Preliminary results from 2025-2030 U.S. technology and cost assessment

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April 2017

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Executive summary

- Based on the ICCT's latest technology assessment of the potential to reduce vehicle CO_2 emission in the 2025-2030 timeframe, we draw the following conclusions –
  - *In 2025, more cost-effective efficiency technology is emerging*. Based on state-of-the-art updated data, new technologies provide 8-10% more CO_2 reduction, and costs for U.S. 2025 standards are projected to be 34-40% lower, than the latest official U.S. analysis.
  - *In 2030, 4 – 6% annual rate of improvement is cost effective.* A 4%-6% lower CO_2/mile from 2025 to 2030 can be achieved cost-effectively. Such improvements would gradually increase vehicle price by $800 to $1,300 in 2030 (compared with 2025), with 2-3 times greater consumer fuel savings than costs.
  - *In 2030, electric vehicles are a more cost effective regulatory compliance pathway*. Due to lower battery costs, our modeling shows that the use of 13%-23% electric vehicles would reduce overall manufacturer costs to comply with the CO_2 standards.

Project scope

- Assess technology potential for 2025-2030 standards
  - Modeling
    - Technology inputs and packages: U.S. EPA Lumped Parameter Model
    - Fleet modeling: U.S. EPA OMEGA
  - ICCT applies updates for technologies' CO_2 effectiveness and cost
    - ICCT technology papers: Turbo, hybrids, lightweighting, EVs, etc
    - Focus is on technologies for more widespread 2025-2030 introduction
  - Key research questions
    - What is the cost of 2025 compliance with less conservative technology assumptions?
    - What is the cost of a 2030 fleet with 4-6% lower CO_2 per mile annually from 2025-2030?

ICCT's modified individual technology inputs

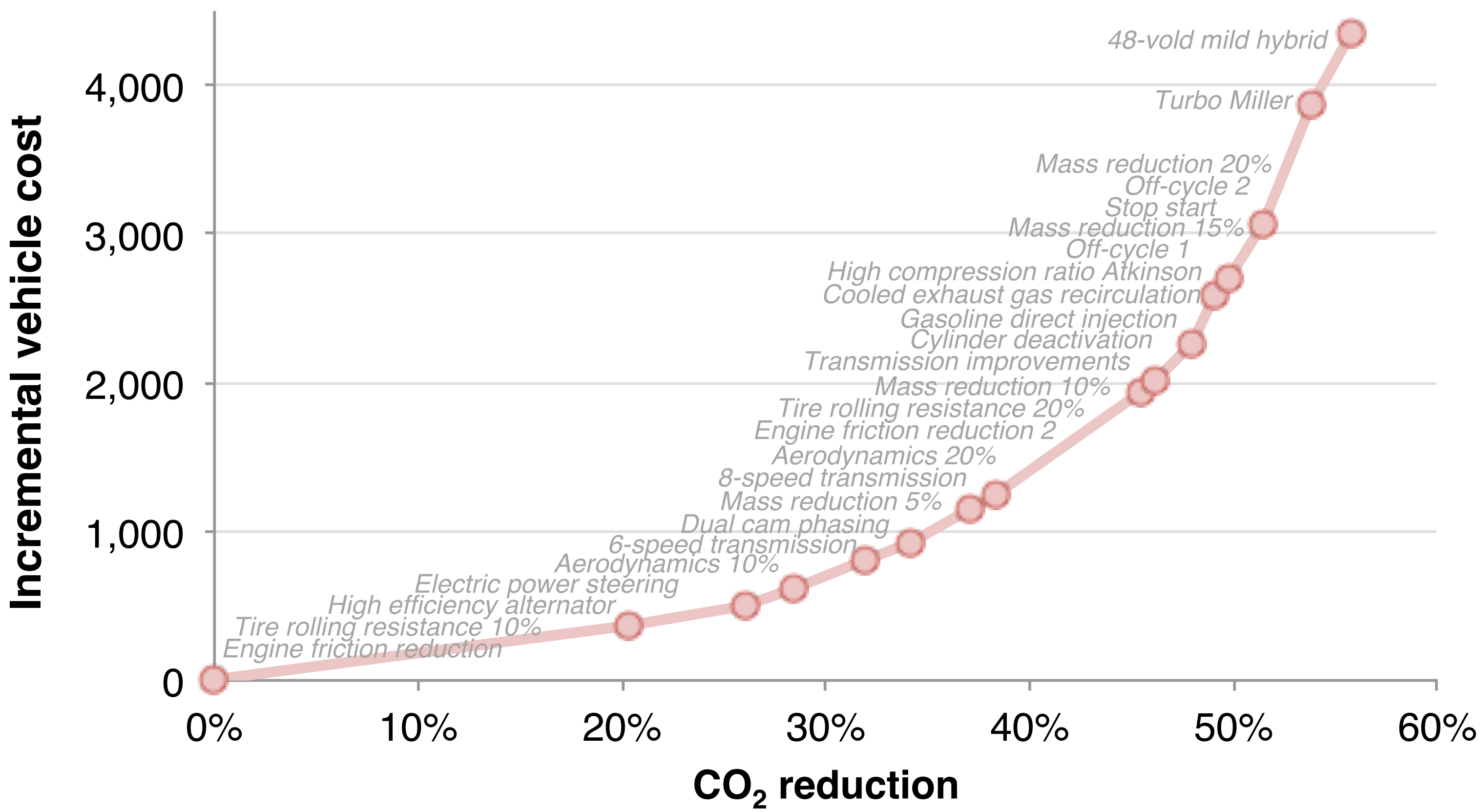
- ICCT has updated several areas for 2025-2030 technology potential and costs, as compared to EPA's Proposed Determination analysis for 2022-2025

