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King Abdullah Petroleum Studies and Research Center

Drivers of Transportation Fuel Demand: Fuel-Efficient Mobility From the Consumer's Perspective

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About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment, across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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Key Points

The working assumption of most policymakers and automakers is that light-duty vehicle buyers either undervalue fuel economy or behave as if they do – perhaps because of the complexity in evaluating discounted fuel cost savings. If one accepts this argument then huge benefits can be gained from public policies that mandate fuel-efficient mobility through performance standards.

Increasing vehicle fuel economy at the expense of performance has an opportunity cost for consumers as they value performance more than fuel economy. However, it remains an open question as to whether public policy, such as fuel economy standards, should incorporate opportunity costs arising from consumers' tendency to maximize personal over societal benefit.

Consumer concerns over the adoption of high fuel economy plug-in electric vehicle (PEV) centers around driving range, recharging time, charging infrastructure, value for money and highway performance, which continue to be major barriers. Evidence suggests that awareness and knowledge about PEVs have not yet increased substantially in many consumer segments. Finding better ways for consumers to gain firsthand experience with PEVs may help overcome this knowledge shortfall.

Short-term incentives to induce PEV sales are expensive; more than $50,000 per incremental vehicle sold according to some estimates. There is scope to improve cost-effectiveness by developing a targeted incentive structure. Alternatively, devoting resources to technology development rather than deployment might represent a more cost-effective policy approach.

Shared use of automated electric vehicles represents one possible path for achieving deep decarbonization, but its cost-effectiveness versus alternative paths has yet to be confirmed. PEVs seem unlikely to succeed if they are just a decarbonized replacement for today's vehicles, but this can be achieved if they provide a better customer experience at a lower price point.

Summary for Policymakers

Transportation accounts for nearly 14 percent of global greenhouse gas (GHG) emissions, around 40 percent of which come from light-duty vehicles (LDVs), i.e., passenger cars and trucks. To reduce GHG emissions from the LDV sector, policymakers have employed various supply side and demand side policies. These include fuel economy standards, zero emission vehicle mandates, renewable fuel standards, low carbon fuel standards and carbon taxes, as well as financial and nonfinancial incentives. Understanding consumer adoption of fuel-efficient vehicles is crucial for assessing the likelihood and costs of these policies in achieving their intended goals.

Published studies suggest that consumers undervalue fuel economy and future fuel cost savings. In addition, most consumers do not have the time, patience and ability to calculate discounted fuel cost savings. This suggests that consumers may be better served by fuel economy standards. However, increasing fuel economy at the expense of performance leads to opportunity costs for consumers, whose revealed preferences are to value performance more than fuel economy. Recent studies suggest that accounting for these opportunity costs wipes out all the benefits of fuel economy standards. However, a key question is whether a public policy such as fuel economy standards should embrace consumers' tendency to maximize personal benefit over societal benefit. There are many areas including tobacco and alcohol consumption where society's answer is no, but for now there is no consensus yet over mobility.

High performance plug-in electric vehicles (PEVs) might represent a good choice, at least for city driving, if consumers continue to value performance over fuel economy. Nonetheless, concerns over driving range, recharging time, charging infrastructure, value for money and highway performance represent genuine barriers to universal PEV adoption.

The current policy approach is to set targets for automakers and create short-term incentives for consumers. These include subsidies, tax incentives, entry to high-occupancy vehicle lane, and free parking, amongst others. However, additional PEV sales as a result of these incentives remain low. Marginal costs of additional PEV sales are high because everyone gets the subsidy, even those who might have bought a PEV without it. Overall, consumers want PEVs with better features and thus devoting resources to technology development rather than deployment might represent a more cost-effective policy approach.

To achieve deep levels of decarbonization within the light-duty vehicle sector, policies aimed at incremental improvements can have high social cost implications. This includes a carbon tax policy under which conventional vehicles might be able to remain competitive through efficiency gains and lower fuel prices in the long term (particularly if oil demand declines).

