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Fuel Economy Costs and Benefits

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OECD

Impacts of Fuel Economy Standards

- Improved engine efficiency
- Improved vehicle performance and fuel efficiency

Estimating the impacts of standards using cost-benefit analysis

- One of the factors agencies consider when determining appropriate standards to propose
- Costs and benefits of proposed standards are often compared to a baseline scenario without such standards

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Assessing the Costs of Fuel Economy Standards (1)

(Anderson et al., 2011)

Engineering Approach

- Increase fuel-saving technologies

- Costs and fuel savings assessed for different technologies
- Estimates of lifetime fuel savings subtracted from technology adoption costs

Market-Modelling Approach

- Broader behavioural responses

- Simulate effects of fuel economy standards on gasoline consumption, automaker profits and consumer welfare
- Vehicle production costs depend on fuel economy and technology cost assessments
- Consumer demand functions derived from econometric models or elasticities

Assessing the Costs of Fuel Economy Standards (2)

(Anderson et al., 2011)

Engineering Approach

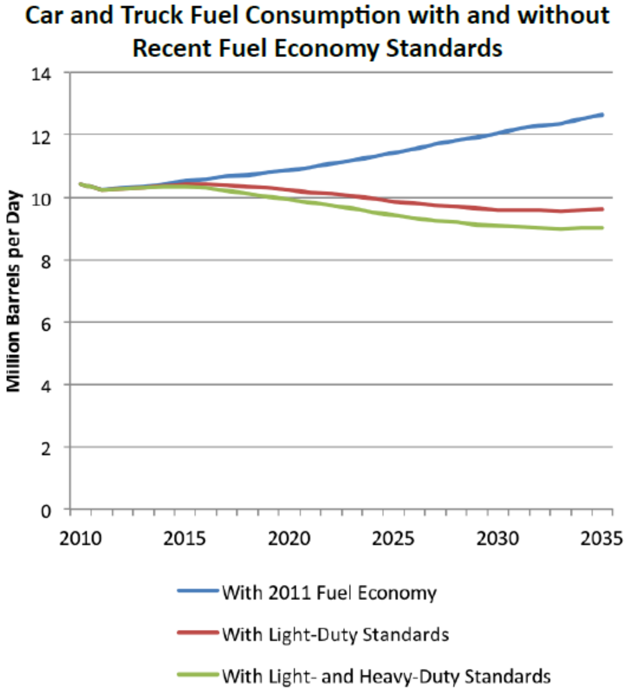
- US$900 in incremental technology costs for the average new vehicle in 2016 but generate about US$3,200 in fuel savings and other private benefits (e.g., reduced refueling time)
- Negative net private cost of US$2,300 per vehicle (NHTSA, 2010)

Market-Modelling Approach

- Standards impose non-negligible costs on automakers and consumers
- Short run cost estimates for a small increase in the CAFE standard > long run cost estimates by a factor of 2 – 3
- Gasoline taxes can be more cost-effective than CAFE standards, especially in the short run

Cost-Benefit Assessments

- Health benefits
  - Reductions in local air pollutants
- Climate benefits
  - Reductions in carbon emissions
- Oil savings
  - Including improved energy security
- Compliance costs
  - Auto and fuel industries



