An All-Hands-On-Deck Approach to Address Lifecycle Emissions
About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia’s energy sector and inform global policies through evidence-based advice and applied research.

This publication is also available in Arabic.

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Key Points

Increasing demand for mobility will result in an increase in energy consumption and emissions from transportation. Governments worldwide are implementing regulations and policies to reduce vehicle tailpipe emissions, such as tailpipe CO₂ emission standards, zero-tailpipe-emission vehicle mandates, and tailpipe criteria pollutant emission regulations. Historically, transportation technology and policy have been evaluated based on exhaust emissions; however, ignoring those emissions generated during fuel and vehicle production, distribution, and disposal in favor of zero-tailpipe-emission technologies in the future could have unintended consequences.

- Lifecycle assessment (LCA), a holistic approach that considers the entire emission lifecycle, is necessary to assess the various transport technologies and fuel options.

- While zero-tailpipe-emission vehicles such as battery electric vehicles (BEVs) have gained traction, it is not feasible to replace fossil-fuel-based transportation immediately. Therefore, improving the efficiency of internal combustion engines and the hybridization of those vehicles running on fossil fuels can bring about an immediate reduction in emissions.

- Renewable synthetic e-fuels have the potential to provide a sustainable alternative to fossil fuels in the long term, as these e-fuels are produced using renewable energy sources. e-Fuels also have the benefit of being compatible with existing internal combustion engine vehicles (ICEVs) and fossil fuel infrastructure, making them both scalable and cost effective.

- A combination of short-term efficiency improvements and long-term transition to renewable synthetic fuels could be a viable pathway through which to achieve the decarbonization goals of the transportation sector.

- A holistic approach that considers the entire lifecycle of emissions and is technology neutral is crucial to achieving a reliable, affordable, and sustainable vision for the transportation sector. Policies that focus on technology elimination rather than emissions may prove to be costly.
Demand for transportation is increasing as the global population and economy continue to grow. It is anticipated that this increase in demand for mobility will lead to a rise in transport energy consumption, thus resulting in higher emissions. As a result, governments worldwide have introduced regulations and policies to lower vehicle tailpipe emissions. These regulations include tailpipe CO₂ emission standards, zero-tailpipe-emission vehicle mandates, and emissions regulations related to tailpipe criteria pollutants. As a result, there has been an increase in the adoption of zero-tailpipe-emission vehicle technologies, including battery electric vehicles (BEVs), in recent years.

Historically, the performance of transportation technology and policy has been evaluated based on tailpipe emissions, which take into account only those emissions generated during vehicle operation. This approach, however, does not account for those emissions generated during the production, distribution, and disposal of fuels and vehicles, known collectively as cradle-to-grave emissions. Consequently, there is a growing awareness of the need to assess the environmental impact of various transport options holistically, taking their entire lifecycle into account. This method, known as lifecycle assessment (LCA), provides a more thorough understanding of the environmental impact of transportation and allows policymakers and industry stakeholders to identify and prioritize low-emission technologies and fuels based on their overall environmental performance. By adopting a cradle-to-grave approach to emission assessment, we can ensure that the transportation sector is moving toward solutions that are sustainable and have a low level of emissions throughout their entire lifecycle.

Furthermore, despite the ongoing shift toward zero-tailpipe-emission vehicle technologies, liquid fuels are anticipated to remain the dominant source of energy for the transportation industry for the foreseeable future. The reason for this is the existing infrastructure, the low cost and high energy density of liquid fuels, and the convenience they provide for long-distance travel. Despite efforts to increase the use of zero-tailpipe-emission vehicles, liquid fuels such as gasoline and diesel may continue to play a significant role in powering cars, trucks, ships, and planes, especially in developing countries, where access to alternative fuels and technology is limited. To achieve global climate goals, it is crucial to investigate ways in which to make liquid fuels more sustainable and reduce their environmental impact.

