survey of Tier 1 automotive suppliers in the U.S. in order to gather information on the views of these companies with respect to the cost and performance data included in the 2015 NAS report.

This survey followed the Delphi approach and was conducted in two stages, giving respondents the opportunity to review the aggregate responses and amend their responses if necessary. The objective of a Delphi survey is to obtain the consensus of a group of experts on a specific question/problem. The method is mainly applied for analysing issues that are particularly complex and hence involve significant uncertainty.

The first stage of the survey included questions covering the following topics:

- Background information (relating to the respondent)
- 2025 GHG and fuel economy targets
- Effect of oil prices
- Policies and employment
- Estimates for reductions in fuel consumption from the NAS report
- Costs and performance of vehicle technologies
- Approaches used in the NAS report

Following completion of the first stage of the survey, the results were anonymised, summarised and incorporated into Stage 2 of the survey. In line with the Delphi method, these results were distributed to the Stage 1 respondents in order to give them the opportunity to comment on the responses of the other participants, reconsider their view and revise their answer to the issue being analyzed.

Telephone interviews were also conducted with some of the survey respondents in order to collect further details and follow up on comments made during the survey.

Overall, the stakeholders recognized the scale of the challenge of processing the data and information required to assess the fuel consumption reductions and cost estimates of the wide range of technologies included in the NAS report.

There were a number of key areas where there was a high level of consensus among the stakeholders:

- The majority of Tier 1 suppliers who participated in this study agreed with the 2025 fuel efficiency target as set by the EPA and the NHTSA.
- The majority of suppliers surveyed believe that this target should not be changed under the next administration, indicating that the target helps industry by providing regulatory certainty in order to help plan investments and strategies for developing new technologies.
- Stakeholders generally agreed that it is important to start planning and setting targets now for beyond 2025. New technologies have long development lead times so regulatory certainty is essential.
- Most respondents broadly agreed with the approaches used in the NAS report, recognising the challenges of assessing the costs and performance of such a wide range of technologies.

In addition, there were a number of areas where the responses from stakeholders were more mixed:

- Regarding the cost estimates, there was less agreement amongst respondents who were able to express an opinion. The majority of respondents felt unable to comment on costs in the majority of technology categories.
- There was no clear consensus on the importance of electrification of vehicles in order to meet the 2025 target. Although some survey respondents felt that there would be sufficient improvements in ICE technologies, lightweighting and hybridization technologies to meet the 2025 targets without additional electrification, other survey respondents indicated that a high level of EV penetration would be required to achieve the target.
- The effect that oil price has on the sales of fuel efficiency technologies garnered a mixed response from the survey respondents. About 45% indicated that low oil prices do not have a noticeable effect on these sales, whereas 45% indicated that low prices reduce the demand for, and sales of, fuel efficiency technologies.

The results of this survey will be used by CALSTART to provide a response to the midterm evaluation of the U.S. federal light-duty vehicle greenhouse gas emissions standards.

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1 Introduction

CALSTART has commissioned Ricardo Energy & Environment to conduct a Delphi survey in two stages to investigate suppliers' views on the data included in the 2015 National Academies of Sciences (NAS) report entitled "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles" and develop, on an aggregate basis, the view of the supplier community of the 2025 standards.

CALSTART is a national non-profit corporation dedicated to supporting and accelerating the growth of the clean transportation technologies industry. CALSTART has more than 150 member companies engaged in developing and producing cleaner, lower carbon cars, trucks, buses, and fuels.

1.1 Policy context

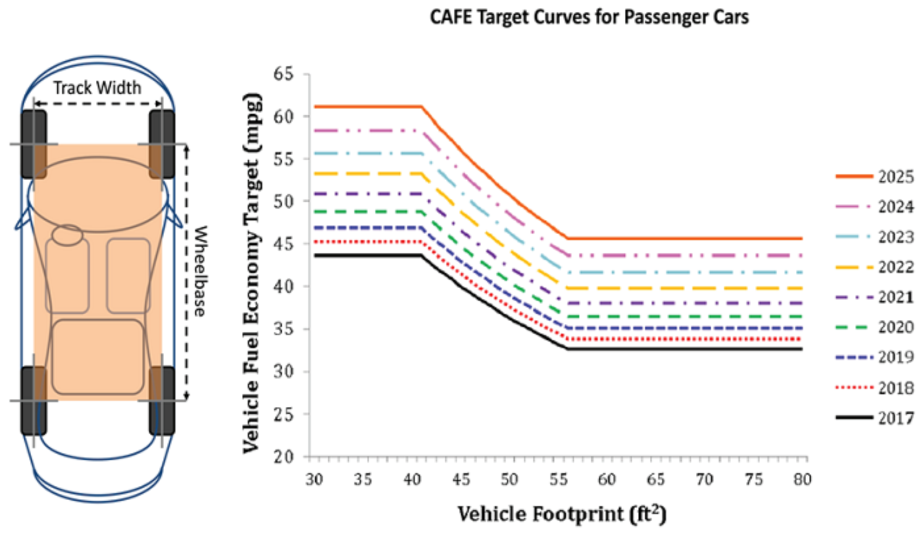
1.1.1 National Program for greenhouse gas emissions and fuel economy standards

The National Program for greenhouse gas emissions (GHG) and fuel economy standards was developed jointly by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA). The first phase of the National Program for the model years (MYs) 2012-2016 vehicles, is projected to result in an average light-duty vehicle tailpipe carbon dioxide level of 250 grams per mile by MY 2016, equivalent to 35.5 miles per gallon (mpg) (if achieved exclusively through fuel economy).

In 2012, EPA and NHTSA issued a joint Final Rulemaking to extend the National Program of harmonized greenhouse gas and fuel economy standards for MY 2017-2025 passenger vehicles. This second phase of the program projected an average industry fleet-wide level of 163 grams per mile of carbon dioxide (CO_2) in model year 2025, which is equivalent to 54.5 mpg if achieved exclusively through fuel economy improvements, with passenger cars accounting for 67% of sales, and light trucks accounting for 33%.

The actual targets set in the Final Rulemaking are in the form of curves that show the required fuel economy and CO_2 levels as a function of vehicle footprint. Vehicle footprint is defined as vehicle wheelbase multiplied by average track width, and is used as a proxy for vehicle size (see Figure 1). The fuel economy targets are footprint-specific in order to allow for the fact that larger vehicles generally have greater energy requirements. Setting a footprint-specific target aims to spread the effort of meeting the target evenly between manufacturers, regardless of whether they predominantly produce small or large vehicles. Separate footprint-based targets have been set for passenger cars and light trucks, with targets for passenger cars requiring higher fuel economy at equal footprint. Again, this reflects the goal of spreading the effort, allowing for the fact that light trucks tend to have greater energy requirements at equal footprint size compared to passenger cars because they are taller and heavier.

Figure 1: CAFE target curves for passenger cars (NAS, 2015)



The targets set out in the 2012 Final Rulemaking are only binding from 2017 to 2021, due to the fact that NHTSA does not have a mandate to legislate CAFE standards for more than five years at a time. Moreover, vehicle manufacturers expressed concerns about setting binding ambitious targets very far in advance without the possibility of them being adjusted in light of new developments. Therefore, as part of the 2017-2025 rulemaking, a midterm evaluation (MTE) was agreed. The aim of the MTE, undertaken by the EPA in cooperation with NHTSA and CARB, is to decide whether the standards for model years 2022-2025, established in 2012, are still appropriate given the latest available data and information. Possible conclusions are: the standards are still appropriate, the standards should be more stringent, or the standards should be less stringent.

The midterm evaluation consists of several steps, the first of which is the Draft Technical Assessment Report (TAR) for public comment which was published in July 2016 (EPA, NHTSA & CARB, 2016). Should it be found that the standards are no longer appropriate (i.e. they should be either more or less stringent), the EPA will prepare a Proposed Determination, based on the Draft TAR's findings and the public input in response to the Draft TAR, foreseen to be published in mid-2017. Following further public input, the Final Determination would be foreseen for publication by April 2018.

The Draft TAR was published on July 18, after large parts of the Delphi survey undertaken as part of the present study had already been completed. Therefore, the Draft TAR's findings were not the subject of the survey and will not be discussed at length in this report. However, some respondents commented on the Draft TAR during the follow-up interviews which the project team undertook with some respondents. It is therefore worth highlighting some of the draft TAR's key findings:

First, the Draft TAR projected that fleet average fuel economy (in MPG-e) would not reach 54.5 mpg as projected in 2012. Instead, values between 50 and 52.6 mpg are expected (see Figure 2). This is because low oil prices have helped shift consumer preferences from cars to light trucks, as well as towards larger vehicles with larger footprints. This trend is expected to continue to 2025. Drawing on oil price forecasts from the 2015 Annual Energy Outlook (AEO), the Draft TAR projects higher average footprints and a greater share of trucks for the 2025 MY fleet.

Figure 2: Extract from Draft TAR with revised projections on average fuel economy (EPA, NHTSA & CARB, 2016)

Table ES- 1 Projections for MY2025: Car/Truck Mix, CO2 Target Levels, and MPG-equivalent[1]

		AEO 2015 Fuel Price Case		
	2012 Final Rule	AEO Low	AEO Reference	AEO High
Car/truck mix	67/33%	48/52%	52/48%	62/38%
CAFE (mpg)[2]	48.7	45.7	46.3	47.7
CO_2 (g/mi)	163	178	175	169
MPG-e	54.5	50.0	50.8	52.6

Notes:

[1] The CAFE, CO_2 and MPG-e values shown here are 2-cycle compliance values. Projected real-world values are detailed in Chapter 10.1; for example, for the AEO reference fuel price case, real-world EPA CO_2 emissions performance would be 220 g/mi and real-world fuel economy would be 36 mpg.

[2] Average of estimated CAFE requirements.

[3] Mile per gallon equivalent (MPG-e) is the corresponding fleet average fuel economy value if the entire fleet were to meet the CO2 standard compliance level through tailpipe CO2 improvements that also improve fuel economy. This is provided for illustrative purposes only, as we do not expect the GHG standards to be met only with fuel efficiency technology.

A second key finding from the Draft TAR was that, with regard to the technical options for saving fuel, '*a wider range of technologies exist for manufacturers to use to meet the MY2022-2025 standards, and at costs that are similar or lower, than those projected in the 2012 rule*'.

1.1.2 The NAS Report on Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles

The National Academies of Science (NAS) Report on Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles (NAS, 2015) was published in 2015, timed to inform the EPA midterm evaluation. The report includes an extensive literature review and modeling to analyze CO_2-reducing technologies in the 2020 to 2030 timeframe, and provides key output tables, which estimate the costs and expected fuel savings of deploying a wide range of different technologies on three different types of light-duty vehicle.

The NAS has informed vehicle fuel economy policy on several occasions, having published relevant reports since 1992. The NAS sets up ad-hoc expert committees to draft these reports and asks other experts to peer-review the findings and recommendations. The Energy Independence and Security Act of 2007 requires NHTSA to task the NAS with developing regular reports evaluating vehicle fuel economy standards at five year intervals, the first of which was published in 2011. The aforementioned 2015 report is the second report.

As previously mentioned, a key output of the NAS report is a series of tables with quantified estimates of the reductions in fuel consumption from different technologies and the estimated costs of these technologies for the years 2017, 2020 and 2025. Most of these are updates to figures compiled from various studies undertaken as part of the EPA/NHTSA rulemaking for the 2017-2025 period in 2012. The original figures are generally based on teardown studies and full-system simulation. The NAS reviewed these figures and the underlying methodology and undertook its own analysis, drawing on presentations, expert opinions, and published literature from industry, regulators and others to develop revised estimates. In addition, estimates for technologies which had not been covered under the previous EPA/NHTSA analysis for the development of the 2017-2025 standards were developed. In its analysis, the NAS put emphasis on technologies with big potential benefits in terms of fuel consumption, or technologies for which particular methodological issues were raised.

A committee of 18 experts from industry, academia and NGOs plus support staff are responsible for the content of the NAS report, and a draft version was independently reviewed by a further 15 experts of similarly diverse backgrounds. This approach ensured high quality critical analysis and conclusions which reflect a consensus view among a wide range of stakeholders.

However, as has also been argued by one of the reviewers (ICCT, 2015), this approach is likely to have led to overly conservative technology cost assumptions. Generally, earlier studies have tended to forecast higher costs of vehicle technologies than were observed once the technologies became widely deployed. The NAS report have produced similar overestimates. First, the approach accounts for cost reductions through learning, but not through technical innovations, some of which are already underway, while the report can only provide a snapshot at a given point in time. Second, it is suggested that the report generally tends towards making conservative assumptions. For example, for some technologies, a range of technology cost estimates is provided, and the 'most likely high' estimates are judged to be '*in essence, an inventory of what might go wrong*' rather than a likely estimate. Third, some technologies, especially lightweighting, are likely to provide additional value to customers (performance, handling, etc.) beyond fuel consumption reductions. Consequently, their cost should not be exclusively measured against fuel consumption or fuel economy standards.

It is within this context that CALSTART sought the views of tier 1 automotive suppliers on the NAS report's cost and fuel saving estimates. Tier 1 suppliers produce a wide range of vehicle components and systems essential for reducing fuel consumption, including engine parts (injection systems, valve trains, turbochargers, etc.), hybrid and electrical systems, transmission systems and lightweight components throughout the vehicle. Tier 1 suppliers are therefore well-placed to comment on the levels of fuel consumption reduction that can be achieved in future as well as associated costs. Moreover, developing effective fuel consumption reducing technologies may allow tier 1 suppliers to differentiate themselves and increase profits within a very competitive and cost-driven market environment.

1.2 Objectives of the study

Ricardo Energy & Environment was commissioned to carry out a survey of Tier 1 automotive suppliers in order to gather information on the views of these companies with respect to the cost and performance data included in the NAS report.

The main objectives of this study were to:

- Gain insight into automotive suppliers' views on the cost and performance estimates presented in the NAS study for current and future technologies
- Understand the suppliers' views of the 2025 standards and whether they are driving innovation and investment in the United States

- Identify which automotive technologies suppliers feel are most likely to contribute to meeting the 2025 targets.

The aggregate results of this survey will be used by CALSTART to provide a response to the midterm review of the U.S. federal LDV greenhouse gas emissions standards. CALSTART recognizes the importance of obtaining first hand expertise from suppliers to ensure that the conclusions of this study are accurate and informative.

2 Methodology

This section provides an overview of the Delphi survey of Tier 1 automotive suppliers that was carried out to gather information on their views with respect to the findings of the NAS report. This section includes a general introduction to the Delphi method and an overview of the design and implementation of the survey. Annex 3 presents the complete survey documents sent to participants.

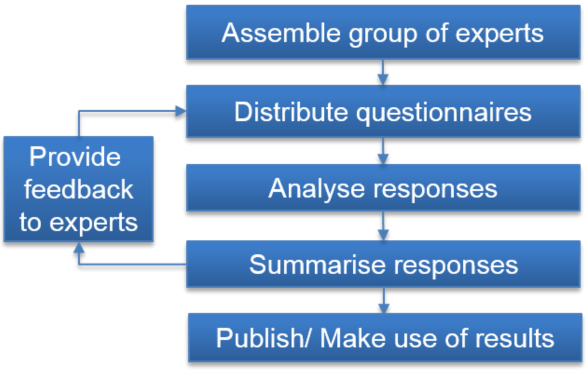
2.1 General introduction to the Delphi method

The Delphi survey method originated in a series of studies conducted by the RAND Corporation in the 1950s (Okoli, S.D. Pawlowski, 2004). Since then it has found a multitude of applications, in such different sectors as telecommunications, public policy, automotive and health care.[1]

The objective of a Delphi survey is to obtain the consensus of a group of experts on a specific question/problem. The method is mainly applied for analysing issues that are particularly complex and hence involve significant uncertainty. Frequently such issues concern forecasts of future developments that cannot be resolved by pure analytical methods because they are dependent on a multitude of undetermined or uncertain parameters. The researcher hence has to revert to a method that collects and analyzes the opinions from a group of experts that all have profound knowledge of the subject area and informed views on the issue in question.

The Delphi method allows the engaged expert panel to communicate anonymously via the administrator of the survey. The task of this administrator is to gather the opinions of the survey participants, collate these in an adequate format and distribute the anonymous summary to all participants. Each survey participant then gets the opportunity to comment on the responses of the other participants, reconsider their view and revise their answer to the issue being analyzed. This iterative process can take the form of several stages as shown in Figure 3Figure 3.

Figure 3: The Delphi Process



The number of participants in the Delphi panel is dependent on the design of the survey and will be constrained by i) what is manageable by the administrator and ii) the number of experts with profound knowledge about the research topic in question. Generally, the panel size requirements are modest (commonly 10-20 participants; Yousuf (2007)). Of more importance is a certain dynamic among the group that allows a consensus on a potentially controversial topic to be achieved. It is important to highlight that the outcome of a Delphi survey is not analytical evidence, but rather an aggregated opinion that is only as valid as the opinions of the experts who made up the panel.

[1] EICT (2009), CAR (2012), Clay-Wiliams, Braithwaite (2009)

2.2 Design and set-up of the survey

2.2.1 Selection of respondents

As discussed above, the outcome of a Delphi survey heavily relies on the expertise and knowledge of its survey participants. The expert panel therefore has to be chosen carefully and only people who can demonstrate significant knowledge in the topic area covered should participate.

The study team identified 98 potential participants from its pool of contacts as having extensive knowledge in the automotive industry and/or regarding technology cost estimation procedures. These 98 potential participants were either individuals or organisations and each of these was approached by the study team. Initial information regarding the study was provided via email, including an overview of the objectives of the study, a letter of introduction from CALSTART, and information regarding the confidentiality of responses. This email was then followed up with phone calls by the survey team.

Out of these 98 approached contacts, 23 participated by answering the Stage 1 survey questions. This number was seen to be manageable for the specific design of the survey. The respondents' companies manufacture a wide range of technologies (summarized in Table 1 below) which are included in the NAS report. The survey respondents therefore have expert, first-hand knowledge of the costs and performance of these technologies and were able to provide useful insight into the findings from the NAS report.

Table 1: Vehicle technologies

Light-duty vehicle technologies manufactured by survey respondents
Engine and propulsion system parts/systems/components:
Engine valvetrain/valve-timing systems, ignition systems, piston systems, cylinder components, powertrain engineering, engine & powertrain cooling, drives, powertrain control/engine control technology, diesel systems, turbochargers, starters & alternators, micro hybrid systems, lead acid batteries, hybrid vehicle batteries, battery systems
Exhaust systems:
Emission systems, exhaust treatment systems
Transmission & drivetrain parts/systems/components:
Automatic transmissions, continuously variable transmissions, transmission-clutch systems, transmission-control systems & torque management systems, axles, drive shafts, fluid power systems, bearings, aluminum wheels
Body, suspension and steering:
Chassis, dampers, steering systems, aluminum body panels, aluminum frames
Electronic and electric systems (non-tractive):
electrical systems and components, lighting systems, small motors, drives, electrical driven auxiliaries, cockpit electronics, telecommunications, camera/sensor technology
HVAC parts/systems/components:
heating, cooling, and ventilating devices, climate compressors, sealing, thermal management products, climate control
Interior:
Complete automotive seats and seat components

2.2.2 Survey schedule

The Delphi survey for this study was designed with the objective of carrying out two questionnaire stages. These two stages would allow respondents to obtain and react to feedback on first stage responses and refine their answers as needed.

The survey took place within a time frame of approximately two months (from making first contact with potential participants to sending out the final feedback), between May and July 2016. After sending out each questionnaire, participants were asked to return their answers within two weeks. This time period was then extended to four weeks due to the delays in some responses. Table 2 gives an overview of the overall schedule of the whole Delphi survey process within this study.

