An Interpretive Summary of the 1997 Asilomar Conference on Policies for Fostering Sustainable Transportation Technologies

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INTRODUCTION

Those taking part in the 1995 Asilomar Conference, "Is Technology Enough?" concluded that technology could provide sustainable transportation within the next two decades. That conference touched on most transportation sectors: both light and heavy duty highway vehicles, as well as rail freight and aircraft. The 1997 Asilomar Conference focused primarily on the nature of the technological opportunities in the light vehicle highway sector, and on the policies

needed to integrate those technologies into the transportation system to achieve the proper contribution of this sector to a sustainable transportation system. The conference addressed (1) what worked in the United States in the past (regulation of vehicle "criteria pollutant" emissions and fuel economy), (2) the recent and projected tendency of past U.S. progress in terms of reductions in emissions and fuel use to either slow down or be reversed, (3) the need to adjust priorities to reflect new concerns about previously unregulated emissions (global warming and fine particulates), and (4) how to get back to a situation where refocused desires for reductions in fuel use and emissions are achieved (for example, which is more effective, the recent European emphasis on pricing or the regulatory approach taken in the past in the United States?).

The term "sustainability" was not redefined or even argued in this conference, but it was noted that the term means different things to different individuals and organizations. One group saw sustainability as the need to assure an adequate flow of funds and investment to maintain a specified level of service in transportation. Another group -- the one predominating at this conference -- tended to see the operative system design objective differently; this group was interested in including measures to reduce the aggregate undesirable side effects of an ever-enlarging transportation system, even if that enlarging system provides each new user as good a level of transportation service as that for existing users. In short, from the perspective of the majority at the conference, if the per-unit-of-service rates of emissions and oil use remain the same, expanding use of the service will also increase both oil use and emissions: an "unsustainable" situation if it continues indefinitely. A significant fraction of those attending the conference would probably consider a "cap" on emissions and oil use from transportation insufficient; instead, they would like to see significant reductions from present levels.

T.R. Lakshmanan, Director of the Bureau of Transportation Statistics, offered the following definition from the Bruntland Commission: "Sustainable development is development that meets the needs of the present generations without compromising the ability of future generations."

The technologies and policies that received the most attention would provide per-unit-of-service reduction of three kinds of social costs (external costs, in economist's terminology) with respect to light duty transportation. The main factors to be reduced were oil use, greenhouse gases, and air pollution. Undesirable side effects of continually expanding transportation activity, including congestion and habitat loss, were also discussed. The conference included debate about priorities among these five categories of social cost, about which organizations should take action to achieve the reductions needed in each, and about what specific actions these organizations should take.

SPEAKERS AND ORGANIZATIONS REPRESENTED

Organizationally, the conference included speakers from industry, the federal government, state government, academia, public interest groups, and a consulting firm. Industry representation was from three manufacturers of light duty vehicles (R. Purcell and C. Sloane of GM, J. Beseda of

Toyota, and S. Wallman of Volvo), one firm that hopes to market an advanced technology to significantly improve the efficiency of vehicles and reduce their emissions (G. Ballard of Ballard), and one firm that provides fuel for present-day vehicles (T. Finizza of ARCO).

Federal government representatives came primarily from agencies and research institutions operating under the executive branch of U.S. government. The U.S. Department of Energy (DOE) provided, directly or indirectly (through national laboratories), David Greene and Paul Leiby of Oak Ridge National Laboratory, Larry Johnson of Argonne National Laboratory, Phil Patterson of the DOE Office of Transportation Technologies, and Barry McNutt of the DOE Office of Policy Planning and Analysis. Jonathan Rubin, coauthor with Paul Leiby and professor at the University of Tennessee, was also a representative of research done for DOE. The U.S. Department of Transportation was represented by T.R. Lakshmanan, Director of the Bureau of Transportation Statistics. Carl Nash, Adjunct Professor of Engineering at the George Washington University, and a retired executive from NHTSA, represented his own views. Howard Wesoky of the National Aeronautics and Space Administration (NASA) spoke on civil aeronautics R&D. Linda Lance of the White House Council on Environmental Quality and two multi-government representatives -- Lee Schipper and Stephen Peake from the International Energy Agency (IEA) -- also spoke.

Tom Cackette represented the regulatory experience of the California Air Resources Board (CARB), an organization considered by some to be as influential in determining air quality regulation as the U.S. Environmental Protection Agency (EPA), with legal authority independent of the EPA.

Academics contributing to the conference were Mark Delucchi, Dan Sperling, Tom Turrentine, and Robert Johnston of the University of California at Davis; Lester Lave of Carnegie-Mellon University; Charles Lave of the University of California at Irvine; and Genevieve Giuliano of the University of Southern California.

Public interest group representatives included John DeCicco of the American Council for an Energy Efficient Economy, Michael Cameron of the Environmental Defense Fund, and Don Chen of the Surface Transportation Policy Project. K.G. Duleep of the consulting firm Energy and Environmental Analysis also spoke.

Some of these speakers, and several other conference registrants representing a similarly diverse mix of organizations, also provided previously unscheduled comments during the "open-mike" portion of the conference. This session included 12 subjects, with 13 speakers.

AIR POLLUTION

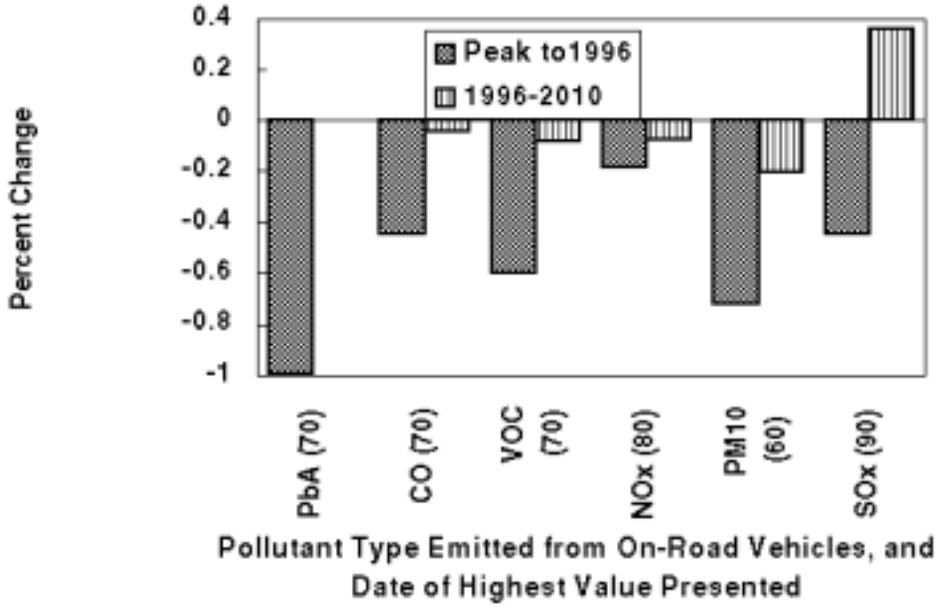
Among the three primary goals, reduction of air pollution provides one conceptual model for moving successfully toward a sustainability goal that includes the social costs of the

transportation system as a whole. Since the late 1960s, the per-unit-of-service emissions (grams per mile) from highway motor vehicles have been reduced dramatically in the United States. Consequently, air quality in U.S. cities has improved significantly, despite the sharp increase in use of highway motor vehicles.