Thus, to achieve the decarbonization goals of the transportation sector, it is essential to explore an all-hands-on-deck approach to reduce greenhouse gas (GHG) emissions. While zero-tailpipe-emission-producing BEVs have gained traction in recent years, it is not feasible to completely replace fossil-fuel-based transportation in the short term. Therefore, improving the efficiency of internal combustion engines and the hybridization of vehicles running on fossil fuels can provide an immediate reduction in emissions. Moreover, the amount of lifecycle GHG emissions of BEVs can vary significantly based on the power generation profile of the region. In regions where the electricity grid relies heavily on coal-based fossil fuels, for example, the production of electricity can result in a significant amount of GHG emissions, which may outweigh the emissions savings from operating BEVs. In regions where the electricity grid relies heavily on renewable energy
sources, however, the amount of GHG emissions associated with BEVs can be substantially lower than those of internal combustion engine vehicles (ICEVs). As shown in Figures 1 and 2, the GHG mitigation potential of BEVs in India and China is location dependent. Specifically, a comparison of BEVs and ICEVs in India indicates that BEVs have the potential to reduce GHG emissions by 40% in the northeastern states but to emit 15% more in the eastern and western regions (Figure 1). Similarly, the GHG emission intensity of BEVs is found to be greater than that of HEVs in 19 of China’s 31 provinces (Figure 2). Finally, when evaluating the environmental impact of BEVs and determining the most effective policies through which to promote sustainable transportation, it is essential to account for their total lifecycle emissions, including production and charging emissions, as well as the regional power generation profile.

Figure 1. GHG emission reduction potential of BEV models relative to their ICEV counterparts at the regional level in India.

Source: Abdul-Manan et al. (2022).
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Figure 2. Comparison of well-to-wheel GHG emission intensities between BEVs and ICEVs at the provincial level in China.

In the long term, renewable synthetic fuels such as e-fuels also have the potential to act as a sustainable alternative to fossil fuels. By being produced using renewable energy sources such as wind and solar power, these fuels can significantly reduce GHG emissions compared to conventional fossil fuels. Recent research from the U.S. Argonne National Laboratory indicates, for example, that an HEV fueled by e-fuel produced using renewable energy has the potential to achieve comparably lower levels of GHG emissions as those of a 400-mile BEV powered by decarbonized electricity, as depicted in Figure 3, while costing the same on a levelized cost of driving basis, as shown in Figure 4. Additionally, renewable synthetic fuels have the benefit of being compatible with existing ICEVs and fossil fuel infrastructure. Unlike alternative fuel vehicles such as BEVs or hydrogen fuel cells, which require new vehicle designs and infrastructure, e-fuels can be used in conventional ICEVs without significant modifications. Moreover, unlike BEVs, which rely on critical metals such as lithium, cobalt, and nickel for battery production, ICEVs powered by e-fuels are not as constrained by supply chains and price volatility concerns related to critical metals.
Figure 3. GHG emission intensity for various vehicle-fuel technologies under current and future scenarios. For more details, refer to Kelly et al. (2022).

Figure 4. Levelized cost of driving for future vehicle-fuel technology combinations. For more details, refer to Kelly et al. (2022).
This finding indicates that e-fuels can provide a scalable solution to reduce GHG emissions from transportation without requiring expensive and time-consuming infrastructure upgrades. Moreover, e-fuels can provide a solution for difficult-to-electrify sectors, such as the aviation and shipping sectors, where liquid fuels are essential due to their high energy density and long-range capabilities. Consequently, e-fuels are attracting attention as a viable option for decarbonizing the transportation sector while maintaining the existing infrastructure and ensuring energy security. Therefore, a combination of short-term efficiency improvements and the long-term transition to renewable synthetic fuels also appears to be a viable pathway through which to achieve the decarbonization goals of the transportation sector.

In conclusion, satisfying the growing demand for transportation energy worldwide while simultaneously lowering emissions must be accomplished in a reliable, affordable and sustainable manner. The realization of such a vision is dependent on taking an approach that is both comprehensive and all-inclusive and that is underpinned by a transportation policy that is neutral regarding the underlying technology and based on LCA. It is possible that policies that choose winners and losers by concentrating on the elimination of technologies rather than on emissions may prove to be expensive.


APSARC hosted a webinar titled “Future of Mobility: An All-Hands-On-Deck Approach to Address Lifecycle Emissions.” In this webinar, experts from Argonne National Laboratory, a research center affiliated with the U.S. Department of Energy, from industry, i.e., Aramco Americas, and KAPSARC, an advisory think tank, discussed a multitechnology, multifuel approach to addressing lifecycle carbon emissions from the passenger car sector, as well as the cost-effectiveness of some of the current policy instruments. More than 150 individuals from diverse backgrounds, including government agencies, regulatory authorities, academia, the automotive industry, think tanks, and consulting firms, attended the webinar.
About the Team

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Rubal is a research fellow at KAPSARC working on vehicle regulatory policy and shared mobility research from the consumer perspective. He holds a Ph.D. from KAUST, Saudi Arabia, an M.Sc. from the University of Pennsylvania, and a B.Tech. from the Indian Institute of Technology, Roorkee.