Table 2: Schedule of Delphi survey process

Milestone	Deadline
First contact with potential survey participants	May 6, 2016
Circulate Stage 1 documents to participating experts	May 26, 2016
Deadline for return of Stage 1 questionnaire	June 8, 2016
Extended deadline for return of Stage 1 questionnaire	July 12, 2016
Circulate Stage 2 documents to participating experts (including summary results of Stage 1)	July 15, 2016
Deadline for the return of Stage 2 questionnaire	July 26, 2016

2.2.3 Design of the survey and survey material

Stage 1 survey

The survey questionnaire was designed by the project team and included questions covering the following seven sections:

- Background information (relating to the respondent)
- 2025 GHG and fuel economy targets
- Effect of oil prices
- Policies and employment
- Estimates for reductions in fuel consumption from the NAS report
- Costs and performance of vehicle technologies
- Approaches used in the NAS report

Each section included a set of questions relating to the topic, as well an overview of any information from the NAS report needed to answer the questions.

The survey presented respondents with tables for the NAS cost forecasts for 2017 as well as the fuel consumption reduction estimates. Largely following the presentation in the NAS report, tables were subdivided into different technology areas so that respondents could comment on each (presented in Appendix 1 and 2).

The survey was designed and distributed using Survey Gizmo[2], a survey software tool which has all the necessary features required for this project. In particular, it allows the primary respondent to save their draft response and circulate it to other experts at the company as required. Given the wide range of technologies included in the survey, this feature was particularly useful if different individuals were required to comment on different technology areas.

The full set of survey questions is provided in Appendix 3.

Stage 2 survey

Following completion of the first stage of the survey, the results were anonymized, summarized and incorporated into Stage 2 of the survey. In line with the Delphi method, these results were distributed to the Stage 1 respondents in order to give them the opportunity to comment on the responses of the other participants, reconsider their view and revise their answer to the issue being analyzed.

The Stage 2 survey, including the summary of Stage 1 results, was distributed via Survey Gizmo to the Stage 1 respondents. The respondents were each given a unique password and username so that they could access and review their initial responses before deciding whether they wanted to change their answers or provide additional comments.

2.2.4 Expert interviews

Following completion of Stage 2 of the survey, all survey respondents were approached to see if they would be willing to participate in a telephone interview. These interviews provided a useful opportunity for the project team to follow up on any comments provided by the respondents in the survey and collect some further details.

In addition, the interviews provided an opportunity to ask survey respondents for their views on the Draft Technical Assessment Report (TAR) (EPA, NHTSA & CARB, 2016). The Draft TAR was published in July shortly after Stage 2 of the survey began. The stakeholders interviewed were able to provide useful comments on the main report findings and explain what the findings would potentially mean for their business. Furthermore, the interviewees were given the opportunity to comment on what the next steps should be in terms of fuel economy standards and how GHG targets could be achieved.

Out of the 23 respondents from Stage 1 of the survey, experts from the following four companies agreed to participate in telephone interviews:

- BorgWarner Inc.
- Eaton Corporation plc
- Honeywell International Inc.
- Johnson Controls Inc.

The comments from these interviews are highlighted in the following sections.

[2] https://www.surveygizmo.co.uk/

3 Survey Results

A total of 23 experts provided responses to the Stage 1 survey; 16 of these experts also provided a response to Stage 2 of the survey. The responses to Stage 2 of the survey did not show any significant departures from the responses provided during Stage 1 of the survey. In general, the Stage 2 survey respondents expressed interest in seeing the results from the first stage of the survey, but did not change their opinions based on the aggregate information provided.

The results presented below are based on the full set of 23 survey responses to Stage 1 of the survey. Wherever possible, details from the expert interviews have been included.

3.1 Headline results

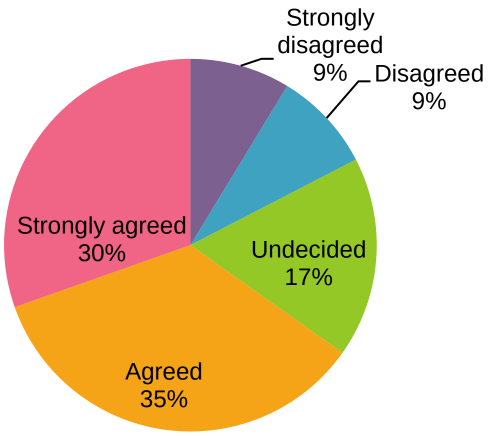
3.1.1 2025 Fuel Efficiency Target

The majority of survey respondents agreed with the policy decision to set a 54.5 mpg target for 2025 and did not think that the target should be changed.

The majority of respondents agreed with the decision to set a 54.5 mpg target for the average light-duty vehicle fleet for 2025 and felt that the target should not be changed under the next administration.

Almost all of those respondents who felt that the target should be kept selected *'The industry needs regulatory certainty so investments and strategies can be planned in advance. Uncertainty around the 2025 target will be a costly delay for this process.'* In addition, many selected further answer options; half the respondents felt that the target is a driver for innovation and a third felt that it was an opportunity for their company to differentiate themselves from their competitors.

Figure 4: Survey response to *'Did you agree with the policy decision to set a 54.5 mpg target for 2025 when it was announced?'*



However, not all respondents agreed with the target. A total of 18% of respondents either disagreed or strongly disagreed with the 54.5 mpg target, and 22% felt that the target should be lowered or abolished. Of those who did feel the target should be lowered or abolished, the majority indicated that this was related to concerns about harm to the industry from higher costs. There were concerns expressed that the Tier 1 suppliers would not be able to pass on associated increases in R&D or production costs to OEMs, which would harm their business. One respondent objected on the basis that the targets are not market-driven and expressed a preference for regulation via fuel taxation.

Following on from the survey, the project team was able to gain more detailed feedback via phone interviews from two companies who had stated agreement with the target and another two who had stated disagreement. Two of the interviewees confirmed that they felt the targets were achievable at reasonable costs.

Johnson Controls Power Solutions clarified that they were against explicitly setting a fleet average of 54.5 mpg as a target, but had no issue with the proposed footprint-based targets set out in the current draft legislation. Their main concern is that the recent drop in gasoline prices and the resulting shift from passenger cars to light trucks, and generally to vehicles with larger footprints (as was highlighted in the EPA's recent Draft TAR), could motivate regulators to set more stringent target curves than in the previous draft legislation in order to maintain a fleet average reduction in the order of 54.5 mpg. This could have negative consequences for industry. The introduction of more stringent footprint curves in 2018 for model years 2022-2025 would leave insufficient time for industry to undertake the required revisions to planning and investment priorities. Current consumer surveys show that given the low gasoline prices, willingness to pay for fuel saving technology is currently very low and therefore so is the ability for industry to pass the extra costs onto consumers. In addition, more stringent targets would be likely to require greater levels of high-voltage vehicle electrification, which is likely to shift manufacturing and jobs away from the US.

Another interviewee expressed concern over the time schedules for implementation of the emission target. An amendment to the time frame for the standards to be consistent with the pace of typical technology rollouts would be beneficial. The interviewee also highlighted that previous overachievements of standards by manufacturers for the 2012 – 2014 period were due to flex-fuel credits which resulted in manufacturers rolling out technologies more quickly in order to obtain such credits. After the phase-out of the credit system and many of the easy technologies having been put in production, manufacturers will be hard pressed to meet the increasingly stringent standards. The interviewee suggested that a more powerful measure to achieve GHG targets would be to introduce fuel taxes which would encourage people to buy more efficient vehicles but would also push them to plan their trips accordingly and use their cars less.

The majority of survey respondents felt it is important to start planning and setting targets now for beyond 2025.

Three quarters of respondents advocated that it is 'important to start planning and setting targets now for beyond 2025'. The most frequent justifications which had to be provided as free text focussed on long development lead times and the consequent need for regulatory certainty. Also, having a sense of certainty in the regulations was seen to reduce the risk of investment and will act as a driver for innovation. From those who objected, one argument was uncertainty around the costs and feasibility of the current targets, suggesting a "see-where-we-are-then" approach before introducing new targets.

This opinion was supported by the findings from the interviews. All of the respondents agreed that targets have to be set early enough to help the industry to plan and invest accordingly.

The majority of respondents make or plan investments based on the 2025 target and indicated that the target causes at least a slight shift in production output towards technologies optimized for fuel saving.

Almost three quarters of respondents felt the targets were causing a 'significant shift in investment towards more fuel-saving technologies'. Similarly, over 85% indicated a significant or slight shift in production output towards more fuel-saving technologies.

Just under 15% of respondents disagreed, indicating that that the target does not significantly affect their investment priorities. Only one respondent felt that the 2025 target is having no effect on production output of products designed for saving fuel.

There was no clear consensus on the effect that weakening the 2025 target would have on Tier 1 suppliers' investments.

There was less agreement on the implications of weakening of the target. Around half of respondents indicated that it would shift investment priorities away from fuel saving technologies while the other half indicated it would not greatly affect investment priorities.

The majority of stakeholders who felt that a weakening of the 2025 target would not cause a shift in investment priorities indicated that the reason for this was that fuel economy standards in global markets (such as the EU and China) would continue to encourage investments into fuel-saving technologies. Some stakeholders also suggested that even if the 2025 target was weakened, competition for better fuel economy within the industry would continue to drive investments in fuel-saving technologies.

Stakeholder interviews indicated that the new Draft TAR did not affect stakeholders' views on the fuel economy standards

When asked about their opinion on the new EPA Draft Technical Assessment Report, which calculates a new average of 50.0 to 52.6 mpg (see Section 1.1.1), stakeholders who participated in interviews emphasized that the actual target had not changed, rather the expected distribution of vehicle sales across the fleet. Therefore, they did not expect impacts on the sales of fuel saving technologies.

Eaton indicated that they believe the target is still achievable and that it is achievable at reasonable costs. What is not certain is whether the average figure will end up being exactly 54.5 mpg because this will depend on the actual sales. Another stakeholder commented that the Draft TAR's findings were broadly as expected with regards to the shift in fleet composition; however, they would have welcomed a re-affirmation of the current targets based on the technical assessment. Instead, they wondered whether there is a possible intention of setting higher targets.

3.1.2 Effect of low oil prices and employment implications

There was no clear consensus on the effect that low oil prices have on sales of fuel efficiency technologies.

The effect that oil price has on the sales of fuel efficiency technologies garnered a mixed response from the survey respondents. About 45% indicated that low oil prices do not have a noticeable effect on these sales, whereas 45% indicated that low prices reduce the demand for, and sales of, fuel efficiency technologies.

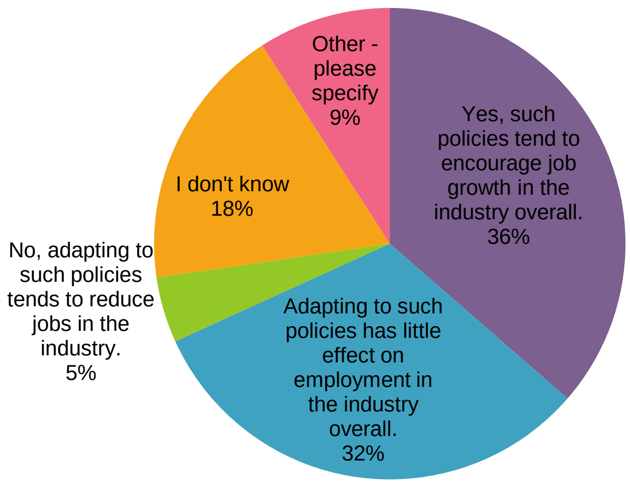
The opinions voiced during interviews were also divided. One stakeholder felt that consumers are currently willing to pay very little for fuel economy improvements; while fuel economy is still amongst the top considerations for car buyers, the number of hybrid vehicle drivers who were also choosing a hybrid as their next vehicle had fallen to 27% in a consumer survey this year -- less than half of the 2014 value. Two stakeholders also expected short-term negative effects on the sales of efficient vehicles due to low oil prices, although one expected that the effect of low oil prices should subside in the long term because all vehicles will need to meet their emission standards. Another stakeholder, on the other hand, stated that the correlation between oil prices and the types of LDVs sold is debatable. In the past, sometimes opposite developments could be observed (e.g. sales of electric vehicles showing a counterintuitive correlation with oil prices).

The majority of respondents indicated that US policies that encourage the uptake of new technologies also encourage job growth at their companies.

A majority (59%) felt that policies which force or encourage the uptake of new technologies tend to further job growth at their companies. Around 30% of respondents felt such policies do not tend to have an impact on the number of jobs at their companies.

Respondents were less confident about the effects on overall job growth in the US with around 32% expecting little change in overall employment, seeing winners and losers, or stating that they don't know. Just over a third of respondents felt that net employment would increase.

Figure 5: Survey response to *'Will the current 54.5 mpg target for 2025 help encourage job growth in the wider US economy?'*



3.1.3 NAS fuel consumption reduction and technology cost estimates

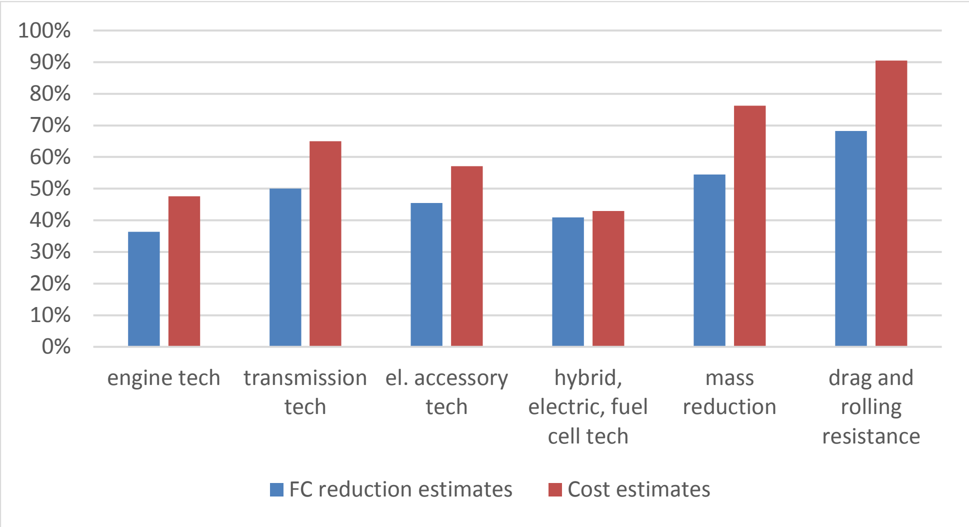
Respondents who expressed a view about fuel consumption reduction and technology cost estimates as presented in the NAS report provided some indication that the figures were about right.

Regarding the assessment of the figures in the NAS report, many respondents did not feel qualified to comment on all figures. Depending on the technology category and on whether they were asked to comment on fuel consumption reduction potential or on technology costs, between one third and 90% of respondents answered 'I don't know' (Figure 6).

Generally, participants appeared most comfortable assessing estimates on engine technology and hybrid, electric and fuel cell technologies which have the lowest 'don't know' rates. 'Don't know' rates are highest for mass reduction and drag/rolling resistance reduction, both areas for which costs in particular are inherently difficult to generalize, as these improvements affect a potentially large number of different parts with different characteristics, entail design changes with implications for consumer acceptance, and in the case of mass reduction may include varying degrees of material substitution with a whole host of different implications, depending on the substitute material chosen.

It should also be noted that the proportion of respondents answering 'I don't know' was consistently higher for the cost estimates than for the fuel consumption reduction estimates. This was to be expected, as uncertainty surrounding costs is generally higher (and available information more closely guarded) than uncertainty on fuel consumption reduction potentials, which can be widely modeled and measured.

Figure 6: Proportion of respondents answering 'I don't know'



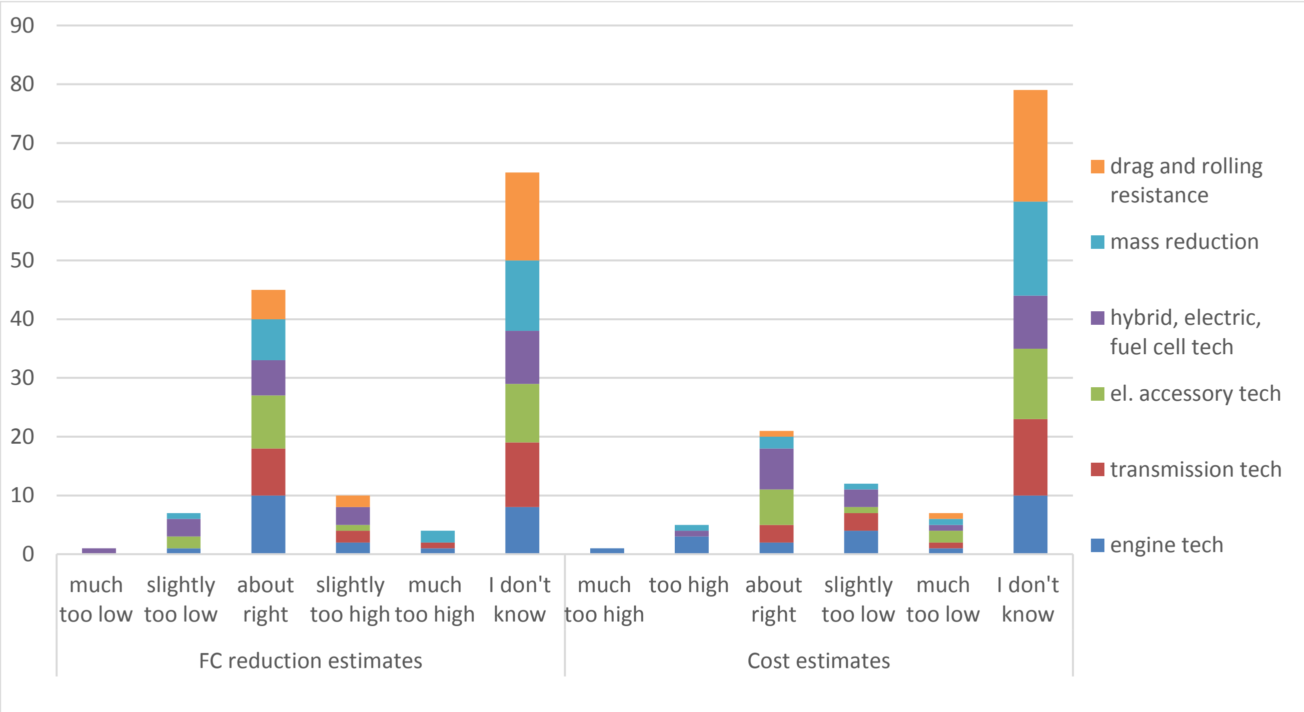
Among the responses expressing an opinion about NAS estimates, most felt that the fuel consumption reduction estimates were 'about right' (Figure 7).

During the interviews, the fuel consumption estimates were generally supported, although one stakeholder stated that the estimates overall were too optimistic. In particular, the fuel consumption estimates for engine and transmission technologies were considered much too high. The issue highlighted for transmission technologies is that some of these technologies attack the same loss mechanisms as some of the engine technologies. A combination of both might result in an improvement in driving performance but not necessarily in emissions. While the performance for many of the technologies listed may be achieved in some instances, these performances cannot realistically be achieved in a fleet average when combined with other technologies. Another stakeholder noted that some technology combinations are impossible to model, and felt that estimates were potentially too optimistic with large numbers of different technologies combined.

With regards to hybrid, electric and fuel cell technology, stakeholders stated that the vehicles should be treated on a well-to-wheel basis for both CO_2 and constituent emissions, in order to account for the significant upstream impact of these technologies. The environmental performance of electric vehicles is highly linked to the carbon emissions of the grid and is therefore regionally-specific.

