33rd Electric Vehicle Symposium (EVS33)
Portland, Oregon, June 14 - 17, 2020

Redefining Goods Movement: Building an Eco-System for the Introduction of Heavy-Duty Battery Electric Vehicles

Dawn Fenton[1], Aravind Kailas[2]

[1] *Volvo Group North America, 2900 K Street NW #410, Washington, DC 20007, dawn.fenton@volvo.com*

[2] *Volvo Group North America, 575 Anton Blvd, Ste 860, Costa Mesa, CA 92626, aravind.kailas@volvo.com*

Summary

Electric heavy-duty trucks are more than just "buzz." Soon, major OEMs will introduce heavy-duty electric trucks in the marketplace, but their success will require collaboration among many stakeholders not currently engaged in the traditional heavy-duty commercial truck market. A paradigm shift in commercial trucking will emerge, forcing greater interdependence among fleets, utilities, truck manufacturers, and policymakers. The Volvo LIGHTS project, a multi-faceted public/private project in Southern California, provides some early insights and a model for successful fleet adoption of heavy-duty electric trucks.

Keywords: electric vehicle, government, heavy-duty, infrastructure, policy

1 A Paradigm Shift in Commercial Trucking

The transition to greater use of electric-powered vehicles, to mix metaphors, has picked up steam. Electric passenger car sales in the U.S. grew from 17,763 to 326,644 between 2010 and 2019 [1], while in this same timeframe hybrid buses grew from 7 percent to 17.7 percent of all transit buses sold [2]. During the last few years, there's been growing anticipation about similar trajectories in the truck market. Greater utilization of battery electric commercial trucks will not only improve working conditions and simplify vehicle maintenance, but also bring larger societal benefits, such as noise reductions and air quality improvements, especially in crowded urban areas and freight corridors.

Unfortunately, market penetration of electric trucks is moving much more slowly, especially in the commercial trucking sector which depends on batteries with high energy density and commercial customers with different purchase motivations. While there is frustration among some stakeholders at the slow pace of progress, it is important to realize we are on the cusp of a complete paradigm shift in commercial trucking, one with unmatched impact since the introduction of the diesel engine in 1893 [3].

The diesel engine has rightly been called the workhorse of the economy and has maintained its leadership as the heavy-duty powertrain of choice for more than 100 years due in part to the unparalleled energy density of diesel fuel [4]. Since 1998, diesel engines have reduced PM and NOx emissions by 98% [5], yet these technological advancements have had relatively few operational implications for truck drivers. With the advent of this anticipated shift to electric battery-powered trucks, commercial fleets must not only plan for increased vehicle cost, but also significant operational impacts to their business, including fueling, maintenance, and route optimization.

Diesel is a ubiquitous fuel, with roughly 55% of retail fueling stations nationwide offering diesel fuel [6]. Currently, there are no public charging stations for heavy-duty battery electric vehicles ("electric trucks"), thereby requiring commercial fleets to consider multiple implications of their fueling decisions. Fleets can expect sharp learning curves to understand vehicle operation, maintenance, power needs, and the cost and time for charging equipment procurement and installation. Beyond these initial infrastructure considerations, there are also other more complex factors to be considered, such as the impact of charging time and speed on fuel costs, route optimization, battery life, and the seamless integration of electric trucks into existing operations.

While this paradigm shift will complicate fleet operational decisions in many ways, it will have little impact on the lens through which these battery electric trucks are evaluated and accepted. All too often, assumptions on penetration rate of electric trucks are extrapolated from the light-duty electric car market, with technology advocates and policymakers assuming familiarity and growth in electric cars will facilitate a quicker acceptance of electric trucks. The truth is that the motivations for commercial trucking (fleets and independent operators) are vastly different from car owners, based more dispassionately on uptime and total cost of ownership ("TCO") rather than the social perceptions of electric car ownership. Maybe most importantly, the overall cost of owning and operating electric trucks must be equal (at the very least) or better (preferable) than today's diesel equivalent to motivate fleets to purchase them.

2 Non-Traditional Transactional Actors

Traditionally, the acquisition of a new truck has been a relatively simple transaction between the buyer, seller, and potentially a third-party financier. Understanding customer needs is fundamental to building market demand. and truck Original Equipment Manufacturers ("OEMs") consult regularly with fleets to assess technology impacts on fuel economy, driver comfort, and energy efficiency. With the advent of electric trucks, OEMs and fleets will need to consider additional factors. such as range and its relation to changing duty cycles and payload, service and repair needs, cost and availability of charging infrastructure (private and public), and charging rates, to name a few.

