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Before the

Subcommittee on Regulatory Affairs, Stimulus Oversight & Government Spending

Committee on Oversight and Government Reform

U.S. House of Representatives

January 25, 2012

Mr. Chairman, good morning. My name is John German, Senior Fellow and Program Director for the International Council on Clean Transportation (ICCT), with primarily responsibility for technology innovation and U.S. policy development. In earlier stages of my career, I spent 8 years in Powertrain Engineering at Chrysler working on fuel economy issues, followed by 13 years doing research and writing regulations for EPA's Office of Mobile Sources and 11 years as Manager of Environmental and Energy Analyses for American Honda Motor Company. Thank you for the opportunity to appear before the House Committee on Oversight and Government Reform to present our views on safety of Li-ion batteries and electric vehicles and of the role that electric vehicles play in the 2017-2025 proposed CAFE and greenhouse gas (GHG) standards.

Background: Li-ion battery characteristics

It is well known that Li-ion batteries have the potential to generate high temperatures and thermal runaway, including fires. Pictures of blazing laptops and the recall of almost 6 million Sony Li-ion laptop battery cells in 2006 made this very clear. Pure Lithium is highly reactive and it generates hydrogen gas when exposed to water. Among other safety measures, the cells are rigorously sealed to exclude water.

It is essential to understand that, unlike lead-acid and nickel-metal-hydride (NiMH) batteries, Li-ion refers to a broad family of chemistries. Lead-acid and NiMH batteries both have consistent chemistries and there is little difference in the safety characteristics across the range of applications. This is not true of Li-ion batteries, which can have a virtually infinite number of different compounds. These different compounds are all based on Lithium, but depending on material choices the voltage, capacity, durability, and safety of a lithium-ion battery can change dramatically.

Batteries for laptops are generic and sales are highly competitive. Thus, there is massive pressure for laptop battery manufacturers to pack more power into less space, and to do it at lower cost. At least before the Sony battery fires, safety was a secondary consideration. Certainly safety was important, but the consideration was whether safety was "good enough" and it was not a characteristic on which suppliers competed for sales. The most common chemistry for consumer grade electronics is lithium-cobalt oxide (LCO), which has high energy density and is low cost. However, the reliability, durability, and abuse tolerance of LCO are poor, which makes it a poor choice for vehicle use.

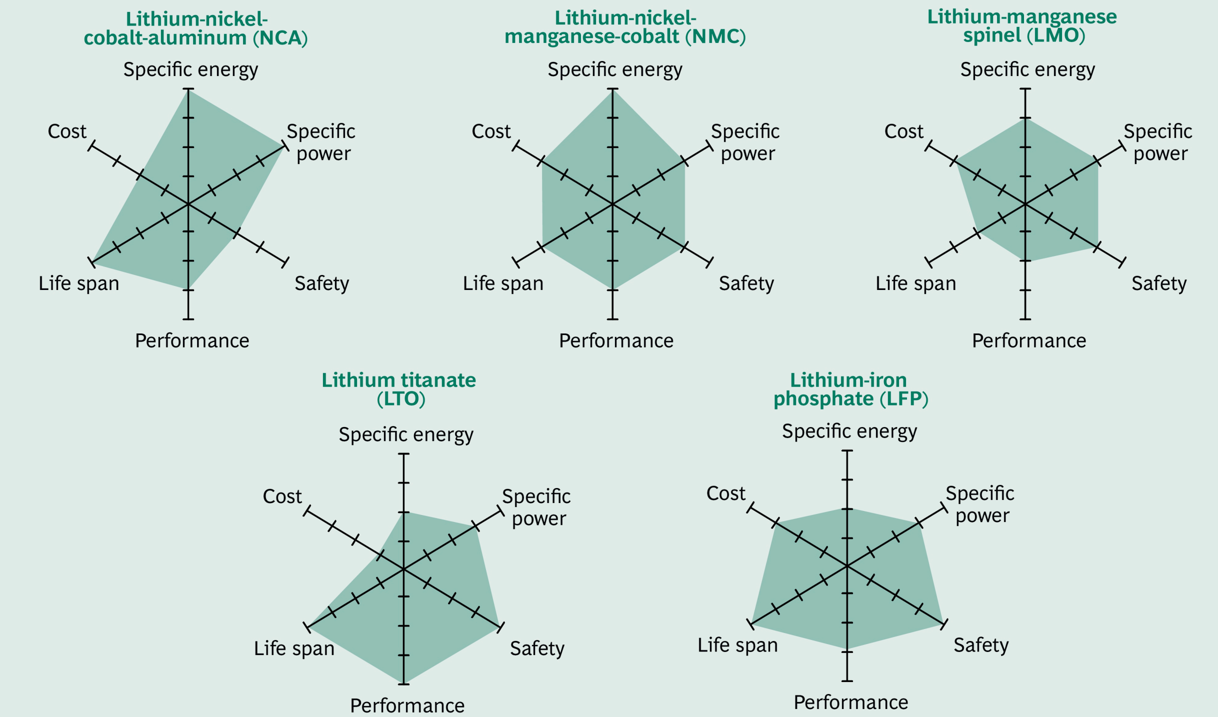
Virtually every manufacturer has worked individually and with battery suppliers to develop Li-ion chemistries that are much more abuse tolerant, as well as being more durable and reliable. Still, there are substantial tradeoffs between these automotive-grade Li-ion chemistries. The following table provides a summary of the more prominent Li-ion cell designs that have developed, although the list is far from exhaustive and may be a little out of date.