Regarding the cost estimates, there was less agreement amongst respondents who were able to express an opinion. The overall number of responses indicating that costs were either too high or too low exceeds the number of respondents indicating that costs were 'about right'. However, it should be emphasized that the majority of respondents felt unable to comment on costs in the majority of technology categories. The result should therefore not be viewed as representative of the wider supplier community.

Figure 7: Number of responses to questions on the NAS's fuel consumption reduction and 2017 cost estimates



All four respondents who took part in the follow-up phone interviews were able to comment on some of the costs presented. Three respondents broadly agreed with the costs presented in the report, while one interviewee stated that he considered the presented costs too low overall.

One interviewee commented that a practical issue for industry is the substantial upfront investment required for new technologies which needs to be spread over large production volumes in order to reach the levels quoted in the report. As a rule of thumb, for technologies that give CO_2 improvements of 3% or less per year (i.e. combinations of technologies which tend to require lower levels of investment), there is capital available to make these sorts of investments for auto industry development departments; to achieve CO_2 improvement rates of 4-5%, it is more difficult to obtain the capital needed to make all required investments simultaneously.

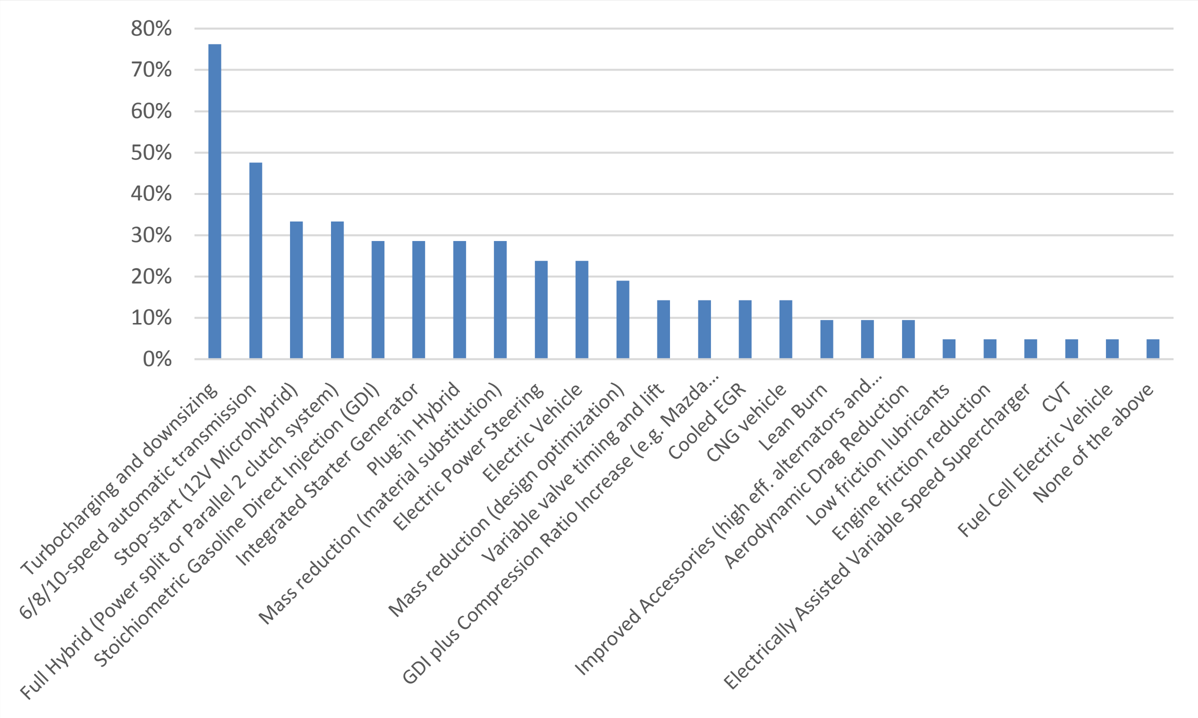
Cost estimates that were highlighted to be too low included hybrid technology and transmission technologies (in particular DCT estimates). On the other hand, technologies were identified with cost estimates that were too high, e.g. stop-start hybrid technology and the integrated starter/alternator. One interviewee also mentioned that the estimates for diesel technologies were nearly two times too high. One reason for that discrepancy could be a difference in the definition of the advanced diesel technology which is not included in the NAS report.

3.1.4 Key technologies

Respondents indicated that 'turbocharging and downsizing' and '6/8/10-speed automatic transmissions' are the two technologies which are most important for meeting the 2025 target.

The technology that was most frequently viewed as key to meeting the 54.5 mpg target for 2025 was turbocharging and downsizing – three quarters of respondents opted for this technology as one of the five most important technologies from the NAS report. Almost half the respondents also chose gearboxes with an increased number of gear ratios (6/8/10-speed). Additionally, various hybridization and electrification technologies were frequently seen to be among the most relevant technologies for improving fuel efficiency (Figure 8).

Figure 8: Proportion of respondents choosing the following technologies analyzed within the NAS report as one of their five most important technologies for meeting the 54.5 mpg target for 2025



There was no clear consensus on the importance of electrification of vehicles in order to meet the 2025 target.

Deployment of electric vehicles is required under the ZEV mandates that exist in California and various other states (requiring electrification in 15% of new light-duty vehicle sales by 2025, which equates to about 4% of new light-duty vehicle sales nationwide). 29% of respondents indicated that they would expect at least an additional 2% of electrified light-duty vehicles above the ZEV mandate requirements to be necessary to meet the 2025 targets. In comparison, 24% of survey respondents felt that there would be sufficient improvements in ICE technologies, lightweighting and hybridization technologies to meet the 2025 targets without additional electrification.

During the interview, Eaton indicated that achieving the GHG targets is dependent on the level of EV penetration. While the targets are still achievable without a large increase in the EV penetration rate, the targets could be achieved more easily if they were complimented by investments in EV charging infrastructure. BorgWarner suggested that an electrification level of 30% will be needed to meet the targets, which is even higher than the estimate presented by the EPA in the latest midterm report.

Respondents identified additional technologies which are being pursued and could help achieve the 2025 target.

In terms of further technologies not currently in the NAS report which are being seriously pursued and could deliver contributions towards the target, 48V mild hybrid/start-stop-coast technologies were named by three respondents. A further respondent mentioned P0 hybrids/e-assist. It should be noted these technologies resemble what has been included as 'Integrated Starter-Generator' in the NAS report: an e-motor/generator directly coupled to the internal combustion engine. However, this architecture can deliver a range of different degrees of hybridisation with different fuel savings and associated costs depending on the motor and electrical system design chosen, as shown for example in Valeo (2014).

For the P0 hybrid technology, one interviewee estimated fuel consumption savings between 10% and 20%. Another respondent mentioned alternative configurations to the P2 hybrid system (electric motor on the gearbox output (P3) or on the axle (P4) instead of between engine and gearbox). Here again, depending on the specific design, a range of different options with different fuel savings and costs are conceivable. In one interview, electrically assisted turbo technologies and their attendant impact on engine power density and downsizing potential were highlighted. Rough estimates given were 15% of fuel savings and $800 to $1,200 (including a 48V mild hybrid) in cost.

Moreover, some changes to standard ICE engine design were mentioned as further options for meeting the target, including Miller cycle gasoline engines (by two respondents). The Miller cycle is generally understood as a variant of the Otto cycle where the opening time of the intake valve is altered to ensure that the compression stroke is effectively shorter than the expansion stroke, and loss in torque compared to standard gasoline engines is compensated through supercharging (e.g. electrical). While the Miller cycle is not explicitly mentioned in the NAS report, the concept is similar to '*Compression Ratio Increase (CR~13:1, exh. scavenging, DI (a.k.a. Skyactiv, Atkinson Cycle))'*, although the additional supercharging may allow for downsizing and hence additional fuel consumption improvements. Opposed piston engines were also mentioned by one respondent. This technology is briefly covered in the NAS report as an option for diesel engines, but not covered amongst the tables, presumably because it is currently at an experimental stage. For this technology an interviewee gave estimates of roughly 10% in fuel savings. The fuel saving estimate, however, is a result of different technologies together and highly linked to the compression ratio.

Another respondent also mentioned an enhanced cylinder deactivation technology allowing for higher fuel consumption reductions and higher costs, compared to the cylinder deactivation estimates provided by NAS.

3.1.5 Approaches used in the NAS report

The majority of respondents agreed with the approaches used in the NAS report.

The majority of respondents agreed with the approaches used in the NAS report to estimate the fuel consumption and cost estimates. In particular, there is strong agreement for the use of learning curves to estimate how time and experience influences the direct manufacturing costs of a technology. Overall, 67% of respondents agreed with the method, whilst no responses expressed any disagreement.

Even stakeholders who criticized some of the results in terms of cost and performance acknowledged that the EPA and NHTSA did a good job in processing a lot of data and estimating cost and performance. However, the modeling struggles to capture all the complexities of reality and underestimates the impact of other requirements that manufacturers have to meet, such as consumer demand for performance and driveability.

One criticism that was brought forward was that some of the advanced technologies are missing from the list. In general the report should be more forward-looking and not only consider existing and proven technologies.

Also, 67% agreed with the approach of using 'stranded capital', where losses associated with retiring incumbent technologies before their normal depreciation lifetime are applied to the replacement technology. However, 19% were undecided as to whether this approach is appropriate, whilst 14% expressed disagreement. Respondents' comments indicated that whilst there is a cost of stranded capital in replacing old technologies with new technologies, these costs are necessary to maintain business competitiveness. Additionally, if these costs are to be accounted for, then there needs to be some quantitative appreciation of the costs of not replacing old technologies with new ones in terms of public acceptance and environmental costs.

4 Conclusions

Ricardo Energy & Environment has conducted a survey of Tier 1 automotive suppliers in the U.S. in order to gather information on the views of these companies with respect to the cost and performance data included in the 2015 NAS report. This survey was conducted in two stages, giving respondents the opportunity to review the aggregate responses and amend their responses if necessary.

Overall, the stakeholders recognized the scale of the challenge of processing the data and information required to assess the fuel consumption reductions and cost estimates of the wide range of technologies included in the NAS report. Although the stakeholders broadly agreed with the approaches used in the NAS report, some issues were raised where the modeling approaches used did not always reflect the complexities of the technologies in reality.

There were a number of key areas where there was a high level of consensus among the stakeholders:

- The majority of Tier 1 suppliers who participated in this study agreed with the 2025 fuel efficiency target as set by the EPA and the NHTSA.
- The majority of suppliers surveyed believe that this target should not be changed under the next administration, indicating that the target helps industry by providing regulatory certainty in order to help plan investments and strategies for developing new technologies.
- Stakeholders generally agreed that it is important to start planning and setting targets now for beyond 2025. New technologies have long development lead times so regulatory certainty is essential.
- Most respondents broadly agreed with the approaches used in the NAS report, recognising the challenges of assessing the costs and performance of such a wide range of technologies.

In addition, there were a number of areas where the responses from stakeholders were more mixed:

- Regarding the cost estimates, there was less agreement amongst respondents who were able to express an opinion. The majority of respondents felt unable to comment on costs in the majority of technology categories.
- There was no clear consensus on the importance of electrification of vehicles in order to meet the 2025 target. Although some survey respondents felt that there would be sufficient improvements in ICE technologies, lightweighting and hybridization technologies to meet the 2025 targets without additional electrification, other survey respondents indicated that a high level of EV penetration would be required to achieve the target.
- The effect that oil price has on the sales of fuel efficiency technologies garnered a mixed response from the survey respondents. About 45% indicated that low oil prices do not have a noticeable effect on these sales, whereas 45% indicated that low prices reduce the demand for, and sales of, fuel efficiency technologies.

Going forward, stakeholders emphasised that the industry is going to need time to adjust and develop cost effective technology. Some suggested a need for industry and regulators to sit down and develop realistic targets that allow for more time and flexibility.

In general, many stakeholders noted that long-term regulation is needed to help the industry to plan and invest accordingly. Recognising the challenges of assessing the costs and performance of so many technologies as in the NAS report, stakeholders broadly agreed with the approaches used and recognised the importance of the assessment. One stakeholder noted that the current regulation is a good example of a long-term vision, and that the midterm review is a very strong and data-driven process which is helping companies to make the right investments and decisions to develop the right technologies to meet the targets.

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Appendices

Appendix 1 - Percent Incremental Fuel Consumption Reductions (NAS, 2015)

Engine Technologies				
Technologies	**Midsize Car I4 DOHC**	**Large Car V6 DOHC**	**Large Light Truck V8 OHV**	**Relative to**
Spark Ignition Engine Technologies				
NHTSA Technologies				
Low Friction Lubricants - Level 1	0.7%	0.8%	0.7%	Baseline
Engine Friction Reduction - Level 1	2.6%	2.7%	2.4%	Baseline
Low Friction Lubricants and Engine Friction Reduction - Level 2	1.3%	1.4%	1.2%	Previous Tech
VVT- Intake Cam Phasing (CCP - Coupled Cam Phasing - OHV)	2.6%	2.7%	2.5%	Baseline for DOHC
VVT- Dual Cam Phasing	2.5%	2.7%	2.4%	Previous Tech
Discrete Variable Valve Lift	3.6%	3.9%	3.4%	Previous Tech
Continuously Variable Valve Lift	1%	1%	0.9%	Previous Tech
Cylinder Deactivation	N/A	0.7%	5.5%	Previous Tech
Variable Valve Actuation (CCP + Discrete VVL)	N/A	N/A	3.2%	Baseline for OHV
Stoichiometric Gasoline Direct Injection	1.5%	1.5%	1.5%	Previous Tech
Turbocharging and Downsizing Level 1 - 18 bar BMEP 33% downsizing	7.7 - 8.3%	7.3 - 7.8%	6.8 - 7.3%	Previous Tech
Turbocharging and Downsizing Level 2 - 24 bar BMEP 50% downsizing	3.2 - 3.5%	3.3 - 3.7%	3.1 - 3.4%	Previous Tech
Cooled EGR Level 1 - 24 bar BMEP, 50% downsizing	3.0 - 3.5%	3.1 - 3.5%	3.1 - 3.6%	Previous Tech
Cooled EGR Level 2 - 27 bar BMEP, 56% downsizing	1.4%	1.4%	1.2%	Previous Tech
Other Technologies By 2025:				
Compression Ratio Increase (with regular fuel)	3%	3%	3%	Baseline
Compression Ratio Increase (with higher octane regular fuel)	5%	5%	5%	Baseline
Compression Ratio Increase (CR~13:1, exh. scavenging, DI (e.g. Skyactiv))	10%	10%	10%	Baseline
Electrically Assisted Variable Speed Supercharger	26%	26%	26%	Baseline
Lean Burn (with low sulfur fuel)	5%	5%	5%	Baseline
After 2025:				
Variable Compression Ratio	Up to 5.0%	Up to 5.0%	Up to 5.0%	Baseline
Dedicated Exhaust Gas Recirculation	10%	10%	10%	Turbocharging and Downsizing Level 1
Homogeneous Charge Compression Ignition (HCCI) + Spark Assisted CI	Up to 5.0%	Up to 5.0%	Up to 5.0%	Turbocharging and Downsizing Level 1
Gasoline Direct Injection Compression Ignition (GDCI)	Up to 5.0%	Up to 5.0%	Up to 5.0%	Turbocharging and Downsizing Level 1
Waste Heat Recovery	Up to 3.0%	Up to 3.0%	Up to 3.0%	Baseline

Alternative Fuels*:				
CNG-Gasoline Bi-Fuel Vehicle (50% of mileage on CNG)	Up to 5% Incr [42%]	Up to 5% Incr [42]	Up to 5% Incr [42%]	Baseline
Flexible Fuel Vehicle (50% of mileage on ethanol)	0% [40%]	0% [40%]	0% [40%]	Baseline
Ethanol Boosted Direct Injection (CR = 14:1, 43% downsizing) (UF~0.05)	20% [24%]	20% [24%]	20% [24%]	Baseline
** Fuel consumption reduction in gge (gasoline gallons equivalent) [CAFE fuel consumption reduction]*				
Diesel Engine Technologies				
NHTSA Technologies				
Advanced Diesel	29.4%	30.5%	29%	Baseline [change over baseline petrol engine]
Other Technologies				
Low Pressure EGR	3.5%	3.5%	3.5%	Advanced Diesel
Closed Loop Combustion Control	2.5%	2.5%	2.5%	Advanced Diesel
Injection Pressures Increased to 2,500 to 3,000 bar	2.5%	2.5%	2.5%	Advanced Diesel
Downspeeding with Increased Boost Pressure	2.5%	2.5%	2.5%	Advanced Diesel
Friction Reduction	2.5%	2.5%	2.5%	Advanced Diesel
Waste Heat Recovery	2.5%	2.5%	2.5%	Advanced Diesel

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Transmission Technologies

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
Improved Auto. Trans. Controls/Externals (Aggressive Shift Logic—Level 1 (ASL1) and Early or Aggressive Torque Converter Lockup)	2.5 - 3.0%	2.5 - 3.0%	2.5 - 3.0%	4 sp AT
6-speed AT with Improved Internals - Lepelletier (Rel to 4 sp AT)	2.0 - 2.5%	2.0 - 2.5%	2.0 - 2.5%	Improved Auto. Trans. Controls
6-speed AT with Improved Internals - Non-Lepelletier (Rel to 4 sp AT)	2.0 - 2.5%	2.0 - 2.5%	2.0 - 2.5%	Improved Auto. Trans. Controls
6-speed Dry DCT (Rel to 6 sp AT - Lepelletier)	3.5 - 4.5%	3.5 - 4.5%	N/A	6 sp AT
6-speed Wet DCT (Rel to 6 sp AT - Lepelletier) (0.5% less than Dry Clutch)	3.0 - 4.0%	3.0 - 4.0%	3.0 - 4.0%	6 sp AT
8-speed AT (Rel to 6 sp AT - Lepelletier)	1.5 - 2.0%	1.5 - 2.0%	1.5 - 2.0%	Previous Tech
8-speed DCT (Rel to 6 sp DCT)	1.5 - 2.0%	1.5 - 2.0%	1.5 - 2.0%	Previous Tech
High Efficiency Gearbox Level 1 (Auto) (HETRANS)	2.3 - 2.7%	2.3 - 2.7%	2.3 - 2.7%	Previous Tech
High Efficiency Gearbox Level 2 (Auto, 2017 and Beyond)	2.6 - 2.7%	2.6 - 2.7%	2.6 - 2.7%	Previous Tech
Shift Optimizer (ASL-2)	0.5 - 1.0%	0.5 - 1.0%	0.5 - 1.0%	Previous Tech

Secondary Axle Disconnect	1.4 - 3.0%	1.4 - 3.0%	1.4 - 3.0%	Baseline
Other Technologies				
Continuously Variable Transmission with Improved internals (Rel to 6 sp AT)	3.5 - 4.5%	3.5 - 4.5%	N/A	Previous Tech
High Efficiency Gearbox (CVT)	3%	3%	N/A	Previous Tech
High Efficiency Gearbox (DCT)	2%	2%	2%	Previous Tech
High Efficiency Gearbox Level 3 (Auto, 2020 and beyond)	1.6%	1.6%	1.6%	Previous Tech
9-10 speed Transmission (Auto, Rel to 8 sp AT)	0.3%	0.3%	0.3%	Previous Tech

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

• Spark ignition (SI) engine
• Naturally aspirated
• Four valves per cylinder (except two valves per cylinder for OHV engines)
• Port fuel injection (PFI)
• Fixed valve timing and lift
• Four-speed automatic transmission.