Similar to the emergence of natural gas trucks, addressing the aforementioned factors will necessitate engaging non-traditional actors in the commercial trucking market such as electric utility companies, charging station providers, local permitting authorities, and many others. Electric utility companies have limited knowledge of commercial fleet operations and needs, and the electric grid impacts from charging electric trucks/fleets. Therefore, they need to be engaged early in the process when fleets are considering electric trucks for their operations. Moreover, the involvement of electric vehicle charging stakeholders is further complicated by the

confusing overlap among actors providing hardware, software, and customer-facing solutions that are flooding the market as each seeks to build its niche and competitive advantage. Fleet managers are forced to work with new suppliers and understand new terminology for charging levels, types, and standards.

Finally, local, state, and national policymakers will have a newfound influence on purchase decisions and product acceptance given their role in creating funding incentives to offset higher vehicle and charging equipment costs, local permitting for charging infrastructure deployment, and public utility system upgrades. These new factors in the wide scale rollout of electric trucks will forever change the traditional bilateral commercial transactions between OEMs and fleet owners. As OEMs and fleets lose control over the impact of their decisions, policymakers will have responsibility for building greater regulatory flexibility to account for the growing influences that are beyond the control of the regulated entities. For example, in California, zero emission vehicle sales and purchase mandates for commercial trucks are being developed to advance state objectives [7], yet these proposals are adding to the concern and uncertainty in the trucking industry, in part because they are being evaluated through an ill-fitting frame of reference (i.e., the electric car market) and fail to account for the market realities of commercial trucks. This has the potential to inhibit, and even delay, the adoption of electric trucks in the state.

3 Volvo Low Impact Green Heavy Transport Solutions ("LIGHTS")

According to Volvo Group CEO Martin Lundstedt, "Partnership is the new leadership." [8] This sentiment was borne from Volvo Group's participation in "ElectriCity," a partnership launched in 2013 with city and regional public agencies, the private sector, and academic institutions to promote sustainable and electrified travel and transportation [9]. Although originally focused on public transport and the first all-electric bus route with indoor stations in Gothenburg, Sweden, ElectriCity's scope has been expanded to include other forms of electrified transportation and related services, including high-power charging stations, urban planning, and electric truck demonstrations.

This successful model was the inspiration behind the Volvo LIGHTS project, an extraordinary partnership of 15 private and public organizations to introduce heavy-duty all-electric trucks and revolutionize freight facilities in Southern California [10]. In addition to Volvo Trucks North America, other project partners include private fleets, government agencies, ports, community colleges, a utility company, a research university, community leaders, and equipment suppliers, all working together to create an ecosystem to propel battery electric freight movement beyond the demonstration phase into a widespread reality.

Volvo LIGHTS was launched in 2019 to test critical innovations in vehicle technologies, install charging infrastructure, and establish the groundwork for an electric truck sales and service network. The project will deliver 23 battery electric trucks of varying configurations, 29 battery electric freight handling vehicles, 58 vehicle chargers, including the first public electric truck charging station, a 1.8 MW solar installation, and two new training curricula in nearby community colleges. The project will continue until April 2021, but already lessons are being learned, which can help ease and accelerate the experiences of other communities preparing for this paradigm shift.