To avoid the possibility of expensive 'dead-ends' along the path to deep decarbonization, regulators are betting on policies promoting radical innovations such as the zero emission vehicle (ZEV) mandate. The hope is that better low carbon technologies would reduce fossil fuel consumption so policymakers would not need to set the carbon price at the higher level that is required to achieve deep decarbonization. However, recent studies estimate high CO2 abatement costs for innovative PEVs at greater than $500 per metric ton of CO2, even when benefiting from the economies of scale that would come with bigger sales volumes.

Thus, deep decarbonization will require a radically different paradigm for personal mobility, perhaps

dominated by low-cost shared use of automated high fuel economy vehicles. Policy intervention would still be needed, however, to prevent congestion and mass transit decline. In the end, PEVs are no different from many consumer goods. Unless they provide a better customer experience at a lower price point, they will struggle to displace the incumbent vehicles and infrastructure. Decarbonization may be a collateral benefit of this improved customer experience.

Background to the Workshop

On April 26, 2017, KAPSARC hosted a one-day workshop in Washington, D.C., focused on research aimed at understanding the demand for fuel-efficient and plug-in electric vehicles (PEVs) from the consumer's perspective. Topics discussed in detail included – consumer valuation of fuel economy and PEVs; drivers and barriers to PEV adoption and cost-effective strategies for achieving deep decarbonization. The workshop discussion centered on four main questions, which are covered in the following sections of this paper:

- How highly do consumers value fuel economy and what are the implications for policy choices?
- Are incentives for PEVs actually priming the pump?
- What are the barriers to PEV adoption?
- How much GHG emission reduction do different policy tools provide and what are the social costs associated with them?

Consumer Valuation of Fuel Economy

The fuel economy of light-duty vehicles (LDVs) is increasing steadily at about 3-4 percent each year in line with fuel economy standards. Based on agencies' cost-benefit analyses, fuel savings to consumers account for about 70 percent of benefits from these standards, which also include climate and security benefits. In addition, fuel saving benefits alone are said to exceed the entire cost of the standards. This raises the question: Why do consumers need regulation to realize the fuel economy benefits?

A commonly cited argument is that consumers undervalue fuel economy. As a result, they are not willing to spend more on technologies that improve fuel economy and automakers do not have enough incentives to increase fuel economy. This results in a market failure for fuel economy known as the energy efficiency gap. It is therefore argued that, standards would make consumers better off – provided the cost of fuel saving technology is less than the future fuel cost savings.

However, published evidence for the existence of the energy efficiency gap is largely inconclusive. More recently, researchers have recognized that improvements in energy-related technologies can be used to improve vehicles in multiple dimensions involving trade-offs among fuel economy, performance and vehicle weight/size. For example, during periods of relatively constant fuel economy standards automakers have used improved energy efficiency technologies to increase performance or weight instead of fuel economy.

Even if consumers value fuel savings, the analysis is incomplete if the opportunity cost of diverting technologies to alternative purposes is not taken into account. Recent study suggests that consumers are willing to pay much more for performance improvements than fuel economy improvements, which is consistent with historical observation. While this does suggest the existence of an energy efficiency gap, it also calls into question the conclusion that the existence of such a gap means that fuel economy regulations would yield direct net consumer benefits.

Consequently, how should public policy address such trade-offs between individual consumer and societal welfare? Should public policy embrace consumers' tendency to maximize personal benefit over societal benefit? Smokers gain value from tobacco, even though it harms their health and increases healthcare costs borne by society. In such cases, the public policy approach is still to give people choice, while offsetting the externality costs imposed by their choice on society through tobacco duties. This is reinforced by vigorous awareness campaigns aimed at changing public perceptions of its social acceptability and banning smoking in enclosed public spaces.

This balance is what the fuel economy standards is trying to achieve – give consumers a choice while encouraging automakers to increase fuel economy. The standards encourage automakers to innovate and install fuel saving technologies. This would have the net effect of nudging the average consumer and society at large toward greater fuel economy choices. The subset of consumers that prefer higher performance can still choose to do so, but pay a premium if automakers resort to cross-subsidization – using the premium to make more fuel efficient cars cheaper and so meet the overall fleet fuel economy standards.