Electrified Accessories Technologies

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
Electric Power Steering	1.3%	1.1%	0.8%	Baseline
Improved Accessories - Level 1 (70% Eff Alt, Elec. Water Pump and Fan)	1.2%	1%	1.6%	Baseline
Improved Accessories - Level 2 (Mild regen alt strategy, Intelligent cooling)	2.4%	2.6%	2.2%	Previous Tech

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

• Spark ignition (SI) engine
• Naturally aspirated
• Four valves per cylinder (except two valves per cylinder for OHV engines)
• Port fuel injection (PFI)
• Fixed valve timing and lift
• Four-speed automatic transmission.

Hybrid, Electric and Fuel Cell Technologies

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
Stop-Start (12V Micro-Hybrid) (Retain NHTSA Estimates)	2.1%	2.2%	2.1%	Baseline
Integrated Starter Generator	6.5%	6.4%	3%	Previous Tech
Strong Hybrid - P2 - Level 2 (Parallel 2 Clutch System)	28.9 - 33.6%	29.4 - 34.5%	26.9 - 30.1%	Baseline
Strong Hybrid - PS - Level 2 (Power Split System)	33.0 - 33.5%	32.0 - 34.1%	N/A	Baseline
Plug-in Hybrid - 40 mile range	N/A	N/A	N/A	Baseline

Electric Vehicle - 75 mile	N/A	N/A	N/A	Baseline
Electric Vehicle - 100 mile	N/A	N/A	N/a	Baseline
Electric Vehicle - 150 mile	N/A	N/A	N/A	Baseline
Other Technologies				
Fuel Cell Electric Vehicle	N/A	N/A	N/A	Baseline

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Mass reduction

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
0 - 2.5% Mass Reduction (Design Optimization)	0.8%	0.8%	0.85%	Baseline
0 - 5% Mass Reduction (Material Substitution) With Engine Downsizing (Same Architecture) 3/	1.6%	1.6%	1.69%	Baseline
0 - 10% Mass Reduction (HSLA Steel and Aluminum Closures)	6.1%	6.1%	4.49%	Baseline
0 - 15% Mass Reduction (Aluminum Body)	9.15%	9.15%	6.73%	Baseline
0 - 20% Mass Reduction (Aluminum Body, Magnesium, Composites)	12.21%	12.21%	8.98%	Baseline
0 - 25% Mass Reduction (Carbon Fiber Composite Body)	15.26%	15.26%	11.22%	Baseline

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Rolling resistance and drag reduction

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
Low Rolling Resistance Tires - Level 1 (10% Reduction)	1.9%	1.9%	1.9%	Baseline
Low Rolling Resistance Tires - Level 2 (20% Reduction)	2%	2%	2%	Previous Tech
Low Drag Brakes	0.8%	0.8%	0.8%	Baseline
Aerodynamic Drag Reduction - Level 1 (10% Reduction)	2.3%	2.3%	2.3%	Baseline

Aerodynamic Drag Reduction - Level 2 (20% Reduction)	N/A	2.5%	2.5%	Previous Tech

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Appendix 2 - 2017 model year Incremental Direct Manufacturing Costs (2010$) (NAS, 2015)

Spark Ignition Engine Technologies				
Technologies	**Midsize Car I4 DOHC**	**Large Car V6 DOHC**	**Large Light Truck V8 OHV**	**Relative to**
NHTSA Technologies				
Low Friction Lubricants - Level 1	$ 3	$ 3	$ 3	Baseline
Engine Friction Reduction - Level 1	$ 48	$ 71	$ 95	Baseline
Low Friction Lubricants and Engine Friction Reduction - Level 2	$ 51	$ 75	$ 99	Previous Tech
VVT- Intake Cam Phasing (CCP - Coupled Cam Phasing - OHV)	$ 37 - 43	$ 74 - 86	$ 37	Baseline for DOHC
VVT- Dual Cam Phasing	$ 31 - 35	$ 72 - 82	$ 37 - 43	Previous Tech
Discrete Variable Valve Lift	$ 116 - 133	$ 168 - 193	$ 37 - 43	Previous Tech
Continuously Variable Valve Lift	$ 58 - 67	$ 151 - 174	N/A	Previous Tech
Cylinder Deactivation	N/A	$ 139	N/A	Previous Tech
Variable Valve Actuation (CCP + Discrete VVL)	N/A	N/A	$ 157	Baseline for OHV
Stoichiometric Gasoline Direct Injection	$ 192	$ 290	$ 277 - 320	Previous Tech
Turbocharging and Downsizing Level 1 - 18 bar BMEP 33%DS	$ 288 - 331	$ -129 to -86	$ 942 - 1,028	Previous Tech
V6 to I4 and V8 to V6		$ -455* to -369*	$ 841* to 962*	
Turbocharging and Downsizing Level 2 - 24 bar BMEP 50%DS	$ 182	$ 182	$ 308	Previous Tech
I4 to I3	$ -92* to -96*			
Cooled EGR Level 1 - 24 bar BMEP, 50% DS	$ 212	$ 212	$ 212	Previous Tech
Cooled EGR Level 2 - 27 bar BMEP, 56% DS	$ 364	$ 364	$ 614	Previous Tech
V6 to I4			$ -524* to -545*	
Other Technologies				
By 2025:				
Compression Ratio Increase (with regular fuel)	$ 50	$ 75	$ 100	Baseline
Compression Ratio Increase (with higher octane regular fuel)	$ 75	$ 113	$ 150	Baseline
Compression Ratio Increase (CR~13:1, exh. scavenging, DI (e.g. Skyactiv))	$ 250	$ 375	$ 500	Baseline
Electrically Assisted Variable Speed Supercharger	$ 1302	$ 998	N/A	Baseline
Lean Burn (with low sulfur fuel)	$ 800	$ 920	$ 1040	Baseline
After 2025: Costs for the following technologies are provided only for 2025				
Variable Compression Ratio				Baseline
Dedicated Exhaust Gas Recirculation				Turbocharging and Downsizing Level 1

Homogeneous Charge Compression Ignition (HCCI) + Spark Assisted CI (With TWC aftertreatment. Costs will increase with lean NOx aftertreatment)				Turbocharging and Downsizing Level 1
Gasoline Direct Injection Compression Ignition				Baseline
Waste Heat Recovery				Baseline
Alternative Fuels:				
CNG-Gasoline Bi-Fuel Vehicle	$ 6000	$ 6900	$ 7800	Baseline
Flexible Fuel Vehicle	$ 75	$ 100	$ 125	Baseline
Ethanol Boosted Direct Injection (incr CR to 14:1, 43% downsizing)	$ 740	$ 870	$ 1000	Baseline
** Costs with reduced number of cylinders, adjusted for previously added technologies.*				
Diesel Engine Technologies				
NHTSA Technologies				
Advanced Diesel	$ 3023	$ 3565	$ 3795	Baseline
Other Technologies				
Low Pressure EGR	$ 133	$ 166	$ 166	Advanced Diesel
Closed Loop Combustion Control	$ 68	$ 102	$ 102	Advanced Diesel
Injection Pressures Increased to 2,500 to 3,000 bar	$ 24	$ 26	$ 26	Advanced Diesel
Downspeeding with Increased Boost Pressure	$ 28	$ 28	$ 28	Advanced Diesel
Friction Reduction	$ 64	$ 96	$ 96	Advanced Diesel

Note: *Baseline* describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Transmission Technologies				
Technologies	**Midsize Car I4 DOHC**	**Large Car V6 DOHC**	**Large Light Truck V8 OHV**	**Relative to**
NHTSA Technologies				
Improved Auto. Trans. Controls/Externals (ASL-1 & Early TC Lockup)	$ 50	$ 50	$ 50	Baseline 4 sp AT
6-speed AT with Improved Internals - Lepelletier (Rel to 4 sp AT)	$ -13	$ -13	$ -13	Improved Auto. Trans. Controls
6-speed AT with Improved Internals - Non-Lepelletier (Rel to 4 sp AT)	$ 195	$ 195	$ 195	Improved Auto. Trans. Controls
6-speed Dry DCT (Rel to 6 sp AT - Lepelletier)	$ -149 to 31	$ -149 to 31	N/A	6 sp AT
6-speed Wet DCT (Rel to 6 sp AT - Lepelletier)	$ -88 to 88	$ -88 to 88	$ -88 to 88	6 sp AT
8-speed AT (Rel to 6 sp AT - Lepelletier)	$ 56 - 151	$ 56 - 151	$ 56 - 151	Previous Tech
8-speed DCT (Rel to 6 sp DCT)	$ 179	$ 179	$ 179	Previous Tech
High Efficiency Gearbox Level 1 (Auto) (HETRANS)	$ 120	$ 120	$ 120	Previous Tech

High Efficiency Gearbox Level 2 (Auto, 2017 and Beyond)	$ 194	$ 194	$ 194	Previous Tech
Shift Optimizer (ASL-2)	$ 26	$ 26	$ 26	Previous Tech
Secondary Axle Disconnect	$ 100	$ 100	$ 100	Baseline
Other Technologies				
Continuously Variable Transmission with Improved internals (Rel to 6 sp AT)	$ 179	$ 179	N/A	Baseline
High Efficiency Gearbox (CVT)	$ 125	$ 125	N/A	Baseline
High Efficiency Gearbox (DCT)	$ 150	$ 150	$ 150	Baseline
High Efficiency Gearbox Level 3 (Auto, 2020 and Beyond)	$ 150	$ 150	$ 150	Baseline
9-10 speed Transmission (Auto, Rel to 8 sp AT)	$ 75	$ 75	$ 75	Baseline

Note: Baseline describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Electrified Accessories Technologies

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
Electric Power Steering	$ 87	$ 87	$ 87	Baseline
Improved Accessories - Level 1 (70% Eff Alt, Elec. Water Pump and Fan)	$ 71	$ 71	$ 71	Baseline
Improved Accessories - Level 2 (Mild regen alt strategy, Intelligent cooling)	$ 43	$ 43	$ 43	Previous Tech

Note: Baseline describes a 2008 model year vehicle with the following basic features:

- Spark ignition (SI) engine
- Naturally aspirated
- Four valves per cylinder (except two valves per cylinder for OHV engines)
- Port fuel injection (PFI)
- Fixed valve timing and lift
- Four-speed automatic transmission.

Hybrid, Electric, and Fuel Cell technologies

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
Stop-Start (12V Micro-Hybrid)	$ 287 - 387	$ 325 - 425	$ 356 - 456	Baseline
Integrated Starter Generator	$ 1,087 - 1,253	$ 1,087 - 1,377	$ 1,087 - 1,438	Previous Tech
Strong Hybrid - P2 - Level 2 (Parallel 2 Clutch System)	$ 2,463 - 3,126	$ 2,908 - 3,726	$ 2,947 - 3,762	Baseline
Strong Hybrid - PS - Level 2 (Power Split System)	$ 3139	$ 3396	N/A	Baseline

Plug-in Hybrid - 40 mile range	$ 13,019 - 14,776	$ 17,649 - 20,141	N/A	Baseline
Electric Vehicle - 75 mile	$ 14,812 - 15,446	$ 19,275 - 20,393	N/A	Baseline
Electric Vehicle - 100 mile	$ 16,831	$ 21,123	N/A	Baseline
Electric Vehicle - 150 mile	$ 22,257	$ 26,193	N/A	Baseline
Other Technologies				
Fuel Cell Electric Vehicle	N/A	N/A	N/A	Baseline

Note: Baseline describes a 2008 model year vehicle with the following basic features:

• Spark ignition (SI) engine
• Naturally aspirated
• Four valves per cylinder (except two valves per cylinder for OHV engines)
• Port fuel injection (PFI)
• Fixed valve timing and lift
• Four-speed automatic transmission.

Mass reduction

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
NHTSA Technologies				
0 - 2.5% Mass Reduction (Design Optimization)	$ 0 - 22	$ 0 - 28	$ 0 - 39	Baseline
0 - 5% Mass Reduction (Material Substitution) With Engine Downsizing (Same Architecture) (Includes mass decompounding: 40% for cars, 25% for trucks)	$ 0 - 88	$ 0 - 113	$ 0 - 154	Baseline
0 - 10% Mass Reduction (HSLA Steel and Aluminum Closures)	$ 154 - 413	$ 198 - 531	$ 270 - 726	Baseline
0 - 15% Mass Reduction (Aluminum Body)	$ 452 - 767	$ 581 - 986	$ 792 - 1,353	Baseline
0 - 20% Mass Reduction (Aluminum Body, Magnesium, Composites)	$ 980 - 1,421	$ 1,260 - 1,827	$ 1,716 - 2,497	Baseline
0 - 25% Mass Reduction (Carbon Fiber Composite Body)	$ 2,153 - 2,870	$ 2,768 - 3,690	$ 3,795 - 5,046	Baseline

Note: Baseline describes a 2008 model year vehicle with the following basic features:

• Spark ignition (SI) engine
• Naturally aspirated
• Four valves per cylinder (except two valves per cylinder for OHV engines)
• Port fuel injection (PFI)
• Fixed valve timing and lift
• Four-speed automatic transmission.

Rolling resistance and drag reduction

Technologies	Midsize Car I4 DOHC	Large Car V6 DOHC	Large Light Truck V8 OHV	Relative to
Low Rolling Resistance Tires - Level 1 (10% Reduction)	$ 5	$ 5	$ 5	Baseline
Low Rolling Resistance Tires - Level 2 (20% Reduction)	$ 58	$ 58	$ 58	Previous Tech
Low Drag Brakes	$ 59	$ 59	$ 59	Baseline

Aerodynamic Drag Reduction - Level 1 (10% Reduction)	$ 39	$ 39	$ 39	Baseline
Aerodynamic Drag Reduction - Level 2 (20% Reduction)	$ 117	$ 117	$ 117	Previous Tech

Note: Baseline describes a 2008 model year vehicle with the following basic features:

• Spark ignition (SI) engine
• Naturally aspirated
• Four valves per cylinder (except two valves per cylinder for OHV engines)
• Port fuel injection (PFI)
• Fixed valve timing and lift
• Four-speed automatic transmission.

Appendix 3 – Online survey copy

Survey of Tier 1 automotive suppliers with respect to the costs and performance of vehicle technologies

Background

ID 77

1. Respondent information

Name *

Email address *

Company name *

Street Address

Contact telephone number

2025 target

ID 119

Background information on the 2025 Target

The National Program for greenhouse gas emissions (GHG) and fuel economy standards was developed jointly by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA). The first phase of the National Program for the model years (MYs) 2012-2016 vehicles is projected to result in an average light-duty vehicle tailpipe carbon dioxide level of 250 grams per mile by MY 2016, equivalent to 35.5 mpg (if achieved exclusively through fuel economy).

In 2012, EPA and NHTSA issued a joint Final Rulemaking to extend the National Program of harmonized greenhouse gas and fuel economy standards to model year 2017 through 2025 passenger vehicles. This second phase of the program is projected to result in an average industry fleet-wide level of 163 grams/mile of carbon dioxide in model year 2025, which is equivalent to 54.5 miles per gallon (mpg) if achieved exclusively through fuel economy improvements.

Further information is available from:

https://www3.epa.gov/otaq/climate/regs-light-duty.htm
https://www3.epa.gov/otaq/climate/documents/420f12051.pdf

ID 8

2. Did you agree with the policy decision to set a 54.5 mpg target for 2025 when it was announced?

Strongly disagreed	Disagreed	Undecided	Agreed	Strongly agreed
○	○	○	○	○

LOGIC Show/hide trigger exists.
ID 9
3. Do you think that the 54.5 mpg target for 2025 should be adjusted under the next administration?

The target should be lowered or abolished	The target should not be changed	The target should be raised	I don't know
○	○	○	○

LOGIC Hidden unless: Question "Do you think that the 54.5 mpg target for 2025 should be adjusted under the next administration?" #3 is one of the following answers ("The target should be lowered or abolished")
ID 10
4. Why should the target be lowered or abolished? Please select all that apply.

- ☐ It will increase the cost of vehicles, which will reduce sales and harm the sector
- ☐ We will not be able to pass on associated increases in R&D or production costs to OEMs, this harms our business
- ☐ It will harm the position of the US industry relative to international competitors
- ☐ Other - please specify

LOGIC Hidden unless: Question "Do you think that the 54.5 mpg target for 2025 should be adjusted under the next administration?" #3 is one of the following answers ("The target should not be changed")

ID 11

5. Why should the target be kept? Please select all that apply.

- ☐ The industry needs regulatory certainty so investments and strategies can be planned in advance. Uncertainty around the 2025 target will be a costly delay for this process
- ☐ The target will be a driver for innovation in the sector
- ☐ The target will allow us to develop products/sell products which differentiate us from our competitors
- ☐ Other - please specify

LOGIC Hidden unless: Question "Do you think that the 54.5 mpg target for 2025 should be adjusted under the next administration?" #3 is one of the following answers ("The target should be raised")

ID 113

6. Why should the target be raised? Please select all that apply.

- ☐ A more ambitious target could help our company develop more of a leadership role in future vehicle technologies and help us stay competitive in the long run
- ☐ A more ambitious target could further drive innovation in the sector and help the US industry remain competitive
- ☐ A more ambitious target will allow us to develop products/sell products which differentiate us from our competitors
- ☐ Other - please specify

ID 114

7. In your view, is it important to start planning and setting targets **now** for beyond 2025? Please provide an explanation for your response choice.

- Yes
- No
- I don't know

ID 109

8. Further comments

2025 target

ID 14

9. Are you making or planning investments based on the 2025 target (both production and R&D)?

- Yes, the 2025 target causes a **significant** shift in investment towards more fuel-saving technologies
- Yes, the 2025 target causes a **slight** shift in investment towards more fuel-saving technologies
- No, the 2025 target **does not** significantly affect investment priorities
- I don't know

ID 15

10. What effect is the 54.5 mpg target for 2025 having on your expected production output of products designed or optimized for saving fuel?

- It is causing a **significant** shift in production output towards technologies optimized for fuel saving
- It is causing a **slight** shift in production output towards technologies optimized for fuel saving
- It is having **no effect** on production
- I don't know

LOGIC Show/hide trigger exists.

ID 16

11. What effect would a weakening of the 2025 target have on your (planned) investments?

- It would cause a shift in investment away from fuel-saving technology
- It would not cause a significant shift in investment priorities
- I don't know

LOGIC Hidden unless: Question "What effect would a weakening of the 2025 target have on your (planned) investments?" #11 is one of the following answers ("It would not cause a significant shift in investment priorities")

ID 115

12. Why not? Which factors are more relevant for determining investments into fuel-saving technologies? Select all that apply.

- Fuel economy standards in global markets (e.g. EU, China)
- Competition for better fuel economy within the industry even in the absence of government standards
- Other - please specify

LOGIC Show/hide trigger exists.

ID 18

13. What effect would a weakening of the 2025 target have on your production of fuel-saving technologies?

- ○ I would expect lower demand for products designed or optimized for saving fuel
- ○ I would not expect any significant changes to the demand for fuel-saving technology
- ○ I don't know

LOGIC Hidden unless: Question "What effect would a weakening of the 2025 target have on your production of fuel-saving technologies?" #13 is one of the following answers ("I would not expect any significant changes to the demand for fuel-saving technology")

ID 20

14. Why not? Which factors are more relevant for driving demand for fuel-saving technology? Select all that apply.

- ☐ Fuel economy standards in global markets (e.g. EU, China)
- ☐ Competition for better fuel economy within the industry even in the absence of government standards
- ☐ Other - please specify

ID 94

15. What effect do low oil prices have on your sales of the fuel efficiency technologies your company produces?

- Low oil prices result in an increase in sales of fuel efficiency technologies.
- Low oil prices result in a decrease in sales of fuel efficiency technologies.
- Low oil prices do not have a noticeable effect on our sales of fuel efficiency technologies.
- I don't know

ID 110

16. Further comments

ID 21

17. In general, do US policies that encourage or force the uptake of new technologies also encourage job growth for your company in the US?

