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Technology Assessment and Standard Development

California Environmental Protection Agency
AIR RESOURCES BOARD

Technology Assessment and Standard Development

- Setting the standard
- Per vehicle compliance cost
- Alternative fuel vehicles
- Early credits and alternative compliance

Setting the CO_2-Equivalent Vehicle GHG Emission Standard

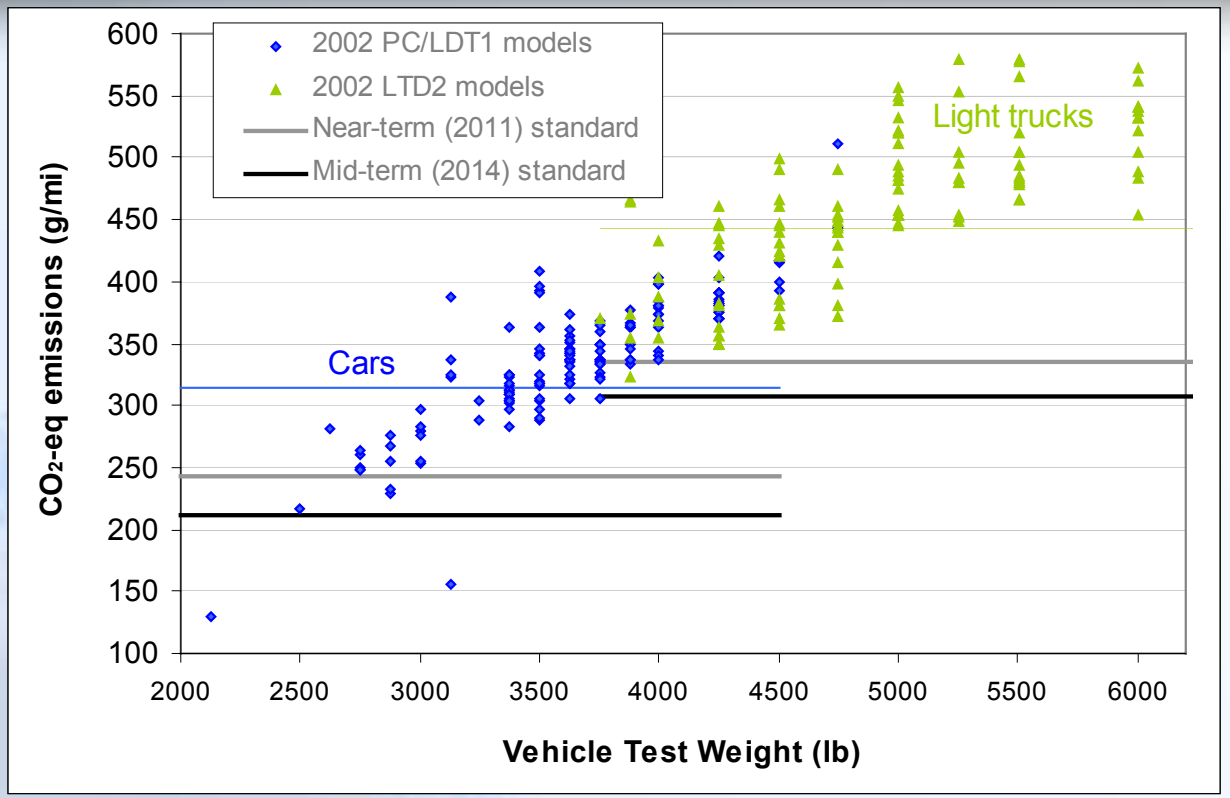
Setting the GHG Standard

- Summary
- Steps in setting standard
  - Compliance with a CO_2-equivalent standard
  - Determination of 2002 CA baseline emissions
  - Maximum feasible emission reduction technologies for near- and mid-term standard
  - Inclusion of air conditioning credits
  - The form of standard
  - Manufacturer-specific feasibility
- Estimation of per vehicle costs of compliance

Proposed GHG Standard by Vehicle Model Year

	Year	CO_2-equivalent emission standard by vehicle category (g/mi)	
		PC/LDT1	LDT2
2002 Baseline		312	443
Near-term phase-in	2009	315	422
	2010	284	385
	2011	242	335
Mid-term phase-in	2012	233	328
	2013	223	321
	2014	211	311

Proposed GHG Standard by Vehicle Model Year



Tested CO_2-equivalent emission reductions (from 2002):

