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Before The
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On The Road to Tomorrow: Energy Innovation in Automotive Technologies
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I would like to thank Chairman Murkowski, Ranking Member Cantwell, and the Members of the Committee for this opportunity to address the committee regarding the opportunities and challenges before the U.S. automotive industry related to energy-relevant vehicle technologies. I am Carla Bailo, the President, and CEO of the Center for Automotive Research (CAR). CAR is an independent, non-profit 501(c)3 organization based in Ann Arbor, Michigan that produces research and fosters multi-stakeholder forums on critical issues facing the automotive industry and its impact on the U.S. economy and society.

We are in a critical period for the U.S. automotive industry. U.S. light vehicle sales grew to a record 17.5 million units in 2016 and closed 2017 slightly below that at 17.2 million units.[1] Sales are plateauing at a very high level and include a rich mix of pickup trucks, SUVs, and CUVs that are highly profitable. In fact, these popular vehicles dominated the main show floor at the North American International Auto Show in Detroit last week. Despite all the shiny new metal on the show floor, everyone was talking about connected and autonomous technologies, new mobility service models, and advanced powertrain solutions. These are the technologies in which automakers and suppliers are investing billions of dollars to secure their competitive position in the future of our industry.

Investing in advanced technologies is not only costly but also brings considerable risk. In all things related to automotive technology, consumer acceptance is critical. Regulatory technology mandates can mitigate the risks, but the auto industry operates in many different regulatory environments and must meet many different sets of targets. Even while the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) are completing work on the Mid-Term Evaluation, automakers and suppliers are aggressively pursuing electrification to meet requirements and CO_2 emissions reduction targets set across Europe, Asia, and South America. In North America, Canada and Mexico have signed agreements to align their regulatory frameworks with that of the California Air Resources Board.[2] All of this means that automakers and suppliers—nearly all of which are large multi-national companies—must keep up with the most aggressive regulatory environments if they wish to remain globally competitive.

When you do not know exactly where you are going, it helps to have a map—and many associations, academics, consultants, and research organizations have produced advanced technology roadmaps that can help guide the automotive industry and key stakeholders to what the future may hold. New outlooks and forecasts come across my desk nearly every week. With support from the Government of Canada, CAR recently undertook an effort to make sense of the future of automotive technologies. Our researchers reviewed over 100 automotive technology roadmaps, synthesized the documents into one

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[1] IHS|Markit
[2] Memorandum of Understanding to Enhance Cooperation on Climate Change and the Environment Between the State of California of the United States of America and the Ministry of Environment and Natural Resources and the National Forestry Commission of the United Mexican States, 28 July 2014, https://www.gov.ca.gov/docs/7.28_Climate_MOU_Eng.pdf

document, and validated the resulting roadmap with key automaker and supplier leaders. The result is CAR's 2017 *Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion* summary report that I would like to submit as an addendum to my statement here today.[3] While there are synergies between each of these technology areas (e.g., electrification and connected and automated vehicle technologies or lightweighting and advanced powertrains), I will provide a brief overview of CAR's light-duty vehicle propulsion technology outlook as this area is most relevant to this committee.

While CAR researchers found general agreement on the direction of changes in the area of light-duty vehicle propulsion, there is tremendous uncertainty regarding the timeframe of specific changes, and each manufacturer is following its unique technology pathway. Automakers need to balance the needs of their customers with the corporation's need to comply with a wide array of government regulations. Suppliers that have developed new powertrain technologies are eager to have stricter fuel economy and emissions targets that create demand for their products.

Automakers are investing heavily and making significant commitments to advanced propulsion and vehicle electrification[4]:

- BMW plans to offer 12 fully-electric vehicles by 2025.
- Daimler plans to sell 100,000 electrified vehicles by 2020.
- FCA is planning to offer half of all Maseratis as EVs by 2022.
- Ford is spending $11B and plans to offer 40 electrified vehicles by 2022.
- GM will offer 20 all-electric models by 2023.
- Honda announced two electric vehicles in 2017 and plans to have two-thirds of its lineup electrified by 2030.
- Mercedes is planning an electrified version of every model it sells.
- Renault-Nissan has sold nearly 500,000 Leafs—the highest volume of EVs of any automaker—and expects to have zero-emission vehicles make up 20 percent of its sales by 2020.
- Tesla is planning to build 500,000 all-electric Model 3s annually by 2020—which would be six times the total number of EVs sold in 2016.
- Toyota plans to offer all zero-emission vehicles by 2050.
- VW is investing $11.8B to roll-out 80 new electric models across all of its brands by 2025.
- Volvo announced it would only launch electrified vehicles after 2019.