- Yes, such policies tend to encourage job growth at our company.
- Adapting to such policies does not change the number of jobs at our company.
- No, adapting to such policies tends to reduce the number of jobs at our company.
- I don't know
- Other - please specify

ID 22

18. Will the current 54.5 mpg target for 2025 help encourage job growth in the wider US economy?

- Yes, such policies tend to encourage job growth in the industry overall.
- Adapting to such policies has little effect on employment in the industry overall.
- No, adapting to such policies tends to reduce jobs in the industry overall.
- I don't know
- Other - please specify

ID 23

19. If a higher fuel efficiency target was introduced, do you think that it would help encourage job growth in your sector?

- Yes, a higher target would help encourage job growth in the industry overall.
- Adapting to such policies has little effect on employment in the industry overall.
- No, adapting to such policies tends to reduce jobs in the industry overall.
- I don't know
- Other - please specify

ID 111

20. Further comments

Estimates for reductions in fuel consumption

ID 117

The following questions relate to the estimates for reductions in fuel consumption for different technology categories covered in the NAS report. If you don't have knowledge of the fuel consumption performance of the technologies in a particular group, please answer "I don't know" and continue to the next question.

If you only have knowledge of some of the technologies included in a particular category, please answer the question based on your knowledge of those technologies. If possible, please indicate in the comments which technologies are relevant to your answer.

ID 25

21. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for engine technologies? Use the table below for guidance.

- The estimates for reductions in fuel consumption are much too low
- The estimates for reductions in fuel consumption are slightly too low
- The estimates for reductions in fuel consumption are about right
- The estimates for reductions in fuel consumption are slightly too high
- The estimates for reductions in fuel consumption are much too high
- I don't know

Comments

ID 56

22. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for transmission technologies? Use the table below for guidance.

- The estimates for reductions in fuel consumption are much too low
- The estimates for reductions in fuel consumption are slightly too low
- The estimates for reductions in fuel consumption are about right
- The estimates for reductions in fuel consumption are slightly too high
- The estimates for reductions in fuel consumption are much too high
- I don't know

Comments

ID 57

23. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for electrified accessory technologies? Use the table below for guidance.

- The estimates for reductions in fuel consumption are much too low
- The estimates for reductions in fuel consumption are slightly too low
- The estimates for reductions in fuel consumption are about right
- The estimates for reductions in fuel consumption are slightly too high
- The estimates for reductions in fuel consumption are much too high
- I don't know

Comments

ID 58

24. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for hybrid, electric and fuel cell technologies that your company produces? Use the table below for guidance.

- The estimates for reductions in fuel consumption are much too low
- The estimates for reductions in fuel consumption are slightly too low
- The estimates for reductions in fuel consumption are about right
- The estimates for reductions in fuel consumption are slightly too high
- The estimates for reductions in fuel consumption are much too high
- I don't know

Comments

ID 106

26. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for rolling resistance and drag reduction technologies? Use the table below for guidance.

- The estimates for reduction in fuel consumption are much too low
- The estimates for reductions in fuel consumption are slightly too low
- The estimates for reductions in fuel consumption are about right
- The estimates for reductions in fuel consumption are slightly too high
- The estimates for reductions in fuel consumption are much too high
- I don't know

Comments

ID 34

27. Which technologies analyzed within the NAS report do you view as key for meeting the 54.5 mpg target for 2025? Please select the five most important technologies.

- ☐ Low friction lubricants
- ☐ Engine friction reduction
- ☐ Variable valve timing and lift
- ☐ Stoichiometric Gasoline Direct Injection (GDI)
- ☐ GDI plus Compression Ratio Increase (e.g. Mazda SkyActiv-G)
- ☐ Turbocharging and downsizing
- ☐ Cooled EGR
- ☐ Compression Ratio Increase
- ☐ Electrically Assisted Variable Speed Supercharger
- ☐ Lean Burn
- ☐ 6/8/10-speed automatic transmission
- ☐ DCT (6/8/10 speed)
- ☐ CVT
- ☐ Electric Power Steering
- ☐ Improved Accessories (high eff. alternators and motors, intelligent cooling and alternator operation)
- ☐ Stop-start (12V Microhybrid)
- ☐ Integrated Starter Generator
- ☐ Full Hybrid (Power split or Parallel 2 clutch system)
- ☐ Plug-in Hybrid
- ☐ Electric Vehicle
- ☐ Fuel Cell Electric Vehicle
- ☐ CNG vehicle
- ☐ Flex-fuel vehicle
- ☐ Mass reduction (design optimization)
- ☐ Mass reduction (material substitution)
- ☐ Low Resistance Rolling Tires
- ☐ Aerodynamic Drag Reduction
- ☐ None of the above

ID 36

28. Are there other innovations not described in the NAS study that are being seriously pursued and could contribute to hitting the 54.5 mpg target by 2025?

ID 116

29. Electric vehicle deployment is required under ZEV mandates that exist in CA and various other states (15% of new light-duty vehicle sales by 2025 in these states, equating to about 4% of new light-duty vehicle sales nationwide). To what extent can OEMs meet the federal 54.5 mpg target without a significant increase in electrification (either 100% electric or plug-in hybrids) **beyond what is required in the ZEV mandates**?

- ☐ Nationally, we expect an additional 2% (or more) of new light-duty vehicles would need to be electrified in order to reach the target (beyond what is required in ZEV mandates).
- ☐ Nationally, we expect an additional 0 - 2% of new light-duty vehicles would need to be electrified in order to reach the target (beyond what is required in ZEV mandates).
- ☐ Nationally, sufficient fuel economy improvements in ICE technologies, lightweighting and hybridisation will mean the target could be reached without additional electrification of light-duty vehicles.
- ☐ Nationally, sufficient fuel economy improvements through a shift to smaller cars and technology improvements will mean the target could be reached without additional electrification of light-duty vehicles.
- ☐ I don't know.

Costs and Performance of Technologies

ID 118

The following questions relate to the cost estimates for different technology categories covered in the NAS report. If your company does not make the technologies included in a particular category, please answer "I don't know" and continue to the next question.

If your company only makes some of the technologies included in a particular category, please answer the question based on your knowledge of those technologies. If possible, please indicate in the comments which technologies are relevant to your answer.

ID 40

30. Are the cost estimates for engine technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.

- The cost estimates are generally much too low
- The cost estimates in the report are slightly too low
- The cost estimates are about right
- The cost estimates are too high
- The cost estimates are generally much too high
- I don't know

Comments

ID 97

31. Are the cost estimates for transmission technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.

- The cost estimates are generally much too low
- The cost estimates in the report are slightly too low
- The cost estimates are about right
- The cost estimates are too high
- I don't know

Comments

ID 98

32. Are the cost estimates for electrified accessory technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.

- The cost estimates are generally much too low
- The cost estimates in the report are slightly too low
- The cost estimates are about right
- The cost estimates are too high
- I don't know

Comments

ID 99

33. Are the cost estimates for hybrid, electric and fuel cell technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.

- The cost estimates are generally much too low
- The cost estimates in the report are slightly too low
- The cost estimates are about right
- The cost estimates are too high
- I don't know

Comments

ID 100

34. Are the cost estimates for mass reduction technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.

- The cost estimates are generally much too low
- The cost estimates in the report are slightly too low
- The cost estimates are about right
- The cost estimates are too high
- I don't know

Comments

ID 108

35. Are the cost estimates for rolling resistance and drag reduction technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.

- The cost estimates are generally much too low
- The cost estimates in the report are slightly too low
- The cost estimates are about right
- The cost estimates are too high
- The cost estimates are generally much too high
- I don't know

Comments

ID 95

Extract from NAS report on learning curves:

EPA and NHTSA developed learning curves that provide learning factors as a function of the model year. Examples of these learning curves are shown in Figure 8.1 of the NAS report (page 8-5). An important feature of the learning curve is the basis, which is the year in which the learning factor equals 1.00, indicating that the technology is mature. NHTSA defines a mature technology as one that has reached a production volume of 450,000 units per year in North America. The learning factor is applied to the direct manufacturing cost for the base year to determine the direct manufacturing costs for the other years of interest. The effects of learning curves are reflected in the estimated direct manufacturing costs shown in Tables 8.A2a, b, and c.

Generally the committee applied the same learning curves used by NHTSA, although a learning curve different from NHTSA's assumption was used for mass reduction, as discussed in Chapter 6. A variety of learning curves is shown in Figure 8.1. Learning curve 6 is flat with no learning, which, for example, was applied to low friction lubricants. Typical learning curves have a basis in 2012, 2015, or 2017. However, learning curves for newer technologies have their basis as late as 2025. The base year of these learning curves tends to be preceded by steep learning schedules, which is the concept of applying "negative learning" to estimate the initially higher costs of new technologies. Steep learning curves assume 20 percent decreases in the learning factor every two years during the initial years of production, for a maximum of two learning cycles, before converting to the flatter learning curves.

LOGIC Show/hide trigger exists.

ID 48

36. Do you agree with the approaches used in the NAS study for dealing with the impacts of learning effects on future costs of technologies?

Strongly disagree	Disagree	Undecided	Agree	Strongly disagree
○	○	○	○	○

LOGIC Hidden unless: Question "Do you agree with the approaches used in the NAS study for dealing with the impacts of learning effects on future costs of technologies?" #36 is one of the following answers ("Strongly disagree","Disagree","Undecided")

ID 49

37. Why?

Approaches

ID 101

Extract from NAS report on stranded capital:

If the rate of fuel economy improvement or GHG reduction required by the standards necessitates replacing capital investments before their normal depreciated lifetime, it may be appropriate to attribute the remaining amortized cost of the capital equipment, the "stranded capital," to the replacement technology.

The NRC Phase 1 report also noted that accelerated rates of redesign and technology adoption could demand more engineering resources than are available, potentially driving up labor costs.

LOGIC Show/hide trigger exists.

ID 50

38. Should the costs of "stranded capital" associated with retiring incumbent technologies earlier than expected be taken into account when developing technology cost estimates for public policy?

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
○	○	○	○	○

LOGIC Hidden unless: Question "Should the costs of "stranded capital" associated with retiring incumbent technologies earlier than expected be taken into account when developing technology cost estimates for public policy? " #38 is one of the following answers ("Strongly disagree","Disagree","Undecided")

ID 51

39. Why do you think this?

Approaches

ID 37

The approaches used in the NAS study to estimate fuel consumption reductions were:

1. fundamental technical analyses
2. literature reviews, including the Phase 1 National Research Council (NRC) study
3. full system simulation
4. EPA certification test data
5. inputs received from vehicle manufacturers and suppliers
6. comparisons with extensive EPA and NHTSA evaluations using full system simulations, including the lumped parameter model
7. expert opinions

More information can be found on page 8-2 of the NAS report

LOGIC Show/hide trigger exists.

ID 38

40. Overall, do you agree with the approaches used in the NAS study for estimating reductions in fuel consumption?

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
○	○	○	○	○

LOGIC Hidden unless: Question "Overall, do you agree with the approaches used in the NAS study for estimating reductions in fuel consumption?" #40 is one of the following answers ("Strongly disagree","Disagree","Undecided")

ID 39

41. Why?

Approaches

ID 102

The approaches used in the NAS study to estimate technology costs were:

1. developing cost estimates for key subsystems and components for each technology,
2. using the detailed cost teardown studies conducted by EPA with appropriate updates,
3. considering input from the vehicle manufacturers and suppliers,
4. referring to the Phase 1 NRC Study, and
5. evaluating estimates provided by experts through presentations and publications

More information can be found on page 8-3 of the NAS report.

LOGIC Show/hide trigger exists.

ID 52

42. Overall, do you agree with the approaches used in the NAS study for estimating technology costs?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

LOGIC Hidden unless: Question "Overall, do you agree with the approaches used in the NAS study for estimating technology costs?" #42 is one of the following answers ("Strongly disagree","Disagree","Undecided")

ID 53

43. Why do you think this?

Further comments

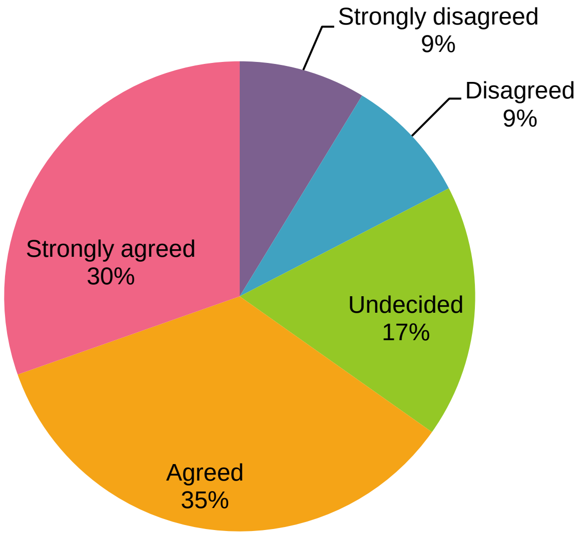
ID 54

44. Do you have any further thoughts or comments about the methodology or conclusions of the NAS report?

Thank You!

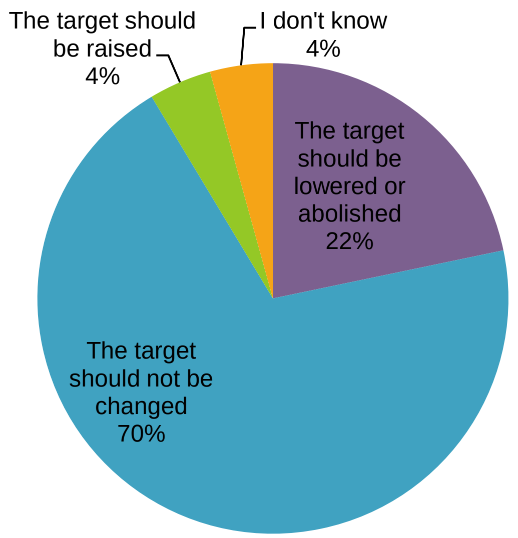
Appendix 4 – Full survey results

Q2. Did you agree with the policy decision to set a 54.5 mpg target for 2025 when it was announced?



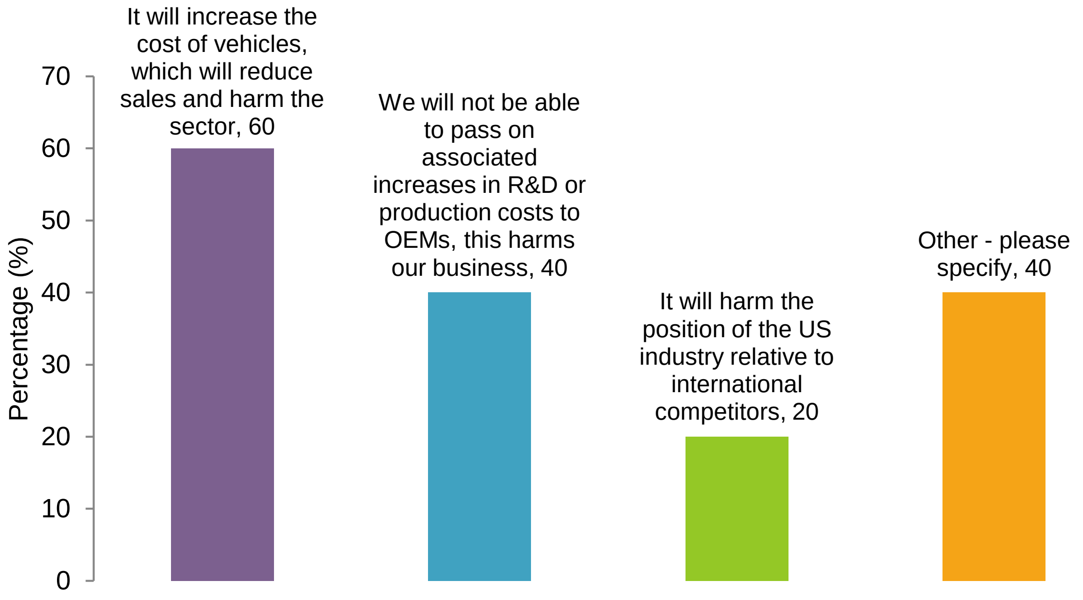
Value	Percent	Count
Strongly disagreed	8.7%	2
Disagreed	8.7%	2
Undecided	17.4%	4
Agreed	34.8%	8
Strongly agreed	30.4%	7

Q3. Do you think that the 54.5 mpg target for 2025 should be adjusted under the next administration?



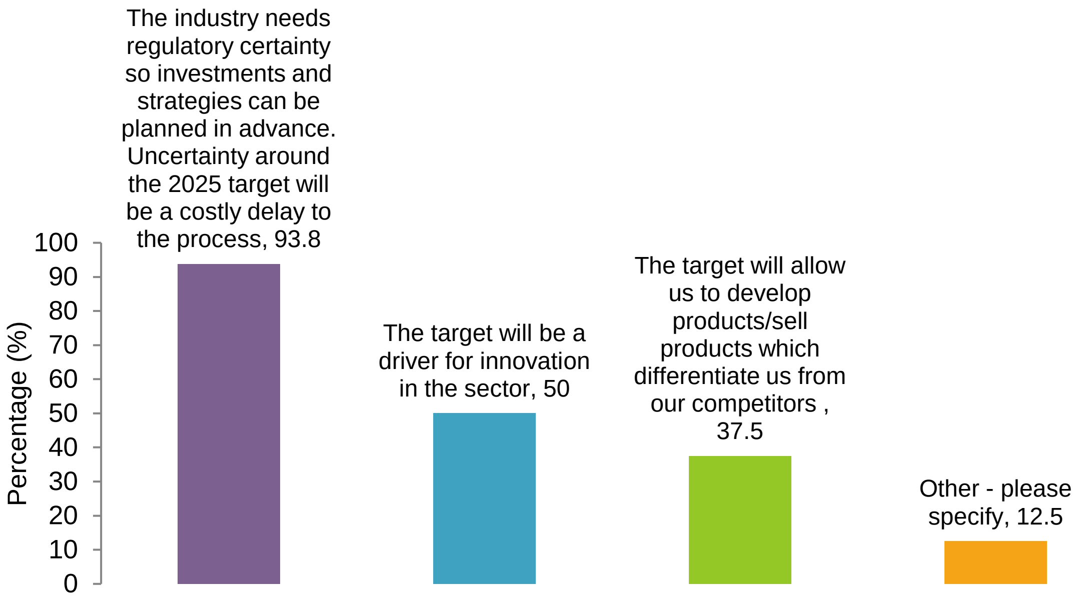
Value	Percent	Count
The target should be lowered or abolished	21.7%	5
The target should not be changed	69.6%	16
The target should be raised	4.3%	1
I don't know	4.3%	1

Q4. Why should the target be lowered or abolished? Please select all that apply.