- Near-term (2011): 22% for PC/LDT1, 24% for LDT2
- Mid-term (2014): 32% for PC/LDT1, 30% for LDT2

CO_2-Equivalent Standard

$$\begin{pmatrix} CO_2 - equivalent \\ emissions \\ (g/mi) \end{pmatrix} = CO_2 + N_2O + CH_4 - MAC_{credit}$$

- Where:
  - CO_2 = exhaust drive cycle emissions
  - N_2O = exhaust drive cycle emissions (g/mi*296 CO_2-eq.)
  - CH_4 = exhaust drive cycle emissions (g/mi*23 CO_2-eq.)
  - MAC_{credit} = credit for mobile air conditioning system improvements, if applicable (CO_2-eq.)

Maximum Feasible Emission Reduction Technologies

- Designate technology packages as near-, mid-, and long-term according to potential for high production volume
  - Near-term: Available for 2009-2011 phase-in
  - Mid-term: Available for 2012-2014 phase-in
- Choose GHG emission reduction technology packages for each of the five vehicle types
  - Near-term: Two largest GHG reductions
  - Mid-term: Specific promising technologies
- Take average test cycle CO_2 emission rate of chosen technology packages

Maximum Feasible Emission Reduction Technologies – Near-term

- Engine, drivetrain, and vehicle technology packages
  - Available for 2009-2011 phase-in
  - Technologies: cam phasing, variable valve lift, gasoline direct injection, cylinder deactivation, turbocharging, automated manual transmission, electric power steering, improved alternator
  - 18-27% reduction in CO_2 emissions from modeled tech packages
  - Average $328 (for PC/LDT1) and $363 (LDT2) cost per controlled vehicle
  - Average 2.6-year payback period
- Air-conditioning system technologies
  - Improved low-leak R-134a system
  - Improved air conditioning compressor and/or control system

Mobile Air Conditioning (MAC) Credit

	Indirect CO_2 Equivalent Reduction from Advanced AC VDC system [1] (g/mi)	Direct CO_2 Equivalent Emission Reduction (g/mi)		Total A/C System Reduction [4] (g/mi)	
		Near-term[2]	Mid-term[3]	Near-term	Mid-term
Small car	7.1	3	8.5	10.1	15.6
Large car	8.1	3	8.5	11.1	16.6
Minivan	10.0	3	8.5	13.0	18.5
Small truck	10.0	3	8.5	13.0	18.5
Large truck	10.0	3	8.5	13.0	18.5

[1] reduced CO_2 air conditioning VDC or FDC system; actual credit amount may differ based on compressor size. [2] improved low leak HFC 134a system. [3] improved low-leak HFC 152a. [4] sum of direct and indirect emission reduction credits.

Maximum Feasible Emission Reduction Technologies – Near-term

Vehicle Class	Combined Technology Packages	Test CO_2, without A/C (g/mi)	Test CO_2 equivalent with A/C credit (g/mi)	Maximum feasible reduction tested CO_2 equivalent with A/C credit for vehicle class (g/mi)
Small car	DVVL,DCP, AMT,EPS,ImpAlt	229	219	209
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	210	200	
Large car	GDI-S,DeAct,DCP, AMT,EPS,ImpAlt	259	248	241
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	245	234	
Minivan	CVVL,CCP,AMT, EPS,ImpAlt	299	287	283
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	290	279	
Small truck	DeAct,DVVL,CCP, AMT,EPS,ImpAlt	321	308	303
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	311	298	
Large truck	DeAct,DVVL,CCP, A6,EHPS,ImpAlt	410	398	387
	DeAct,DVVL,CCP, AMT,EHPS,ImpAlt	389	376	

