Societal Lifecycle Cost of Hydrogen Fuel Cell Vehicles

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ABSTRACT

Among various fuel/propulsion options available, hydrogen fuel cell vehicle (FCV) stands out due to its zero emissions from vehicle operation. However, emissions from upstream processes of hydrogen, high fuel cell system costs and investments needed for hydrogen infrastructure in the early stages of a hydrogen transition are non-trivial issues for FCV commercialization. From a social welfare perspective, the crucial index for evaluating the alternatives is the **Societal Lifecycle Cost (SLCC)** over the full fuel cycle and vehicle lifetime, including not only consumer lifetime cost, but also external costs that are not priced in the current markets. We use the **Advanced Vehicle Lifetime Cost and Energy-Use Model (AVCEM)** developed by Dr. Mark Delucchi to study how the SLCC for hydrogen FCVs compares to that for reference gasoline vehicles. A learning curve model is employed to estimate fuel cell system cost changes with cumulative production under the USDOE scenarios for hydrogen and FCV market penetration from 2010 to 2025. During this transition period, we assume hydrogen is produced from onsite natural gas reforming. We further perform the sensitivity analysis regarding fuel cell system learning rate and externalities cost. Our results show that though consumer lifetime cost of hydrogen FCVs is higher than conventional gasoline internal combustion engine (ICE) vehicle, the externality cost of hydrogen FCVs is lower.

SOCIETAL LIFECYCLE COST

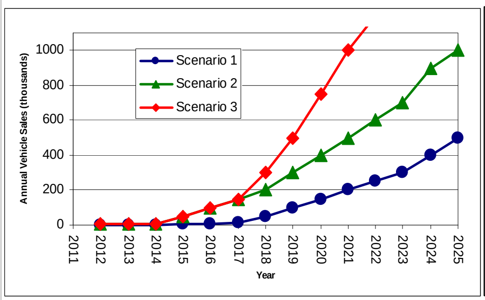
SLCC definition: sum of the present values of consumer lifetime cost and externalities costs over full fuel cycle and vehicle lifetime.

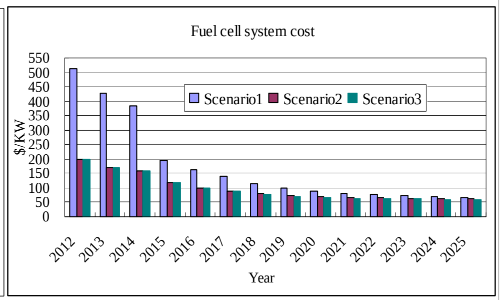
Consumer lifetime cost = vehicle cost + fuel cost + operation & ownership cost from the purchase to the scrap of a vehicle (i.e. over the whole vehicle lifetime).

Externalities cost = damage costs from air pollution, oil use (SPR, price-shock, wealth transfer, and water pollution), noise and Greenhouse Gas (GHG) emissions from full fuel cycle and vehicle operation.

Fuel cell system cost includes costs of membrane, GDL, electrode, bipolar plates, platinum, other peripherals, auxiliary subsystems (BOP), assembly and other vehicle-related electronics. Each cost item is calculated as a function of first unit cost C(1), cumulative production volume (N) and progress ratio (PR) with a lowest bound.

Learning curve model: $C(N)=C(1)*N^{\log(PR,2)}$, PR - Progress Ratio, PR=1-r, r - Learning rate (0.20 used in the figure below for major components);