Tesla's Model 3 plug-in electric vehicle (PEV) represents an interesting case study to suggest that imposing standards to bridge the efficiency

gap may be misdirected. Hundreds of thousands of consumers placed a $1,000 refundable deposit to buy the car, based only on a prototype. The zero emission vehicle (ZEV) mandate might have initially played a role in Tesla's early success, but it does not seem to be spurring the demand for the Model 3. An alternative hypothesis is that it is satisfying the demand for an innovative high performance vehicle, which also happens to have high fuel economy. Other PEVs including the Chevrolet Bolt would represent a good choice, at least for city driving, if consumers continue to value performance over fuel economy. However, within their current size categories, the price of PEVs is still a financial stretch for the average consumer. Improving their highway performance would make them more valuable in the eyes of the customer but at a higher cost.

Consumer Valuation of Plug-in Electric Vehicles

Technological innovation, policy support and consumer attitudes play a critical role in new technology adoption. Modern PEV offerings began in 2011-2012. Technology issues such as high costs, limited range, lack of charging infrastructure, limited make/model diversity as well as consumer awareness, knowledge and attitudes represent some of the early barriers that continue to play a role. At the same time, as more of these vehicles penetrate the auto market, there is measurable evidence that consumer attitudes toward PEVs are slowly evolving, as might be expected.

Early adopters were those that value fuel economy, environment friendliness and technical innovation very highly, whereas with increasing penetration beyond the early adopters, the average measures on these factors are declining to be more representative of the mainstream. A combination of financial subsidies (federal, state and automaker rebates) and other incentives (e.g., high-occupancy vehicle (HOV or carpooling) lane use, free parking and subsidized charging in some areas) have all helped accelerate this process. At the same time, abrupt removal of such incentives can result in a significant drop in PEV sales, as seen recently in the U.S. state of Georgia. This raises the question: Are the incentives, especially the subsidies, actually priming the pump or just creating a short-term bonus for customers?

Vehicle choice models, incorporating consumer heterogeneity, reveal that the marginal cost of subsidy for each additional PEV sale is high at more than $50,000. This is because everyone gets the subsidy, even those who might have bought the PEV without it. Even with a targeted subsidy, the marginal cost remains high at around $30,000 and the additional sales remain low. This suggests that money alone is not enough to boost uptake. Consumers want PEVs with better features and thus devoting resources to technology development rather than deployment may prove more cost-effective.

An additional complication is the tendency for policy discussions to be framed around the idea of a representative consumer. But, in reality, consumers are highly heterogeneous. Choice models incorporating consumer heterogeneity can help to quantify the gap between policy targets and sales driven purely by market forces. Such models can also help understand what consumers are likely to buy and identify cost-effective alternatives to nudge their behavior toward the intended direction. However, choice models based on aggregated demand data, i.e., models missing appropriate consumer heterogeneity, may not lead to useful results.

Consumer Receptivity Toward Plug-in Electric Vehicles

The U.S. PEV market seems to be in the innovator and early adopter phase of the adoption curve. For the market to evolve and reach the early majority, it needs to 'cross the chasm' of price and practicality issues. Recent survey studies suggest the fraction of consumers considering PEVs has not changed much over the last three years. Perhaps the PEV market has already tapped out the environment friendly, technology savvy, innovators. Hopes of breaking into the early majority segment of the market may not be realized as awareness and knowledge levels also appear to be increasing rather slowly.

For example, the majority of recent survey respondents say that they do not have any actual experience driving PEVs. Yet they are willing to offer explanations for why they have excluded PEVs from their consideration set, hinting at either a lack of knowledge or misunderstandings about the vehicle's features and specifications. For most consumers, however, a small amount of information or anecdotal evidence may be enough for them to decide to filter out alternatives from their consideration set. This is consistent with the theory on the use of heuristics by consumers to lessen the burden of decision making.