From both a cost- and performance-perspective the internal combustion engine (ICE) remains a challenging target to beat. There is a proliferation of technologies that can boost ICE efficiencies—

[3] Smith, Brett, Adela Spulber, Shashank Modi, and Terni Fiorelli. (2017). Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light-Duty Vehicle Propulsion. Center for Automotive Research, Ann Arbor, MI. http://www.cargroup.org/wp-content/uploads/2018/01/Technology_Roadmap_Combined_23JAN18.pdf

[4] Reuters Staff. (2017, November 17). "Factbox: Automakers get serious about electric cars." Reuters. https://www.reuters.com/article/us-autos-electric-factbox/factbox-automakers-get-serious-about-electric-cars-idUSKBN1DH28A; Edward, T., & Preisinger, I. (2017, September 7). "BMW gears up to mass produce electric cars by 2020." Reuters. https://www.reuters.com/article/us-autoshow-frankfurt/bmw-gears-up-to-mass-produce-electric-cars-by-2020-idUSKCN1BI1LM; Carey, N., & White, J. (2018, January 14). "Ford plans $11 billion investment, 40 electrified vehicles by 2022." Reuters. https://www.reuters.com/article/us-autoshow-detroit-ford-motor/ford-plans-11-billion-investment-40-electrified-vehicles-by-2022-idUSKBN1F30YZ; Tajitsu, N. (2017, June 8). "Honda says its self-driving cars will hit the streets in 2025 — but that could be too late." Business Insider. https://www.businessinsider.com/r-honda-to-focus-on-self-driving-cars-robotics-evs-through-2030-2017-6 ; Welch, D. (2017, October 2). "GM Plans 20 All-Electric Models by 2023." Bloomberg. https://www.bloomberg.com/news/articles/2017-10-02/gm-pledges-electric-future-with-20-all-electric-models-by-2023

including gasoline direct injection that is expected to exceed 75 percent market penetration by 2025, mechanical turbocharging that could be on more than three of every five vehicles sold by 2025, and 12-volt stop-start that could be on half of the vehicles sold by 2025.[5] Fewer vehicles will have Atkinson cycle engines or engines that use variable compression ratios or homogeneous charge compression ignitions—all essential technologies that improve the efficiency of the ICE. Globally, diesel engines will remain part of the mix, but these engines will face headwinds from increasingly stringent NOx and particulate regulations, as well as consumer acceptance in the wake of several widely-publicized testing scandals.

Countries including China, France, Germany, Great Britain, India, Norway have announced plans to phase out gasoline and diesel-powered engines. Also, Austria, Denmark, Ireland, Japan, the Netherlands, Portugal, Korea and Spain have set government targets for EV sales.[6] Despite these headlines that countries and companies are moving away from conventional engines, ICEs remain the dominant propulsion globally and in North America. The CAR roadmap shows ICE engines will still be in over 90 percent of all new light vehicles sold globally in 2030 and over 95 percent of new light vehicles sold in North American by 2025. In roughly 20 percent of those vehicles with ICE, the engine will be part of a hybrid system—be it a plug-in hybrid electric (PHEV), hybrid electric (HEV), or mild hybrid (MHEV or 48-volt systems). The point is, electrification does not always mean full battery-electric (BEV).[7]

HEVs have been in the market since the mid-1990s, but in 2017 electrified vehicles of any type have only achieved a 3.3 percent market share.[8] The cost of having two propulsion systems hinders HEV cost-competitiveness. BEVs face an even higher cost-competitiveness hurdle, as well as lagging market acceptance due to performance (range, recharge time). Fuel cell vehicles (FCEVs) offer another alternative that several manufacturers are pursuing, but these vehicles have cost, hydrogen production, distribution infrastructure, and onboard storage challenges.