	Fuel consumption and CO_2 reduction (average) [a]		Direct manufacturing cost (average) [b]	
	U.S. EPA	ICCT	U.S. EPA	ICCT
Cylinder deactivation	3.5%-5.8%	No change	$75-$149	No change
Dynamic cylinder deactivation [c]	Not included	6.5%-8.3%	Not included	$138-$256
Direct Injection [d]	1.5%	No change	$196-$356	$91-$185
Cooled exhaust gas recirculation	1.7%-5.3%	No change	$216	$95-$114
Advanced diesel	20%-25%	No change	$2,104-$2,950	$1,491-$2,096
E-boost	Not included	5.0%	Not included	$338
Mild hybrid (48-volt)	7.0%-9.5%	10.5%-12.9%	$580	No change
High compression ratio [e]	3.4%-7-7%	10.1%-14.1%		
Miller cycle [f]	12%-20%	No change	Varies	$93-$222 lower
Plug-in hybrid electric vehicle [g]	72-84%	No change	$5,534-$10,371	$3,564-$7,805
Battery electric vehicle [g]	100%	No change	$5,131-$10,663	$2,410-$9,098
Mass Reduction (20%)	11.2%-13.7%	11.6%-13.7%	$0.17-$1.15 per pound	No change

[a] Benefits vary by vehicle type, engine size; improvements shown for individual technology; effects for multiple technologies handled in lumped parameter model
[b] Costs are direct manufacturing costs and vary by vehicle type and engine size
[c] Includes variable valve lift technology
[d] Direct injection technology without synergistic technologies such as cooled exhaust gas recirculation and turbocharging
[e] Includes Atkinson cycle, direct injection, and cooled exhaust gas recirculation
[f] Includes Atkinson cycle, 24 bar turbocharging, cooled exhaust gas recirculation, and engine downsizing;
[g] Range shown for vehicle type #1 through #6, including low and high electric range and in-home charger

Technology package cost curve

- The typical EPA cost curve for 2025 below shows the increase in technology to reduce CO_2, and the associated incremental cost



Vehicle type #6, near mid point of passenger car CO_2; includes cars and light truck crossovers; air conditioning technologies and costs are not shown

