ACEEE Attachment 1
Full-size pickup analysis methodology

This attachment contains information referenced in our comments on full-size pickups.

1. Determination of future model full-size pickup fuel economy

1. Choose representative truck (Crew cab, Standard bed)
2. Obtain fuel economy certification values; for trucks without official fuel economy values, estimate percent improvement over the comparable outgoing model's official fuel economy estimate
3. Determine future fuel economy standard for trucks based on footprint
4. Factor in the use of greenhouse gas credits that are applicable to the fuel economy standard (A/C efficiency and off-cycle technology credits)
5. Estimate resulting fuel economy value, with credits, for comparison with standards
6. For models eligible for the full-size pickup advanced technology greenhouse gas credits as per specifications or performance, and meeting sales threshold requirements, factor in these credits before estimating a resulting fuel economy value

Full-size pickups are available in a variety of configurations, trims, and footprints. Fuel economy certification values cover more than one configuration and thus footprint of a particular truck. As a result, we are unable to determine footprint-based fuel economy targets for each available configuration. Considering this limitation, we chose a single configuration across all three manufacturers. Our representative truck is equipped with a crew cab (or equivalent) and standard bed length. This likely represents the most popular configuration sold today[1], and was verified by evaluating the available nationwide dealer inventory by cab type and bed size.[2]

We use fuel economy certification values from the EPA Fuel Economy Guide for truck and engines which have already been certified. However, for engines not yet certified, as noted in table 1, we estimate the percent fuel economy improvement for each engine over its comparable outgoing model's fuel economy certification value based on EPA's Lumped Parameter Model, and either verified or based on a number of manufacturer or OEM statements for the particular engine.[3]

	Fuel economy source	**CO2 Reduction (g/mi)**	**Source or LPM inputs**
2018 Ford F-150		% over outgoing engine	
All Engines	EPA FE Guide[4]		
2019 RAM			
V6 MH	EPA FE Guide		

[1] https://www.consumerreports.org/pickup-trucks/are-pickup-trucks-becoming-the-new-family-car/
[2] www.cars.com; August 2018.
[3] The LPM model provides a percent reduction in CO_2 emissions from a combination of select technologies. Fuel economy values were thus converted to CO_2 emissions (in grams CO_2 per mile) based on fuel type before adjustment, before being converted back to the equivalent in fuel economy (miles per gallon).
[4] www.fueleconomy.gov.

V8	EPA FE Guide		
V8 MH	EPA FE Guide		
Diesel	ACEEE Estimate	7.10%	LPM (5% MR, 10% DR, EPS, IA)
2.0L I4 MH*	ACEEE Estimate	23.90%	LPM (5% MR, 10% DR, MH, EPS, 24B)
2019 GM C/K			
2.7L I4 Turbo	ACEEE Estimate	20.30%	LPM (6% MR, 5% DR, SS, 21B, CD, 5SPD)
4.3L V6	ACEEE Estimate	8.70%	LPM: cylinder deac, 6% MR, 5% drag
3.0L I6 Diesel	ACEEE Estimate		Based on mfgr claim
5.3L V8	EPA FE Guide		
6.2L V8 - 4WD	EPA FE Guide		
6.2L V8 - 2WD	ACEEE Estimate	12.4%	LPM (6% MR, 5% Drag, Cyl Deac., 5spd)

Table 1. Method for obtaining fuel economy values for each engine evaluated. ACEEE estimates include manufacturer statements and EPA Lumped Parameter Model (LPM)

Footprint-based fuel economy targets for each future model year is calculated for each footprint of the trucks evaluated (table 2). Footprints were obtained through vehicle specifications on each of the manufacturers' websites.

Manufacturer & Model	Footprint (ft^2)	2019	2020	2021	2022	2023	2024	2025
2018 Ford F-150	68.1	25.3	25.3	26.7	28.0	29.3	30.7	32.1
2019 GM Silverado/Sierra	72.5	25.3	25.3	26.4	27.7	29.0	30.4	31.8
2019 RAM 1500	68.6	25.3	25.3	26.7	28.0	29.3	30.7	32.1

Table 2. Footprint and associated fuel economy standard by model year

Manufacturers are expected to apply an increasing number of A/C and off-cycle technologies eligible for greenhouse gas credits. Our estimate of future credit use is based on the known per-vehicle average credits claimed in MY2016 along with ICCT's projected credit use under the mid-range credit scenario,[5] interpolating for interim model years (table 3). As per ICCT's analysis, the number of off-cycle credits claimed for light trucks is 25% greater than average. These estimates are applied to the equivalent greenhouse gas emissions (in grams-per-mile) for the fuel economy determined above.