Source: ACEEE, using Argonne National Laboratory's VISION Model

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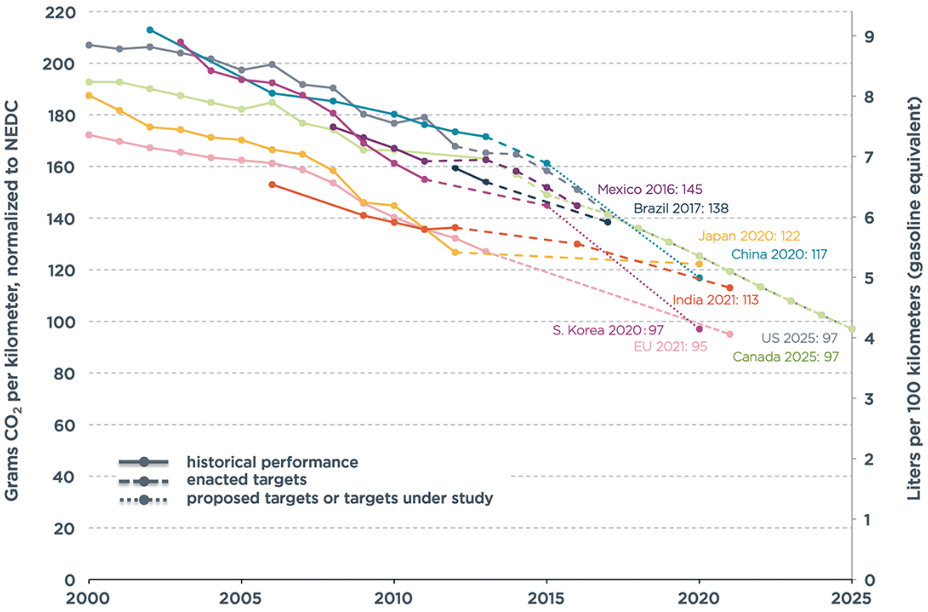
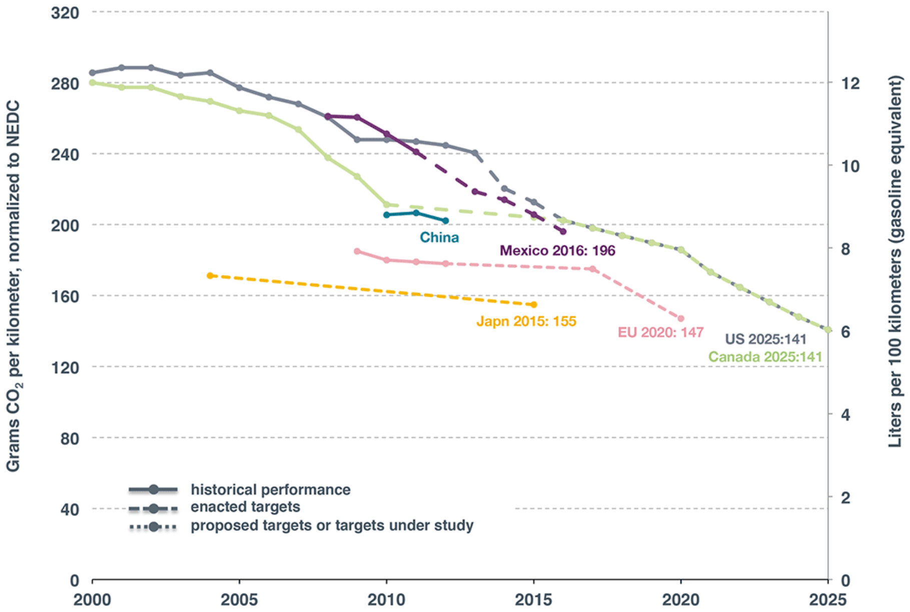
Vehicle CO_2 Emissions and Fuel Economy Standards

Passenger Vehicle Standards

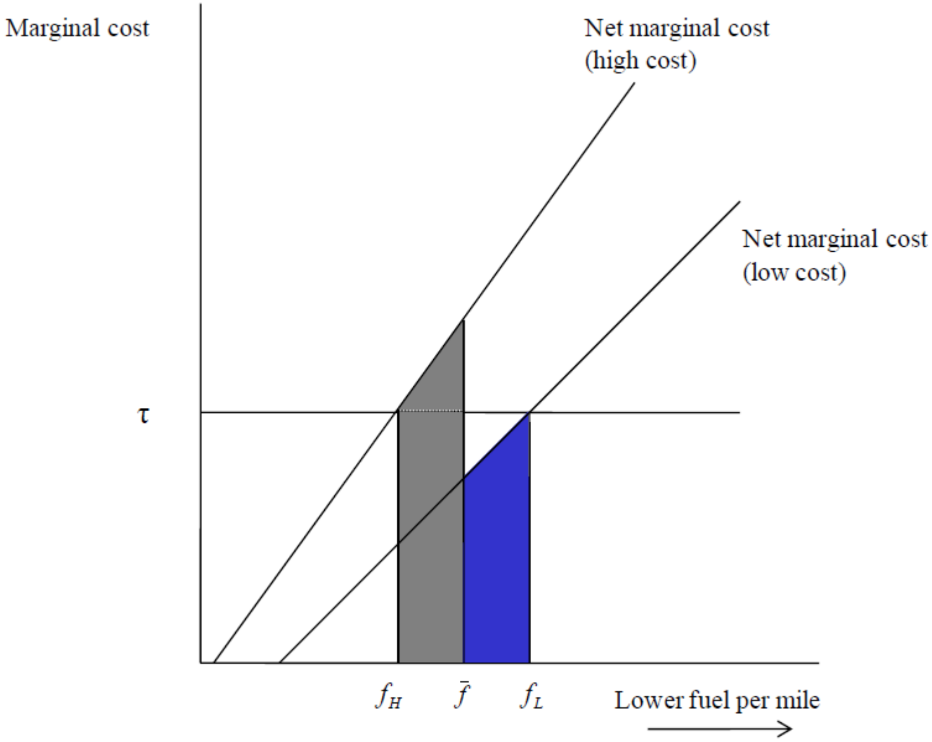


Light Commercial Vehicle/ Light Truck Standards



Source: ICCT, 2014

Cost Effectiveness



- MC for reducing fuel consumption per mile for high-cost and low-cost firms
- Costs of meeting $\bar{f}$ gallons per mile (average standard) are min when fuel consumption per mile is reduced to f_H and f_L
- Different marginal compliance costs across firms
- Efficiency loss = difference between shaded areas
- τ = feebate