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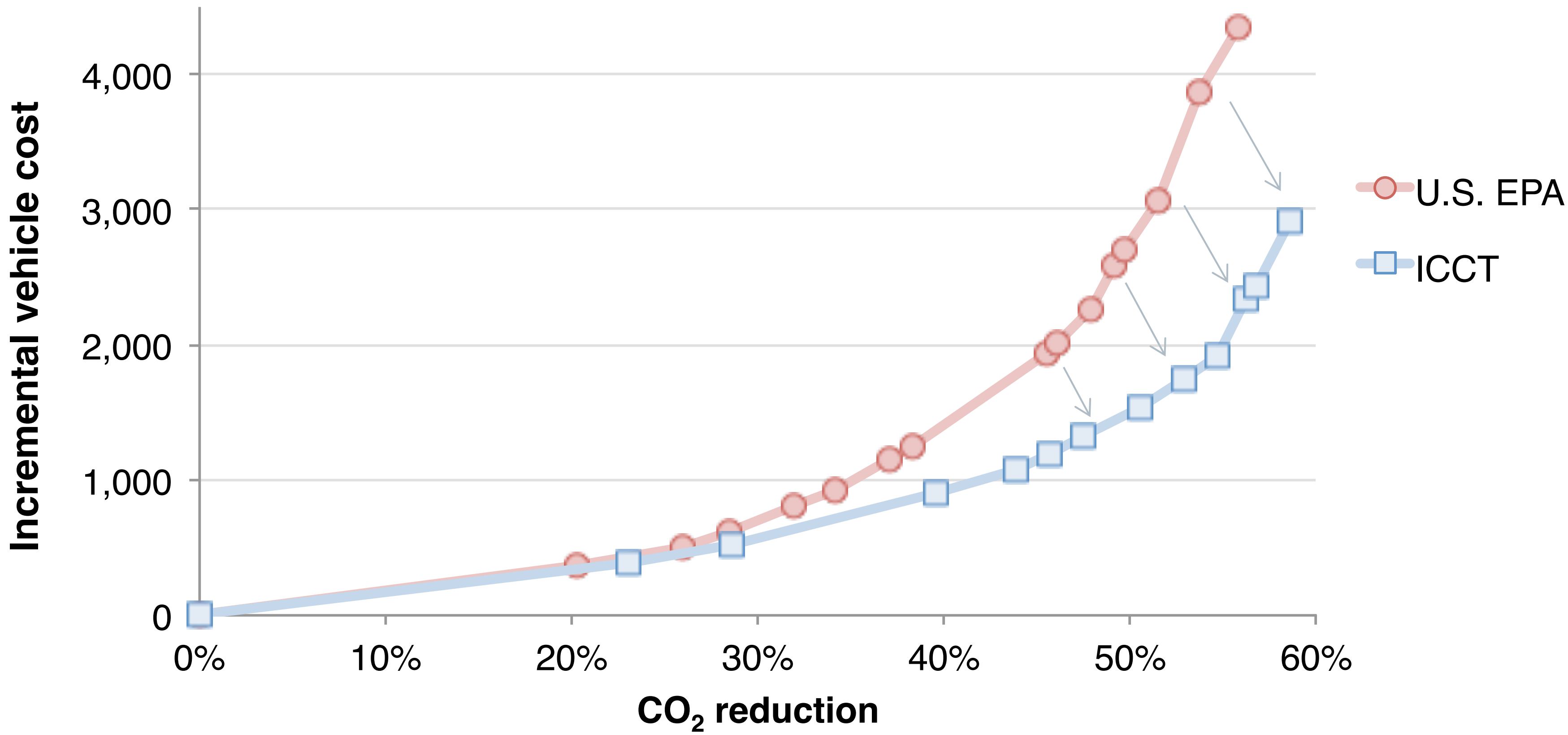
Technology package cost curve

