Modeling the economic, oil security and carbon footprint of alternative vehicles in the APEC region to 2035

Luke H Leaver, Asia-Pacific Energy Research Centre, (+81)3-5144-8545, leaver@aperc.ieej.or.jp
Ralph D Samuelson, Asia-Pacific Energy Research Centre, (+81)3-5144-8545, samuelson@aperc.ieej.or.jp

Overview

APEC economies are promoting alternative vehicle technologies and alternative fuels as a means to reduce oil consumption and improving energy efficiency while reducing greenhouse gas emissions (APEC, 2011). While the use of alternative fuels has the obvious benefit of replacing oil use, the impact of alternative fuels on CO_2 emissions is less obvious. This is because the emissions from fuel production for specific alternative fuels, such as hydrogen and electricity, must be considered. Therefore, the difference in emissions between vehicle technologies depends on both the efficiency of the vehicle itself (the energy use per km) and the emissions intensity of its fuel (emissions per energy unit).

An important obstacle to the adoption of alternative vehicles is consumer acceptance of higher upfront costs in return for later fuel-cost savings over the vehicle life. Research suggests consumers weigh the upfront vehicle capital cost more heavily than the potential lifecycle fuel savings in their decision-making (Hidrue et al., 2011). This finding implies that discount rates in relation to consumer choice are high which may inhibit the adoption of alternative vehicles.

Four scenarios are used to assess the merits of four alternative vehicles, with their benefits in the form of reducing oil use and CO_2 emissions compared to their increased capital investment cost. The four scenarios examined are defined as follows:

- Hyper Car Vehicle Transition – This scenario assumes market acceptance of ultra-light weight carbon composite vehicles employing hybrid power trains, advanced aerodynamic design and low rolling resistance, powered by an oil product-fuel internal combustion engine.
- Electric Vehicle Transition – This scenario assumes market acceptance of battery electric vehicles with a range of 320km per recharge.
- Hydrogen Vehicle Transition – This scenario assumes market acceptance of hydrogen fuel cell propulsion using an electric power train.
- Natural Gas Vehicle Transition – This scenario assumes market acceptance of conventional internal combustion vehicles adapted to run on compressed natural gas.

Methodology

We utilize the APERC (Asia Pacific Energy Research Centre) fleet accounting transport model to calculate the change in fuel consumption as a function of the change in macroeconomic indicators as well as the change in vehicle retirements, travel, fuel economy, technology and ownership per capita.

In each of the four scenarios, we assume sales of new alternative vehicles increase incrementally from our business-as-usual case, starting in 2013, and rise to a market share 50 percentage points above our business-as-usual (BAU) case by 2020 and thereafter. For example, if the market share of natural gas vehicles is 5% of new vehicle sales in 2020 in the business-as-usual case, the share of natural gas vehicles would be 55% of new vehicle sales in 2020 in the Natural Gas Vehicle Transition scenario.

The market share of new conventional vehicles in each scenario would be correspondingly reduced. To continue the example, if the market share of conventional vehicles is 90% of new vehicle sales in 2020 in the BAU case, it would be 40% of new vehicle sales in 2020 in the Natural Gas Vehicle Transition scenario. At the same time, the share of alternative vehicles other than natural gas vehicles remains the same in the Natural Gas Vehicle Transition scenario as it was in the BAU scenario. Note that, while the market share of the alternative vehicles in new vehicle sales levels-off at its maximum value by 2020, the actual number of alternative vehicles in the fleet does not level-off until some years later, reflecting the time required for all vehicles in the fleet in 2020 to be replaced.

These assumptions are not intended to be realistic depictions of how alternative vehicle technology might enter the marketplace. Given that it will take many years to implement new vehicle designs and fuelling infrastructures, the assumptions are probably quite unrealistic. However, the assumptions do have two advantages in an exercise designed to compare the merits of the vehicle technologies. First, the number of additional alternative vehicles in each year is always the same in all four cases, allowing an apples-to-apples comparison. Second, the planned transition to at least 50% alternative vehicles in the vehicle fleet can be almost entirely completed by 2035, the final year of this outlook period.

For consistent comparison and to avoid double counting of benefits, no additional use of renewable resources was assumed in any of the scenarios. Emissions from electricity production in the Electric Vehicle Transition were calculated from the marginal source of production simulated in each APEC economy. Emission from Hydrogen production reflected the emissions associated with hydrogen production using natural gas steam methane reforming.

Results

Reflecting its high fuel efficiency, the Hyper Car Transition has the highest potential for CO_2 emissions reductions in APEC economies. The reduction would be about 32% compared to BAU. Emissions reductions for the Electric Vehicle Transition were more modest but still a significant 7%. This more modest reduction reflects the conversion losses in producing electricity from fossil fuels and, in some economies, the use of carbon-intensive coal as a primary energy source. The Natural Gas Vehicle Transition offered a smaller CO_2 reduction of 6%, reflecting the slightly lower carbon intensity of natural gas compared to oil, although efficiency improvement prospects compared to conventional vehicles are lower. The Hydrogen Vehicle Transition actually increased CO_2 emissions, reflecting the losses in the two conversions involved (gas to hydrogen in the hydrogen plant, then hydrogen to electricity in the vehicle).

Conclusions

Meeting the twin challenges of energy security and climate change in the transport sector is a problem that will require multiple solutions. Vehicle technology changes alone will probably not be sufficient. We find that the most appropriate alternative vehicle technology to pursue is the Hyper Car in achieving credible reductions in both carbon emissions and oil use with an investment cost within lifecycle fuel savings.

Transitioning to Hyper Cars would be relatively easy to achieve compared to the other alternative vehicles. It would require no change in fuelling infrastructure and the vehicles would have a driving range and performance characteristics similar to conventional vehicles. Finally, we find that the economic and carbon pathways of alternative fuels such as hydrogen and electricity appear challenging. However electric and hydrogen propulsion offer a long-term path to a truly low-carbon light vehicle fleet.

References

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