Properties of Near-Term Li-ion Battery Cells

Type	Cathode (all include Li)	Anode	Cathode voltage (approx.)	Cell Structure	Battery Developer	OEM customers
NCA	Nickel cobalt aluminum oxide	Graphite	3.6v	Cylindrical	Johnson Controls/Saft	Mercedes, BMW HEV
				Prismatic – metal can	PEVE	Toyota
LMO	Manganese spinel	Graphite	3.7v	Pouch	LG Chem	GM, Ford
				Pouch	AESC (NEC & Nissan)	HEV & Nissan Leaf
				Cylindrical	HVE (Hitachi)	Future GM HEVs
LTO	Manganese spinel	Li Titanium Oxide	2.5v	Prismatic	EnerDel	Think City EV
LFP	Iron Phosphate	Graphite	3.3v	Pouch	A123	Fisker PHEV
				Cylindrical	A123	BMW, Mercedes HEV
NMC	Nickel manganese cobalt		3.6v	Prismatic – metal can	Sanyo	VW, Suzuki HEVs Future Toyota HEVs
				Prismatic – metal can	SB LiMotive (Samsung & Bosch)	BMW
	LMO-NMC blend	Graphite	3.7v	Prismatic	Lithium Energy Japan (GS-Yuasa & Mitsubishi)	Mitsubishi
				Pouch	SK Energy	

(Source: John German, Hybrid Powered Vehicles, SAE Technology Profile T-119, 2nd edition, book published by Society of Automotive Engineers, Warrendale, Pa., 2011)

The tradeoffs between these different cell chemistries are somewhat subjective. A 2010 report by the Boston Consulting Group offered their assessment of these tradeoffs, as presented in the following figure.



Source: BCG research.
Note: The farther the colored shape extends along a given axis, the better the performance along that dimension.

(Source: The Boston Consulting Group - Batteries for E-cars report 2010)

The battery cells used by the Chevy Volt are supplied by LG-Chem and GM assembles the battery pack itself. LG-Chem uses a magnesium spinel (LMO) cell chemistry. Of the five automotive-grade cell chemistries assessed by the Boston Consulting Group, LMO rates about in the middle on safety. Note that consumer grade cells, such as LCO, are not included in the table. Their safety characteristics are much worse than any of the automotive-grade chemistries in the table.

Of course, overall safety is determined by more than just the cell chemistry. The type and effectiveness of the cooling system, internal pack construction and cell isolation, and external packaging of the battery pack also have major impacts on the safety of the battery pack. To make it even more difficult to assess the relative safety impacts, it is often difficult to assess potential safety effects under laboratory conditions.