Battery costs are rapidly declining, and performance is increasing. The current cost of lithium-ion battery packs is estimated to be approximately $275 per kilowatt-hour (kWh).[9] Lithium-ion battery development continues at a rapid pace and is expected to achieve even better performance and lower costs. Beyond lithium-ion, there are battery chemistries such as solid-state lithium metal and lithium air that could reach theoretical densities much greater than current lithium-ion technology. Battery technology developments are difficult to forecast, but could drastically change the BEV equation, and must be carefully watched.

As of today, there are vast differences between regional generation emission of CO_2 in the United States. For example, a PHEV or BEV charged from the grid in Alaska, California, and Washington emits far less CO_2 than one charged using the grid mix that exists in states like Colorado, Michigan, West Virgina.[10] The United States must continue to develop and implement low CO_2 and renewable energy electricity

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[5] Smith, Spulber, Modi, Fiorelli, *op.cit.*

[6] Petroff, A. (2017, September 11). "These countries want to ban gas and diesel cars." CNN Money. https://money.cnn.com/2017/09/11/autos/countries-banning-diesel-gas-cars/index.html

[7] Smith, Spulber, Modi, Fiorelli, *op.cit.*

[8] Center for Automotive Research analysis of data from Ward's Automotive Reports and HybridCars.com

[9] Smith, Brett, Adela Spulber, Shashank Modi, and Terni Fiorelli. (2017). Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light-Duty Vehicle Propulsion. Center for Automotive Research, Ann Arbor, MI. http://www.cargroup.org/wp-content/uploads/2018/01/Technology_Roadmap_Combined_23JAN18.pdf

[10] Sivak, Michael and Brandon Schoettle. (2017). Fuel Sources for Electricity in the Individual Countries of the World and the Consequent Emissions from Driving Electric Vehicles. University of Michigan Transportation Research Institute, Ann Arbor, MI. http://www.umich.edu/~umtriswt/PDF/SWT-2017-18_Abstract_English.pdf

generation capacity to assure the PHEVs and BEVs reduce, and not merely shift, the country's carbon footprint.

Widespread implementation of PHEVs and BEVs has implications for electricity generation investment. Electric utilities have shown the ability to encourage off-peak vehicle charging to smooth daily and seasonal peaks and valleys in demand. These demand shift strategies can lead to higher utilization rates for the established generation portfolio, and even lessen future investment in new generation capacity.

While EV range and cost are critical, the robustness and reliability of the electrical grid is also a factor for PHEV and BEV penetration, especially for home charging. One day without electrical power is challenging for any household, but even more so if they rely on electricity to power their vehicle. Early experiences indicate there has been relatively little initial impact on current neighborhood grid infrastructure in areas where PHEVs and BEVs have clustered.[11] However, as these vehicles become more prevalent, there is need to monitor both the local and regional grid capacities and capabilities.

Consumers are unlikely to buy a vehicle without a developed refueling infrastructure, and the private sector is not likely to build the infrastructure before there is a critical mass of EVs in-use. VW's diesel settlement may provide some funding for infrastructure development. Investment in grid balancing strategies and the development of microgrids can help reduce the risk of overburdening the U.S. electrical grid. The United States should consider a range of solutions to this challenge: direct public development, public-private partnerships, bonds, and zoning/building code mandates for new construction (e.g., new houses and multi-use developments must have 240V circuits available).

The automotive world is inching ever closer to an electrification tipping point, and automakers and suppliers will develop these technologies for—and in—those countries and markets that provide both the carrot (infrastructure and incentives) and the stick (regulatory mandates). The location of automotive R&D investment and technology manufacturing could shift outside of North America, which would have implications not only for the nation's engineering and skilled talent development institutions but also for the overall technological leadership of the United States.

[11] Allison, Avi and Melissa Whited. (2017). Electric Vehicles Are Not Crashing the Grid:
Lessons from California. Natural Resources Defense Council, Synapse Energy Economics, Cambridge, MA.
http://www.synapse-energy.com/sites/default/files/EVs-Not-Crashing-Grid-17-025_0.pdf