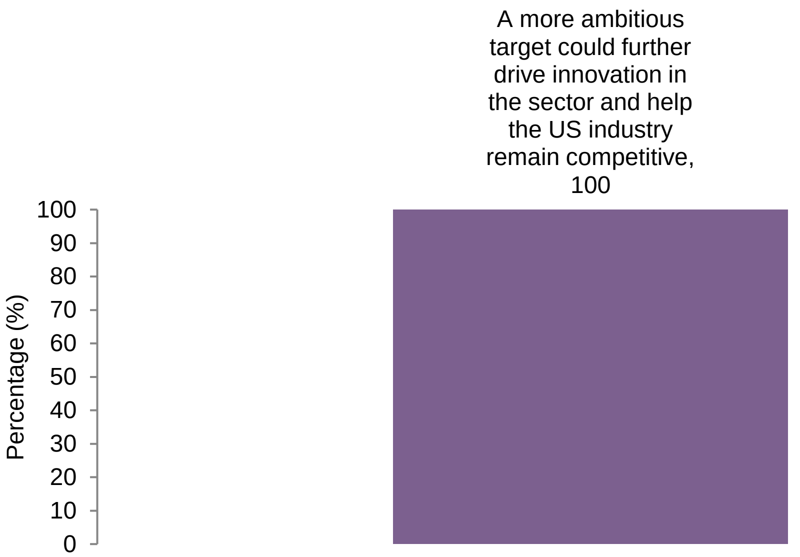
Value	Percent	Count
It will increase the cost of vehicles, which will reduce sales and harm the sector	60.0%	3
We will not be able to pass on associated increases in R&D or production costs to OEMs, this harms our business	40.0%	2
It will harm the position of the US industry relative to international competitors	20.0%	1
Other - please specify	40.0%	2

Q5. Why should the target be kept? Please select all that apply.



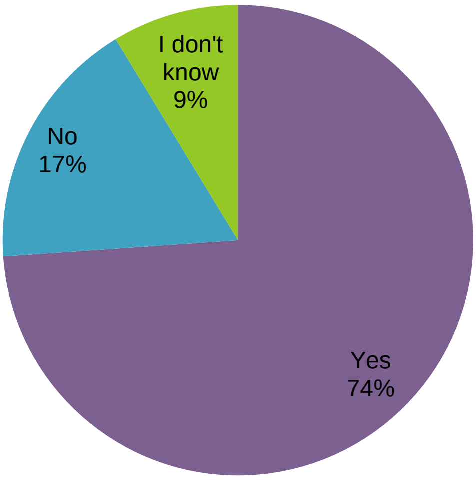
Value	Percent	Count
The industry needs regulatory certainty so investments and strategies can be planned in advance. Uncertainty around the 2025 target will be a costly delay for this process	93.8%	15
The target will be a driver for innovation in the sector	50.0%	8
The target will allow us to develop products/sell products which differentiate us from our competitors	37.5%	6
Other - please specify	12.5%	2

Q6. Why should the target be raised? Please select all that apply.



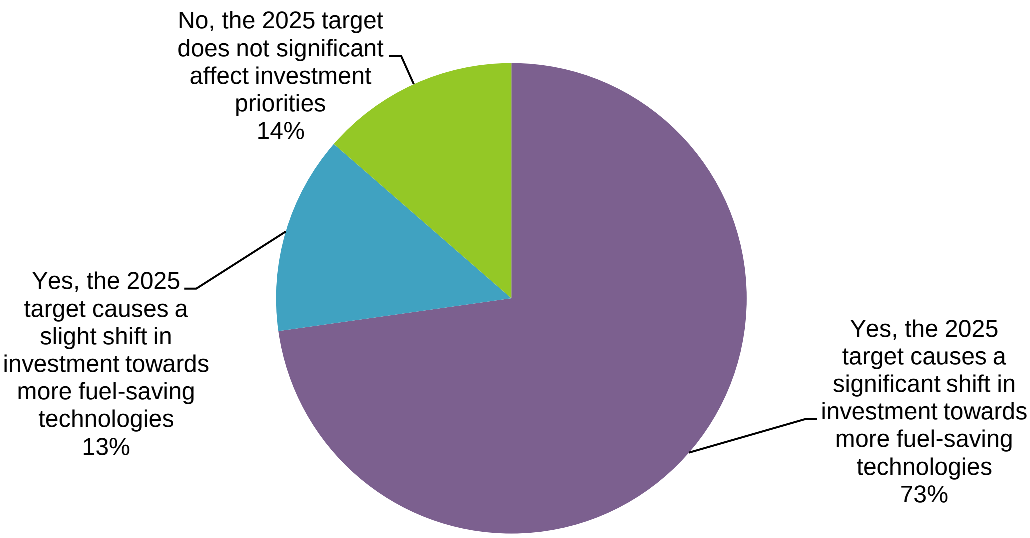
Value	Percent	Count
A more ambitious target could help our company develop more of a leadership role in future vehicle technologies and help us stay competitive in the long run	0.0%	0
A more ambitious target could further drive innovation in the sector and help the US industry remain competitive	100.0%	1
A more ambitious target will allow us to develop products/sell products which differentiate us from our competitors	0.0%	0
Other - please specify	0.0%	0

Q7. In your view, is it important to start planning and setting targets now for beyond 2025? Please provide an explanation for your response choice.



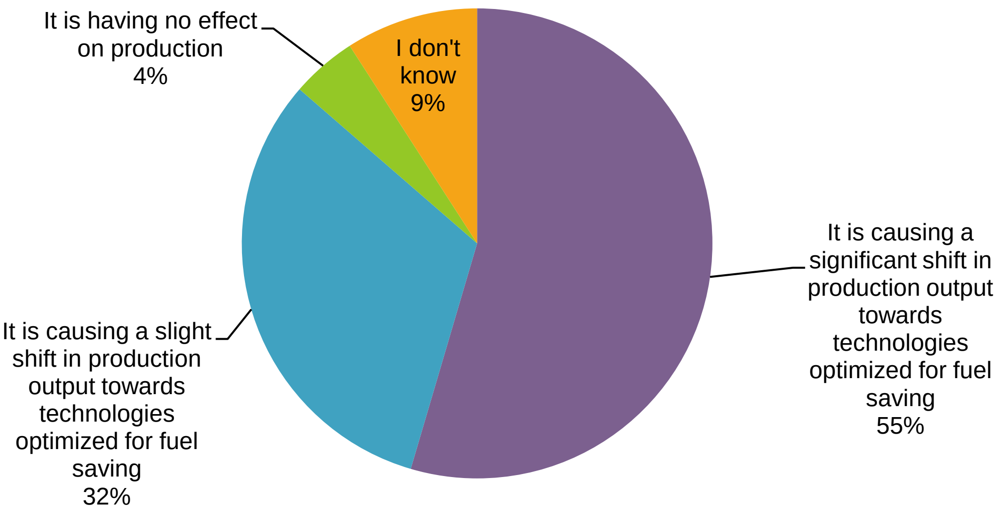
Value	Percent	Count
Yes	73.9%	17
No	17.4%	4
I don’t know	8.7%	2

Q9. Are you making or planning investments based on the 2025 target (both production and R&D)?



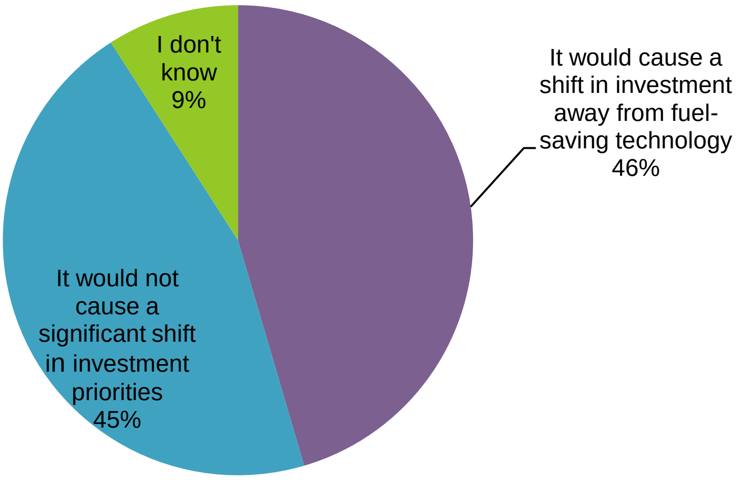
Value	Percent	Count
Yes, the 2025 target causes a significant shift in investment towards more fuel-saving technologies	72.7%	16
Yes, the 2025 target causes a slight shift in investment towards more fuel-saving technologies	13.6%	3
No, the 2025 target does not significantly affect investment priorities	13.6%	3
I don’t know	0.0%	0

Q10. What effect is the 54.5 mpg target for 2025 having on your expected production output of products designed or optimized for saving fuel?



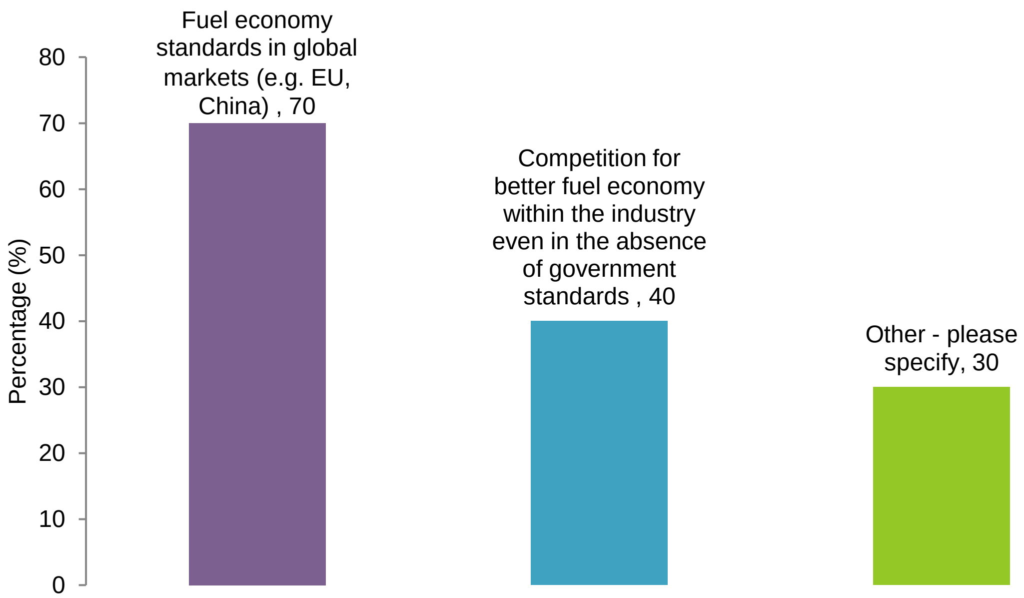
Value	Percent	Count
It is causing a significant shift in production output towards technologies optimized for fuel saving	54.5%	12
It is causing a slight shift in production output towards technologies optimized for fuel saving	31.8%	7
It is having no effect on production	4.5%	1
I don't know	9.1%	2

Q11. What effect would a weakening of the 2025 target have on your (planned) investments?



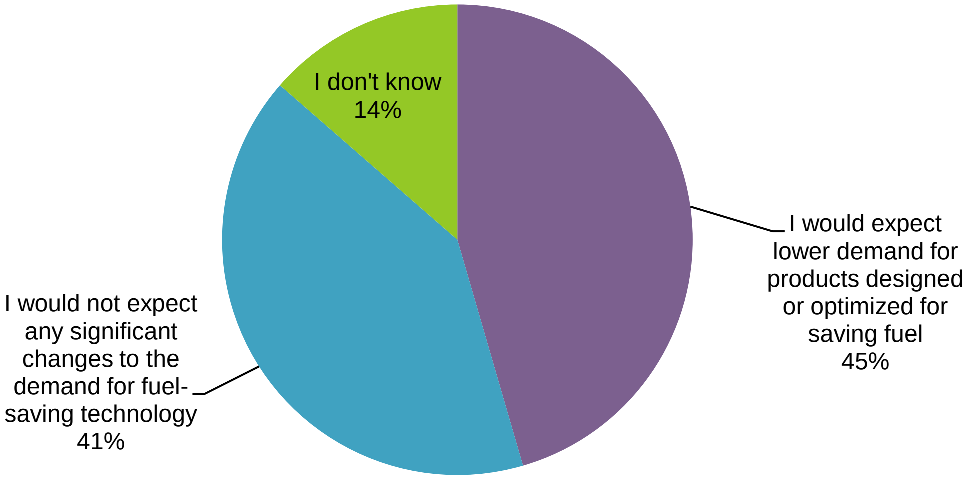
Value	Percent	Count
It would cause a shift in investment away from fuel-saving technology	45.5%	10
It would not cause a significant shift in investment priorities	45.5%	10
I don't know	9.1%	2

Q12. Why not? Which factors are more relevant for determining investments into fuel-saving technologies? Select all that apply.



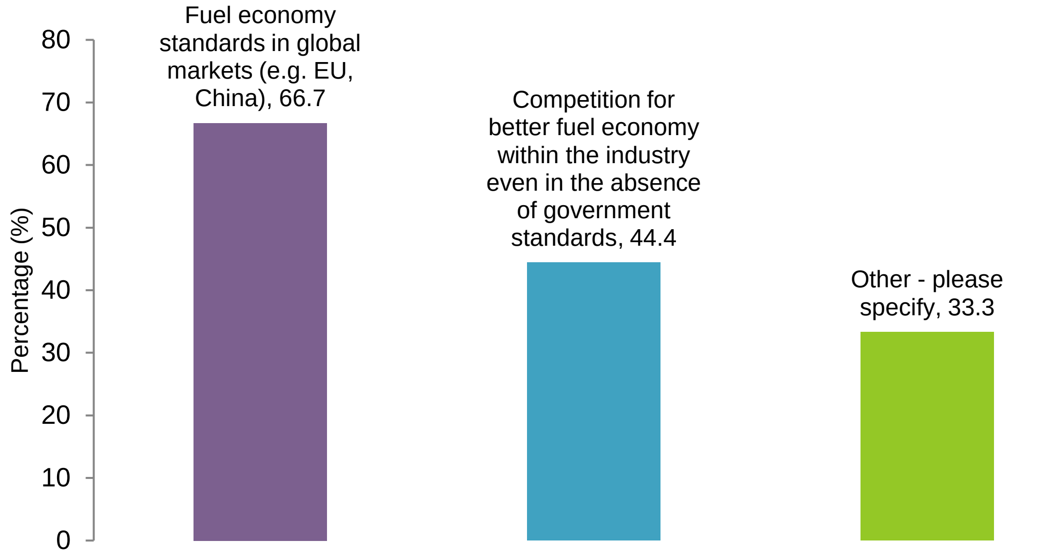
Value	Percent	Count
Fuel economy standards in global markets (e.g. EU, China)	70.0%	7
Competition for better fuel economy within the industry even in the absence of government standards	40.0%	4
Other - please specify	30.0%	3

Q13. What effect would a weakening of the 2025 target have on your production of fuel-saving technologies?



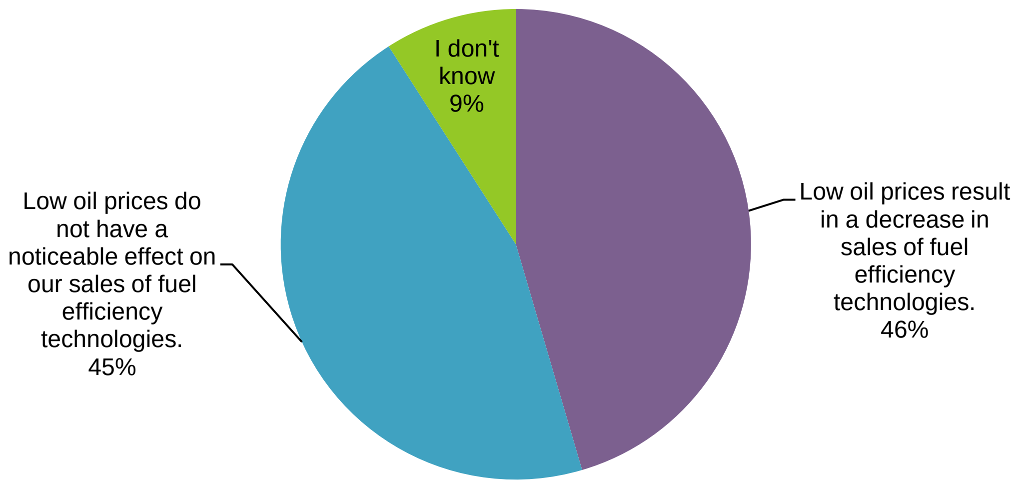
Value	Percent	Count
I would expect lower demand for products designed or optimized for saving fuel	45.5%	10
I would not expect any significant changes to the demand for fuel-saving technology	40.9%	9
I don't know	13.6%	3

Q14. Why not? Which factors are more relevant for driving demand for fuel-saving technology? Select all that apply.



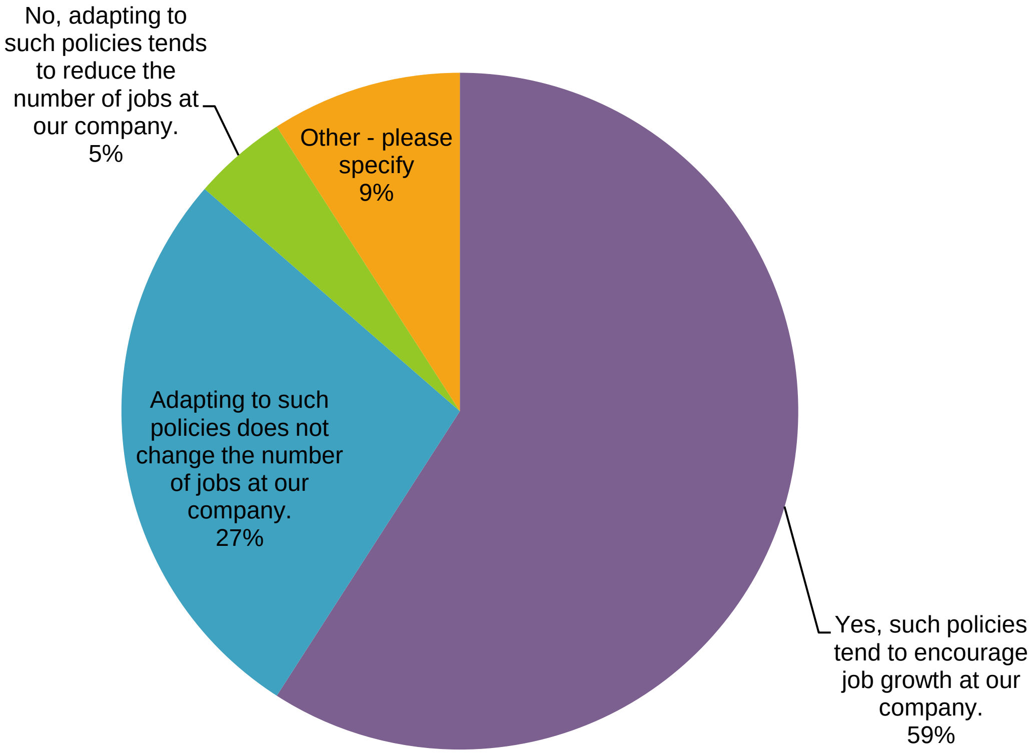
Value	Percent	Count
Fuel economy standards in global markets (e.g. EU, China)	66.7%	6
Competition for better fuel economy within the industry even in the absence of government standards	44.4%	4
Other - please specify	33.3%	3

Q15. What effect do low oil prices have on your sales of the fuel efficiency technologies your company produces?



