The Dynamics of the Zero Emission Vehicle Industry

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"Motor vehicles do not exist in isolation; they are part of a...system."[1]

Introduction

The Federal Clean Air Act of 1990 stipulates that states must meet certain air quality requirements during the decade of the 1990s and beyond, and that those states choosing to require the sale of Zero Emission Vehicles (essentially electric vehicles) to help meet the standards must follow the mandates put forth by the California Air Resources Board (CARB). CARB originally mandated that 2% of the vehicles offered for sale in California be zero emission in 1998, 5% be zero emission in 2001, and 10% be zero emission in 2003. Recently, however, CARB voted to ease the mandates such that, although 10% of the vehicles offered for sale in California must still be zero emission in 2003, automakers may decide for themselves how many ZEVs to sell in California before 2003. The mandates were relaxed because automakers convinced CARB that current ZEV technology cannot meet the needs of the mass consumer market. Massachusetts, however, has vowed to maintain the "2% in 1998" mandate, regardless of what California does.

The Issues

Proponents of electric vehicles argue that their adoption by the mass consumer market is important because they:

1. reduce air pollution in large cities.
2. help to foster energy independence (only 4% of United States electricity is generated via burning oil).
3. are more quiet than internal combustion engine vehicles (ICEs).
4. require <u>less</u> maintenance than ICEs.
5. are more reliable that ICEs.

Opponents argue that electric vehicles are doomed to failure because their:

1. batteries are too weak. The current crop of electric vehicles can only travel an average of 70 miles before needing to be recharged. This is thought by some to be far below the average daily driving needs of American consumers.
2. prices are too high. Electric vehicles will initially be priced twice as high as ICE vehicles due to their large production costs. ZEV production costs are high due to the need for light, yet strong, construction materials (which are relatively expensive), and the initial absence of economies of scale due to mass production.
3. maintenance costs are <u>higher</u> than for ICEs. If the cost of ZEV batteries is counted as being part of the vehicle's operating (fuel) costs, rather than as part of the vehicle's capital costs, maintenance costs are higher than for ICE vehicles. Whether it is appropriate to count battery costs as part of a ZEV's operating costs or capital costs is determined by battery life. Currently, ZEV batteries have average lifespans that are far shorter than the average lifespans of the ZEVs themselves. Thus, battery costs are counted as operating costs.
4. emissions are moved elsewhere, not eliminated. Although ZEVs themselves do not emit any pollution, additional electricity must be generated to charge them. If utilities are producing at capacity, they will have to restart older, dirtier, generating plants to recharge the ZEVs. This merely moves the source of air pollution from tailpipes to smokestacks.
5. discarded batteries will be a significant source of pollution. The emissions generated by the mining, smelting, and recycling of the lead for a large fleet of electric vehicle batteries will be hazardous.
6. recharging facilities (and other required electric vehicle infrastructure) are scarce. If consumers do not believe they will be able to recharge their ZEVs conveniently, they will not buy them.

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[1] Riezenman, Michael J. 1992. "Electric Vehicles: Special Report." <u>IEEE Spectrum</u> (November): 92.

In addition to these points, electric vehicle opponents argue that policies other than the mandates would be more effective at reducing air pollution. They point out, for example, that total air pollution from vehicles is a function of both the dirtiness of ICE vehicles and the number of ICE miles driven. Thus, one alternative tact would be to reduce the number of ICE vehicle miles driven via:

1. higher gasoline taxes.
2. higher parking fees.
3. car pooling.
4. telecommuting.
5. improved mass transit.

Another alternative tact would be to reduce the dirtiness of the motor vehicle fleet via:

1. using hybrid (i.e., "almost" zero emission) vehicles.
2. having the government buy-up old, dirty, ICE vehicles and having people replace them with new, clean, ICE vehicles.

One last issue is that there have been very few, if any, holistic analyses of the CARB mandates and their implications, and there have been no holistic model-based analyses of the mandates and their implications.