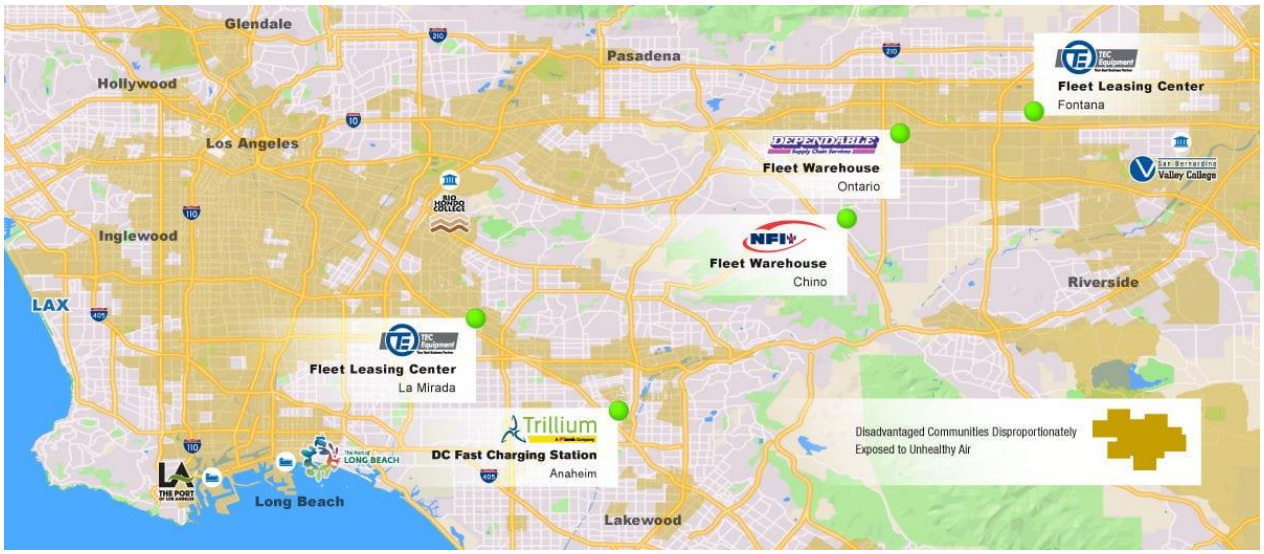

Figure1: The Volvo LIGHTS project is taking place throughout the greater Los Angeles region.

4 Keys to Success: Education and Communication

Most individuals are familiar with the "telephone game," where the first player whispers a message in the ear of the second player, who whispers it in the ear of the third player, and so on. This continues until the message reaches the last player, who recites it out loud to the whole group. The first player then compares the original message with the final version. Although the objective is to pass the message without it being changed along the way, the enjoyment comes from the extreme difficulty and funny distortions that often result. Usually, the message distortion is directly proportional to the number of players. While not a perfect analogy, the "telephone game" and efforts to introduce electric trucks in the marketplace bear similarities in terms of dependence on others and the resulting higher propensity for miscommunication.

As explained above, and witnessed thus far during the Volvo LIGHTS project, close cooperation among the diverse project stakeholders is absolutely critical because no single entity can unilaterally deliver the project. Many of the project partners have no previous experience working together (at least in the context of traditional commercial transactions). This presents additional challenges in terms of establishing common best practices and achieving project milestones. Overcoming these challenges requires education and teamwork. A first step to establishing a common baseline of understanding is education.

Compared with diesel trucks, electric powertrains are vastly different in terms of their parts. A common perception is that electric trucks will have fewer moving parts and are therefore less technically complex than diesel- and gasoline-powered trucks. Although true on one level, electric trucks also have highly specialized components, such as battery systems, advanced power management software and computing systems, regenerative braking systems and high-voltage electrical systems, requiring the development and implementation of appropriate training modules for the safety of service technicians. It should be noted that contrary to some conventional wisdom, the intense use that comes from "normal" commercial vehicle operation means electric trucks will need regular maintenance and service. That service is potentially less intensive than traditional internal combustion engine vehicles, but data will only be developed after the deployment of a sizeable quantity of electric trucks in revenue service.

Commercial sale of Volvo electric trucks will commence before the end of 2020 [11], at which point technicians at dealerships and fleets must already be trained and ready to service them. To prepare for this, Volvo LIGHTS project partners Rio Hondo and San Bernardino Valley Community Colleges are instituting training programs for the next-generation workforce [12].

As noted previously, truck OEMs have always worked closely with customers to inform their product development and build brand loyalty. However, this principle will become exponentially more important with the widespread introduction of electric trucks. Not all trucks are created equal. Manufacturing specs such as gross vehicle weight rating, gross axle weight rating, transmissions, engine, tires, electrical and air systems, and cab configuration, can vary greatly to meet business needs based on geography, duty cycles, and payloads. With the advent of electric trucks, truck manufacturers will need to understand commercial fleet needs and business models even more comprehensively as limited onboard energy and availability of charging affect the range, charging frequency, operational duty cycle, and route optimization for maximizing uptime. Electric powertrains present a whole new "ball of wax" that could lead to new business models for both truck manufacturers and fleets.