Total annual national emissions from on-road mobile sources (highway vehicles) have dropped from 18 to 99%, relative to the estimated peak value, for pollutants of concern to the EPA (EPA 1995). At the start of the process of regulation, the "roll-back" method was used; emissions reductions were sought from all vehicles, largely regardless of location. However, because California acted earlier and more aggressively than the rest of the nation, that state was granted legal authority to do so in the initial Clean Air Act. Early on, large emissions reductions were possible and desirable nearly everywhere, and they could be had at low cost. This is no longer true in the United States, so cleaner fuels and advanced emissions control technologies increasingly tend to be introduced only in areas that need additional reduction to meet air quality standards. Localization and seasonal specificity for the rest of the country were introduced in the Clean Air Act Amendments of 1990, and the focus shifted further toward regulating the fuel as well as the vehicle. In the past few decades, sales of essentially the same type of lower-emissions vehicles occurred nationwide, regardless of need (or lack thereof), leading to emissions reductions everywhere in the nation. In the future, national annual emissions are not projected to change much for most pollutants (Fig. 1); future emissions control efforts will focus on those remaining metropolitan areas at or near "nonattainment" status, and only for the seasons in which the air quality violations tend to occur. Reformulated gasoline, for example, is required only in a limited number of locations, and different fuel requirements exist for winter and summer months.

T. Cackette related how the regulatory process had significantly improved air quality in California. He indicated that the process had changed from a highly adversarial one initially to a much better organized, professional interaction between the regulators and the regulated. He also said that progress had been made in the nature of regulations and that, aside from the California "zero emissions vehicle" (ZEV) requirement, regulations had moved from requiring individual technologies on individual vehicles to requiring aggregate system performance; the latter approach allowed more flexibility for manufacturers to choose the technology mix to provide the required performance. While acknowledging a degree of trial and error in the process, Cackette observed that the history of regulation shows that industry (1) is capable of doing more than it contends is possible when regulations are first proposed and (2) does what it says it can do at less cost. (In his comments, L. Lave acknowledged that CARB had done a good job of cleaning up the air in Los Angeles.)

Figure 1 Change in National Emissions for Criteria Pollutants, Reduction by 1996 Relative to the Prior Peak, and Projection from 1996 to 2010. (Source: EPA 1995)



Concern was expressed at the conference about the potential for conflict among the three goals of reducing oil use, greenhouse gas emissions, and air pollution. M. Delucchi (who has completed a 20-volume study on the social costs of the motor vehicle) and others voiced concern over contemporary interest in substitution of diesel for gasoline engines. This interest has involved both (1) the 3X fuel economy vehicle technology choice "neck down" of the vehicle design for the Partnership for a New Generation of Vehicles (PNGV) and (2) a shift in DOE research toward the development of advanced diesel engines for use in light duty motor vehicles. Those concerned expect that the net air pollution damages from increases of fine particulate matter from diesel engines will offset acknowledged benefits from reductions in oil use and greenhouse gas emissions.

The subject of trade-offs, and the need to deal with them, came up in the "open-mike" session. Delucchi coined the term "NPGV" (Negative Population Growth Vehicle) to express his concern over the diesel-for-gasoline engine trade-off. R. Kassel of the Natural Resources Defense Fund lamented that the lack of coordination in federal legislation (the Energy Policy Act of 1992 and the Clean Air Act Amendments of 1990) leads to setting goals that can be at odds with one another. He gave the example of diesel exhaust in Manhattan constituting one-half of the particulate matter there, so that the use of natural gas buses in that location is well worth the greenhouse gas increase involved. His point was that trade-offs should be recognized to exist and that mechanisms to allow the trade-offs to be made should be incorporated in integrated legislation and regulation.

The subject of trade-offs between other criteria pollutants and oil/greenhouse goals was also brought up. Beseda of Toyota indicated that the high-fuel-efficiency direct-injection gasoline engine technology introduced in Japan has high nitrogen oxides emissions by U.S. standards, and therefore it cannot be introduced here. She suggested that if Toyota were allowed to sell vehicles with an average amount of NOx emissions, then the company could introduce some direct-injection gasoline engines, so long as their other engines had overall NOx emissions rates below the specified standard. Beseda stated that Toyota's strongest suggestion to states, CARB, and the EPA is to allocate to automakers their fair share of (emissions or fuel consumption)

inventory reduction, and then to provide the maximum level of flexibility in meeting the overall requirement.

Beseda also mentioned the hybrid vehicle introduced by Toyota in Japan, and J. German of the EPA discussed it in the "open mike" session. According to German (who had visited Japan to learn about the vehicle), the technology can increase fuel economy by 80% in a Toyota Corolla body, all else being the same as in the gasoline counterpart. This vehicle, which apparently does not use direct-injection technology in its specially designed engine, can sharply reduce NOx, according to German. Sloane of GM indicated that the Toyota HEV had some "emissions problems," would not triple fuel economy (the PNGV goal for its advanced vehicle likely to use a diesel), and would not sell in the United States. German indicated that emissions from this vehicle were very low, that in a hybrid mode its Atkinson engine could get almost as much efficiency increase as a diesel, and that the use of the diesel by the PNGV would imply "emissions problems" due to particulate matter. He wondered why the PNGV wouldn't be better served to focus on this technological approach instead and yield a little on the fuel economy goal. L. Lave commented on the risk of developing an efficient vehicle that would not be acceptable in urban environments, arguing that one could distribute the vehicle widely, so long as one did so where there weren't any people.

S. Peake of the IEA cautioned that Delucchi's concerns with particulates may be overblown, and S. Wallman of Volvo asked "What problem are we trying to solve?" Wallman noted that Europe considers the CO_2 and fuel use issues to be top priority. Europe is already rapidly increasing the use of conventional diesel vehicles. L. Schipper, affiliated both with Lawrence Berkeley National Laboratory and with the International Energy Agency, listed rising particulate emissions in Europe and (in the event of increased U.S. use of the diesel) potentially rising particulate emissions in the United States as being among the remaining "Deadly Sins of Transport.