Technology Costs

- Direct costs depend on three factors
  - Inherent production costs
  - Timing of investments (i.e. to recover existing sunk costs)
  - Market risk
- Declining costs could occur with cumulative production
- Some technologies are more appropriate in some regions than others
- Technologies are consistent across regions

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Cost Effectiveness Analyses of Fuel Economy

(ICCT, 2015)

Rule	Per-Vehicle Cost	Payback Period
US LDV 2017–2025[1]	$1,800	3.5 years
US LDV 2012–2016[2]	$950	3 years
US HDV Phase 1 2014 – 2017[3]	$378–$6,215	1–2 years
California Advanced Clean Cars Program 2017 – 2025[4]	$1,340–$1,840	3 years
Canada LDV 2017-2025[5]	$2,095	2 to 5 years
Canada LDV 2011-2016[6]	$1,195	1.5 years
European 95g CO_2/km Standard 2020[7]	€1,300	4-5 years
India LDV 2020[8]	$400 to $600	2–3 years

1. For EPA's and NHTSA's formal discussion of the rule's costs and benefits, see www.gpo.gov/fdsys/pkg/FR-2012-10-15/pdf/2012-21972.pdf. For a summary, see EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks, www.epa.gov/otaq/climate/documents/420f12051.pdf.
2. The final rule, with cost-effectiveness estimates, is available at www.gpo.gov/fdsys/pkg/FR-2010-05-07/html/2010-8159.htm. For a summary, see EPA and NHTSA Finalize historic national program to reduce greenhouse gases and improve fuel economy for cars and trucks, epa.gov/otaq/climate/regulations/420f10014.pdf
3. For a summary, see Regulatory announcement: EPA and NHTSA adopt first-ever program to reduce greenhouse gas emissions and improve fuel efficiency of medium-and heavy-duty vehicles, http://www.epa.gov/otaq/climate/documents/420f11031.pdf.
4. California Air Resources Board, Amendments to the low-emission vehicle program—LEV III. http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm
5. For a summary, see http://www.ec.gc.ca/lcpe-cepa/eng/regulations/DetailReg.cfm?intReg=215. For the regulatory impact analysis, see http://www.gazette.gc.ca/rp-pr/p2/2014/2014-10-08/html/sor-dors207-eng.php
6. For summary and regulatory impact analysis, see http://www.gazette.gc.ca/rp-pr/p1/2010/2010-04-17/html/reg1-eng.html
7. OECD and International Transport Forum, Joint Transport Research Center. The cost and effectiveness of policies to reduce vehicle emissions (2008). Retrieved from http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200809.pdf
8. Bansal and Bandivadekar, Overview of India's vehicle emissions control program: Past successes and future prospects.

European Commission (2015) – CBA for HDV

- Overview of the national manufacturing industry (truck)
- Overview of possible policy and technical measures
- Testing options of GHG emissions from vehicles
  - Chassis dynamometer measurements
  - On-road testing with PEMS
  - Simulation tool and component testing
- Analysis of certification and validation costs for industry, and monitoring and reporting costs for industry and government