Electric Vehicle Safety

Established vehicle manufacturers are extremely risk averse. They have to be. Just mislocating the position of the acceleration petal by a fraction of an inch cost Toyota over a billion dollars.

Introducing new technology carries an additional risk, which is that the new technology is highly scrutinized. Any problems with safety, drivability, and reliability are highly publicized and can create the impression that the new technology has problems, even if it is just as good as existing technologies. Established manufacturers know that their new technology must be better to avoid the *perception* of an issue. It is also important to start with low volume production, so that any unanticipated problems affect a relatively small number of vehicles and can be individually monitored and corrected on an expedited basis.

This can clearly be seen in the launch of the first hybrid models. To keep the initial sales low, the first Prius was sold only in Japan and Honda's first hybrid, the Insight, was a small 2-seater. After any initial teething problems were identified and fixed, they were followed by higher volume products. Sales of the second generation Prius were expanded to the US and Europe and Honda brought out the Civic Hybrid. In addition, according to Consumers Report and J.D. Power, the Prius and Honda hybrid models have been among the most reliable vehicles sold in the U.S.

Another example is the use of hydrogen for fuel cell vehicles. Although interest in fuel cell vehicles has given way recently to electric vehicles, there are hundreds of fuel cell demonstration vehicles on the roads in the US and many more in Europe and Japan. The perception of safety concerns with hydrogen has been a major focus for fuel cell vehicle manufacturers. In reality, hydrogen is safer than gasoline, as it dissipates rapidly and is more difficult to ignite. Only if the hydrogen is trapped will it become dense enough to ignite. And, in fact, there has not been a single reported instance of any of these fuel cell demonstration vehicles catching on fire after years of in-use operation. However, many people still believe hydrogen is unsafe, which is one of the obstacles that must be overcome if fuel cell vehicles are ever to achieve widespread use.

The issue of Li-ion batteries catching on fire is similar. Nissan and GM started with limited production of the Leaf and the Volt and have gradually increased production. Even though the battery fire did not occur in a customer's vehicle, GM still showed strong backing by offering to provide loaner cars or to buy back vehicles. This is consistent with the rollout of any new technology and the concern about perceived problems.

It is extremely important to put the Chevy Volt battery fire into context.

- This was a single incidence that occurred after a highly invasive crash test, not in-use.
- It took three weeks for the fire to start.
- The battery was not discharged after the crash test. All junkyards know to discharge the battery pack before storing, just as they remove any fuel from the tank. Thanks to hybrid vehicles, emergency responders know to disconnect the battery pack when necessary and body shops and garages know to disconnect or discharge the battery pack before beginning any work. Toyota and Honda conducted extensive outreach and education to emergency responders and repair organizations when they first introduced hybrids.

- The fire was extremely difficult for NHTSA to reproduce. Simply repeating the crash test did not produce another fire. NHTSA had to design a special test to intentionally damage the battery, rupture the cooling system, and flip the battery in order to generate another fire. This illustrates the care that GM has taken to minimize the risk of fire from their battery pack.
- There have been no fires related to Li-ion batteries reported by any customer on the Volt, the Leaf, or on hybrid vehicle using Li-ion batteries (2011 Hyundai Sonata Hybrid, 2011 Infinity M35 hybrid, 2012 Buick LaCrosse e-assist, 2010 Mercedes S400 hybrid).

Most importantly, the risk of fire from Li-ion batteries is being evaluated in isolation. The relevant question is not whether Li-ion batteries can cause a fire under extreme conditions, but are electric vehicles safer than conventional vehicles?

A 2010 report from the National Fire Protection Association found that:

> "In 2003-2007, U.S. fire departments responded to an average of 287,000 vehicle fires per year. These fires caused an average of 480 civilian deaths, 1,525 civilian injuries, and $1.3 billion in direct property damage annually. Cars, trucks and other highway vehicles (meaning a vehicle designed for highway use, not that the fire occurred on a highway) accounted for 93% of the vehicle fires and 92% of the vehicle fire deaths."
> (Source: U.S. VEHICLE FIRE TRENDS AND PATTERNS, Marty Ahrens, National Fire Protection Association, June 2010).