An Overview of the Model

Figure 1 presents a subsector overview of a system dynamics model of the motor vehicle industry and the zero emission vehicle problem. The model consists of nine interacting sectors: ZEV, ICE, Vehicle, ZEV Infrastructure, Utility, Pollution, Government, Gasoline, and Customer. The model can be modified and used from three different perspectives:

1. ZEV sector's perspective. From this perspective, a model user makes decisions for the ZEV sector in competition with the ICE sector.
2. Utility's perspective. From this perspective, a model user makes decisions for the utility sector in an effort to improve its profitability.
3. Society's perspective. From this perspective, a model user makes decisions for the government sector with an eye toward mitigating pollution problems.

Some Interesting Simulation Runs

Figure 2 presents some time series plots from a single simulation of the electric vehicle model. This simulation is based on two noteworthy assumptions. The first is that the "2% in 1998" mandate remains in effect (e.g., in Massachusetts). The second is that the model starts and remains in equilibrium throughout the simulation run, with the exception that emissions from new ICEs are substantially less than those of older ICEs. Inspection of the figure reveals that, although the number of ICE and ZEV owners stays the same over time, total metric tons of pollutants emitted, average emissions per old ICE, average emissions per new ICE, average emissions per total ICEs, and average emissions per total vehicles, all drop substantially due to the natural turnover of the ICE fleet. This is precisely what the opponents of ZEVs predict, although it clearly takes decades to drop average emissions to negligible levels.

Figure 3 presents another set of time series plots from a simulation of the electric vehicle model. In this run, the government institutes a policy of buying up 50% of the old ICE vehicle fleet in the year 2000. This policy change knocks the system out of equilibrium because the owners of ICE vehicles purchased by the government suddenly reenter the motor vehicle market and begin making new purchasing decisions. In the run shown in Figure 3 (given the model's parameters), customers begin buying relatively more electric vehicles after the policy change and, as a result, activate some of the system's positive feedback loops (e.g., a bandwagon or popularity effect). These loops eventually lead to the total dominance of the motor vehicle market by ZEVs. It is also clear from the figure that the changing mix of the motor vehicle fleet causes the total and average emissions created by the fleet to drop.