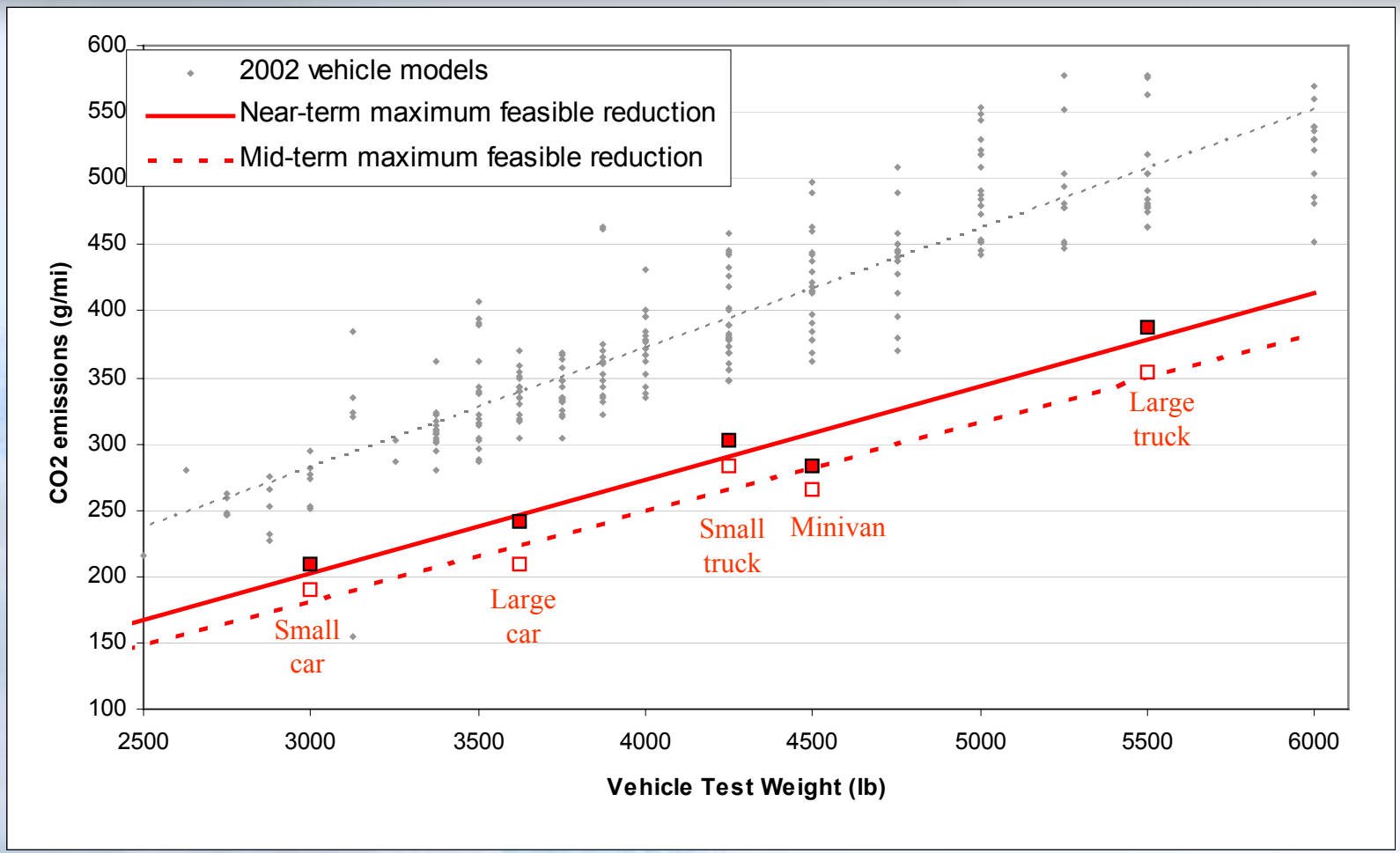
Maximum Feasible Emission Reduction Technologies – Mid-term

- Engine, drivetrain, and vehicle technology packages
  - Available for 2012-2014 phase-in
  - Additional technologies: integrated starter generator, camless valve actuation, gasoline homogeneous charge compression ignition
  - 24-35% reduction in CO_2 emissions from modeled tech packages
  - Average $1,047 (for PC/LDT1) and $1,210 (LDT2) cost per controlled vehicle
  - Average 5.3-year payback period
- Air-conditioning system technologies
  - Improved low-leak R-152a system
  - Improved air conditioning compressor and/or control system

Maximum Feasible Emission Reduction Technologies – Mid-term

Vehicle Class	Combined Technology Packages	Test CO_2, without A/C (g/mi)	Test CO_2 equivalent with A/C credit (g/mi)	Maximum feasible reduction tested CO_2 equivalent with A/C credit for vehicle class (g/mi)
Small car	CVVL,DCP,AMT, ISG-SS,EPS,ImpAlt	212	196	190
	gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	200	184	
Large car	CVAeh,GDI-S, AMT,EPS,ImpAlt	236	220	210
	gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	226	209	
	GDI-S,Turbo,DCP, A6,ISG,EPS,eACC	218	202	
Minivan	CVAeh,GDI-S, AMT,EPS,ImpAlt	282	266	265
	GDI-S,CCP,AMT,ISG, DeAct,EPS,eACC	280	263	
Small truck	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	309	290	284
	CVAeh,GDI-S, AMT,EPS,ImpAlt	302	283	
	HSDI,AMT, EPS,ImpAlt	298	280	
Large truck	CVAeh,GDI-S, AMT,EHPS,ImpAlt	374	355	354
	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	370	352	