In addition to the technology and business implications, it is equally important to understand partner motivations and frames of reference driving different actions and decisions. Most business transactions are profit-driven, providing a quality product for a reasonable cost. The shift to electric trucks will not change this, yet the addition of new actors with different motivations will complicate and potentially impinge upon usual timelines. For example, utility companies and local regulators prioritizing traditional ratepayer interests or concerns for community engagement may inadvertently challenge commercial fleet demands for expeditious grid upgrades and infrastructure permits. The key to overcoming potential friction or delays will require sensitivity and clear communication among these stakeholder groups.

In the early days of this paradigm shift to electromobility transport solutions, it will be important to build that common baseline of understanding through education of all stakeholders. The state of California is eagerly trying to expedite this shift to electric vehicles broadly and to trucks more specifically. However, these efforts have led, not unexpectedly, to frustration, vilification, and impatience among many stakeholder groups. Some interest groups and policymakers have been critical of the reticence on the part of utility companies, commercial fleets, and truck manufacturers to support a quicker transition to the use of electric trucks. At the same time, some of these same entities can become frustrated and dismissive of these interest groups and policymakers for their ignorance of operating business challenges. Overall, such sentiments are exacerbated by a failure to appreciate the complexities of this paradigm shift and a sensitivity to the pressures and realities of each stakeholder's frame of reference.

As this paradigm shift continues to unfold, education will have to be supplemented by strong and effective communication practices to help facilitate learning, broaden perspectives and build patience. On a project level, the integration of electric trucks in a fleet is a multi-step process. Education and planning can expedite the process, but there will be obstacles and challenges only some of which could have been foreseen. What challenges do warehouse operators face to installing charging infrastructure if they lease rather than own the property? If a fleet uses trucks for both longer and shorter distance deliveries, do they need to consider new route configurations and related truck utilization to account for charging demands? Can a fleet access public funding incentives and count on utility timing estimates to ensure the infrastructure is available when electric trucks are delivered and the cost to the business will not exceed the budget increase that was expected? Finding answers to these questions will require teamwork, respect, and patience as unfamiliar stakeholders depend on and leverage partner experience to navigate unfamiliar environments.

In many cases, it may be the community leaders, defined broadly, who hold the key to a project's success. Electricity as a fuel depends on utilities that are regionally based. Power upgrades will have an impact on

ratepayers within that community and infrastructure expansion will require local permits. Offsetting the initial high cost of new technology, if desired faster than the current "business-as-normal" trajectories, will require government provisions of incentive funding, tax breaks, or other policy mechanisms to move the market. Citizens want clean air, a strong economy, and a healthy community. Officials at all levels of government need to be responsive to all stakeholder interests, and the utilization of what is seen as a public good (electricity), gives them more influence over industries using that good (trucking) and more responsibility to understand and resolve conflicts among all stakeholder interests.

5 Early Lessons Learned from Volvo LIGHTS

During the last 9-12 months, Volvo LIGHTS partners have invested thousands of hours in pursuit of early project milestones. In some cases, projected timelines were exceeded, such as the arrival of the first five trucks in the state of California. In others, such as the installation of charging infrastructure, there have been delays. In virtually all instances, these delays have been caused by the lack of collaboration among unfamiliar stakeholder groups. Projects like Volvo LIGHTS are revolutionary launching pads for electromobility solutions and not "business-as-usual" for most organizations. Delivering project milestones necessitates project partners and other stakeholders to be more nimble with their processes. Below are some of the lessons learned from the project to date.

- Charging infrastructure deployment will take time - One of the most important lessons in the early stages of the Volvo LIGHTS project is the need to anticipate delays in charging infrastructure installation in order to coincide with vehicle delivery. For instance, early steps were taken in the project to understand power needs and develop site plans for the infrastructure installation. Nevertheless, when the first five electric trucks were delivered in California, there were only two charging stations available, and the timeline for others had been delayed. Fleets need to start the site and equipment planning early, and navigate challenges by being flexible and collaborating with the different partners. Additional challenges can arise if a warehouse is leased rather than owned, requiring consultation with a landlord on how to handle costs, easement rights, and commitments related to infrastructure installation. Clear and timely communication will be key. Fleets or warehouse operators should consider contracting an experienced turnkey installer and appoint a dedicated project manager.