REDUCING CO_2 EMISSIONS AND OIL USE

Switching Fuels

T. Finizza (ARCO) discussed ARCO's aversion to methanol, arguing that gasoline could be an acceptable fuel for fuel cells. He presented three graphs on "total energy efficiency." The ARCO ranking of total energy efficiencies, from most to least efficient, presented in the year 2000 near-term slide was as follows: (1) reformulated gasoline (RFG) fuel cell (FC) hybrid electric vehicle (HEV) (i.e., RFG-fueled FC/HEV); (2) methanol-fueled FC/HEV; (3) non-FC/HEV; (4) hydrogen (H2) FC/HEV; (5) RFG-fueled spark-ignition-engine (SIE) vehicle; and (6) lead-acid-battery electric vehicle (BEV). There was considerable overlap in the estimated ranges for 2, 3, and 4, and for 5 and 6. For 2010, the ranking was (1) petroleum FC/HEV, (2) petroleum ICE modern diesel (MD), (3) petroleum non-FC/HEV, (4) BEV, and (5) RFG/SIE. There was considerable overlap in the ranges estimated for 2 and 3. For 1995, the ARCO ranking was (1)

diesel compression-ignition engine (CIE), (2) gasoline SIE, (3) RFG/SIE, (4) CNG SIE, (5) methanol SIE, and (6) ethanol SIE. There was also considerable overlap in the estimated ranges among 2, 3, and 4. By implication, given the fuels and technologies that were included and excluded in the graphs, petroleum would be the fuel of choice in 2010, but battery electric vehicles would still be in the market. The petroleum fuel cell hybrid vehicle was, in effect, predicted to be the winner of the competition among PNGV technologies to triple fuel economy. Finizza indicated that an oil glut was more likely than a shortage, and that diesel fuel could be produced from natural gas if there were a shortage. However, he did not present total energy efficiency for such a technology pathway. Ethanol was missing in 2010 in Finizza's presentation, but it was a major part of the market in one of the scenarios analyzed by P. Leiby and J. Rubin (see below).

In the last Asilomar conference, ethanol from cellulosic biomass received considerable attention. Although total energy use for such a technology pathway may in fact be higher than for gasoline, the nature of the process, if configured properly, has been estimated to be capable of producing significant reductions in net greenhouse gas emissions. However, a vehicle that tripled fuel economy would also do so, and ARCO predicts that the vehicle of choice to triple fuel economy will be a fuel cell hybrid using a fuel refined from petroleum. That fuel will have to be a very low-sulfur fuel, a refining challenge. In any case, ARCO in effect predicts that fuel efficiency, not fuel switching, will be the path to a reduction in greenhouse gas emissions.

P. Leiby and J. Rubin presented a discussion of the "Transition to Alternative Fuels" (TAFV) model. They indicated that it would be difficult to accomplish a significant switch away from oil. One of their key findings was that the "long-run penetrations for alternative vehicles and fuels anticipated in the earlier EPACT 502b study are not likely to be achieved absent significant policy intervention." (Note: the "502b" study indicated that a 30% share of alternative fuels in 2010 would be possible, given long-run equilibrium and high-volume alternative fuel vehicle production). Another finding was that "it may be hard for the vehicle/fuel market to get started."

At present, the TAFV model includes BEVs, as well as vehicles fueled by CNG, ethanol, methanol, and liquefied petroleum gas (LPG); however, it does not include HEVs. The cheapest vehicles to introduce were alcohol fuel vehicles (ethanol and methanol) and LPG vehicles; these vehicles generally captured market share in the illustrated scenarios, while the other vehicle types did not. According to the TAFV fuels characterizations, ethanol from cellulosic biomass, LPG, and CNG are "low greenhouse gas" fuels, with cellulosic biomass much lower in greenhouse gas emissions than CNG or LPG. (The characterization of biomass ethanol as a very low greenhouse gas fuel is in contrast to its low "total energy efficiency" as estimated by ARCO. Low total energy efficiency is not necessarily equivalent to high greenhouse gas emissions.) Under the assumption that the included fuels will be significantly subsidized (or taxed) according to their greenhouse gas benefits (or disbenefits), the TAFV model estimated that ethanol would capture over 20% of the fuel market in 2010, with a rapid start after 1999. The simulation implied that the ethanol supply would be limited; as the ethanol fuel market share

tended to level off a bit after 2005, LPG would begin to capture an increasing share of the market. Leiby and Rubin pointed out that automakers are planning to introduce a number of flex-fuel trucks capable of running on ethanol in the 1998 and 1999 model years, in part to avoid penalties under the CAFE regulation, taking advantage of rules written into the Alternative Motor Fuels Act (AMFA).

The TAFV model runs presented did not predict that BEVs would obtain more than a minuscule market share, even with long-run incremental vehicle costs at (down to) $4000 per vehicle. In light of Toyota's goal of getting its HEV incremental cost down to $4500, this does not indicate that the HEV is likely to gain significant share when added to the TAFV model. However, criteria pollutant emissions considerations are not yet a part of the model. Leiby and Rubin did not present a TAFV case with a very high fuel efficiency vehicle using a fuel refined from petroleum, in competition with alternative fuels.

Improving Fuel Economy

Historical Background. While U.S. achievements in reducing criteria pollutant emissions are, on a percentage basis, and from the point of view of sustainability, more impressive than achievements in reducing oil consumption, the United States has nevertheless achieved a degree of success in the latter area as well. The U.S. Corporate Average Fuel Economy Standard (CAFE) essentially required a doubling of new car fuel economy by the mid-1980s relative to the early 1970s, and about a 50% increase in new light truck fuel economy. L. Schipper showed that, over the time that the CAFE standards were implemented in the United States, with no counterpart anywhere else in the industrialized world, the fuel economy of U.S. light duty vehicles improved dramatically; the nation closed a gap with other industrialized nations that have historically chosen to impose far higher taxes on motor vehicle fuel than had the United States (and accordingly already had higher fuel economy). Another consequence of the standards, which applied only to light duty vehicles (the vast majority of which use gasoline), was to keep the rise in U.S. gasoline consumption well below the rise in consumption of diesel fuel for heavy duty vehicles and of jet fuel for aircraft.