Credit type	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Source
A/C Efficiency	4	5	5	6	5	7	7	7	7	7	Draft TAR
Off-cycle	4	6	8	10	12	14	16	18	20	22	ICCT[5]
Total	8	11	13	16	17	21	23	25	27	29	

Table 3. Estimated credit use by model year for light trucks, grams per mile (g/mi)

Finally, full-size pickup trucks are eligible for advanced technology or performance-based credits under the EPA program. Trucks equipped with mild hybrid or strong hybrid systems, or exceeding their targets by 15% or 20% or higher, while meeting a sales threshold, are eligible for additional greenhouse gas credits. To determine eligibility, we compare the resulting fuel economy value against the calculated footprint-based target. Sales thresholds are first based on Volpe market input data for full-size pickups

[5] https://www.theicct.org/sites/default/files/publications/Off-Cycle-Credits_ICCT-White-Paper _vF_20180327.pdf.

to determine the sales share of each engine and drivetrain (2WD/4WD) combination. We make a variety of adjustments based on manufacturer statements or recent trends. For example, based on the decline in V8 sales from 2014 through 2017 as Ford introduced its Ecoboost engines, its likely that RAM NA V8 sales will decline from the introduction of the mild hybrid V6 and mild hybrid V8 option as well.

Assumptions regarding the timing or introduction of certain engines and resulting sales share are purely subjective.

2. Additional details for Ford F-150 and Toyota Tundra analysis

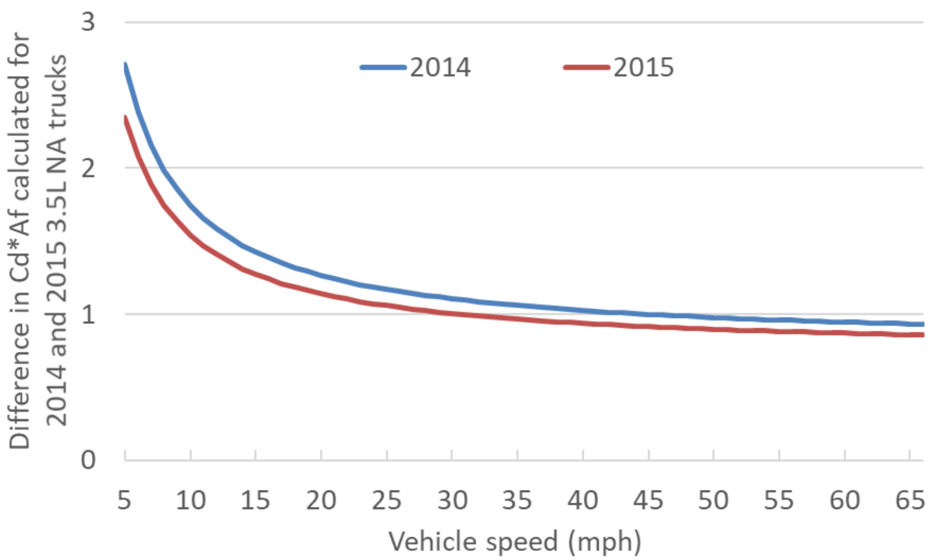

Figure 1: Comparison of the product of drag coefficient (Cd) and pickup frontal area (Af) for 2014 and 2015 MY F-150 3.5L NA trucks[6,7]

Alternative pathway to achieve MY 2025 targets for Toyota Tundra.

Technology	**FE Effectiveness***	**Penetration**	**2025 Cost**
GDI and Turbo 2 from naturally aspirated (NA)	22.2%	100%	$1,868

[6] Annual Certification Data for Vehicles, Engines, and Equipment, 2014 and 2015 data. Available at https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment

[7] We calculated the change in drag from reported road load coefficients using the following equation: $Cd * Af = (B + 2Cv)/(\rho a * v)$, Where Cd is aero drag coefficient, Af is truck frontal area in ft^2, and ρ_a is air density (0.07967 lbf/ft3), and v is vehicle speed.

CEGR#	4.4%	100%	$359
AT8 from AT6	4.8%	100%	$106@
BISG including battery costs	6.1%	100%	$980
MR3	3.8%	100%	$280
ROLL20	2.9%	100%	$42
AERO15	3.0%	100%	$239
Total	**40% (66% FE improvements)**		**$3,874**

Table 4: Non-hybrid pathway to meet 2025 target for Tundra pickup

* Fuel economy effectiveness numbers are taken from the CAFE model for "high-performance" pickups, which include all full-size pickups. Some of the effectiveness numbers are, however, inferred from the model. For example, the model lists TURBO2 effectiveness from TURBO1 only. Therefore, to get the effectiveness of TURBO2 relative to a naturally aspirated engine, we combined the effectiveness of GDI, TURBO1, and TURBO2 from TURBO1.
#The CAFE model assigned no benefits for CEGR, at considerable cost, raising the question of why it was included in the technology package. The ICCT in its comments to the NPRM points out that, "the agencies benchmarking and simulation modeling clearly show that there is a benefit to CEGR on top of turbocharging of 3-4%."[8] In Class 2b/3 pickups, CEGR has demonstrated almost 4% FC effectiveness; savings can be as high as 6-9%.[9]
@AT8 transmission cost implies the combined costs of AT6, AT6L2, AT6L3, and AT8, because the CAFE model prescribes adding costs of preceding transmission technologies from the baseline AT5 transmission.

[8] ICCT Comments to the NPRM docket, p. I-74
[9] https://crcao.org/workshops/2014AFEE/Final%20Presentations/Day%201%20Session%201%20SI-Octane%20Presentations/1-4%20Alger,%20Terry%20%20Review%20of%20Cooled%20and%20DEGR%20concepts.pdf