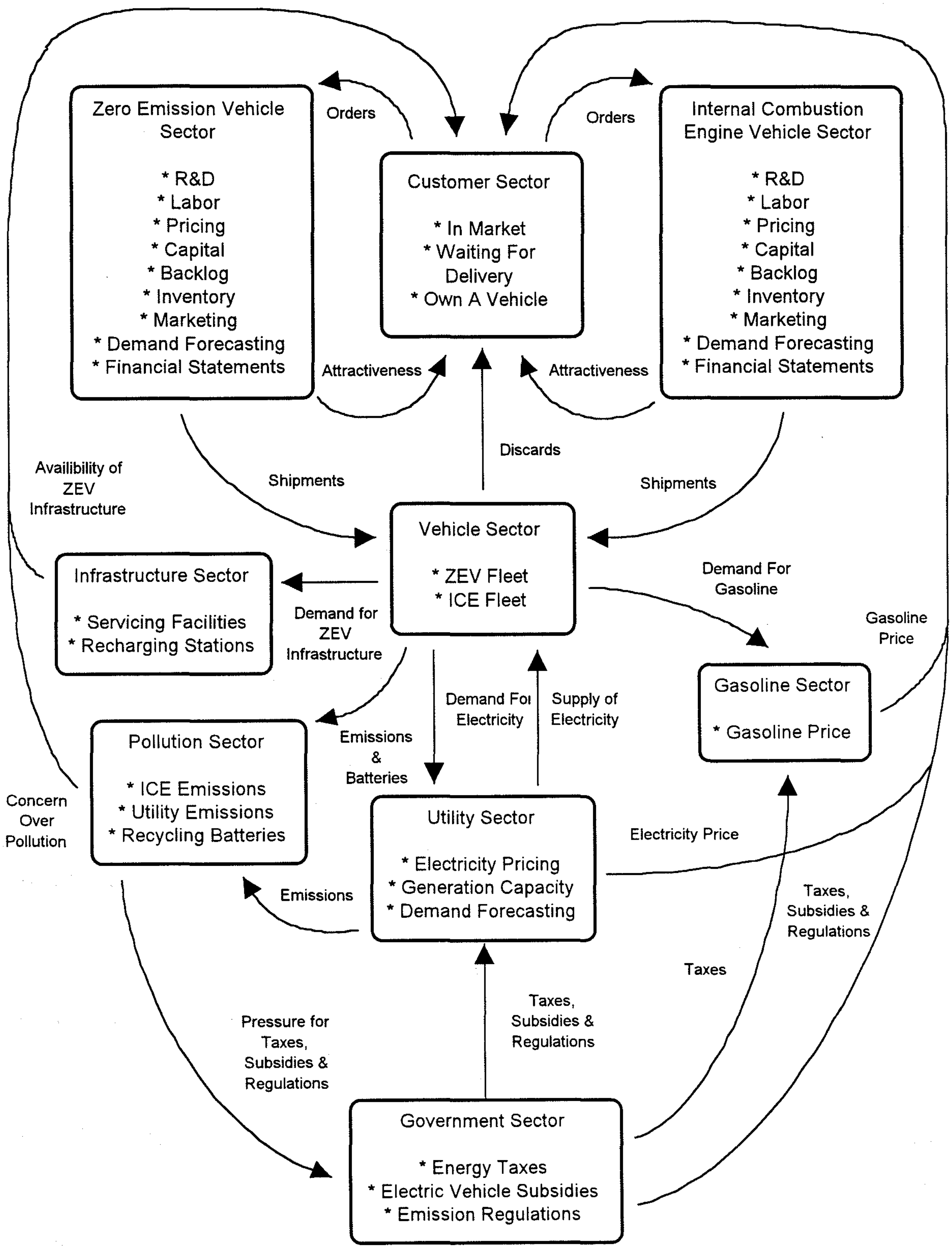

Figure 1: Subsector Diagram of the Electric Vehicle Model

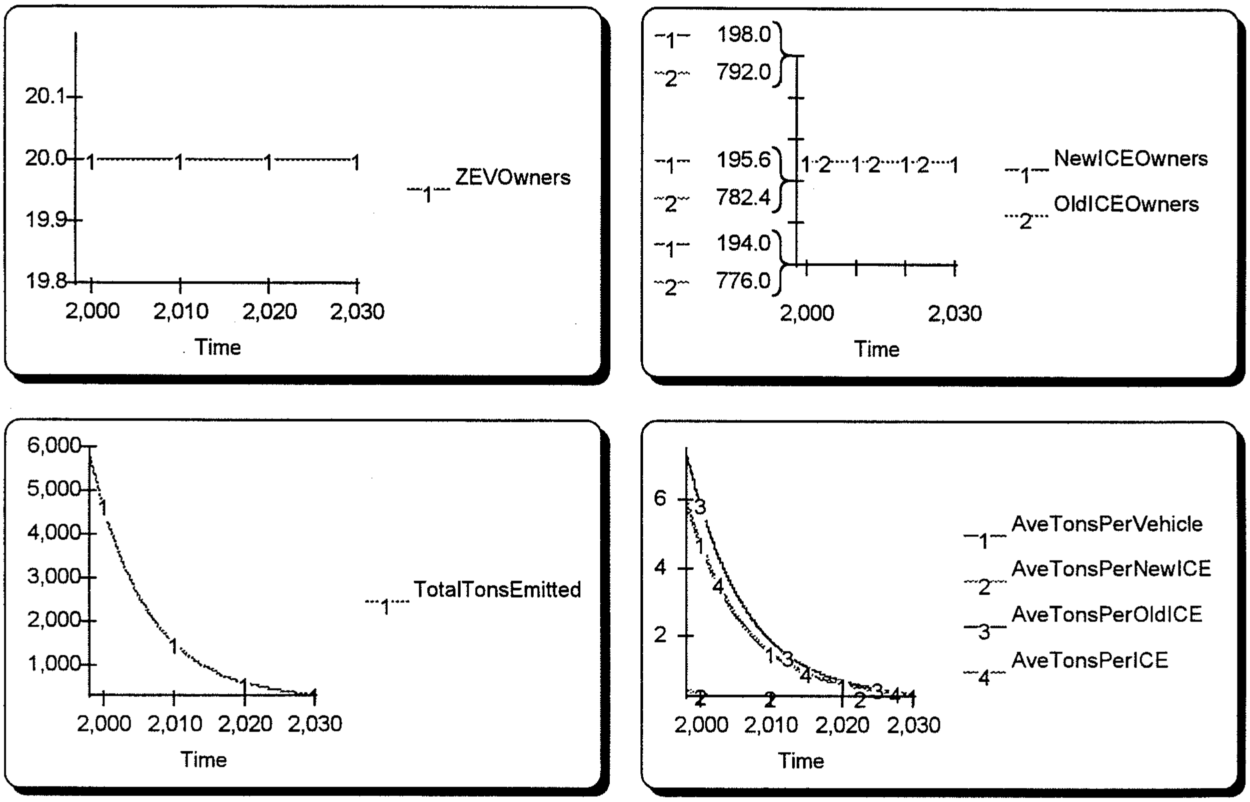

Figure 2: Time Series Plots of Selected