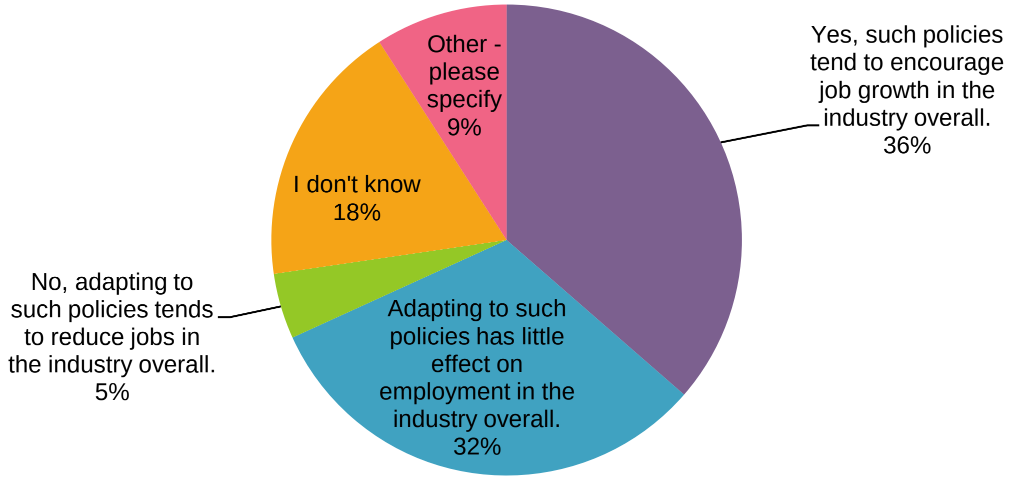
Value	Percent	Count
Low oil prices result in an increase in sales of fuel efficiency technologies.	0.0%	0
Low oil prices result in a decrease in sales of fuel efficiency technologies.	45.5%	10
Low oil prices do not have a noticeable effect on our sales of fuel efficiency technologies.	45.5%	10
I don’t know	9.1%	2

Q17. In general, do US policies that encourage or force the uptake of new technologies also encourage job growth for your company in the US?



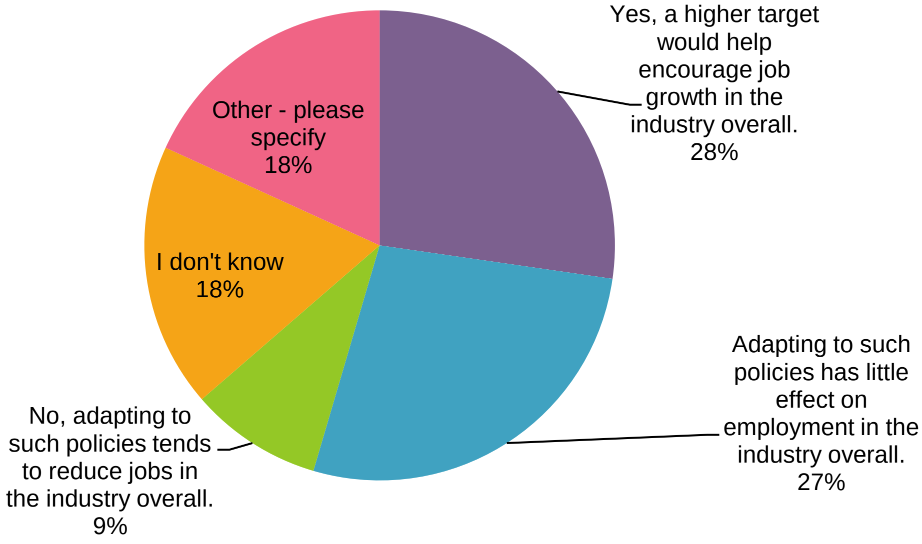
Value	Percent	Count
Yes, such policies tend to encourage job growth at our company.	59.1%	13
Adapting to such policies does not change the number of jobs at our company.	27.3%	6
No, adapting to such policies tends to reduce the number of jobs at our company.	4.5%	1
Other - please specify	9.1%	2

Q18. Will the current 54.5 mpg target for 2025 help encourage job growth in the wider US economy?



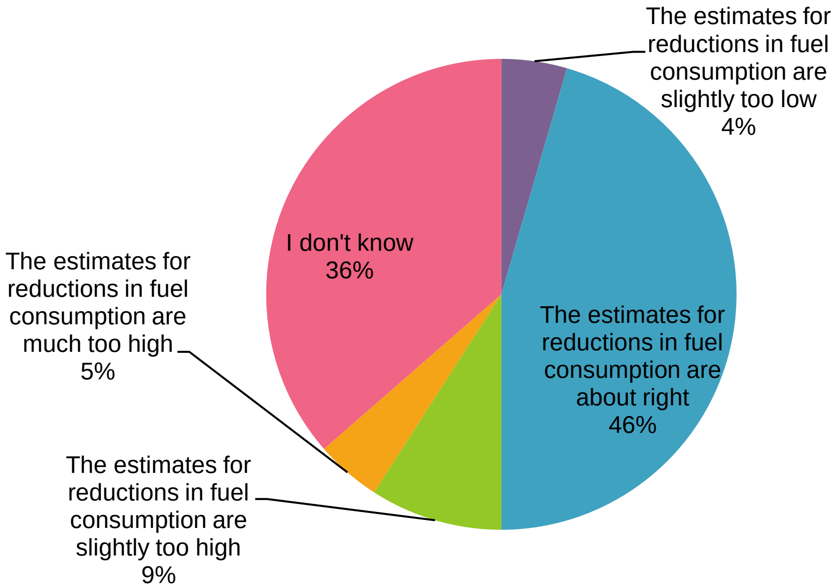
Value	Percent	Count
Yes, such policies tend to encourage job growth in the industry overall.	36.4%	8
Adapting to such policies has little effect on employment in the industry overall.	31.8%	7
No, adapting to such policies tends to reduce jobs in the industry overall.	4.5%	1
I don't know	18.2%	4

Q19. If a higher fuel efficiency target was introduced, do you think that it would help encourage job growth in your sector?



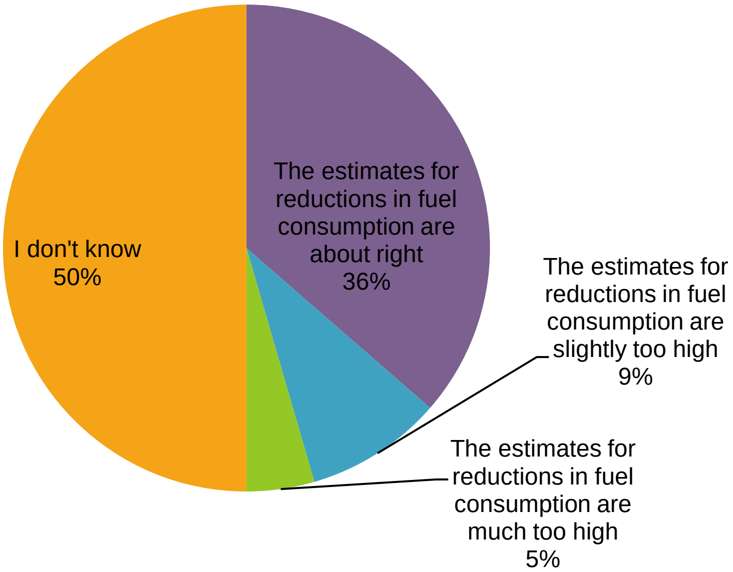
Value	Percent	Count
Yes, a higher target would help encourage job growth in the industry overall.	27.3%	6
Adapting to such policies has little effect on employment in the industry overall.	27.3%	6
No, adapting to such policies tends to reduce jobs in the industry overall.	9.1%	2
I don't know	18.2%	4

Q21. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for engine technologies? Use the table below for guidance.



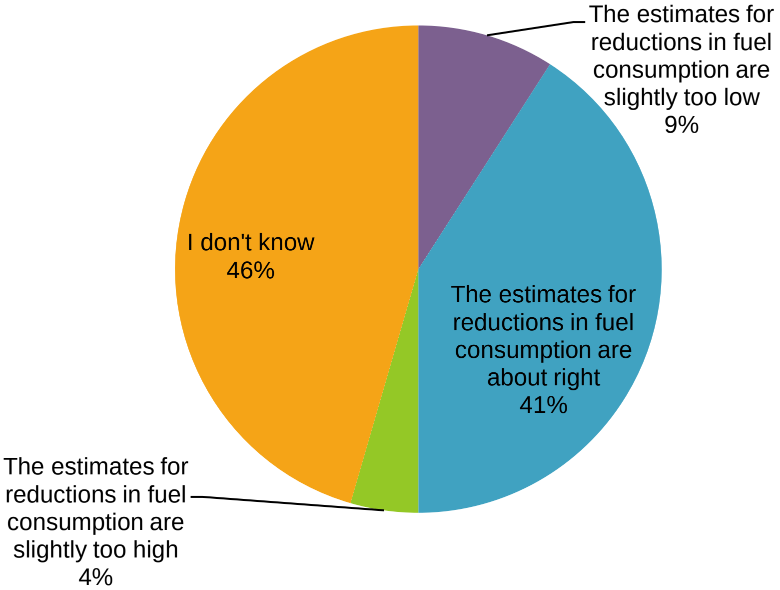
Value	Percent	Count
The estimates for reductions in fuel consumption are much too low	0.0%	0
The estimates for reductions in fuel consumption are slightly too low	4.5%	1
The estimates for reductions in fuel consumption are about right	45.5%	10
The estimates for reductions in fuel consumption are slightly too high	9.1%	2
The estimates for reductions in fuel consumption are much too high	4.5%	1
I don’t know	36.4%	8

Q22. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for transmission technologies? Use the table below for guidance.



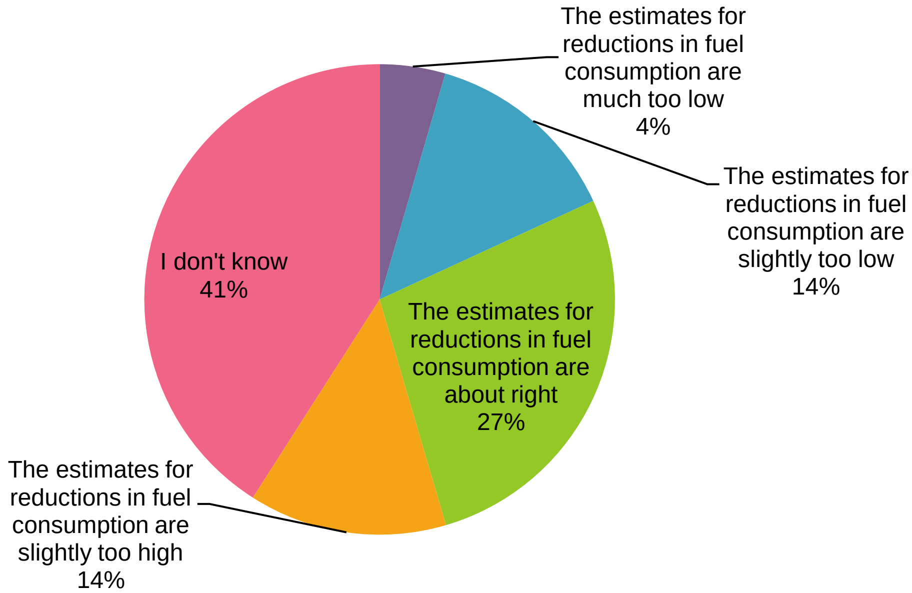
Value	Percent	Count
The estimates for reductions in fuel consumption are much too low	0.0%	0
The estimates for reductions in fuel consumption are slightly too low	0.0%	0
The estimates for reductions in fuel consumption are about right	36.4%	8
The estimates for reductions in fuel consumption are slightly too high	9.1%	2
The estimates for reductions in fuel consumption are much too high	4.5%	1
I don’t know	50.0%	11

Q23. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for electrified accessory technologies? Use the table below for guidance.



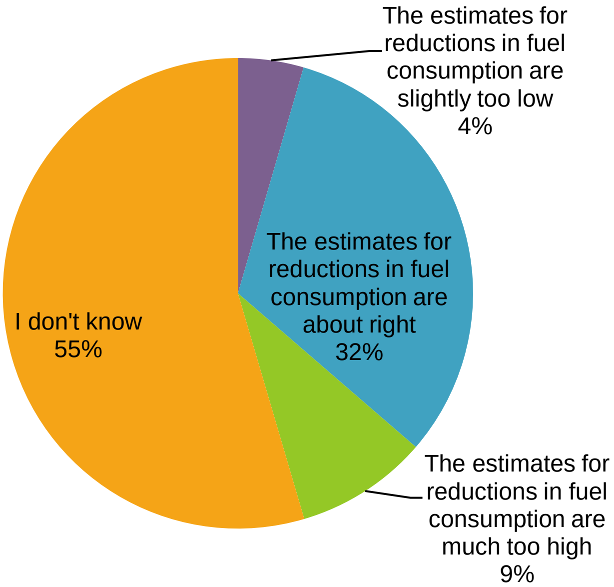
Value	Percent	Count
The estimates for reductions in fuel consumption are much too low	0.0%	0
The estimates for reductions in fuel consumption are slightly too low	9.1%	2
The estimates for reductions in fuel consumption are about right	40.9%	9
The estimates for reductions in fuel consumption are slightly too high	0.0%	0
The estimates for reductions in fuel consumption are much too high	4.5%	1
I don't know	55.5	10

Q24. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for hybrid, electric and fuel cell technologies that your company produces? Use the table below for guidance.



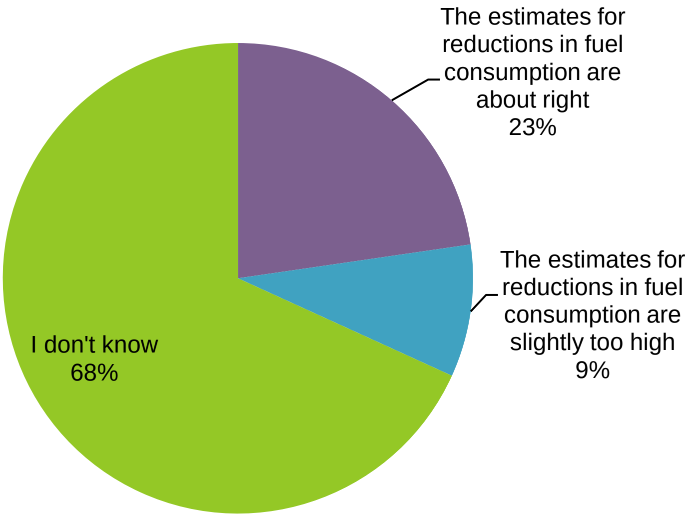
Value	Percent	Count
The estimates for reductions in fuel consumption are much too low	0.0%	0
The estimates for reductions in fuel consumption are much too low	4.5%	1
The estimates for reductions in fuel consumption are slightly too low	13.6%	3
The estimates for reductions in fuel consumption are about right	27.3%	6
The estimates for reductions in fuel consumption are slightly too high	13.6%	3
The estimates for reductions in fuel consumption are much too high	0.0%	0
I don’t know	40.9%	9

Q25. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for mass reduction technologies? Use the table below for guidance.



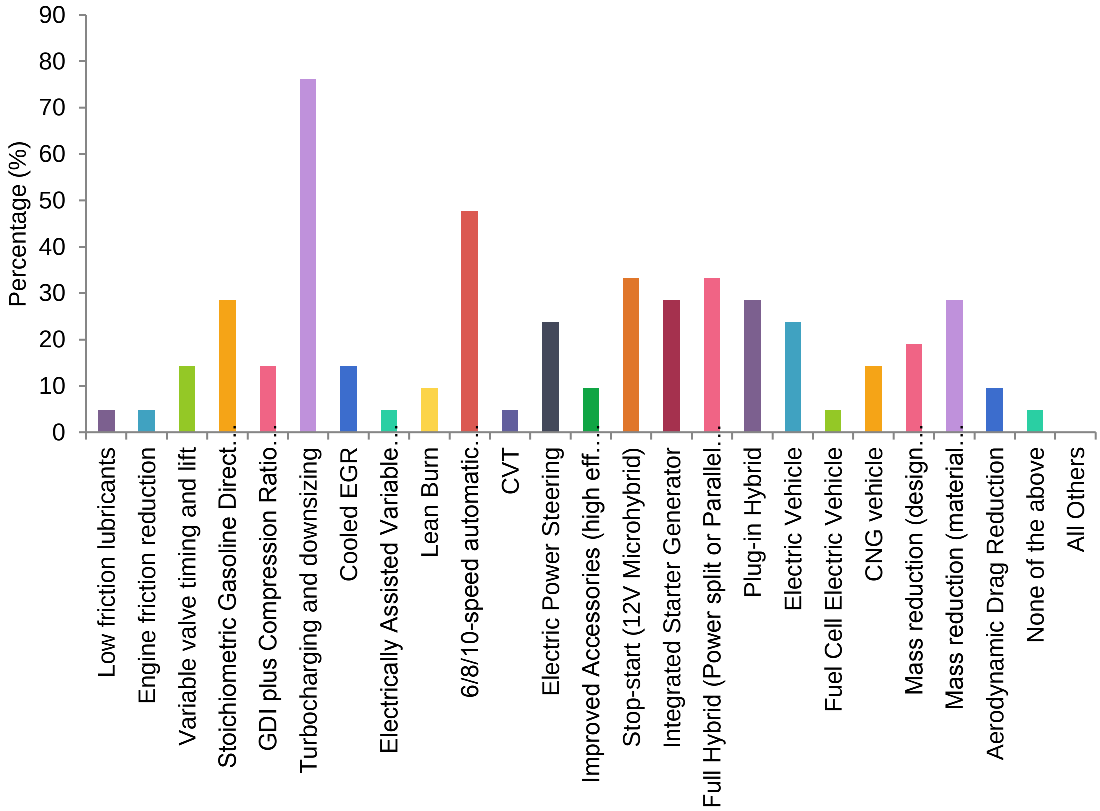
Value	Percent	Count
The estimates for reductions in fuel consumption are much too low	0.0%	0
The estimates for reductions in fuel consumption are slightly too low	4.5%	1
The estimates for reductions in fuel consumption are about right	31.8%	7
The estimates for reductions in fuel consumption are slightly too high	0.0%	0
The estimates for reductions in fuel consumption are much too high	9.1%	2
I don’t know	54.5%	12

Q26. Are the estimates for reductions in fuel consumption outlined in the NAS study reasonable for rolling resistance and drag reduction technologies? Use the table below for guidance.