Baseline vs. Maximum Feasible GHG Emission Reduction



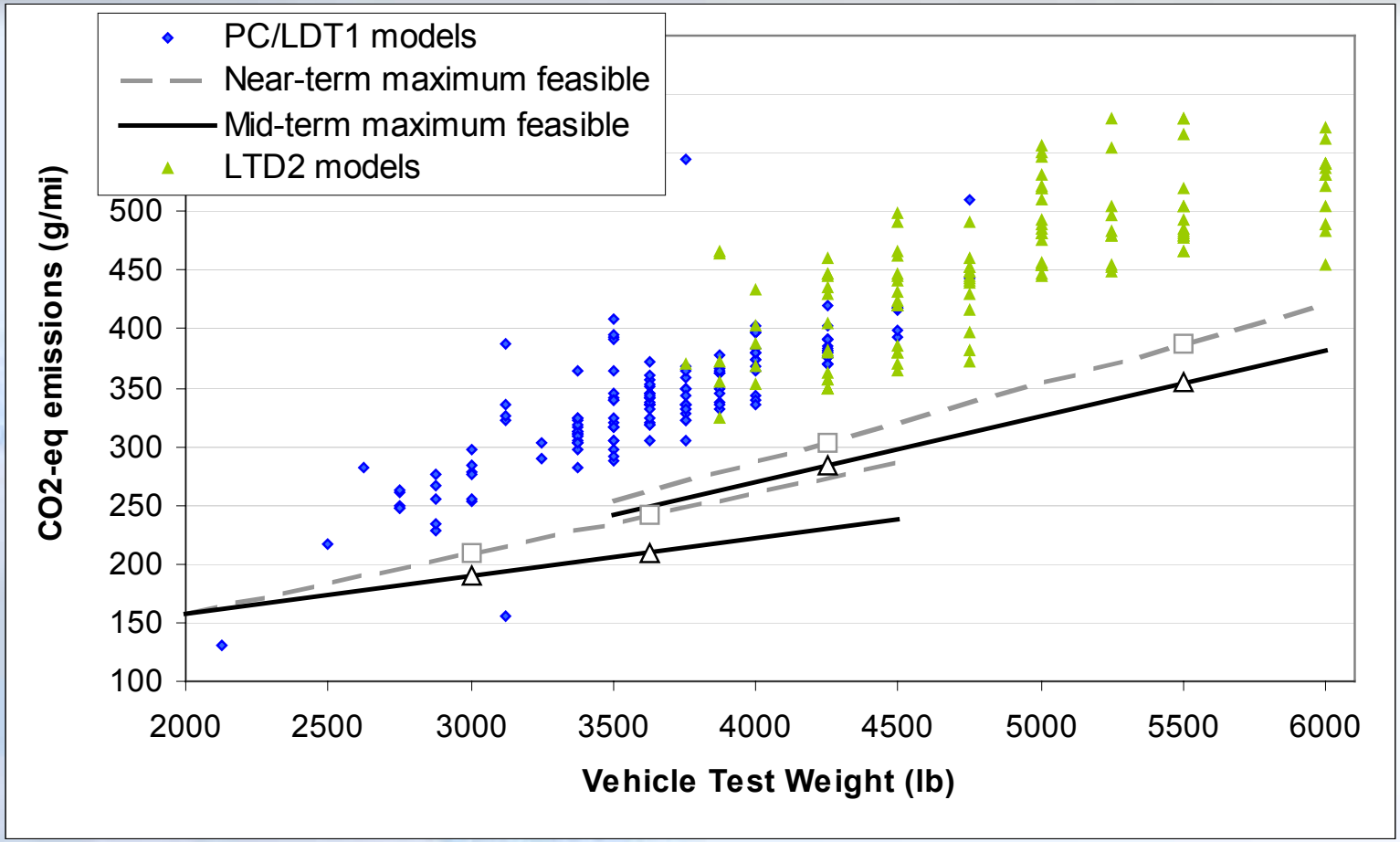
Form of Standard

- Form of standard options considered
  - Uniform fleet average emission reduction
  - Two categories (as in LEV II): PC/LDT1 and LDT2
  - Attribute-based – by vehicle weight, size
- Criteria
  - Total GHG emission reductions over time
  - Manufacturer competitiveness
  - Consumer choice