There are approximately 250 million vehicles on the road, so there is an average of about one vehicle fire per year for every 1,000 vehicles. This is a high rate of vehicle fires, which would be completely unacceptable for any new technology or fuel. It is only our long familiarity with gasoline fires and related deaths and injuries that has caused us to accept the high risk of gasoline fires - and for news agencies to think that an isolated battery pack fire three weeks after a crash test with no one in the vehicle is somehow far more important than the people who die every day from gasoline-related fires.

At least with respect to fire risk, electric vehicles are far safer than gasoline-fueled vehicles.

Relationship to CAFE fuel economy standards

Of course, as discussed above, the perceived risk can be very different from the actual risk and it is possible that excessive publicity about rare Li-ion battery fires could impact electric vehicle sales. However, even if this occurs, it will have no impact on the ability of manufactures to comply with the proposed 2017-2025 CAFE/GHG standards from NHTSA and EPA. This is because battery-electric and plug-in hybrid vehicles are not needed to meet the proposed standards.

The opportunities to reduce fuel consumption and climate change emissions in the near term using conventional technology are far larger than most people realize. The internal combustion engine is widely perceived as being a century-old technology that is at the end of its development, but the reality is exactly the opposite. Rapid improvements in computer-based tools are opening up technology gains that were never possible before. Computer simulations and computer-aided-design are enabling vastly improved designs and technologies. On-board computers controls provide unprecedented integration of engine, transmission, and hybrid operation. Instead of slowing down, the pace of technology development just keeps accelerating.

To support development of 2025 standards, EPA contracted with Ricardo Inc., an engineering services company, to conduct full-system simulation modeling simulations using the latest technology developments. Ricardo is a highly respected engineering organization that does the vast majority of its work for OEMs and suppliers. ICCT highly respects Ricardo's work and recently contracted with Ricardo to conduct simulation modeling specifically for vehicles sold in Europe.

As a result of our work with Ricardo, it is clear to us that the technologies assessed by Ricardo for EPA are on the conservative side. In fact, this is unavoidable due to the restriction to currently available data and engine maps. Engine technology is improving much faster than we can keep up with and engines better than those modeled by Ricardo are already in development. For example, the diesel maps used by Ricardo for the US simulations are already out of date and ICCT paid Ricardo to rerun the diesel simulations for Europe using updated maps representative of the latest diesel technology. Another example is the engine map for the gasoline engine with boosted-EGR. The map used by Ricardo in the simulations is shown in Appendix A. Appendix B shows a boosted-EGR engine map provided by the HEDGE consortium in February 2010. The brake-specific fuel consumption (BSFC) for the HEDGE engine is almost 5% lower than the map used by Ricardo in the simulations. Further, the HEDGE map in Appendix B is for a single stage turbocharger. The HEDGE consortium is already working on a two-stage turbocharger system that will enable larger amounts of EGR, higher compression ratio, and lower fuel consumption.

This rapid technology improvement can also be seen by looking at historical data. For example, the 2001 National Research Council report found that turbocharging and downsizing would improve fuel economy by 5 to 7 percent. Recent estimates generally agree that turbocharging and downsizing alone will provide a 10 to 15 percent improvement, such as the Ford EcoBoost engines. This is a 2 times increase in the efficiency benefit of turbocharging. It is not due to the older estimates being wrong, but rather to rapid improvements in combustion and turbocharging technology over the last 10 years. The 2025 rules are 13 years away. It would be completely irrational to assume that there will be no further technology improvements beyond what is known today. The efficiency estimates in the draft rule are actually quite conservative.

Computer simulations will especially impact lightweight material design. In the past, interactions between the thousands of parts on the vehicles and their impacts on safety, ride, noise, and vibration were impossible to predict. Optimization of materials was a long, slow process of gradually changing a few parts at a time to avoid unanticipated problems. Secondary weight reductions were similarly difficult to achieve. The recent development of sophisticated and accurate vehicle simulations is opening up a new world. The initial use of these models was to improve safety design. The simulations are so effective that 5-star crash ratings became almost universal and NHTSA had to revise their rating criteria for the 2011 model year. The simulations are continuing to rapidly improve, to the point where they are starting to be used to simultaneously optimize the material composition, shape, and thickness of every individual part, including secondary weight reductions.