- Engage utility companies early in the design process - The utility company will install new lines and determine load demands on the grid when there is a fleet of electric trucks. The utility company can also provide guidance on taking advantage of demand-response pricing that will enable the commercial fleets and the utility to save money by charging during off-peak periods. Early engagement can help clarify funding and timeline ramifications for your overall project, including applications for vehicle funding and avoiding the potential for idle vehicles while waiting for a site to be powered up.

- Engage local permitting agencies early in the design process - Whether a project is a renovation, addition, or new construction, all facility designs are subject in some form to compliance from local permitting agencies. Cities and counties have different permitting officials and regulations resulting in unique mindsets and requirements. Codes and their interpretations can change city to city and county to county. Therefore, ensuring a code-compliant design by involving the appropriate permitting authority early can minimize construction and electrical engineering activity delays. Building relationships with local officials and community leaders may help alleviate unnecessary bottlenecks in the permitting process.

- Pursue funding opportunities where applicable – Fleets or warehouse operators must also pursue government funding opportunities to improve the economics from vehicle acquisition to operation. For instance, the Hybrid and Zero-emission Voucher Incentive Project (HVIP), the Carl Moyer Program for small fleets, and other regional incentives may help with vehicle purchases. Infrastructure costs are not insignificant, and competitive investor-owned and municipal utility incentives, such as the Southern California Edison ("SCE") Charge Ready Transport and Volkswagen Mitigation Trust funds, can potentially help offset these costs. Utilities can help fleets understand their ability to qualify for such programs and electric vehicle ("EV") rate incentives for demand charges (for example, SCE offers zero demand charges until 2024), as well as other avenues to procure supplemental funding. Unfortunately, there is a serious lack of funding for electric truck and charging infrastructure purchase incentives and many of the programs are not coordinated.

- Consider the entire charging ecosystem - The transition to an electric fleet is not just about selecting trucks, but also requires figuring out the charging solution that will best serve fleet needs, scale, and the business bottom line. To do this, fleets must consider highest-powered technologies, highly efficient chargers, ability to expand power capabilities, utility needs, etc. Choose a solution that allows for adding charging power or more chargers easily and relatively inexpensively. Upgrading infrastructure can be very expensive, especially if one does not plan for it. For example, one might want to consider a good mix of high- and low-power DC fast-charging stations. Most commercial sites have three-phase power, and this might motivate having high power AC charging stations at one-tenth of the cost of DC fast-charging stations. Onsite renewable energy generation and storage, reusing electric truck batteries, and deploying alternative charging options (such as using wireless charging) will advance the agenda of becoming sustainable, energy efficient, and emission-free freight facilities. Therefore, it is prudent to keep in mind the long-term business vision to ensure that the charging infrastructure and other freight facility enhancements can scale with business growth.

- Training EV technicians is critical - The advanced electric drivetrains and increasingly sophisticated technology on electric trucks will require a highly skilled and specialized workforce to support, maintain, and repair them. Vehicle technicians will require new, advanced skills and a supportive training ecosystem to successfully address the evolving needs of an industry's technology in transition. However, this will take time. So, it is important to have either people already on staff trained to service electric trucks when they arrive and/or to ensure that a local dealer is prepared to help address these needs.

6 Concluding Remarks

Advances in electric powertrain and battery technologies have the potential to transform the traditional commercial trucking sector by reducing the emissions and noise footprint of goods movement, and bringing novel asset ownership and business considerations to fleets. The advanced technologies will demand new expertise; novel training programs are needed to prepare the next-generation workforce for the challenges of electric trucks. Skillful preparation and change management within the trucking sector will be critical in light of the industry's importance to the broader U.S. economy given that the trucking industry moves nearly 71 percent of freight tonnage in the U.S. [13], and employs about one of every 15 workers in the nation [14].

As illustrated through the Volvo LIGHTS project, it will take more than just the truck to switch from diesel to electric power. This paradigm shift will lead to greater interdependence among a wider number of stakeholders. For instance, fleet operations will need to be more connected (than ever before) with maintenance technicians,

drivers, and management to maximize vehicle range and efficiency, configure charging strategies, and implement the necessary charging infrastructure. Education and communication are key to fostering these close collaborations among the various stakeholders and enabling them to be pioneers together.