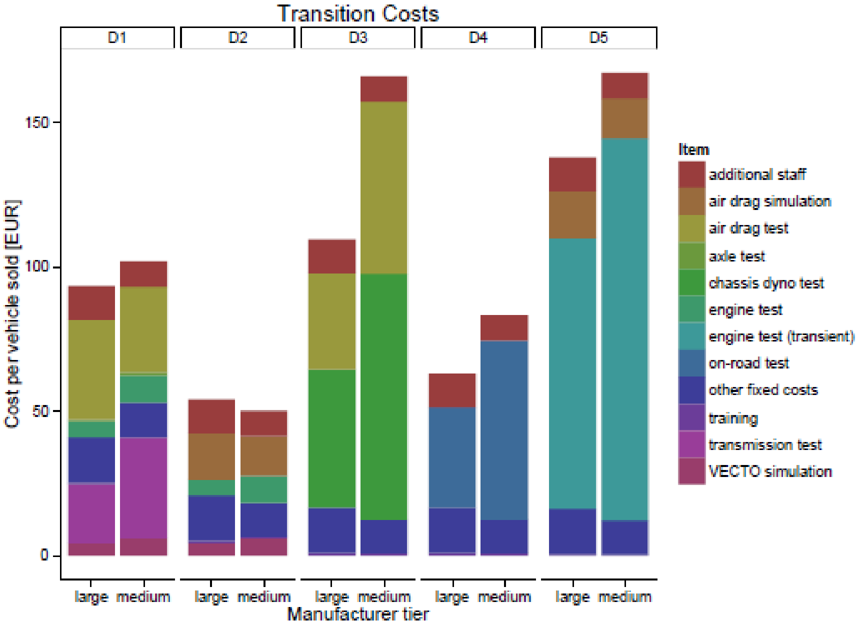
Simulation Tool

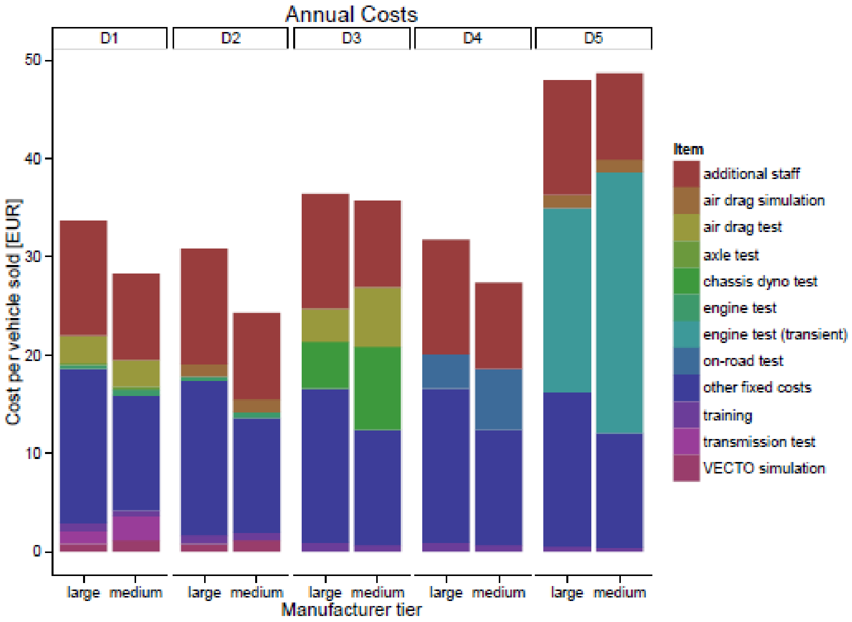
- VECTO (HDV)
  - Simulate CO_2 emission and fuel consumption of each vehicle produced, based on input data of vehicle components
  - Developed by the European Commission for 17 vehicle classes

Certification procedure ensures CO_2 and fuel consumption values are comparable between manufacturers, verifiable by a third party and monitorable by authorities

Transition and Annual Cost Estimates - HDV

(European Commission – DG CLIMA, 2015)





D1-Simulation & component test; D2-Simulation & reduced effort component testing; D3-Chassis dynamometer; D4-On-road testing; D5-Simulation & transient engine testing

US EPA Regulatory Impact Analysis (2010) (1)

- The US Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) established new LDVs standards to reduce GHG emissions and improve fuel economy

- The standards require vehicles to meet an estimated combined average emissions level of 250 grams of CO_2 per mile in MY 2016 under EPA's GHG program, and 34.1 mpg in MY 2016 under NHTSA's CAFE program

- Approximately 960 million metric tons of CO_2 emission reductions and 1.8 billion barrels of oil savings over the lifetime of vehicles sold in model years 2012 through 2016.

US EPA Regulatory Impact Analysis (2010) (2)

Methodology

- Development of technology costs and effectiveness

- Uncertainty and sensitivity analyses (EPA)
  - Associated with quantified and monetized non-GHG health impacts

- Monte Carlo simulation (NHTSA)
  - Variation around chosen parameters and their impact on fuel savings
  - Parameters include technology costs, technology effectiveness, fuel prices, oil consumption externalities and rebound effect

Technology Packages, Cost and Effectiveness (EPA, 2010) (1)

- Vehicle technology packages are inputs to EPA's Optimization Model for Emissions of Greenhouse gases from Automobiles (OMEGA)
  - Inputs: vehicle fleet; technology type (cost & effectiveness); vehicle operational data; CO_2 emission standards
- Vehicle packages represent potential ways of meeting the CO_2 standards
- Major technology upgrades that affect multiple systems of the vehicle occur at the vehicle redesign stage and not between redesigns