Note that weight will be reduced only through the use of lightweight materials and better design, not with vehicle downsizing. NHTSA changed the CAFE standards to be based on footprint, starting with the 2008 to 2011 light truck standards. Footprint-based standards have more stringent targets for smaller vehicles, so there is no incentive to downsize vehicles.

Future weight reduction will be accomplished primarily with the use of high strength steel and aluminum and with better vehicle design. High strength steel and aluminum both have better crash properties than standard steel. Reducing weight using these better materials will improve vehicle crash performance and reduce fatalities, even in small cars. In fact, Honda has moved aggressively towards the use of high-strength steel in small cars in part due to the safety benefits

This shift in material design capabilities also impacts the cost to reduce vehicle weight. Previous lightweight material cost studies did not assess part interactions and secondary weight reductions. While they may have accurately reflected historical costs for lightweight materials, they all overstate the cost of future vehicle weight reduction using better vehicle designs.

The proposed rules include incentives for electric vehicles and may induce some manufacturers to produce additional electric vehicles. However, this is not necessary to meet the standards. Improvements in engine combustion and turbocharging technology, automatically shifted manual transmissions, lightweight materials and part design optimization, and improved aerodynamics and tire rolling resistance, possibly combined with a modest number of conventional hybrid systems, will be more than adequate to meet the standards.

Importance of Role of Government in supporting development of clean vehicle technologies

There are huge advantages to society from reducing the amount of fuel we consume. The benefits for energy security are the same as investing in new oil wells – reduced oil imports, improved balance of trade, and downward pressure on worldwide oil prices. Plus there are additional benefits to the economy, as the fuel savings are two to three times the cost of the technology. This effectively puts billions of dollars into consumers' pockets to buy other products, raising their standard of living and creating economy-wide jobs.

Efficiency standards or incentives tied directly to vehicle efficiency are necessary to capture these huge benefits for energy security and the economy. There are no other options. Certainly care must be taken to set the standards appropriately, but rolling back or stopping the standards is equivalent to shutting down oil wells in the US. In fact, worse, due to the missed opportunity to improve the economy.

Countries worldwide are also adopting efficiency standards and promoting technology improvements (Appendix C). Similar standards are needed in the US to ensure that our domestic manufacturers remain fully competitive in the world market and maintain domestic employment.

Efficiency standards are a win for consumers, a win for energy security, a win for manufacturers, and a win for the economy. So, who pays for this? The oil exporting countries, as efficiency standards will both reduce their oil exports and depress the amount they get paid per barrel.

Conclusion

In conclusion, vehicle manufacturers understand the negative impact on consumer acceptance should there be any safety defects associated with any new technology. This is also true of Li-ion batteries. All established vehicle manufacturers will use abuse-tolerant Li-ion chemistries and will package them appropriately to prevent virtually all fires. In fact, electric vehicles are far safer than gasoline vehicles, which are responsible for over 200,000 fires and over 400 related deaths each year.

Even if electric vehicle sales are affected by negative publicity, this will not have any impact on the manufacturers' ability to comply with the 2017-2025 efficiency standards. Conventional technology is improving rapidly due to ever more sophisticated computer simulations, computer-aided-design, and onboard computer controls. In fact, the pace of technology development just keeps accelerating. As an engineer with extensive technology experience at two auto manufacturers and the EPA, I can confidently state these are achievable standards that manufacturers can comply with using conventional technology improvements, perhaps combined with a modest number of conventional hybrids. No electric vehicles will be needed.

Efficiency standards are needed to capture huge energy security and economic benefits to society and to ensure that domestic manufacturers remain competitive on technology.

This concludes my statement and I would be happy to address any questions.