It does, however, raise the question of how to get more consumers to try PEVs, so that their opinion might change based on the experience of driving or riding in one. For example, PEVs' lively acceleration often surprises uninitiated drivers and PEV owners often report driving a PEV as 'fun', at least in city traffic. Nonetheless, concerns around driving range, recharging time, charging infrastructure, value for money and highway performance represent genuine barriers to PEV adoption. Thus, the majority of consumers exclude PEVs from their choice set without serious, informed consideration.

To encourage adoption, the current policy approach is to set targets for automakers and create short-term incentives for consumers. The aim is to reach a point where automakers can achieve economies of scale and adoption becomes organic and self-sustaining without the support of incentives. However, this is very challenging in a highly differentiated market where a wide variety of vehicles are available to fit the specific needs of a highly heterogeneous set of consumers. There is limited diversity of PEV models, which in itself can limit consideration for many different types of consumers.

Maintaining legitimacy for policies requires that the burdens imposed appear reasonable and time-bound. It is, therefore, important to understand the timelines and costs required to achieve specific policy objectives and whether the benefits will outweigh the costs. A related question is whether similar target levels of decarbonization could be achieved over a similar timeframe by other policy prescriptions.

Cost-effective Decarbonization of Light-Duty Vehicle Sector

At the global level, transportation accounts for 14 percent of GHG emissions. But in the U.S., this is a quarter of the total, two-thirds of which come from LDVs. The GHG emissions from the LDV sector depend on four factors:

- Vehicle miles traveled (VMT).
- Vehicle size and weight.
- Vehicle efficiency.
- Vehicle fuel type.

Policymakers have proposed and tried different tools that affect behavioral changes related to each of the four factors. These policies include carbon taxes, fuel duties, renewable fuel and low carbon fuel standards, and fuel economy standards.

Besides GHG emissions, there are other social costs arising from the use of LDVs for personal mobility including local air pollution, congestion and accidents. An important question arises: What level of emissions reductions do these different policy tools achieve and what is the social cost associated with them?

Current U.S. federal government policy relies on fuel tax, fuel economy standards and renewable fuel standards. A recent study suggests that this policy mix leads to approximately 8 percent decarbonization at a CO2 abatement cost of around $44/ton. A carbon tax alone could be expected to achieve similar decarbonization at a lower cost – around $15/ton. The carbon tax also performs well when one considers the social costs and damages associated with pollution, congestion and accidents.

Carbon tax performs better because it reduces emissions by driving improvements in all four factors by incentivizing:

- Reductions in VMT.
- Adoption of smaller, lighter vehicles.
- Higher fuel economy.
- Alternative energy carriers/fuels.

In addition to reducing GHG emissions, lowering VMT also results in less pollution and congestion and fewer accidents. However, a decline in VMT or personal mobility can result in slower economic growth, given the known correlation between the two. Even after accounting for the opportunity cost associated with less driving, a carbon tax remains the more efficient economic choice for the extent of decarbonization (about 8 percent) achieved.

Concerns about whether a carbon tax disproportionately burdens the poor relative to the rich can be handled. Carbon and other energy taxes need not be regressive if the resulting revenues are used to reduce other forms of taxation or fund welfare distributions. Other policy tools such as standard based regulations also have distributional impacts and costs associated with them. They usually cost more than a simple carbon tax ($44/ton for current policies versus $15/ton for carbon tax) but their costs are opaque and harder to assign.

Low to medium levels of decarbonization may result in a carbon tax being the lowest cost solution. However, deep decarbonization of transport and mobility may not be achieved at any acceptable level of carbon tax. Consider a thought experiment in which the target is to reduce consumption of

carbon emitting fuels to half of today's levels. To achieve that, one would need to charge a much higher price for oil products to the consumer – perhaps higher than the equivalent of $200/bbl of crude oil. This level is based on the observation that prices of $150/bbl did not do much to reduce oil consumption in the last decade. Lower demand would put downward pressure on oil prices. But, to reduce production significantly, oil prices may need to fall below $20/bbl. After all, prices at $30/bbl did little to choke off production.