Form of Standard

- Two categories (as in LEV II):
  - PC/LDT1
    - Passenger cars (PC) and light duty trucks with 3750 lb or less loaded vehicle weight (LDT1)
  - LDT2
    - Light duty trucks with from 3,751 lb to 8,500 lb loaded vehicle weight (LDT2) and medium duty passenger vehicles (MDPVs) up to 10,000 lb gross vehicle weight

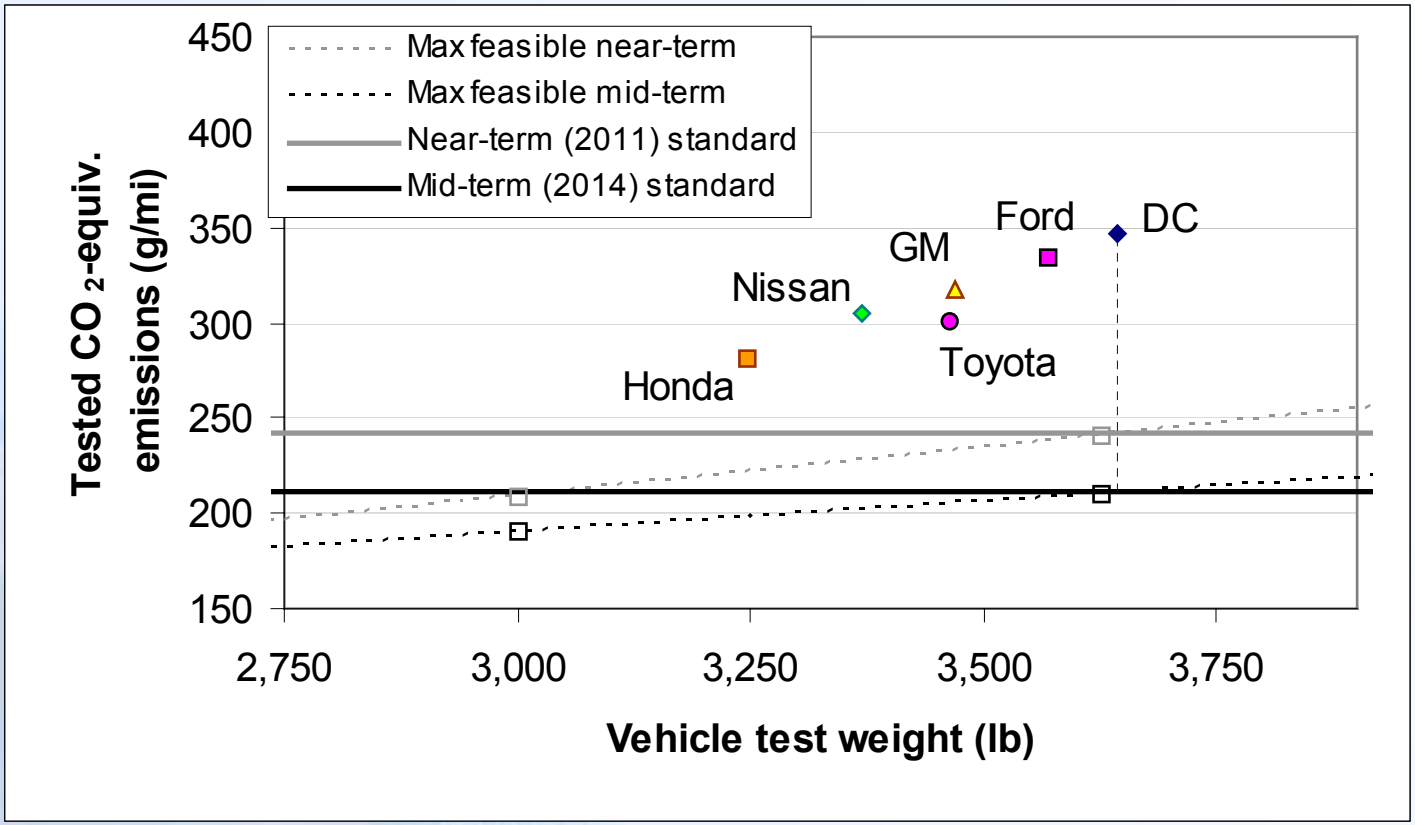
Baseline vs. Maximum Feasible Reduction – By Vehicle Category