Appendix A

EGR-boosted direct-injection (EBDI) engine map. Section 4.2.6.1 of:
Project Report: Computer Simulation of Light-Duty Vehicle Technologies for Greenhouse Gas Emission Reduction in the 2020-2025 Timeframe
Prepared by Ricardo Inc. for the U.S. EPA, EPA Contract No. EP-C-11-007

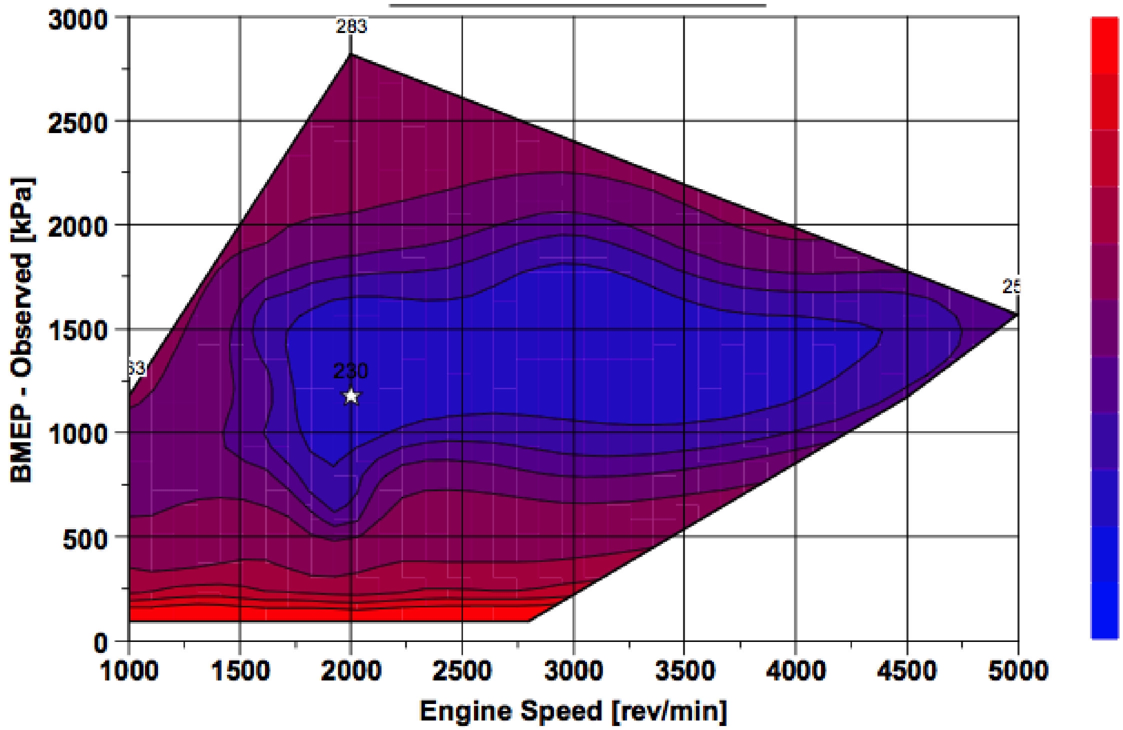
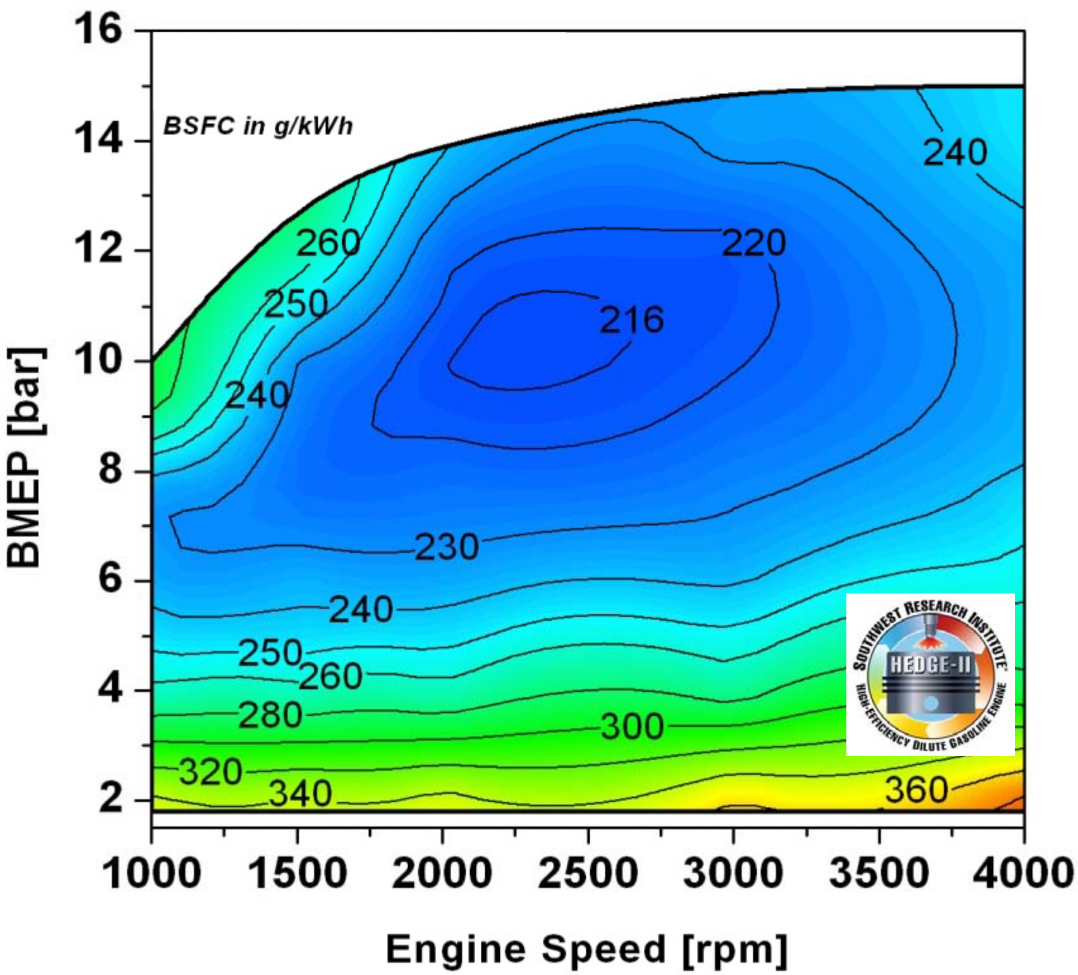