In 1992, U.S. motor gasoline consumption was still 1% less than the prior peak, in 1978. Other motor fuel (predominantly highway diesel oil) consumption, however, was up by over 70% in the same time interval (DOE 1997a, p. 67), and jet fuel supply was up by 39% (DOE 1997b, p. 63). Looked at another way, following the oil price shocks of 1973-74 and 1978-81, U.S. jet fuel consumption peaked in 1979 and did not achieve the same level of consumption until 1984. Total nongasoline motor fuel consumption declined in 1980, but it was greater in 1981 than in 1979. Gasoline consumption peaked in 1978 and did not exceed this value again until 1993 (a 15-year period). Schipper presented a graph illustrating that the CO_2emissions per capita from U.S. automobiles and light trucks decreased from 1973 to 1992, while such emissions for eight major western European countries went up, as did CO_2 emissions in Japan. It is important to note that the fleet fuel economy gains that made this possible are essentially over. "All motor vehicle"

fleet fuel economy rose from a low of 11.9 mpg in 1973, to a high of 16.9 mpg in 1991, and has essentially stayed about the same since (DOE 1997a, p. 67).

It is remarkable that the U.S. reduction in per capita automobile and light truck CO_2 emissions of 1973-92 was achieved even though real gasoline prices in the United States dropped sharply from 1982 to 1992 (DOE 1996, p. 1-7), while gasoline prices in other industrialized nations remained about the same or increased. Despite the sharp real gasoline price drop, the U.S. memory of the pain associated with the oil price shocks and supply concerns a decade before caused the country to stick to the plateau in new-car fuel economy that was required by the CAFE regulations. As a result, the U.S. light duty fleet realized an increase in its on-road fuel economy, as cars about twice as fuel-efficient as in the late 1960s and early 1970s worked their way into the U.S. fleet. According to Schipper's estimates, the U.S. fleet realized a reduction of fuel consumption per kilometer of about 33% from 1973 to 1992, while European countries showed declines of less than 10%, and Japan showed an increase.

Price (tax) vs. Regulation. In past conferences, the subject of price vs. regulation often came up in discussions of CAFE. Many contended (and still do) that the new-car fuel economy increases from 1973 to 1983 were caused by fuel price increases and not by the CAFE regulation. However, proponents of this view have to explain why U.S. fuel economy remained high from 1982 to 1992, when real gasoline prices dropped by about the same amount. There is also the problem of why the EPA's estimates of fuel economy for the light duty vehicle fleet declined slightly from 1988 to 1990, whereas real gasoline prices rose by 16% over that time interval. In any case, at this conference there was little debate about the fact that CAFE has had an important effect on the average fuel economy of the U.S. light duty fleet.

D. Greene presented a partial summary of the paper that he submitted to the conference. He indicated that he had shown in his paper that the use of a fuel economy regulation can be economically efficient. He concluded that such a regulation would be more efficient when combined with an appropriate fuel tax, but that the U.S. economy could still be better off with a well-designed fuel economy regulation alone than without such a regulation. L. Lave commented that the issue was one of economic efficiency, not whether regulation or taxation should be the mechanism to accomplish the improvement. He offered criticisms of the CAFE regulation itself, but these seemed to be more to the effect that the regulation could have been better crafted than that it had been undesirable.(1)

He said that CAFE worked if one's goal was to increase fuel efficiency, but he noted that we cannot seem to agree on our goals. While claiming that gasoline prices alone have "no effect," L. Lave indicated that he would favor an increase in CAFE with a commensurate increase in fuel price, but that the price increases justifiable on the grounds of social costs of greenhouse gas emissions and oil supply security would be less than 40¢ per gallon in total. He implied that even tax levels in Europe were ineffective in increasing fuel economy.

S. Wallman (Volvo) provided information that, to a degree, calls L. Lave's conclusion about fuel prices into question. Wallman estimated that the average European car sold today, tested on the U.S. cycle, gets about 40.4 mpg. The EPA estimated that U.S. cars obtained an average of 28.5 mpg in 1996 (Heavenrich and Hellman 1996). European taxes are on the order of $3/gallon, so a 40¢ tax would induce a change in fuel economy of perhaps one to one-and-a-half miles per gallon. Wallman's estimate amounts to about 40% better fuel economy in Europe than in the United States. This is consistent with the ratio of estimates of on-road fuel consumption in Europe and the United States, as of 1995, presented by L. Schipper in his Fig. 14. Note that the real U.S. gasoline price increase from 1973 to 1981 was on the order of 80¢, and that increase was not sustained. European gasoline prices have been far higher than U.S. prices for years. Accordingly, the portion of the fuel economy increase from 13 to about 27 mpg could only have been accounted for in small part (a few mpg) by the real gasoline price increase.

The preceding conference's featured economist, J. Sweeney, told the registrants that only taxes are an appropriate means toward achieving economic efficiency, in comparison to use of regulation. L. Lave conceded that there are certainly economists who will say that one should use taxes or nothing at all, but not all economists take this position. He noted that the discipline of economics is fundamentally weak in the area of determining effects of technical change, being limited in most cases to analysis using static models that ignore technical change.

One of the many figures presented by Schipper (no. 38) can illuminate another side of the issue of effectiveness of gasoline taxes/prices as determinants of fuel use. In addition to the effect of gasoline prices and regulation on the fuel economy of vehicles, many expect the taxes to affect the rate of use of the vehicles -- i.e., annual miles (km) of travel. Schipper's figure shows a bunching of annual miles (km) of travel per unit of GDP, plotted against fuel prices for the years 1970-94. Three "clusters" are very distinct, including (1) at the top, the U.S. and Australia; (2) in the middle, Germany, France, U.K., and Denmark; and (3) at the bottom, Japan. Japan's real fuel prices are essentially identical to those in Europe (DOE 1996, p. 1-7), yet annual car km per unit of GDP is about half that in Europe. Also, Schipper's figure plots the changes (actually, lack thereof) as real gasoline prices have fluctuated in the selected countries. The figure is striking because, within clusters, it shows no price effect whatsoever. The positioning of the clusters is such that there does appear to be a cross-sectional effect, but this might indicate either a price effect or a land-use population density effect.

In the study discussed by K. Duleep, the existence of a strong density effect was assumed. Duleep selected countries similar to the United States in population density and urbanization -- Sweden, Australia, and Canada -- for analysis along with the U.S. All four countries used the same method of testing fuel economy, so the reported new-car fuel economy results were directly comparable. Duleep's study provided still more evidence that the CAFE regulation had a significant effect on vehicles produced in North America. He observed that, despite the higher gasoline prices in Sweden and Australia, the level of fuel-efficiency-enhancing technology was far greater in the U.S. and Canadian vehicles. He noted that U.S. and Canadian vehicles had

lower coefficients of drag, larger internal volumes (combined with a higher proportion of front-wheel drive vehicles), and more vehicles with four-valve-per-cylinder engines. Consistent with Schipper's Fig. 15 (which plotted the various fuel economy tests all on the same graph), Duleep found that North American cars now have fuel economy similar to their counterparts in his study. Since Duleep observed that U.S. and Canadian light duty vehicles have larger interior volume than their Australian and Swedish counterparts, one might contend that the North American vehicle fuel economy values are understated from a "volume equivalence" basis.