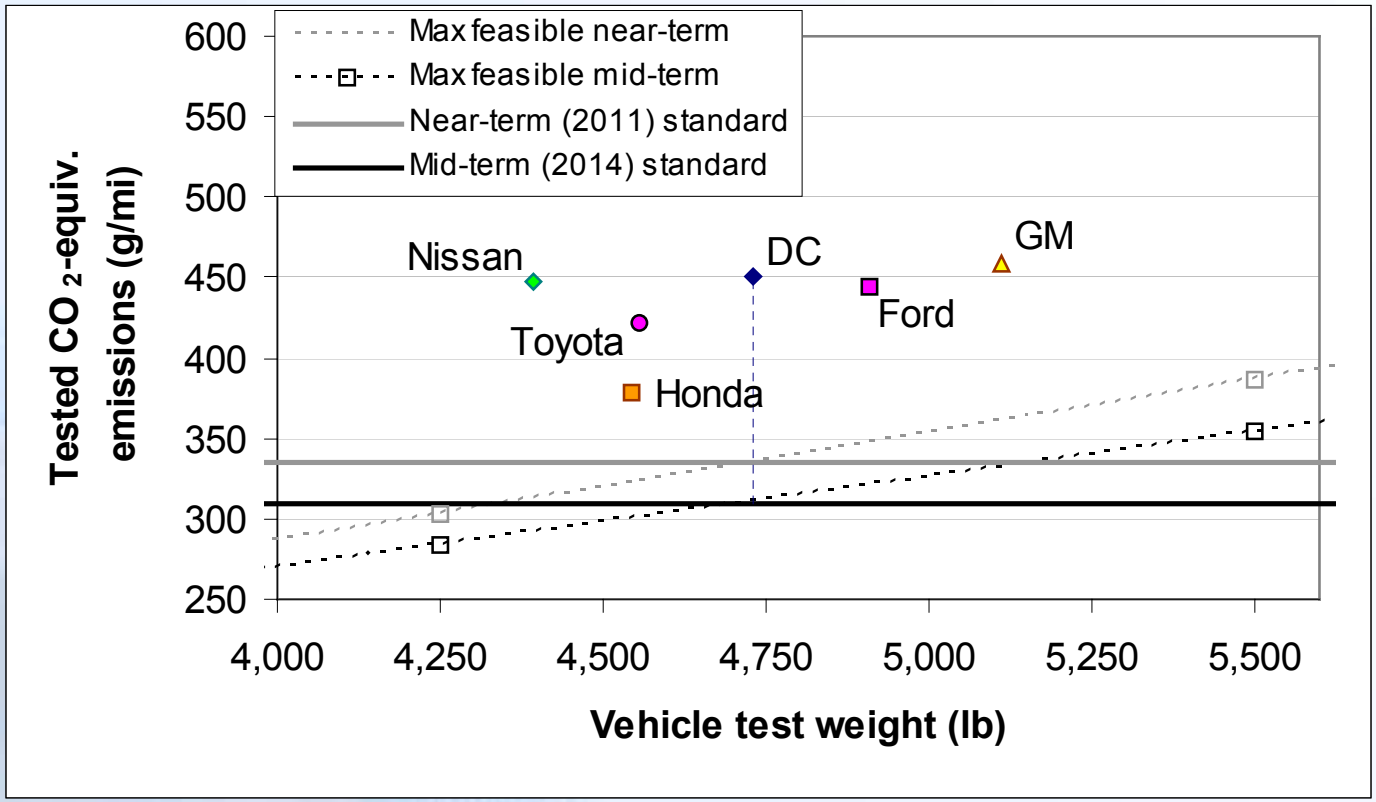
Manufacturer-Specific Feasibility

- Evaluate manufacturer baseline (2002):
  - Sales-weighted CO_2 emission levels and vehicle test weights for the two categories (PC/LDT1 and LDT2)
- Setting the standard, assumptions-
  - Linear regression lines made with maximum feasible GHG emission reduction lines with respect to vehicle test weight
  - Major manufacturers can comply with technologies assessed here (i.e. no sales mix changes)
  - Trading between categories is allowed