  ➔ Five year redesign cycle = each vehicle platform undergoes one full redesign during EPA's regulatory timeframe
- 19 vehicle types used to model entire fleet

Technology Packages, Cost and Effectiveness (EPA, 2010) (2)

- Cost estimates and effectiveness estimated for five vehicle classes

- Technologies are
  - Engine-related (e.g. turbocharging)
  - Transmission-related (e.g. six forward gears in place of four)
  - Accessory-related (e.g. electronic power steering)
  - Vehicle-related (e.g. low rolling resistance tires)

- EPA assumes manufacturers bundle technologies into packages to capture synergies

- Multiple technology packages were created within each of the 19 vehicle types

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US EPA Regulatory Impact Analysis Results (1)

	Car	Truck	Combined
BMW	$ 1,558	$ 1,195	$ 1,453
Chrysler	$ 1,129	$ 1,501	$ 1,329
Ford	$ 1,108	$ 1,442	$ 1,231
Subaru	$ 962	$ 790	$ 899
General Motors	$ 899	$ 1,581	$ 1,219
Honda	$ 635	$ 473	$ 575
Hyundai	$ 802	$ 425	$ 745
Tata	$ 1,181	$ 680	$ 984
Kia	$ 667	$ 247	$ 594
Mazda	$ 855	$ 537	$ 808
Daimler	$ 1,536	$ 931	$ 1,343
Mitsubishi	$ 817	$ 1,218	$ 978
Nissan	$ 686	$ 1,119	$ 810
Porsche	$ 1,506	$ 759	$ 1,257
Suzuki	$ 1,015	$ 537	$ 937
Toyota	$ 381	$ 609	$ 455
Volkswagen	$ 1,848	$ 972	$ 1,694
Total	$ 870	$ 1,099	$ 948

Fleet-wide Costs in 2016

- OMEGA model and technology cost results (per vehicle)

Source: US EPA, 2010

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US EPA Regulatory Impact Analysis Results (2)

Emission Impact

- Total reductions estimated to be 307 MMTCO_2eq / year by 2030
- Equivalent to 21% reduction in US car and light truck emissions compared to reference scenario
- 23% reduction in 2050 compared to control case
- Small changes for criteria emissions

Calendar Year:	**2020**	**2030**	**2040**	**2050**
Net Reduction*	**156.4**	**307.0**	**401.5**	**505.9**
Net CO_2	*139.1*	*273.3*	*360.4*	*458.7*
Net other GHG	*17.3*	*33.7*	*41.1*	*47.2*
Downstream Reduction	**125.2**	**245.7**	**320.7**	**403.0**
CO_2 (excluding A/C)	*101.2*	*199.5*	*263.2*	*335.1*
A/C – indirect CO_2	*10.6*	*20.2*	*26.5*	*33.8*
A/C – direct HFCs	*13.3*	*26.0*	*30.9*	*34.2*
CH_4 (rebound effect)	*0.0*	*0.0*	*0.0*	*0.0*
N_2O (rebound effect)	*0.0*	*-0.1*	*-0.1*	*-0.1*
Upstream Reduction	**31.2**	**61.3**	**80.8**	**102.9**
CO_2	*27.2*	*53.5*	*70.6*	*89.9*
CH_4	*3.9*	*7.6*	*10.0*	*12.7*
N_2O	*0.1*	*0.3*	*0.3*	*0.4*

* includes impacts of 10% VMT rebound rate

Source: US EPA, 2010

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US EPA Regulatory Impact Analysis Results (3)

GHG Emissions and Fuel Savings

CALENDAR YEAR	ANNUAL GHG REDUCTION (CO_2 EQ MMT)	FUEL SAVINGS (MILLION BARRELS PER DAY OF GASOLINE EQUIVALENT)	ANNUAL FUEL SAVINGS (BILLION GALLONS OF GASOLINE EQUIVALENT)
2020	156.3	0.8	12.6
2030	307.4	1.6	24.7
2040	401.5	2.1	32.6
2050	505.9	2.7	41.5

Model Year Lifetime Fuel Savings and GHG Reductions

Model Year	Lifetime GHG Reduction (MMT CO2 EQ)	Lifetime Fuel Savings (Billion Gallons Of Gasoline Equivalent)	Lifetime Fuel Savings (Million Barrels of Gasoline Equivalent)
2012	88.8	7.3	173.1
2013	130.2	10.5	250.35
2014	174.2	13.9	330.5
2015	244.2	19.5	464.7
2016	324.7	26.5	630.7
Total Program Benefit	**962.0**	**77.6**	**1,849.3**

