Green Mobility in Texas: Comparative Environmental Impacts and Lifecycle Cost Analysis of Hybrid, Electric, and Hydrogen Fuel Cell Cars

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Comparing Hybrid, Electric, and Hydrogen Fuel Cell Cars

Compared to gasoline/diesel cars and battery electric cars (BECs), hydrogen fuel cell cars (HFCCs) are relatively new. Two main advantages of HFCCs over electric vehicles are no special requirements for heavy battery and long charging time. There is no HFCC in Texas; thus, exploring the use of electricity or hydrogen produced from renewable energies for personal cars and mitigating vehicle emissions is critical for sustaining a long-term decarburization strategy for megacities like Houston and Dallas under different energy scenarios. The proposed project would address this critical gap and develop environmental impacts and cost assessments for hybrid cars, BECs, and HFCCs in Texas under several possible energy scenarios from now to 2040 using some tools of lifecycle assessment (LCA) and lifecycle cost analysis (LCCA). The carbon footprint of BECs and HFCCs will be determined with respect to the transport, logistics, and supply chain sectors. A new lifecycle cost model for BECs and HFCCs will be designed with the consideration of some uncertainties of renewable resources and vehicle demands. Faculty working on this research will integrate LCA as an important focus area for all senior and graduate-level civil and environmental engineering courses. These students will also be introduced to the techniques of well-to-wheel analysis and production cost evaluation for renewable energy-powered vehicles.

Problem Statement

Transport consumed about 26% of all energy in the U.S. in 2020, and its emissions strongly influence air quality. As the second-largest state in the U.S., Texas has nearly 314,000 miles of roads and highways, more than any other state. On the other side, Texas is the NO.1 generator of renewable energies, including solar and wind power, accounting for one-fourth of the total renewable energies in the U.S. It was estimated that Texas' population might double by 2050, to more than 54 million, thus causing more air pollution through people's commuting with conventional cars. Green mobility targets to reduce air pollution from transport and to address climate change through mitigation and adaptation of modern vehicle technologies, such as hybrid powertrain, vehicle electrification, and fuel cell. A hybrid car combines one electric motor with a gasoline/diesel engine to drive the wheels, and its power system recaptures energy via regenerative braking, thus improving fuel efficiency. Battery electric cars (BECs) and hybrid electric cars are generally perceived as clean alternatives to conventional cars, and BECs are even marketed as "zero-emission" because of their null tailpipe emissions. Hydrogen fuel cell cars (HFCCs) are zero-emission vehicles that emit water vapor and warm air, and HFCCs are more efficient than conventional internal combustion engine vehicles. Similar to the refueling of conventional cars, HFCCs can be fully refueled in minutes. However, BECs are usually recharged in several hours, and some BECs can be recharged up to 80% in less than one hour in a fast charging mode. As the market of BECs has been increasing dramatically in recent years, future developments in the electricity sector need to be considered by decision-makers by including them in lifecycle background databases. Similar things would happen to HFCCs when the cost of electricity generated from solar or wind farms is low enough to produce cost-competitive green hydrogen with gasoline. Green hydrogen, unlike the more common gray or blue hydrogen produced from nature gas, is generated from renewable resources such as wind, power, solar energy or biomass. Thus, exploring the use of electricity or hydrogen produced from renewable energies for personal cars and mitigating vehicle emissions are critical for sustaining a long-term decarburization strategy for megacities like Houston and Dallas under different energy scenarios. To the best of our knowledge, there is no such a principal study of BECs and HFCCs conducted for Texas, although there were some studies in Canada and California.

Objectives

The overall goal of this study is to evaluate the environmental impacts and cost of the wide use of BECs and HFCCs in Texas' transportation by

conducting LCA and LCCA under different energy scenarios in the future.

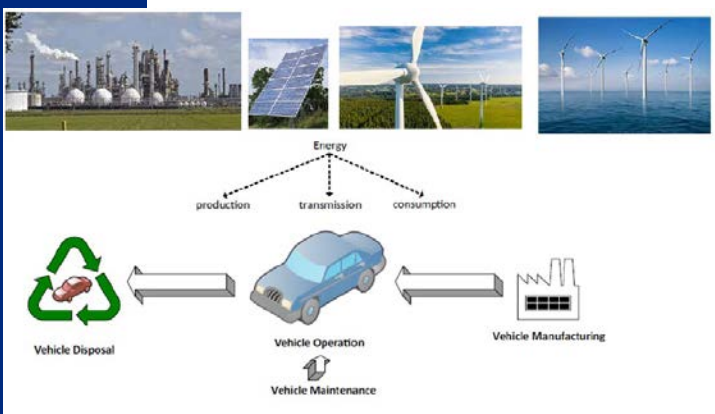

Figure 1. The system boundary of LCA and LCCA

Intended Implementation of Research

The research team will work with the university's existing research and outreach programs and coordinate educational offerings on renewable fuel applications in transportation for minority and underrepresented students in STEM disciplines. It will also contribute toward the integration of LCA and LCCA as an important focus area for all senior-/graduate-level civil and environmental engineering courses. Civil engineering graduates would be introduced to the concept of well-to-tank and well-to-wheels analytical techniques to assess environmental impacts associated with vehicle fuel production and transportation infrastructure.

Anticipated Impacts/Benefits of Implementation

The proposed project would address the key gap in data about the future wide use of BECs and HFCCs in Texas, the largest State in Region 6, and conduct a comprehensive LCA and LCCA for electricity use and environmental impacts of BECs and HFCCs in Texas' transportation. The results from the proposed project would allow for a comparative assessment of hybrid cars, BECs, and HFCCs, and provide valuable insights for future expansions of car recharging stations and hydrogen refueling stations in Region 6. These results would be provided to stakeholders and community leaders in Texas to increase technical awareness and promote sustainable growth of Region 6's transportation. Enhancing the sustainability of the existing infrastructure of highways and urban roads and contributing to an overall improvement in the environmental footprint of this region is the key contribution from the proposed project. The research will also help clarify when or even why the state governments in Region 6 would adopt a subsidy policy of hydrogen refueling stations to implement the expansion of HFCCs and forecast its impact on the HFCCs market.

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.