Figure 4.9: BSFC map (in g/kW•h) for EBDI® engine with EGR. (Beazley, 2010)

Appendix B

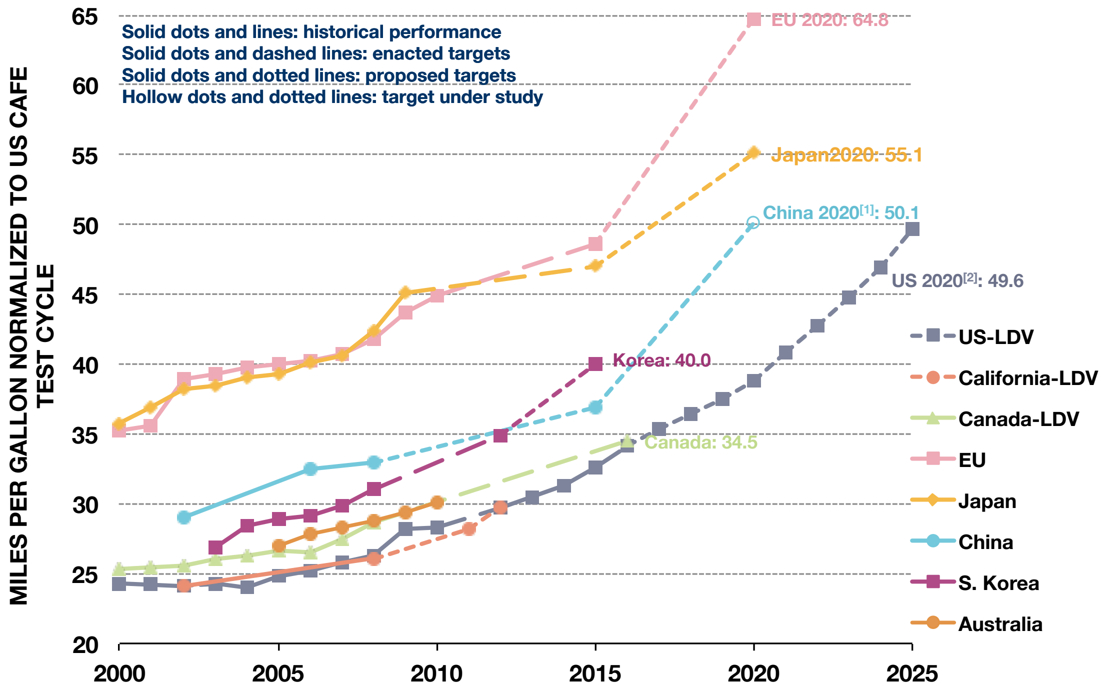
High Efficiency Dilute Gasoline Engines (HEDGE) Application.
2.4L I4, 11.4:1 CR, Max EGR ~ 30%, boost limited (turbocharger hardware could not provide sufficient air), proprietary SwRI ignition system.