A $150-200 gap between the price received by producers and the price paid by consumer is equivalent to around $400/ton of CO2, a price that is probably not politically palatable at nearly 10 times the costs of current policy prescriptions. Of course, oil importers hope that substitute technologies, such as PEVs, will cap this cost but there is still a long way to go. Recent studies estimate CO2 abatement costs of innovative PEVs at more than $500/ton of CO2, even at high sales volumes. It cannot be assumed that innovation in LDV powertrains alone will prove to be the most cost-effective solution for achieving deep decarbonization.

A radically different paradigm of personal mobility led by the shared use of automated, highly fuel efficient vehicles could be a viable path to deep decarbonization. Nonetheless, this might require policy interventions to prevent congestion and mass transit decline, two of the likely counterproductive effects of such automation. The future will certainly happen, but what future? There are several ways to decarbonize oil at less than a quarter of the implied carbon tax level estimated above. It is not an accident that gasoline and diesel have a near monopoly on fueling LDVs – the energy density and convenience of the existing fuels will be hard to dislodge. To succeed, PEVs will need to provide a superior customer experience at a lower price point while delivering the collateral benefit of decarbonization.

About the Workshop

KAPSARC convened a workshop in April 2017 in Washington D.C. with more than 35 international experts to understand the demand for fuel-efficient and plug-in electric vehicles from the consumer's perspective. Specific attention was given to the consumer valuation of fuel economy and PEVs; drivers and barriers to PEV adoption; and cost-effective strategies for achieving deep decarbonization. The workshop was held under a modified version of the Chatham House Rule in which participants consented to be listed below. However, none of the content in this briefing can be attributed to any individual attendee.

Soren Anderson – Associate Professor of Economics, Michigan State University

Prateek Bansal – Research Associate, Cornell University

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Jim Burkhard – Chief Researcher, Global oil markets and energy scenarios, IHS Markit

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Jessica Daniels – Environmental Protection Specialist, U.S. Environmental Protection Agency

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Nancy Homeister – Manager, Ford Motor Company

Dana Jackman – Economist, U.S. Environmental Protection Agency

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Rebecca Lindland – Senior Director, Executive Analyst, Kelley Blue Book

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James Miller – Deputy Division Director, Energy Systems, Argonne National Laboratory

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About the Workshop

Elena Pravettoni – Senior Economist, IHS Markit

Julia Rege – Director, Environment & Energy, Association of Global Automakers

Tamara Sheldon – Assistant Professor of Economics, Darla Moore School of Business, University of South Carolina

Daniel Sperling – Professor and Founding Director of the Institute of Transportation Studies (ITS-Davis)

Tom Stephens – Principal Transportation Systems Analyst, Argonne National Laboratory

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About the Team

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Rubal is a senior research associate at KAPSARC leading vehicle regulatory policy and shared mobility research using the consumer perspective. He holds a Ph.D from KAUST, KSA, a M.S. degree from the University of Pennsylvania, U.S. and a B.Tech degree from IIT Roorkee, India.

David Bunch

David is a visiting researcher at KAPSARC and a professor in the Graduate School of Management and the Institute for Transportation Studies at the University of California, Davis. He has consulted on transportation policy issues for state and federal agencies, public utilities and the airline industry. He holds a Ph.D in Mathematical Sciences from Rice University, Texas.

Tamara Sheldon

Tamara is a visiting researcher at KAPSARC and an assistant professor of economics in the Darla Moore School of Business at the University of South Carolina. Her research interests include environmental and energy economics and how these fields interact with public policy. She holds a Ph.D in Economics from the University of California, San Diego.

About the Project

The workshop series Drivers of Transportation Fuel Demand provides a forum for discussing key sustainability issues in transportation and current policy strategies to address them. In particular, much emphasis is placed on the adoption of fuel-efficient and alternative-fuel vehicles for road transportation, innovation in fuel and vehicle technology mixes and the shift from road to other modes of transportation.

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