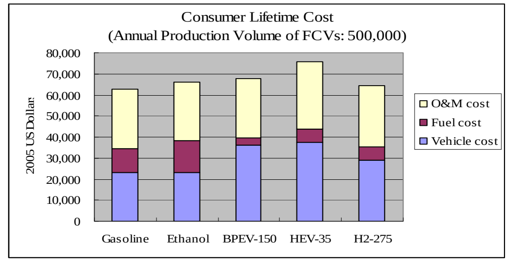


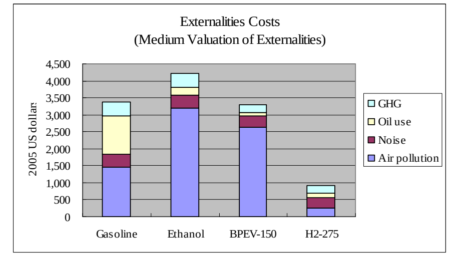
Air pollution data are from LEM model and the corresponding damage cost is scaled by relative contribution to air quality compared to that from vehicle operation in the urban areas of US. For GHGs damage cost, we use $5/tC, $16/tC, and $50/tC as low, medium, high valuations according to Tol's result from an assessment of 28 published studies on marginal cost of CO2 emissions.

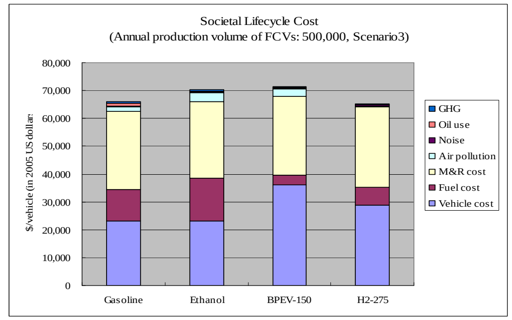
FUTURE WORK

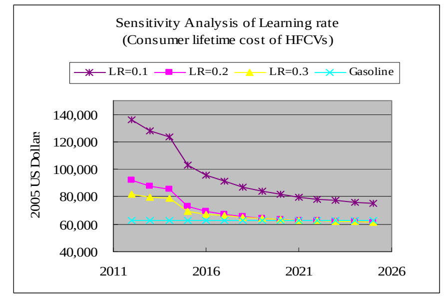
1. Refine fuel cell system cost estimate and upstream air pollution damage cost
2. Do regional analysis for buy-down cost estimate of Hydrogen Fuel Cell Vehicles

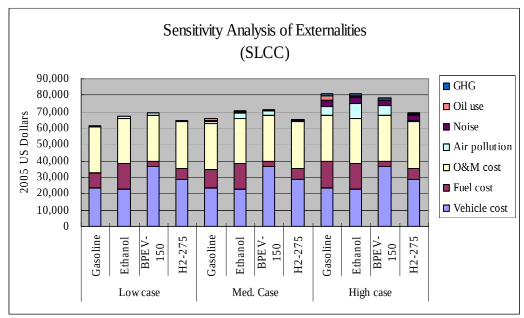
RESULTS

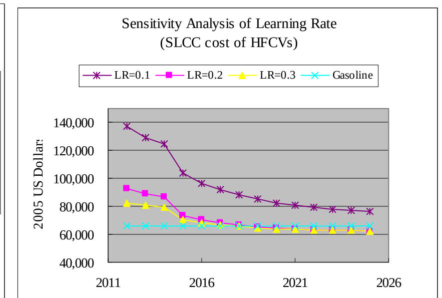












Notes: baseline gasoline vehicle: 1989 Ford Taurus with cost update to meet Tier-1 Standards; US grid mix for electricity generation (charging cost of EVs: 6¢/kwh); Gasoline price: $2.85/gal (high), $1.75/gal (low) and $2.05/gal (reference); FCV cost at annual production volume of 100: $142,000~$222,000; Ethanol vehicle: E90 with ethanol from corn.

CONCLUSIONS

1. When mass produced, consumer lifetime cost of Hydrogen FCVs is still higher than that of conventional gasoline internal-combustion-engine vehicles.
2. Hydrogen FCVs have lowest externalities compared to other alternatives.
3. Higher learning rate and higher valuation of externalities cost would make FCVs competitive with gasoline vehicles earlier on a SLCC basis.

MAIN REFERENCES

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