Duleep raised an interesting point concerning vehicle sales. He observed that affordability (income over vehicle price) was correlated with total industry vehicle sales. His price elasticity estimate was -0.72. If price rises by 1% with income constant, sales should drop by 0.72%. This is consistent with Greene's all-industry estimate of -1 (discussed below). Fuel cost vs. sales had an elasticity of -0.34. Duleep did not discuss the effects of vehicle price and fuel price on vehicle holding. Since the number of vehicles in use, their fuel economy, and the rate of use are the determinants of total fuel use, it is necessary to know the extent to which owners compensate for lack of new vehicle affordability by holding used vehicles longer.

L. Lave and D. Greene agreed that there is a relatively broad range of potential fuel economy values over which the technology cost changes are essentially "in the noise," from the perspective of the consumer. Greene presented a range of fuel economy costs of about 30%, for which net present value costs to the consumer would not vary by more than $100 (the price of a hubcap upgrade). Lave credited Jack Gibbons, U.S. Science Advisor, as also having made this point. In his paper, Greene illustrated the point with a graph from the National Research Council's 1992 study, "Automotive Fuel Economy." This logic implied to Lave that a fuel economy standard of 32-34 mpg would be appropriate for cars, but it would only work if combined with an increased requirement for trucks. Schipper showed that the fuel efficiency of automotive technology actually has been improving when one controls (in the statistical sense) for acceleration capability. However, he showed that for several countries, over the last few years, consumers and automobile manufacturers have chosen to use increases in thermodynamic efficiency of vehicles to obtain more rapid acceleration capability. In other words, if consumers and automobile manufacturers had chosen a constant acceleration capability, they would have obtained an increase in fuel economy during this period.

Acting Alone vs. Acting Together. Greene noted that there are some contradictions in human behavior that are readily understood. These involve a willingness to take collective action if there are rules that everyone must do so, but an unwillingness to take the same action on a voluntary basis. In a presentation by Toyota's Beseda that included an edited video of a focus group discussion concerning young consumer behavior, she emphasized that young consumers indicated a reluctance to sacrifice for the sake of the environment. Greene, however, noted that the young consumers in the video said that they would do so if they were required to, and that they relied on the government and industry to tell them when it was necessary. Greene also quantified the risk for an individual car manufacturer to introduce more costly, but more fuel-

efficient, technology than its competitors. The price elasticity for one manufacturer increasing vehicle cost was indicated to be -5, but if all manufacturers introduced the same level of technology with the same price increase, the loss in sales for an individual manufacturer would involve a price elasticity of -1. Beseda expressed this same point in qualitative terms, stating that no company can unilaterally commit to emission reductions or fuel economy increases that would put them at a cost disadvantage. Greene's point was that a collective agreement, such as CAFE, can eliminate the risk of acting alone.

The implication of a price elasticity of -1 is that revenue to the automobile industry would remain constant, because the per vehicle price increase revenues would be exactly offset by the effect of the decline in vehicle sales.[(2)]

Assuming that profits are earned on a per-dollar-of-sales basis, profits would be constant. However, this does not take into account the positive effect arising from reduced fuel cost, which would increase sales, offsetting the price effect and increasing auto industry revenue. Duleep estimated a vehicle price elasticity of -0.72. According to that estimate, automakers would increase revenue under a tightened CAFE standard that forced them to raise their costs simultaneously in order to provide higher fuel economy. Furthermore, given Duleep's estimate that the elasticity of vehicle sales vs. fuel price is -0.34, and assuming that this has essentially the same meaning as if fuel cost ($/mile) had been used instead of fuel price, then industry revenues would increase nicely under a reasonable CAFE standard. Fuel cost per mile would drop due to (a) increased vehicle efficiency and (b) a decrease in fuel price via reduced demand. It is important to keep in mind that the elasticity estimates apply in the data region for which the estimates were constructed; the estimates should not be construed to imply that these elasticity values would hold regardless of the stringency of the CAFE standard being considered.

L. Schipper also suggested that collective agreements are desirable for improving fuel efficiency and reducing CO_2, but he argued in favor of the voluntary agreements being adopted by manufacturers in some European countries.

C. Nash suggested, from the perspective of a former safety regulator, that auto companies prefer minimum standards to market incentives to produce cars with higher levels of safety. Nash expressed the opinions that (a) industry uses Federal safety standards for credibility, and (b) they use the fact that their vehicles meet all Federal standards in advertising (and in court) to support their contention that their vehicles are safe. J. German (EPA) indicated in comments at the closing session that there is a willingness to embrace policies where everyone shares the pain. C. Sloane seemed to recognize that, to an extent, government plays a role as intermediary that involves a degree of risk. She indicated that credibility with respect to social goals was an important objective of the PNGV program.

Government and Industry Interactions. Cackette noted in his presentation that there were occasions when a company would come to a regulator and suggest a change in regulation

because that company had developed technology that would give it an edge over a competitor if the regulation were tightened. By doing so, the company could change the nature of the social goals to its potential advantage. The regulator, of course, would have an interest in seeing greater improvement in the social goal for which the regulator is responsible and would be receptive to such suggestions. J. Beseda indicated that, for many years, Toyota would not participate in conferences of the sort being held at Asilomar, but they have now decided to become proactive. She offered several suggestions on the nature of regulations that should be adopted in the United States in the future. Both Beseda and J. German indicated that there was a good working relationship between Toyota and EPA, German indicating ongoing cooperation on Tier II standards and Beseda praising the developing EPA "Green Car" program. S. Wallman expressed the opinion that a combined EPA truck and car standard would be acceptable to Volvo, a company that tends to specialize only in sales of larger cars in the United States (a combined standard could well lower the fuel economy requirement for Volvo, reducing the pressure to improve the fuel economy of their cars).