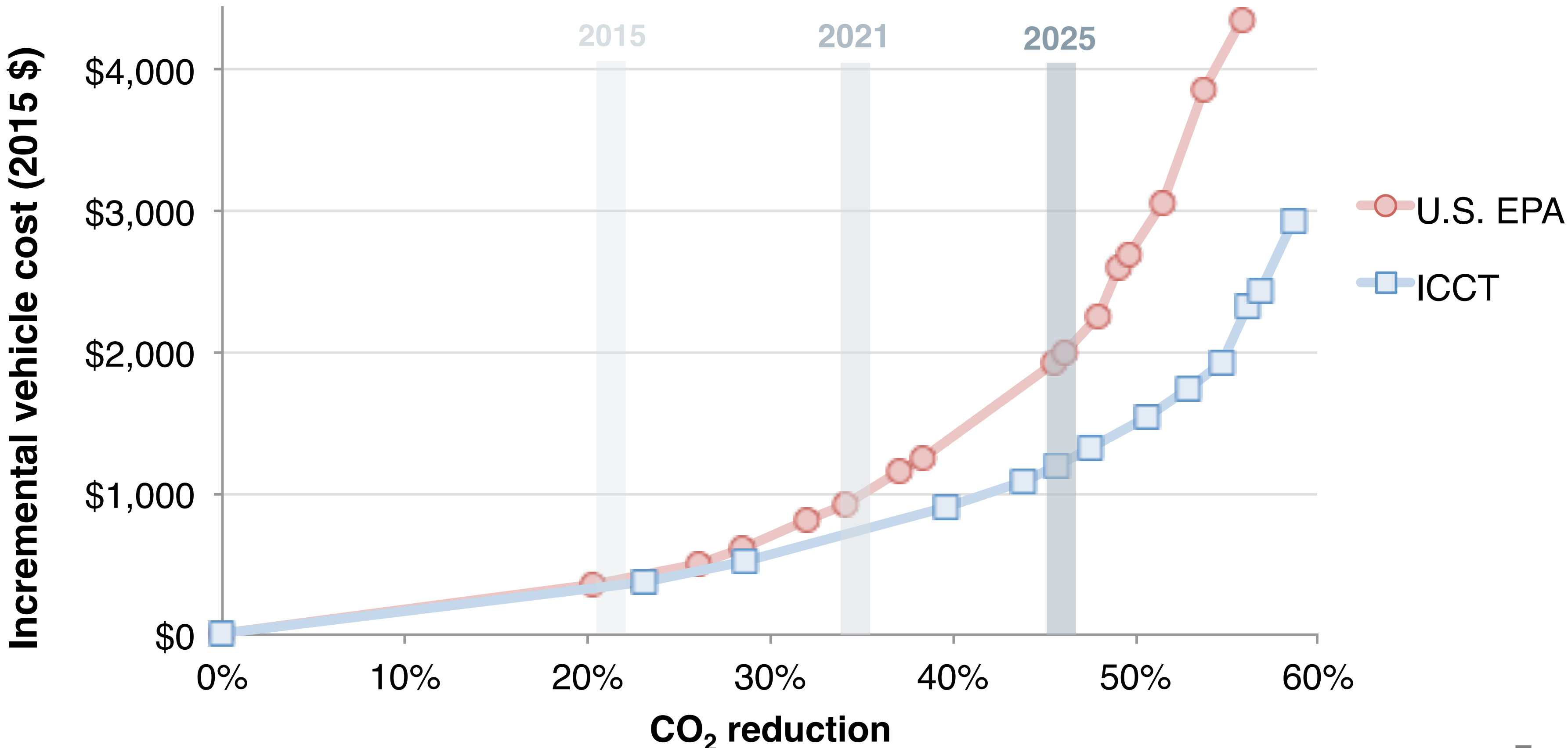
- With ICCT's technology input updates, the 2025+ CO_2-reduction technology frontier expands and costs are lower
  - For given cost, ~8-9% greater CO_2 reduction achievable with advanced combustion



Vehicle type #6, near mid point of passenger car CO_2; includes cars and light truck crossovers; air conditioning technologies and costs are not shown

Technology package cost curve

- The 2015 fleet has added much of the low-cost technologies to ~20% CO_2
- Meeting 2025 standards: Advanced technology ~45% CO_2 reduction
  - Technology cost for 2025: EPA $2,100 versus ICCT $1,300



Vehicle type #6, near mid point of passenger car CO_2; includes cars and light truck crossovers; air conditioning technologies and costs are not shown