ZEV Model Variables – Equilibrium Base Run

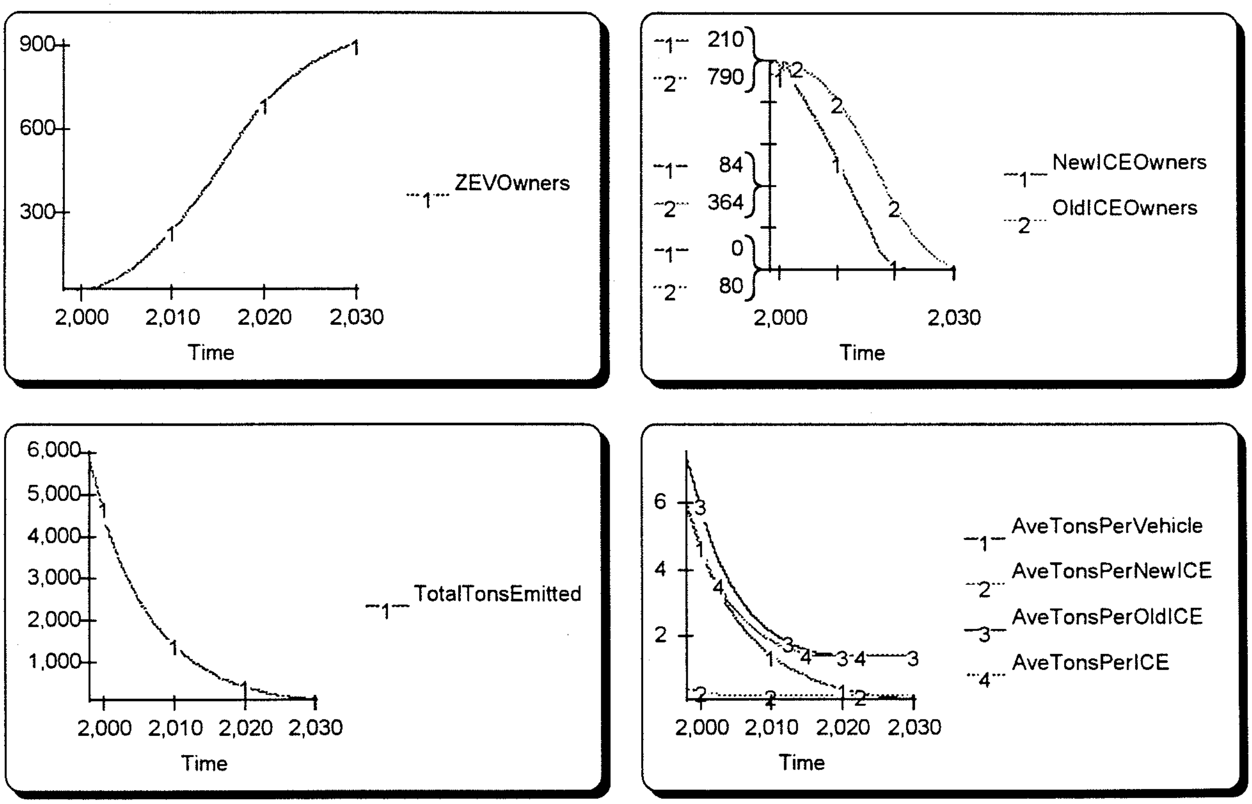

Figure 3: Time Series Plots of Selected ZEV Model Variables – Purchase of Old ICE Vehicles Run