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ANALYSIS

Public policy and the transition to electric drive vehicles in the U.S.: The role of the zero emission vehicles mandates

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ABSTRACT

Together with policies already in place, a transition to zero emission vehicles (ZEVs) could almost eliminate petroleum use by light-duty vehicles and meet U.S. CO_2 emission reduction goals by 2050. However, such a transition poses new challenges for public policy because of the time required, deep uncertainty, strong positive feedback effects, and regional and international interdependencies. An appropriate framework for evaluating public policy is cost/benefit analysis of alternative futures incorporating these elements. Using the same computer model used in a recent National Research Council study, the types, timing and intensity of public policy interventions likely to be necessary to accomplish a transition to electric drive vehicles in the U.S. are investigated, with special attention to the role of California's ZEV mandates. Strong, temporary policies addressing the coevolution of the vehicle and fuels markets appear necessary. Because uncertainty about the transition is profound, policies must adapt as learning reduces uncertainty.

1. Introduction

Transitioning to sustainable energy systems is an essential element of a sustainable global society [1,2]. As the world's vehicle population grows towards 2 billion, motorized transportation is challenged to contribute to protection of the global climate system, energy security and the elimination of the adverse health effects of local air pollution [3]. There is no single solution to these problems [4–6]. However, it is becoming increasingly clear that achieving sustainable transportation implies a large-scale transition from petroleum-based, internal combustion engines to zero emission electric drive [7].[1]

Bringing about a large scale energy transition to achieve public goods is likely to require a new paradigm for public policy. In the mid-twentieth century, the concept of externalities enabled a new understanding of the causes of environmental pollution and provided a paradigm for formulating efficient policy responses. A public policy paradigm appropriate for the transition to electric drive must incorporate the concepts of net social value [9], network external benefits (e.g., [10]), and adaptation to an uncertain future (e.g., [10–12]). An appropriate economic framework is cost/benefit analysis of alternative, path-dependent futures under deep uncertainty. Such an approach is very much in line with Coase's [13] analysis of the general problem of social costs.[2]

> "A better approach would seem to be to start our analysis with a situation approximating that which actually exists, to examine the effects of a proposed policy change and to attempt to decide whether the new situation would be, in total, better or worse than the original one." (Coase [13], p. 43)

Instead of comparing the current situation to a hypothetical alternative the large-scale energy transition problem requires comparing alternative futures.

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[1] The International Institute for Applied Systems Analysis' *Global Energy Assessment* [8] concluded that "In all pathways conventional oil is essentially phased out shortly after 2050. Every scenario that achieves the sustainability goals essentially eliminates petroleum use."

[2] Although Coase was arguing for the allocation of property rights as a more general solution to the problem of social costs than externality taxes, the reasoning applies equally well to the problem of an energy transition.

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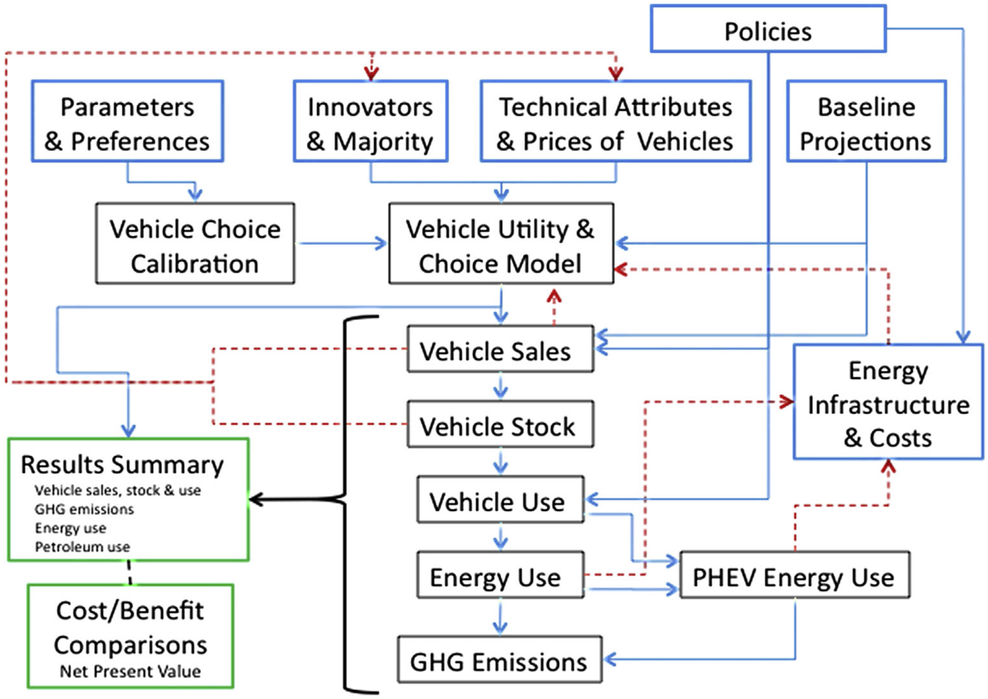

Fig. 1. Diagrammatic representation of the LAVE-Trans Model.