Sloane and Beseda both observed that their interactions with government on issues of either developing or promoting fuel-efficient vehicles are motivated by concerns that fuel efficiency will once more become a concern among consumers. Beseda indicated that Toyota expects that demand will outpace oil production between 2007 and 2014. Sloane noted that, in surveys done in 1980, on average, consumers placed fuel economy as the second priority in vehicle attributes, while in 1994 they gave it only 15th priority. She noted that this is not the whole story, however, and industry knows that today's market is not the future market. Beseda said that Toyota intends to develop advanced products with low emissions and high fuel economy and to conduct "target" marketing to that segment of the population that remains receptive to environmental concerns. She indicated that this group would not be reached by advertising on television, but instead through selective use of print media.

The early 1980s were the last prolonged period during which oil demand outpaced supply, and sales of U.S. vehicles declined by the greatest percentage since the onset of the Great Depression. Along with the rest of U.S. manufacturers, GM's sales plummeted, while sales of fuel-efficient small cars offered by Toyota and other Japanese manufacturers held steady; as Greene showed in his paper, the share of small cars in the market jumped accordingly. Beseda emphasized that Toyota is a full-line vehicle manufacturer; in other words, they have become much like GM. In the event of a future oil demand vs. supply crunch, Toyota can expect its sales to be affected just as GM's would be. In the event of an oil and gasoline price shock, major U.S. manufacturers of full-size vehicles can expect to be hit by a "double whammy," the general loss in sales that follows such a shock (consistent with Duleep's estimate of a gasoline price vs. motor vehicle sales elasticity of -0.34), compounded by the loss of share of high-profit-margin large cars (consistent with a graph presented by Greene, showing a strong positive association of gasoline price and small car market share).

Sloane emphasized that the concept of cooperation fostered in the Partnership for a New

Generation of Vehicles is a difficult one to implement. U.S. automakers (not to mention foreign manufacturers), being in competition, do not wish each other well. Collaboration requires a lot of discipline. Objectives are to achieve technical goals, credibility in social concerns, and national competitiveness. Government's role, in part is to translate regulations and infrastructure issues. Taxes were not mentioned.

THE FUTURE

Sloane restated the goal of producing a proof-of-concept vehicle in 2000 and a prototype in 2004. Many new technologies are being evaluated. In light of the scenario to which Toyota ascribes -- oil demand exceeding supply in the 2007 to 2014 time frame -- would that be soon enough, absent any other fuel efficiency or fuel switching shift until then? C. Nash expressed the opinion that R&D alone would not be enough to cause introduction of a high-fuel-efficiency vehicle developed by PNGV. Nash quoted Jefferson, saying "a little revolution now and then is a good thing, and as necessary in the political world as storms in the physical ... it is medicine for the sound health of government." According to Nash, the American auto market got a valuable boost from the stimulation provided by the oil shortages of 20 years ago and the challenge of Japanese competition. What we need today, Nash suggested, is a similar "cleansing storm," perhaps coming from an economic or environmental crisis, an energy shortage, or a maverick company outside the current club of auto companies. Nash believes that major technical changes are almost always driven by such forces. In order to promote -- without waiting for these forces -- what he considers needed technical change he recommended a gasoline tax of $3/gallon, with the proceeds being used to replace Social Security and Medicare taxes or income taxes for incomes under about $100,000. However, several conference participants lamented that price policy seemed to be "off the table" in the United States.

L. Lance, in response to a query by Nash, indicated that the White House wanted to act before a crisis hits. She was primarily concerned about greenhouse gases, rather than oil supply or air quality. Toyota and GM appeared more concerned that fuel efficiency (or oil use) might once more become a very important priority for the consumer, but both implied that the problem was not today's concern.

What are the odds of the "cleansing storm" that Nash said might come from any of four forces? Participants did not discuss the potential for an economic crisis or its effects. Nor did participants seem to expect either an air quality crisis or weather-related behavior that could be easily blamed on global warming. However, Toyota did subscribe to a prediction concerning the timing of an oil supply crisis, which was expected to be a decade away. Concerns over the worst "El Nino" of the century might be a trigger for action far sooner. Nash suggested that Bill Gates of Microsoft might provide the competition needed. Toyota also might provide some of this "maverick" behavior, perhaps as indicated by its newfound interest in participation in conferences of the type held at Asilomar. Another possible "maverick" firm, Ballard, was also represented.

G. Ballard, founder of Ballard Power Systems, discussed the fuel cell. He was forthright about the marketing strategy that had originally been formulated, and the one that had since evolved. He presented information on a rapidly improving technology, the proton-exchange-membrane (PEM) fuel cell, noting improvements in packaging efficiency, power density, simplicity, reliability, and so forth. He discussed the high capitalization of the company and the implications for profitability within a given amount of time. Ballard's projections were translated into a need to capture 10% of the world's new-vehicle market by 2002. This date, of course, is well before the working prototype date for the PNGV triple fuel economy vehicle. Debate at the conference centered on whether the diesel engine should be selected as the technology of choice for use in this vehicle. Of course, it is not necessary for Ballard to sell a power unit for a vehicle that triples fuel economy. The fuel cell can have very low criteria pollutant emissions, perhaps low enough for regulators to regard the technology as equivalent to a zero emissions vehicle.

S. Wallman pointed out that Europe is in fact considering fairly aggressive emissions standards. He indicated that the goals for 2000 are similar to the California LEV standard in 2000 and to the ULEV standard in 2005. Another European goal is to improve fuel economy in order to lower CO_2emissions, although this goal is far less ambitious than the PNGV 3X fuel economy goal. Germany has a goal of 25% reduction in fuel consumption, as does Volvo. The French also have a low CO_2 goal, but their vehicle fleet is already low in that respect.

With regard to the emergence of an oil supply crisis in the 2007-2014 time frame, T. Finizza indicated that there would not be much competition with gasoline as an ICE fuel over the next 10 years (i.e., until 2007). He made optimistic estimates of the capability of a fuel cell run on gasoline, implying that the fuel cell could be used with the existing gasoline infrastructure, but he also indicated that sulfur would have to be removed from the fuel. Concerning oil supply, he said that the Toyota scenario is not highly probable and that in any case natural gas could be converted to a low-sulfur diesel fuel. If anything, Finizza indicated that there would be a fuel glut (whether of oil only or of oil and gas both, he did not specify). He did not discuss the costs of converting natural gas to low-sulfur diesel, thus avoiding the issue of whether oil prices might have to rise in a decade or so to cause a hydrocarbon glut based on addition of natural gas-based liquid fuels to the infrastructure now supplying crude oil-based liquid fuels. Toyota's concern about the 2007-2014 time frame may well be one of hydrocarbon fuel cost rather than long-term supply, the desire being to avoid the sort of sales losses that Duleep's elasticity estimate implies would occur if gasoline prices rise. Note that the 1973-1981 gasoline price increase in the U.S. was about 75%, so Duleep's fuel price elasticity estimate implies sales losses of about 25%. (Actual short-term U.S. vehicle sales losses exceeded this percentage.) Such losses would be enough to make the major automobile manufacturers unprofitable for a few years if they occurred again as abruptly as before.