Source: US EPA, 2010

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US EPA Regulatory Impact Analysis Results (4)

	2020	2030	2040	2050	NPV, 3%[a]	NPV, 7%[a]
Vehicle Costs	$15,600	$15,800	$17,400	$19,000	$345,900	$191,900
Fuel Savings[b]	-$35,700	-$79,800	-$119,300	-$171,200	-$1,545,600	-$672,600
Reduced Refueling	$2,400	$4,800	$6,300	$8,000	$87,900	$40,100
Value of Increased Driving[b]	$4,200	$8,800	$13,000	$18,400	$171,500	$75,500
Benefits from Reduced CO_2 Emissions at each assumed SCC value[c,d,e]						
Avg SCC at 5%	$900	$2,700	$4,600	$7,200	$34,500	$34,500
Avg SCC at 3%	$3,700	$8,900	$14,000	$21,000	$176,700	$176,700
Avg SCC at 2.5%	$5,800	$14,000	$21,000	$30,000	$299,600	$299,600
95th percentile SCC at 3%	$11,000	$27,000	$43,000	$62,000	$538,500	$538,500
Other Impacts						
Criteria Pollutant Benefits[f,g,h,i]	B	$1,200-$1,300	$1,200-$1,300	$1,200-$1,300	$21,000	$14,000
Energy Security Impacts (price shock)	$2,200	$4,500	$6,000	$7,600	$81,900	$36,900
Accidents, Noise, Congestion	-$2,300	-$4,600	-$6,100	-$7,800	-$84,800	-$38,600
Quantified Net Benefits at each assumed SCC value[c,d,e]						
Avg SCC at 5%	$27,500	$81,500	$127,000	$186,900	$1,511,700	$643,100
Avg SCC at 3%	$30,300	$87,700	$136,400	$200,700	$1,653,900	$785,300
Avg SCC at 2.5%	$32,400	$92,800	$143,400	$209,700	$1,776,800	$908,200
95th percentile SCC at 3%	$37,600	$105,800	$165,400	$241,700	$2,015,700	$1,147,100

SCC = Social Cost of Carbon

Present value depends on discount rate

Source: US EPA, 2010

Key Challenges

- Selection of baseline is important for assessing costs and effectiveness of technologies

- Benefits are more complicated to estimate than costs
  - Some climate variables are difficult to quantify and/or monetized

- Payback period varies by region, more difficult to estimate for HDVs

- Uncertainty about future performance and cost of technologies

Thank you

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Additional Slides

Cost-Benefit Analyses for Emissions Regulations
(ICCT, 2015)

Rule	Benefits	Costs	Benefit-Cost Ratio
US LDV Tier 3[1]	$6.7b–$19b annually (2030)	$1.5b annually (2030)	5:1 to 13:1
US LDV Tier 2[2]	$25.2b	$5.3b	5:1
US 2010 HDV emissions[3]	$70b annually (2030)	$4.2b annually (2030)	16:1
California Advanced Clean Cars Program (LEV-III)[4]	$10.6b cumulative vehicle operating cost savings	$3.4b cumulative annualized incremental cost	3:1
Mexico HDV NOM-044[5]	$135b (cumulative, 2018–2037)	$12b (cumulative, 2018–2037)	11:1
Euro 5/V and 6/VI[6]	$2,13b (2009 price)	$1,55b (2009 price)	1.4:1
China 6/VI[7]	4.4t RMB	1.8t RMB	2.5:1
India Bharat VI[8]	$43.8b in 2025; $107b in 2035	$14.5b in 2025; $14.2b in 2035	8:1 in 2035