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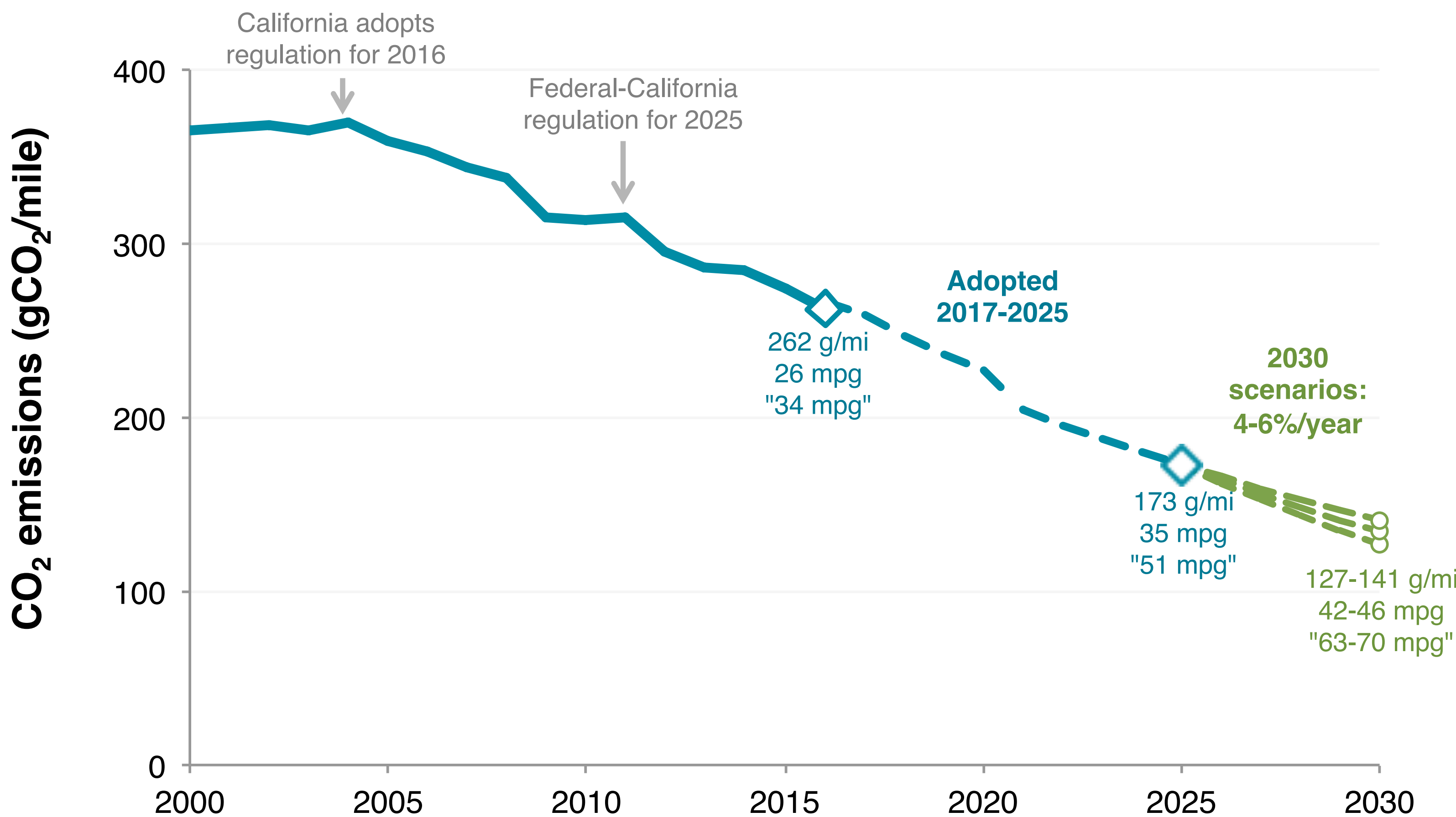
How low might 2030 standards go?

- We evaluate standards that reduce CO_2 by 4-6%/year for 2025-2030
  - This would achieve ~134 g CO_2/mile, ~44 mpg consumer label (nominal ~66 mpg)



