The future of transportation: autonomous and…internal combustion?

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Technology is revolutionizing the way we get around, as illustrated by the millions of people who have used an app to rent, share, or hail a ride. Technological breakthroughs are also enabling computer-controlled "autonomous" vehicles to drive themselves, a fantasy that dates back as far as the 1950s. New transportation technologies and mobility services (together referred to as "new mobility") will have profound impacts on the transportation sector and beyond.

A common, comforting assumption about the future of transportation is that it will be autonomous, shared, and electric, which implies that it will offer deep emissions reductions. The problem with assumptions is that they sometimes turn out to be wrong. In this case, governments will have to take steps now to actively ensure such a low-emissions future, for it may not develop on its own.

The energy and emissions impacts of autonomous vehicles are highly uncertain and depend on many variables. Two key factors influencing the emissions intensity of autonomous vehicles are the extent to which they are shared and electric. We've outlined the new mobility taxonomy and summarized the associated potential environmental impacts here in our recent paper.

Hurdles to the adoption of electric vehicles include high upfront costs, insufficient driving range, lack of widespread charging infrastructure, and

long refueling time requirements. (Although our current focus is on electrification we note that shared mobility has its own unique set of hurdles.)

The barriers to electric autonomous vehicles could be even greater. Autonomous vehicles lower the constraints and costs of driving, and are expected to have much higher utilization than cars today, which typically sit parked 95% of the time. Higher utilization means more hours and miles of travel, which requires larger (more expensive) battery packs and more frequent recharging (downtime) for electric cars.

Possibly the biggest obstacle to widespread adoption of autonomous electric vehicles is that autonomous vehicle technology requires considerable energy to operate and process data from sensors such as cameras, radar, and lasers. The research and industry commentary show that the energy demands of autonomous vehicles can range from 0.5 kilowatts to 5 kilowatts (see here, here, here, here). For example, operating a 3kW autonomous driving system for 2 hours on the 60kWh Chevrolet Bolt would suck up 10% of the battery before any energy goes to actually moving the vehicle.

Several recent industry announcements reflect the challenges to electrifying autonomous vehicles. In December 2017 Ford provocatively outlined why its future on-demand ridehailing autonomous vehicle service will not be electric: because of autonomous vehicles' greater daily utilization, electric vehicles would require recharging multiple times each day and frequent fast-charging would accelerate battery degradation, both of which lead to vehicle downtime and lost profitability. In November 2017, Volvo announced it will supply Uber with 24,000 autonomous XC90 SUVs for Uber's ridehailing fleet – the press release does not mention that electric vehicles will be deployed. Representatives from Hyundai have cited the

large power demands as a key reason that the company will not pursue battery electric autonomous vehicles.

Despite the impediments described above, there are valid arguments supporting the claim that autonomous vehicles will be electric. Autonomous vehicle technology may be easier to implement in electrified vehicles (i.e., hybrid, plug-in hybrid electric, battery electric) due to the greater number of drive-by-wire components, which is thought to be more compatible with autonomous vehicle operation compared to physical mechanisms. Autonomous-vehicle-fleet operators may also choose electric models due to their lower per-mile fueling and maintenance costs and attractive total cost of ownership business case. Other arguments seem less valid. One story offers that federal fuel economy regulations will lead to "substantial" electric vehicle adoption (yet current standards are estimated to lead to about 2% electric vehicle adoption by 2025, and the administration has begun taking steps to roll back the standards). Another considers the refueling needs for autonomous vehicles as only reasonable with electric inductive (wireless) charging (however, automatic gasoline refueling technology already exists). Whether the technical and economic drivers to electrify autonomous vehicles are sufficient to overcome the barriers to their adoption is still unclear. What is clear though is that it will take a concerted effort by manufacturers, tech companies, and policy makers to achieve autonomous vehicle electrification and maximize environmental benefits.

So, there are reasons for skepticism. But there are also reasons to be optimistic, and a handful of promising initiatives are underway. General Motors has manufactured and is testing a fleet of more than 100 self-driving battery electric Bolts. Waymo has launched a public trial of 100 autonomous Chrysler Pacifica plug-in hybrid minivans. NuTonomy and Lyft are publicly testing a small fleet of Renault Zoe battery electric vehicles in

Boston. Auto manufacturer Tesla is rolling out the semi-autonomous Auto Pilot feature on all its vehicles. We'll continue tracking these developments to understand what is needed to overcome the challenges of integrating electric vehicles into autonomous fleets.

Electrification is a core component of lower-carbon transportation, especially in an autonomous-vehicle-future. And while the media and other groups (see here, here, here, here) have told us that the future of transportation will be autonomous and electric, there is certainly no assurance under the current policy landscape. Government support through industrial and regulatory policy, sustained investment in financial incentives and charging infrastructure, and non-fiscal policy at the local level are needed to promote the transition to electrification. Without robust policy measures, the future of transportation will be autonomous and still involve burning dead dinosaurs.