Setting the PC/LDT1 CO2-Eq. Standard



Setting the LDT2 CO2-Eq. Standard



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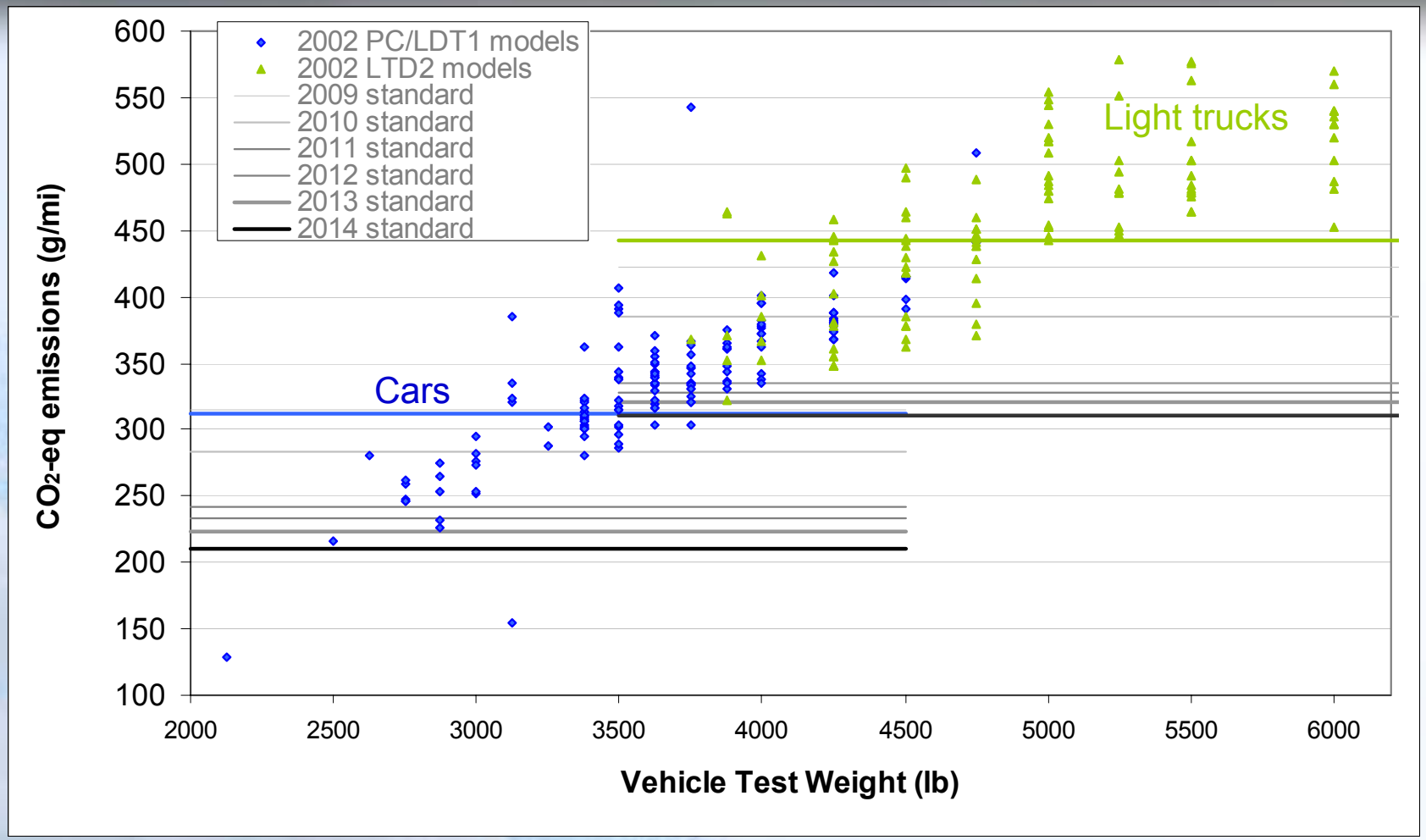
Per Vehicle Compliance Cost