Discussions the authors have had with global automobile manufactures indicate that the most important policy motivating urgent action to develop electric drive vehicles and to sell them in the U.S. has been California's Zero Emission Vehicle (ZEV) mandates. The ZEV program was initiated in 1990 and has been reformulated several times since. Presently, it requires manufacturers selling motor vehicles in California and the "Section 177" states[3] to sell a mixture of vehicles with zero and "ultra-low" tailpipe emissions [14]. The regulations are complex and there are many ways for manufacturers to meet the standards. The latest ZEV regulations are intended to require that about 40,000 ZEVs plus plug-in hybrid electric vehicles (PHEV) be sold each year from 2015 to 2017, increasing to about 230,000 per year in 2025. The sales scenarios used to represent the ZEV mandates in this study are provided below in Table 3.

The model used in this study and its key assumptions are described in Section 2. The LAVE-Trans model estimates the light-duty vehicle sales by type of technology taking into consideration a variety of barriers to their success, as well as positive feedback effects, such as scale economies and learning by doing. It estimates the turnover of the vehicles stock, its usage, fuel use and emissions. An important feature of the LAVE-Trans model is the measurement of transition costs as a component of overall costs and benefits. Sections 3 and 4 present alternative scenarios of the transition to electric drive vehicle in the United States, as well as estimates of their costs and benefits. Section 5 explores the implications of uncertainty about technological progress and market behavior. The final section summarizes implications of the analysis for public policy. Many of the factors that are important to the transition process are not well understood (e.g., the numbers of innovators and their willingness to pay for novel vehicle technologies [15], the intensity and persistence of risk aversion of the majority of consumers, the cost of limited fuel availability, the cost of limited range and long recharging times, etc.).

In a summary paper such as this one it is not possible to fully explain the assumptions and methods of the analysis. However, detailed documentation of the LAVE-Trans model, data and scenario assumptions is available in NRC [7] and Greene et al. [16–18].

2. Modeling the transition to electric drive vehicles

The analyses of transitions to electric drive vehicles summarized in this paper were carried out using the Light-duty Alternative Vehicles and Energy Transitions (LAVE-Trans) model, the same model used in the U.S. National Research Council's study, *Transitions to Alternative Vehicles and Fuels* [7]. It represents consumers' choices among vehicle technologies, the effects of scale, learning and technological change on the costs and performance of vehicles, and the supply of energy for vehicles. Vehicle sales and refueling infrastructure are endogenously determined by economics, technology and policy. Manufacturers', fuel suppliers' and consumers' decisions are based on current conditions; LAVE-Trans does not model expectations. In general, the same version of LAVE-Trans used by the NRC is used in this study, the major difference being the division of the U.S. into two regions: 1) California and the Section 177 states and 2) the rest of the U.S. With a few exceptions, the data and parameter values of the NRC study [7] are used in all scenarios in this study.[4]

LAVE-Trans divides consumers into innovators/early-adopters (16%) and the majority (84%) (Fig. 1). Consumers' choices among drive-train technologies (internal combustion engine (ICE), hybrid electric (HEV), and plug-in hybrid vehicles (PHEV), battery electric (BEV) and fuel cell

[3] The Section 177 states are those that have adopted the California vehicle emissions standards (CT, ME, MA, RI, VT, NJ, NY, PA, DE, MD, AZ, NM, OR and WA).

[4] There are four exceptions. The level of cumulative sales at which innovators' willingness to pay for a novel vehicle technology is reduced to half its initial value reduced from 2 million to 1 million vehicles. Based on recent data, the fractions of plug-in vehicle buyers who also purchase 240v home chargers were reduced from 100% to 50% for battery-only vehicles and from 100% to 20% for plug-in hybrid buyers. The value of reducing CO_2 emissions is less than assumed in the NRC study and increases from $35/ton in 2010 to $65/to in 2050. Finally, benefits of reducing local air pollution, not included in the NRC study, were added.