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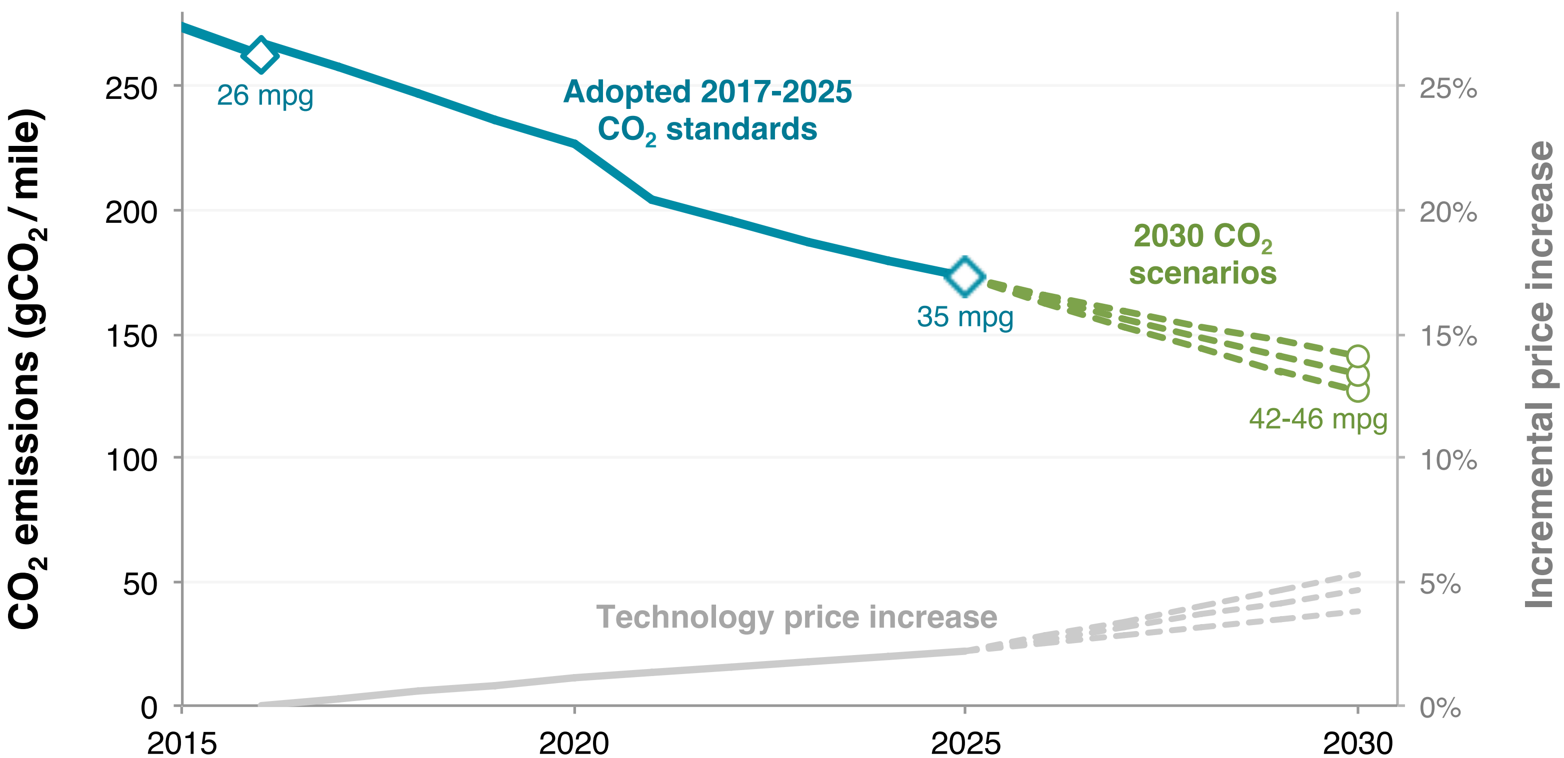
Fleet modeling of 2030 standards

- Technology penetration
  - Cylinder deactivation, high compression Atkinson cycle → 63-80% share in 2030
  - Moderate hybrid penetration (mild and full) → 7-14% share in 2030
  - Beginning of electric vehicle launch → 13-23% share in 2030
- Technology cost
  - Increase from 2015 to 2030 is $1,700-$2,200 (just from 2025 to 2030 is $800-$1,300)

Area	Technology	2025	2030 4%/year	2030 5%/year	2030 6%/year
Advanced combustion (non-hybrid)		93%	80%	72%	63%
Lightweighting (fleet average mass reduction)		9%	12%	13%	13%
Hybrid	Mild hybrid	0%	5%	9%	12%
	Full hybrid	2%	2%	2%	2%
Electric	Plug-in hybrid electric	2%	2%	2%	2%
	Battery electric	3%	12%	16%	21%
Fuel economy, test cycle (mpg)		46	55	57	60
Fuel economy, real world (mpg)		35	42	44	46
CO_2 emissions test cycle (g/mile)		173	141	134	127
Incremental technology cost from 2025		-	$772	$1,038	$1,343

Fleet modeling of potential 2030 standards

- ICCT results: Increased efficiency/CO_2-reduction technology comes with -
  - Cost of $900 (2015 to 2025), plus $800-$1,300 for 4-6%/year CO_2 2026-2030 standards
  - This is about 4-5% increase in vehicle price by 2030
  - These technology costs are ~40% lower than U.S. EPA's



Next steps

- Status update
  - ICCT Report released on March 22, 2017: http://www.theicct.org/US-2030-technology-cost-assessment
  - March-April: Present results to US NGOs, discuss release
  - May-August: Release followup Reports with additional analsyes
- Potential follow-up work
  - Consumer cost, benefit payback (briefing paper)
  - Model costs of multiple technology approaches (naturally aspirated, turbocharged, 48v hybrid, lightweighting) to illustrate there are many cost-effective pathways to comply with the standards
  - Electric vehicle integration in standards (combined US-EU working paper)
  - Applying ICCT new fleet modeling capability to modify OMEGA for Brazil, Mexico, etc