Value	Percent	Count
The estimates for reductions in fuel consumption are much too low	0.0%	0
The estimates for reductions in fuel consumption are slightly too low	0.0%	0
The estimates for reductions in fuel consumption are about right	22.7%	5
The estimates for reductions in fuel consumption are slightly too high	9.1%	2
The estimates for reductions in fuel consumption are much too high	0.0%	0
I don't know	68.2%	15

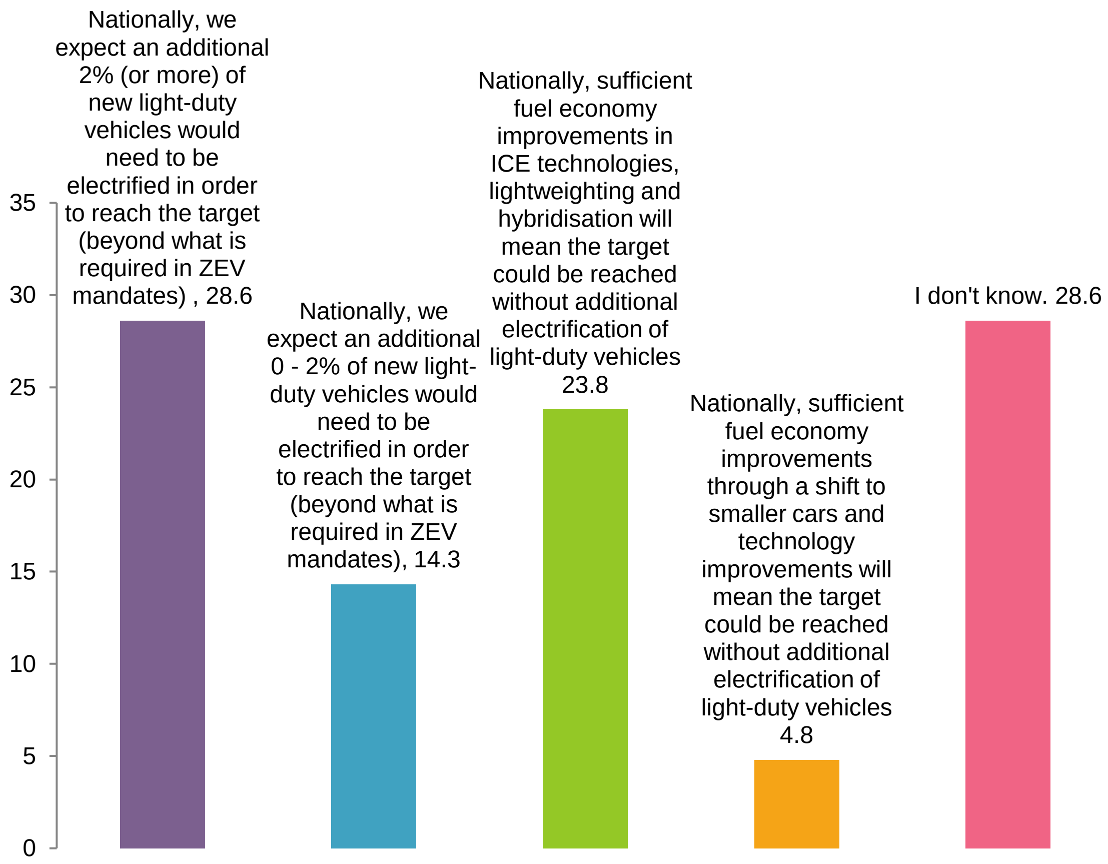
Q27. Which technologies analyzed within the NAS report do you view as key for meeting the 54.5 mpg target for 2025? Please select the five most important technologies.



Value	Percent	Count
Low friction lubricants	4.8%	1
Engine friction reduction	4.8%	1
Variable valve timing and lift	14.3%	3
Stoichiometric Gasoline Direct Injection (GDI)	28.6%	6
GDI plus Compression Ratio Increase (e.g. Mazda SkyActiv-G)	14.3%	3
Turbocharging and downsizing	76.2%	16
Cooled EGR	14.3%	3
Compression Ratio Increase	0.0%	0
Electrically Assisted Variable Speed Supercharger	4.8%	1
Lean Burn	9.5%	2
6/8/10-speed automatic transmission	47.6%	10
DCT (6/8/10 speed)	0.0%	0
CVT	4.8%	1

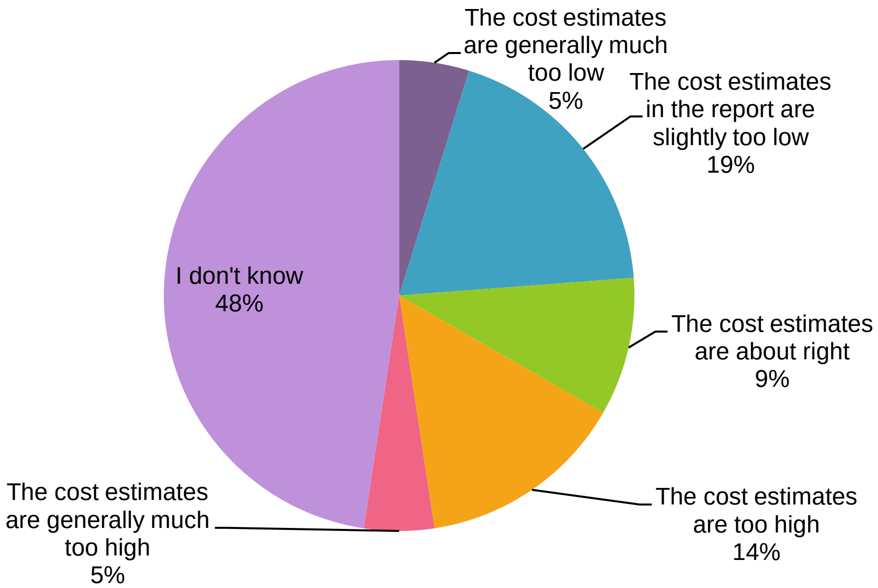
Electric Power Steering	23.8%	5
Improved Accessories (high eff. alternators and motors, intelligent cooling and alternator operation)	9.5%	2
Stop-start (12V Microhybrid)	33.3%	7
Integrated Starter Generator	28.6%	6
Full Hybrid (Power split or Parallel 2 clutch system)	33.3%	7
Plug-in Hybrid	28.6%	6
Electric Vehicle	23.8%	5
Fuel Cell Electric Vehicle	4.8%	1
CNG vehicle	14.3%	3
Mass reduction (design optimization)	19.0%	4
Mass reduction (material substitution)	28.6%	6
Low rolling resistance tires	0.0%	0
Aerodynamic Drag Reduction	9.5%	2
None of the above	4.8%	1

Q29. Electric vehicle deployment is required under ZEV mandates that exist in CA and various other states (15% of new light-duty vehicle sales by 2025 in these states, equating to about 4% of new light-duty vehicle sales nationwide). To what extent can OEMs meet the federal 54.5 mpg target without a significant increase in electrification (either 100% electric or plug-in hybrids) beyond what is required in the ZEV mandates?



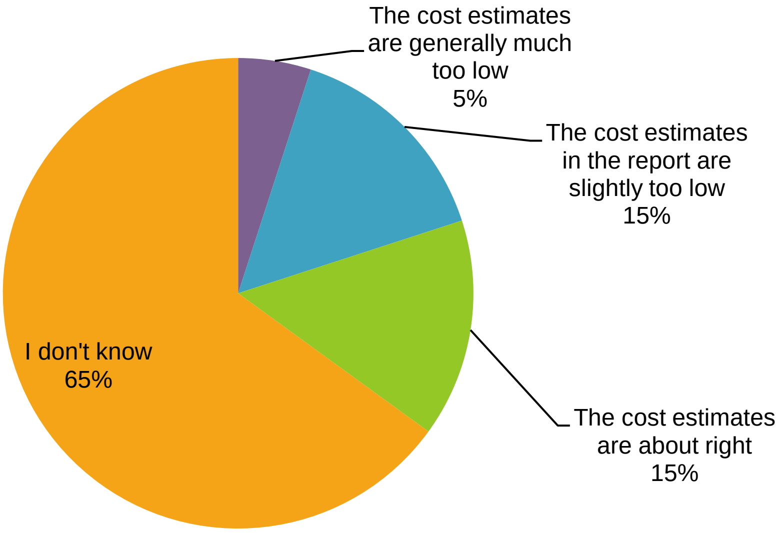
Value	Percent	Count
Nationally, we expect an additional 2% (or more) of new light-duty vehicles would need to be electrified in order to reach the target (beyond what is required in ZEV mandates).	28.6%	6
Nationally, we expect an additional 0 - 2% of new light-duty vehicles would need to be electrified in order to reach the target (beyond what is required in ZEV mandates).	14.3%	3
Nationally, sufficient fuel economy improvements in ICE technologies, lightweighting and hybridisation will mean the target could be reached without additional electrification of light-duty vehicles.	23.8%	5
Nationally, sufficient fuel economy improvements through a shift to smaller cars and technology improvements will mean the target could be reached without additional electrification of light-duty vehicles.	4.8%	1
I don’t know	28.6%	6

Q30. Are the cost estimates for engine technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.



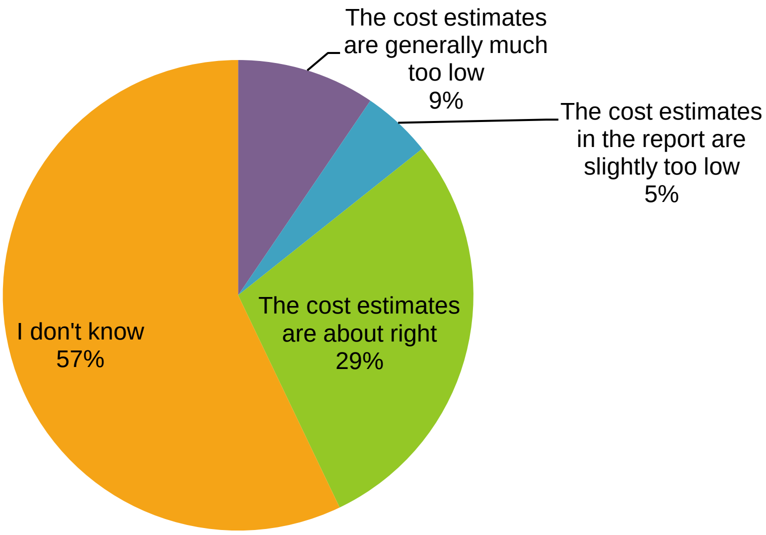
Value	Percent	Count
The cost estimates are generally much too low	4.8%	1
The cost estimates in the report are slightly too low	19.0%	4
The cost estimates are about right	9.5%	2
The cost estimates are too high	14.3%	3
The cost estimates are generally much too high	4.8%	1
I don't know	47.6%	10

Q31. Are the cost estimates for transmission technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.



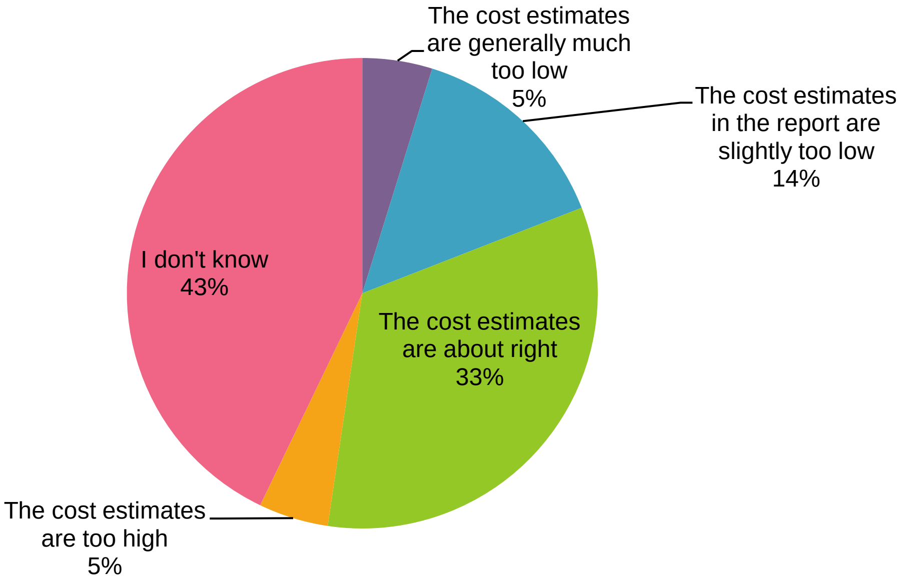
Value	Percent	Count
The cost estimates are generally much too low	5.0%	1
The cost estimates in the report are slightly too low	15.0%	3
The cost estimates are about right	15.0%	3
The cost estimates are too high	0.0%	0
The cost estimates are generally much too high	0.0%	0
I don’t know	65.0%	13

Q32. Are the cost estimates for electrified accessory technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.



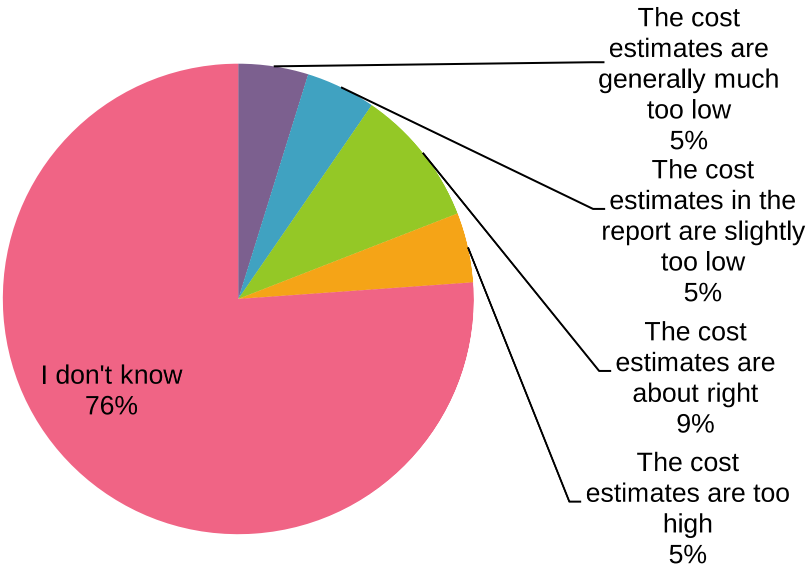
Value	Percent	Count
The cost estimates are generally much too low	9.5%	2
The cost estimates in the report are slightly too low	4.8%	1
The cost estimates are about right	28.6%	6
The cost estimates are too high	0.0%	0
The cost estimates are generally much too high	0.0%	0
I don’t know	57.1%	12

Q33. Are the cost estimates for hybrid, electric and fuel cell technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.



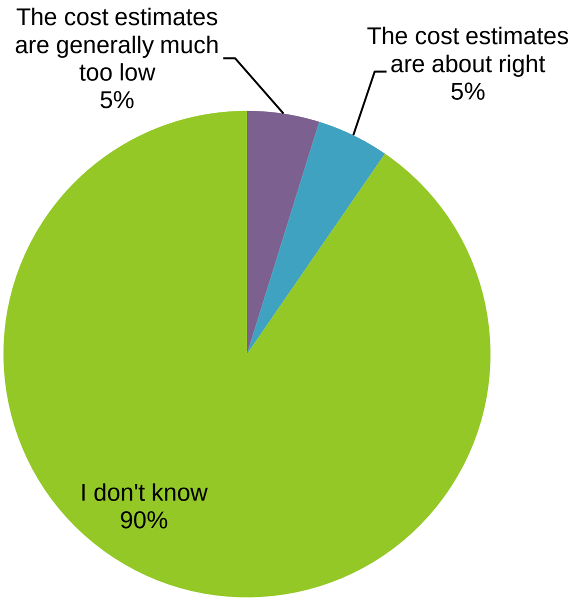
Value	Percent	Count
The cost estimates are generally much too low	4.8%	1
The cost estimates in the report are slightly too low	14.3%	3
The cost estimates are about right	33.3%	7
The cost estimates are too high	4.8%	1
The cost estimates are generally much too high	0.0%	0
I don't know	42.9%	9

Q34. Are the cost estimates for mass reduction technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.



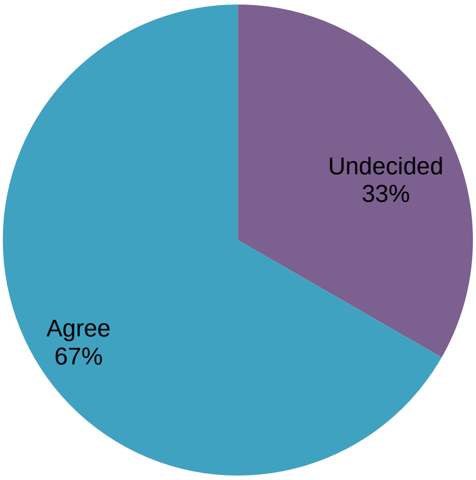
Value	Percent	Count
The cost estimates are generally much too low	4.8%	1
The cost estimates in the report are slightly too low	4.8%	1
The cost estimates are about right	9.5%	2
The cost estimates are too high	4.8%	1
The cost estimates are generally much too high	0.0%	0
I don’t know	76.2%	16

Q35. Are the cost estimates for rolling resistance and drag reduction technologies outlined in the NAS study accurate? Use the tables below for guidance. All costs are in 2010$.



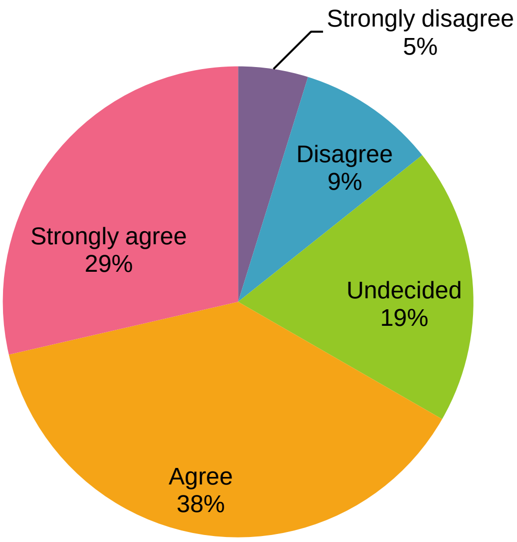
Value	Percent	Count
The cost estimates are generally much too low	4.8%	1
The cost estimates in the report are slightly too low	0.0%	0
The cost estimates are about right	4.8%	1
The cost estimates are too high	0.0%	0
The cost estimates are generally much too high	0.0%	0
I don't know	90.5%	19

Q36. Do you agree with the approaches used in the NAS study for dealing with the impacts of learning effects on future costs of technologies?



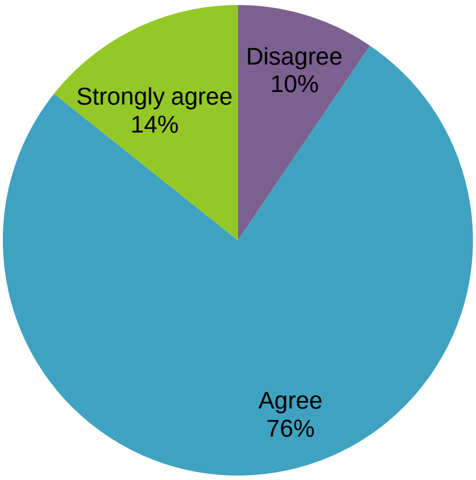
Value	Percent	Count
Undecided	33.3%	7
Agree	66.7%	14

Q38. Should the costs of "stranded capital" associated with retiring incumbent technologies earlier than expected be taken into account when developing technology cost estimates for public policy?



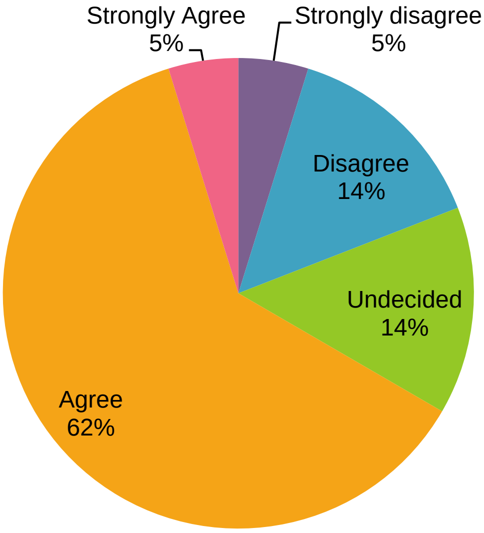
Value	Percent	Count
Strongly disagree	4.8%	1
Disagree	9.5%	2
Undecided	19.0%	4
Agree	38.1%	8
Strongly agree	28.6%	6

Q40. Overall, do you agree with the approaches used in the NAS study for estimating reductions in fuel consumption?



Value	Percent	Count
Strongly disagree	0.0%	1
Disagree	9.5%	2
Undecided	19.0%	4
Agree	76.2%	16
Strongly agree	14.3%	3

Q42. Overall, do you agree with the approaches used in the NAS study for estimating technology costs?



Value	Percent	Count
Strongly disagree	4.8%	1
Disagree	14.3%	3
Undecided	14.3%	3
Agree	61.9%	13
Strongly agree	4.8%	1

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