Methanol (from natural gas) is a very good fuel for the fuel cell, ignoring infrastructure issues. Finizza indicated that methanol would be a problem for the oil industry because it would essentially require starting over with new infrastructure. He also indicated that ARCO's

introduction of EC-1, one of the first nominally reformulated gasolines, was an "anti-methanol" strategy.

Ballard also indicated that there is an emerging communitarian ideology that contrasts sharply with the older, individualistic ideology. Perhaps this is wishful thinking, or perhaps it is prescience concerning receptivity to a round of collective decisions to reduce oil use, criteria pollutant emissions, and greenhouse gases by developing and introducing the technology that Ballard pins its considerable hopes on. In any case, on the basis of Ballard's calculations concerning an expected $2 billion capitalization by 2002, Ballard's decision to pursue an "all possible markets" strategy (of which automotive uses would be only a part) is necessary. Finizza did indicate that electric drive (the drive system that must be used with the fuel cell) is a "high chance" event.

Finizza indicated that transportation would be the chief cause of increased demand for oil. He projected an increase in the demand for oil, an additional 27 million barrels per day from 1997 to 2010; two thirds of the increase (i.e., about 18 million barrels per day) is expected to arise from increased transportation demand. The vast majority of that increase is projected to occur outside the industrialized Organization for Economic Cooperation and Development (OECD) members. To put this in perspective, U.S. gasoline demand in 1996 was about 8 million barrels per day. The U.S. consumed about 18 million barrels of oil per day in 1996, so Finizza's projected rise in worldwide *transportation* oil demand by 2010 is equivalent to adding another United States to the world oil market. Note that in 1973, the nation consumed 17 million barrels per day (DOE 1997b). Schipper's Fig. 5 shows that, although the United States reduced its passenger-movement-related CO_2 emissions per capita from transportation from 1973 to 1992, the U.S. remained a larger generator of CO_2 than the eight major European nations examined by Schipper, plus Japan, combined. So, if the industrialized nations decide that the world should reduce CO_2emissions and have transportation do its fair share, then Finizza's vision of the future will have to be changed by dramatic action. If the OECD's industrialized nations wish to ask less-industrialized and industrializing nations to reduce CO_2 emissions and restrain transportation emissions, those nations will have to ask the United States to provide its share of reductions, to show that industrialized nations really believe global warming is a problem.

On the other hand, if no agreements can be reached, and only research on new technologies is conducted until about 2005, most of the growth projected by Finizza will be well under way. One wonders whether demand for oil one-and-one-half times the present U.S. level of demand can really be added to world demand and still have a glut at the end of that period. In any case, such a future is not the goal of a large fraction of those attending the conference. Many are interested in a broad definition of sustainability and primarily in seeing that the United States can accomplish that goal. Also, where global warming is concerned, many conference participants would likely want the nation to do its share in preventing the increase in world oil demand predicted by Finizza.

RECENT COUNTERPRODUCTIVE TRENDS

The short-term trends in light duty transportation in the United States, the actual focus of this conference, are counterproductive. Since about 1987-88, new light duty vehicle fuel economy has been slowly declining, largely due to expanding truck sales (Heavenrich and Hellman 1996, p. 5). Earlier, it was pointed out that the fleet fuel economy, which lags new-vehicle fuel economy, peaked in about 1992. Those who have chosen cars since 1987 have actually continued to choose an average fuel economy of a little more than 28 mpg, while those choosing trucks have chosen slightly less fuel-efficient vehicles (dropping about 1 mpg from a 1987-88 average of 21.4 mpg). Fatality rates have stopped declining over the last four years. Nash indicated that when heavier, stiffer, higher light trucks collide with passenger cars they are likely to inflict far greater harm to passenger car occupants than do similar crashes between cars. Greene cited an NHTSA study that examined the effect of reducing weight and size of trucks more than for cars, such that the weight and size of the two classes of vehicles converged. Under some circumstances, a net reduction in overall fatalities was obtained. Passenger car occupants and pedestrians and bicyclists (individuals making choices that would reduce fuel consumption, CO_2 emissions, and criteria pollutant emissions) would benefit from this truck mass and size reduction, while the truck owners would have an increase in fatalities. Clearly, there would be a collective benefit in terms of the goals of sustainability. Consumer surveys and projections, however, suggest that the trend toward increasing truck shares will continue.

T. Turrentine coined the phrase "urban assault vehicle" to describe the attributes of trucks that consumers like. Turrentine, an anthropologist, pointed out that the majority of people identify themselves as environmentalists. They believe that green cars should be required, but automakers and big oil are conspiring against it. On the negative side, the popularity of the sport utility vehicle truck configuration works against reducing oil use; on the positive side, the fact that households today purchase multiple specialized vehicles creates an opportunity to exploit market niches. In comments, G. Ballard asked whether it isn't better to observe what people do rather than what they say. Turrentine indicated that self-perception is important as an indicator of potential receptivity to marketing concepts and approaches that are only now being developed. Regarding the nature of actual human behavior, S. Peake used the descriptive phrase "technological optimism and behavioral doom."

One wonders if, in the event of another oil crisis, and after years of advertising the virtues of larger, more powerful vehicles, consumers might blame the automobile and oil industries for leading them down a path of behavior that, in retrospect, they did not really believe to be in the country's best interest. Those who purchase larger vehicles but identify themselves as environmentalists might be prone to such retrospective interpretation of their own supposed weakness; such persons might support more draconian measures by legislators than would ultimately be desirable for the economic health of the auto and energy industries.

Schipper expressed the opinion that several European countries do not really care about CO_2

emissions. Peake called Denmark a "regulatory utopia," indicating that Denmark is combining a package of taxes and regulations. Schipper, however, had earlier observed that the only countries taking significant action on transportation sector CO_2 emissions were Denmark and the Netherlands, neither of which has an indigenous automobile industry, and both of which have a high fraction of coastline per unit of surface area. Both are more threatened by global warming than the average European nation. Perhaps this indicates a critical inconsistency in human behavior. Where the motor vehicle manufacturing industry is a major part of the economy of a nation, the citizens of that nation are less inclined to take actions in their long-run interest that are opposed to the short-term interest of the motor vehicle manufacturing industry, and therefore their own short-term economic interests. Within the United States, the actions of California -- so often disconcerting to the U.S. motor vehicle manufacturing industry -- are largely consistent with this interpretation. Whereas Denmark's and the Netherlands' degree of concern over global warming relative to the rest of Europe probably contributes to their "anti-auto-manufacturer" actions, California's serious air quality problems relative to the rest of the United States have long driven that state's relatively stronger regulation of motor vehicles.