Contact

International Council on Clean Transportation: *http://theicct.org*

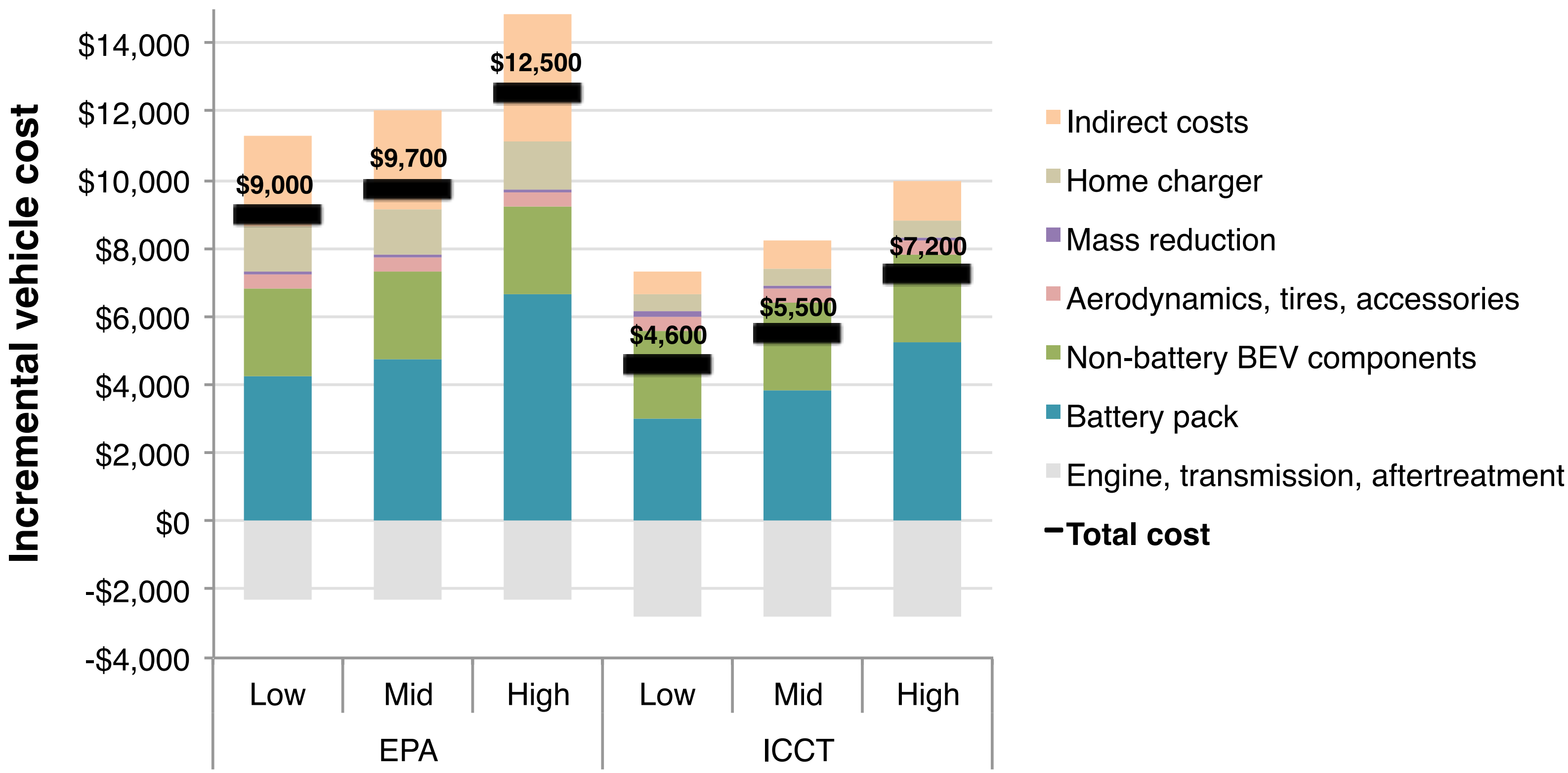
U.S. vehicle efficiency papers: *http://www.theicct.org/policies/us-cafe-standards*