Proposed GHG Standard by Vehicle Model Year



Per Vehicle Compliance Cost

- Assessing "per vehicle" impact on CA vehicle fleet
  - Evaluate level of deployment of near- and mid-term technology packages to meet standards from different manufacturer baselines
  - Estimate average vehicle cost increase associated with introduction of new technologies
  - Assumption: Near-term technologies fully deployed before (more costly) mid-term technologies are used by each manufacturer for compliance with standards

	Vehicle Category	Incremental cost from 2009
Near-term	PC/LDT1	$328
	LDT2	$363
Mid-term	PC/LDT1	$1,047
	LDT2	$1,210

Summary - Average Emission Reduction and Cost by Vehicle Model Year

	Year	Category	Average CO_2-equiv. emission change	Average per vehicle control cost
Near-term phase-in	2009	PC/LDT1	-2%	$25
		LDT2	-5%	$69
	2010	PC/LDT1	-9%	$96
		LDT2	-13%	$176
	2011	PC/LDT1	-22%	$241
		LDT2	-24%	$326
Mid-term phase-in	2012	PC/LDT1	-25%	$300
		LDT2	-26%	$427
	2013	PC/LDT1	-28%	$390
		LDT2	-28%	$603
	2014	PC/LDT1	-32%	$561
		LDT2	-30%	$871

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Alternative Fuel Vehicles

Alternative Fuel Vehicles

- Impact on climate change emissions
- “Well-to-wheels” analysis
- Not included:
  - cost and marketability issues
  - technology improvements identified for conventional vehicles

Alternative Fuels

- Compressed Natural Gas
- Liquid Petroleum Gas
- Ethanol
- Electricity
  - battery electric
  - hybrid-electric (20-mile all-electric capability)

CO_2-Equivalent Emissions Comparison

Vehicle type	Vehicle CO2 emissions (g/mi)	Lifetime CO2 equivalent emissions (ton)	Percent reduction from Conventional Gasoline Vehicle
Conventional vehicles	346.7	99.9	0%
Compressed natural gas (CNG)	284.8	83.9	16%
Liquid propane gas (LPG)	313.9	80.9	19%
HEV20	143.0	53.6	46%
Ethanol (E85)	356.9	76.5	23%
Electric	0	38.0	62%

Life Cycle Cost Comparison

Vehicle-fuel systems	Cost increment from 2009 baseline	Lifetime (16-yr) Net Present Value (2004$)	Payback period
Conventional vehicles	0	(0)	0
Compressed natural gas (CNG)	3300	(1,919)	>16
Liquid propane gas (LPG)	370	1,161	3
HEV20			
	4500	3,298	9
Ethanol (E85)	0	(4,203)	none
Electric	8800	(3,056)	>16

Treatment of Upstream Emissions

- Staff proposal:
  - use the upstream emissions fraction of conventional fuels as a “baseline” against which alternative fuels are compared
  - apply adjustment factor for alternative fuels to exhaust CO_2 emissions to compensate for differences in upstream emissions
  - vehicles with zero direct emissions to use a default value

Fuel Cycle Adjustment

Fuel	Adjustment Factor
Gasoline	1.00
CNG	1.03
LPG	0.89
E85, Corn	0.74
Fuels with no direct CO2 Emissions	
Electricity	130 grams/mile
Hydrogen	210 grams/mile

Alternative Fuels Summary

- Alternative fueled vehicles available in limited quantities
- Substantial reductions in climate change emissions possible from wider use
- Incremental costs and fuel availability hurdles to commercialization

Early Reduction Credits, Alternative Compliance

Early Reduction Credits

- Proposal seeks to:
  - meet the intent of the legislation while avoiding undesirable results
  - ensure that credits are real, surplus, verifiable, enforceable, quantifiable
  - reward early action taken to push commercialization of technologies that reduce climate change emissions

Proposed Approach

- Credits provided for 2000-2008 model years (Staff considering revised approach which would allow manufacturer to opt in at any point)
- Program consistent with form of the proposed standard
- Each automaker's fleet average emissions compared to 2011 standard
- Emissions cumulative for duration of program

Alternative Compliance

- Regulations must provide maximum flexibility, and allow alternative methods of compliance

  But...

- Use of alternatives must not undercut the purpose of the bill, which is to improve vehicles

Alternative Compliance--Draft Proposal

- Allow averaging, banking, trading, aggregation across pollutants
- Use emission credit trading criteria
- No increase in other emissions
- Must be sponsored by auto manufacturer
- Must involve 2009 and later Pavley vehicles, or demonstrated increased use of alternative fuels in such vehicles