“Examples of HEDGE Engines”, Dr. Terry Alger, SwRI, February 2010

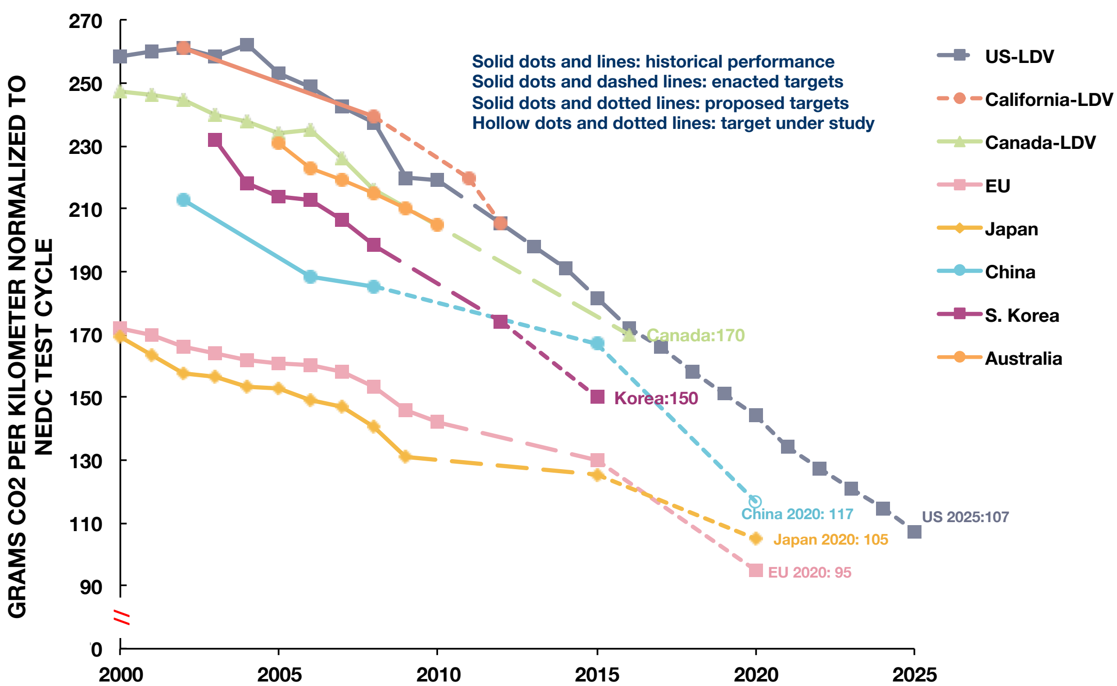


Appendix C

Comparison of vehicle fuel economy standards worldwide:
http://www.theicct.org/global-passenger-vehicle-standards-update



[1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be higher.
[2] US and Canada light-duty vehicles include light-commercial vehicles.



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