Electric trucks are coming to the market, but it will take some time. First and foremost, fleets make decisions on the lifetime costs of buying and operating trucks (total cost of ownership or "TCO"). Electric trucks require more expensive, high-power charging infrastructure than cars, placing additional demands on the electric grid. Lead times for charging infrastructure installation are much longer than for truck deliveries. Availability of incentives is essential to advance fleet interests and ensure the affordability of more expensive electric trucks and charging infrastructure. Today, the public funding and incentives for vehicle and charging infrastructure are disbursed into a variety of programs across the different agencies, adding further complications to decision-making for the fleets.

The transition to electric powertrains will be very different from the introduction of emissions control technology in 2004, 2007, or even 2010, when diesel exhaust fluid became part of the fueling protocol. We are entering a new paradigm, requiring all stakeholders to adjust their frame of reference. Change can be difficult, but Volvo LIGHTS is proving that education and communication, through earnest collaboration, will pave the way for electromobility solutions in the commercial trucking sector.

Acknowledgments

Volvo LIGHTS is part of California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the environment — particularly in disadvantaged communities. The total project cost is $90 million, with a funding award of $44.8 million.

References

[1] Alternative Fuels Data Center, https://afdc.energy.gov/data/, accessed 2020-03-25

[2] Appendix A, Table 34, Public Transportation Fact Book, https://www.apta.com/research-technical-resources/transit-statistics/public-transportation-fact-book/, accessed 2020-03-25

[3] *For earth day 2019, the customer is always right,* Diesel Technology Forum, https://www.dieselforum.org/policyinsider/for-earth-day-2018-the-customer-is-always-right, accessed 2020-03-25

[4] Diesel Technology Forum, https://www.dieselforum.org/news-and-resources/diesel-resource-library/diesel-resource-library, accessed 2020-03-25

[5] *About clean diesel – why diesel isn't dirty*, Diesel Technology Forum, https://www.dieselforum.org/about-clean-diesel/why-diesel-isn-t-dirty, accessed 2020-03-25

[6] *Diesel drivers – fuel locator*, Diesel Technology Forum, https://www.dieselforum.org/diesel-drivers/fuel-locator, accessed 2020-03-25

[7] Advanced Clean Trucks Fact Sheet, https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks, accessed 2020-03-25

[8] J. Cannon, *Bright idea: Volvo Trucks flipping the switch on its LIGHTS project,* https://www.ccjdigital.com/volvo-trucks-lights-project/#, accessed 2020-03-25

[9] ElectriCity, https://www.electricitygoteborg.se/en, accessed 2020-03-25

[10] Volvo LIGHTS, https://www.lightsproject.com, accessed 2020-03-25

[11] Volvo Trucks North America Demonstrates Pilot All-Electric VNR Models as Part of Volvo LIGHTS Innovation Showcase, https://www.volvotrucks.us/news-and-stories/press-releases/2020/february/all-electric-vnr-models/, accessed 2020-03-25

[12] AS in Electric Vehicle and Fuel Cell Technology Technician, https://www.riohondo.edu/academics/electric-vehicle-fuel-cell-technology-tech/, accessed 2020-03-25

[13] American Trucking Associations, https://www.trucking.org/news-insights, accessed 2020-03-25

[14] Truck Drivers in the USA, http://www.alltrucking.com/faq/truck-drivers-in-the-usa/, accessed 2020-03-25

Authors

Dawn Fenton is the Vice President for Government Relations and Public Affairs at Volvo Group North America. She has been with Volvo Group for 8 years and has responsibility for federal government relations as well as California policy issues. Dawn has worked in the government relations field for over 25 years across a range of energy, environment, sustainability, foreign policy and trade-related issues in the public, private, and non-profit sectors. She received her master's degree from the Georgetown University School of Foreign Service and her bachelor's degree from Tufts University.

Aravind Kailas has earned degrees in Electrical and Computer Engineering and Applied Mathematics from the University of Wisconsin-Madison and Georgia Institute of Technology, including a Ph.D. in Electrical and Computer Engineering. Currently, he is the Advanced Technology Policy Director at Volvo Group, where he oversees policy development, technology outreach, and public engagement strategies to further Volvo's interests in transport innovations. By promoting key corporate positions and creative assets in various fora, he has been instrumental in enhancing Volvo's thought leadership in the U.S.