1. On Tier 3 benefits and costs, www.gpo.gov/fdsys/pkg/FR-2014-04-28/pdf/2014-06954.pdf. For a summary, see Regulatory Announcement: EPA sets tier 3 motor vehicle emission and fuel standards (March 2014). Retrieved from www.epa.gov/otaq/documents/tier3/420f14009.pdf.
2. On Tier 2 benefits and costs, see Regulatory announcement: EPA's program for cleaner vehicles and cleaner gasoline (1999). Retrieved from www.epa.gov/tier2/documents/f99051.pdf.
3. On the benefit-cost of the US 2010 HDV emissions regulation, see Control of air pollution from new motor vehicles: heavy-duty engine and vehicle standards and highway diesel fuel sulfur control requirements, sec. v "economic impact", www.gpo.gov/fdsys/pkg/FR-2001-01-18/pdf/01-2.pdf.
4. On LEV-III, see the California Air Resources Board staff report, www.arb.ca.gov/regact/2012/leviiighg2012/levisor.pdf. For a press summary, see www.arb.ca.gov/newsrel/newsrelease.php?id=282.
5. On the benefit-cost ratio of the proposed NOM-044 regulation, see Miller, J., Blumberg, K., and Sharpe, B., Revising Mexico's nom 044 standards: Considerations for decision-making (2014) (ICCT Working Paper 2014-5). Retrieved from www.theicct.org/sites/default/files/publications/ICCT_NOM-044_proposal_20140530.pdf
6. Department of Infrastructure and Regional Development, Final regulation impact statement for review of euro 5/6 light vehicle emissions standards. Retrieved from https://www.infrastructure.gov.au/roads/environment/files/Final_RIS_Euro_5_and_6_Light_Vehicle_Emissions_Review.pdf
7. A forthcoming ICCT paper, Costs and benefits of motor vehicle emission control programs in China, projects emissions, health and climate impacts, and costs under varying scenarios featuring China 6/VI emission standards and ultralow sulfur fuel standards.
8. Bansal, G., and Bandivadekar, A., Overview of India's vehicle emissions control program: Past successes and future prospects (2013). Retrieved from www.theicct.org/sites/default/files/publications/ICCT_IndiaRetrospective_2013.pdf. Estimates costs and benefits of progress to more stringent limits under various scenarios, including Bharat VI.

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Example: Mexico’s Heavy-duty Emission Standards (1)

(ICCT, 2014)

Background

- Existing Norma Official Mexicana 044 (NOM 044) regulation requires new vehicles to meeting EPA 2004 or Euro IV standards
- New standards require manufacturers of HDVs to meet EPA 2010 or Euro VI standards
- ICCT conducted a cost-benefit analysis through the year 2037
- The analysis includes effects on public health and climate, and incremental vehicle and operation costs

Example: Mexico’s Heavy-duty Emission Standards (2)
(ICCT, 2014)

Analysis Framework

- Consistent with EPA’s guidelines
- Costs and benefits of proposed changes to the NOM 044 regulation were estimated in comparison to maintaining current emission limits
- Present value depends on discount rate
- Identifying most important determinants of costs and benefits
- Analysis of uncertainties
- Sensitivity analyses

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Example: Mexico's Heavy-duty Emission Standards (3)

(ICCT, 2014)

Modelling

- Projection of vehicle sales and activity
- Estimation of vehicle emissions (based on vehicle sales, activity per vehicle (VKT) and projected sales growth)

Costs and Benefits Evaluation

- Estimation of **health benefits**
  - Number of avoided premature mortalities from a reduction in tailpipe PM2.5
  - Value of a Statistical Life approach
- Estimation of **climate benefits**
  - Evaluated using the social cost of carbon

- Estimation of **vehicle technology costs** by vehicle type (e.g. HD pickup truck/van; tractor; vocational vehicle)

  Estimation of **diesel exhaust fluid costs** – for meeting NO_x emissions limits using Selective Catalytic Reduction systems

  Estimation of **ultralow-sulfur fuel costs** – fuel production and refinement

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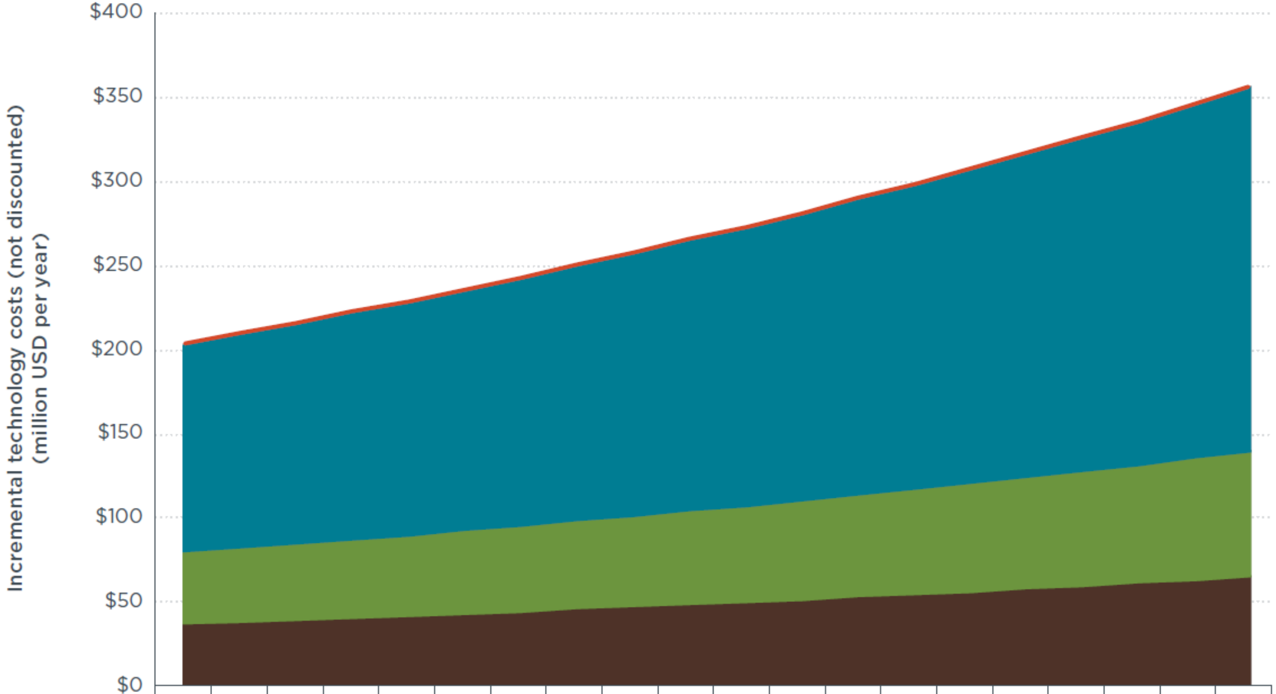
Example: Mexico's Heavy-duty Emission Standards (4)