Acknowledgements

Energy Foundation, Heising-Simons Family

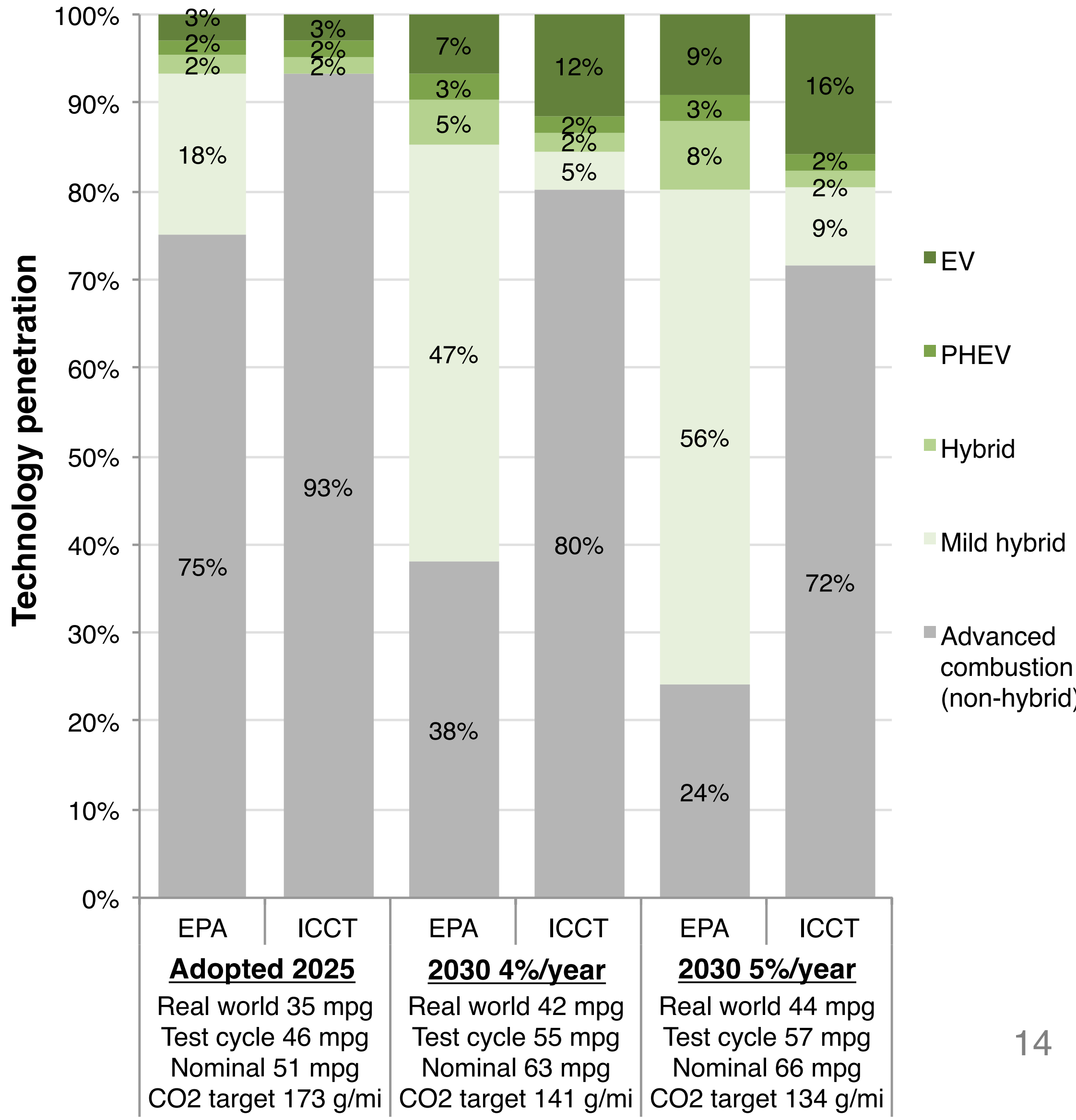
Electric vehicle costs: EPA vs ICCT

- With ICCT's electric vehicle costs ~40% lower than EPA's
  - Mostly this is due to lower battery costs (ICCT $140/kWh vs EPA 180-200/kWh)
  - Other factors: indirect costs, home charger, engine aftertreatment subtraction



Fleet modeling of 2025-2030 standards: EPA vs ICCT

- ICCT: Greater advanced combustion vehicle potential
  - Dynamic cylinder deactivation
  - Greater Atkinson cycle benefit
  - Cooled EGR cost reduction
  - Lower cost lightweighting
  - Greater mild hybrid benefits
- ICCT: EVs become more cost-effective by 2030
  - Battery cost reductions



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