(ICCT, 2014)

Annual Incremental Technology Costs of Proposed Regulation (2018 – 2037)



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Vocational (diesel)	124	128	132	136	140	144	148	153	157	162	167	172	177	182	188	193	199	205	211	218
Tractor (diesel)	43	44	45	47	48	49	51	52	54	56	57	59	61	63	64	66	68	70	73	75
HD Pickup (diesel)	37	38	39	40	41	43	44	45	47	48	49	51	52	54	56	57	59	61	63	64
Total	**204**	**210**	**216**	**222**	**229**	**236**	**243**	**250**	**258**	**266**	**274**	**282**	**290**	**299**	**308**	**317**	**327**	**336**	**346**	**357**

Example: Mexico's Heavy-duty Emission Standards (5)

(ICCT, 2014)

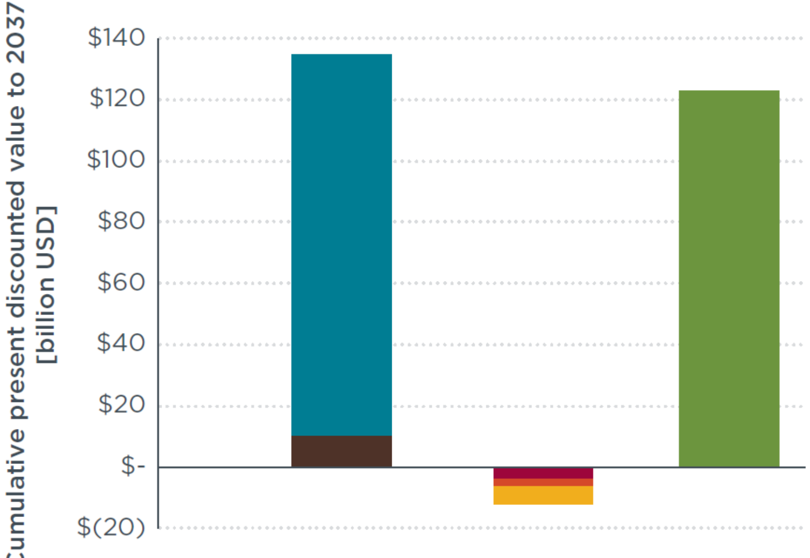
Results

- In 2037, operating and technology costs are US$1.8 billion
- Estimated health benefits are US$22 billion to US$30 billion
- Incremental vehicle technology costs are $5,300 per vehicle on average

Benefits

- 6,800 premature deaths from exposure to $PM_{2.5}$ will be prevented
- 24,000 tons of $PM_{2.5}$ and 410,000 tons of No_x
- 15 - 54 million tons of CO_2-equivalent ($MtCO_2e$)

Cumulative Net Benefits of NOM 044 (2018 – 2037)
(ICCT, 2014)



	Benefits	Costs	Net benefits
Health benefits	$124	$-	$-
Climate benefits GWP-20	$10	$-	$-
Cost of fuel standards	$-	$(6)	$-
Cost of DEF	$-	$(2)	$-
Cost of vehicle technologies	$-	$(4)	$-
Net benefits	$-	$-	$123

- Benefits ($134 billion) are 11 times the total direct and indirect costs ($12 billion)
- Net benefits = $123 billion