CONGESTION AND HABITAT LOSS

M. Cameron of the Environmental Defense Fund gave a presentation on congestion pricing. He cited four examples; one was in the planning stages, two were in effect, and one (increased tolls for the San Francisco Bay Bridge) had failed. Compared to the goals of the conference, the use of congestion pricing is clearly in its infancy, being "in the noise" at present. Cameron provided no estimates of fuel savings. These projects apply only to a few miles of road in the entire nation. Probably the most valuable lesson for the conference from the Bay Bridge example is that equity is important (the issue was used by a key legislator to kill the proposal); also, a plan for appropriate use of tax revenue must accompany a proposal to increase taxes. Perhaps another lesson is that projects sometimes require a very great need before they will be undertaken.

G. Giuliano of the University of Southern California gave a presentation indicating that land use policy cannot be relied on to help achieve environmental or sustainability goals. Giuliano presented examples worldwide that indicated that increased use of the car and decentralization of urban areas will continue. In short, Giuliano said to rely on technology, not land use policies. R. Johnston gave a presentation on land use models. He indicated that it was indeed very hard to get community leaders excited about land use policy when 20-year projections are used. He had come to the conclusion that 50-year scenarios had to be used. When these longer-term scenarios are used, he said that the implications can be alarming. He said that the individuals and organizations interested in the results of his land use modeling are concerned about habitat loss, quality of service, and equity. The individuals that he interacts with are not concerned about those issues emphasized at the conference. Schipper mentioned habitat loss as one of the seven deadly sins of transport, and he included congestion/access.

EDUCATION

In the questionnaire administered at the conference, the areas that obtained the highest percentage of high importance ratings were (1) industry research, (2) federal regulation, and (3) education. No speaker specifically addressed the last issue, but several comments indicated that education about sustainability goals and the means to achieve them is important. In the introductory session, Delucchi expressed an opinion that the highest value of the social cost framework might be as a source of inspiration for a long-term vision of the transportation system. He suggested that social cost analysis could be used as a means for changing our world view, and perhaps as a tool for changing perceptions. He acknowledged that the form of delivery of the message can be as important as the message itself, citing Rachel Carson's *Silent Spring* as an example of effective delivery of an environmental message.

RECOMMENDATIONS

In his closing remarks, economist C. Lave commented that "technology is still the answer."

It is important to note that the conference participants reached no consensus in the closing session. It is an open question whether the participants would consider the recommendations offered below to represent a consensus view on appropriate recommendations. Instead, these recommendations emerged from a more leisurely examination of the conference material, with only moderate extensions of that material.

The issue of whether a CAFE-type regulation or a voluntary agreement among automakers is more or less effective than the use of a fuel tax can be readily addressed, using some of the numbers cited at the conference. Suppose it is desired to have a "holding action" on U.S. light duty transportation greenhouse gas emissions and fuel use until the PNGV results are in. Assume a 20% improvement in vehicle efficiency is needed. The figures provided by Greene from a 1992 NRC automotive fuel economy study suggest that the net cost to the consumer of achieving such a goal would either be positive (i.e., a benefit, not a cost) or perhaps amount to as much as $500 per vehicle. If the 20% increase provides a benefit, then L. Lave's recommendation for a CAFE increase seems obvious. Suppose the real cost is $500. With 15 million light duty vehicles sold each year, this means a cost of $7.5 billion annually. If the alternative were to impose a gasoline tax to achieve the same fuel economy level, what would the cost be? Ignoring, for the moment, the evidence that such a tax would be ineffective, assume the tax level recommended by L. Lave to address the social costs of CO_2emissions and oil imports were imposed (i.e., a tax of about 40¢/gallon). At the present consumption rate of about 8 million barrels of gasoline per day, 123 billion gallons would be consumed per year (8 million barrels per day x 42 gallons/barrel x 365 days per year). A tax of $0.40 per gallon would cost taxpayers $49 billion per year. Admittedly, this tax would be returned to taxpayers in the form of recirculated revenue; from an economist's point of view, this is irrelevant. The tax is recommended essentially as a punishment for behavior; about 25¢ would be for damage to the globe (a largely altruistic tax), and about 15¢ for the oil-supply insecurity imposed on the United States.

In principle, a tax on externalities should be used to either eliminate the undesirable behavior or compensate those damaged.(3)

The available evidence shows that a tax of 40¢/gallon would not lead to a 20% reduction in per-vehicle fuel use, so the tax fails to meet the first criterion. Therefore, the 25¢ tax revenue should be used mainly to set up a fund for those damaged by global warming (assuming one can establish who they are), minus the fuel use reductions caused by the tax (the country can keep the equivalent dollar value of its fuel use reductions). In any case, these are largely theoretical public policy arguments, made to illustrate a point.

M. Cameron demonstrated to the conference that one needs a plan for use of the revenue in order to get approval for imposition of an externality (social cost) tax. D. Howell's proposal for a revenue-neutral tax to subsidize state-level experimentation with technologies and transportation investments designed to reduce CO_2 emissions, oil use, and/or criteria pollutant emissions recognized this need, and he was only arguing for a 1¢/gallon tax. The audience did not receive the proposal with enthusiasm, and S. Wallman lamented this audience non-response. The question is, what are the odds of getting a 40¢/gallon tax approved?

Another way of looking at the issue of what to do with the tax revenue is to assume that those taxed would want the revenue to be used to help address the problem for which they are being taxed (fuel use). A logical use for the funds, consistent with this assumed limitation, would be to subsidize the purchase of fuel-efficient vehicles. This alternative is awkward in terms of equity. New vehicles are purchased predominantly by upper middle and high income consumers. Gasoline is purchased by nearly everyone, and the middle class pays a much higher proportion of income for gasoline than do upper income individuals. It is interesting to note, however, that a 40¢/gallon tax could subsidize about $3300 of vehicle cost, ignoring collection and administrative costs.

What about a CAFE regulation or a voluntary agreement? Either would drive up the cost of cars by $500-750, based on visual inspection of the figures in Greene's paper. Assume that cars cost $15,000 each. The percentage increase in car costs would be 3-5%. Using Duleep's estimate of price elasticity (-0.72), this would lead to an industry-wide sales drop of 2.5-3.5%; using Greene's value of -1, it would lead to a drop of 3-5%. The fuel tax of 40¢, imposed on top of a gasoline price of $1.20, would lead to a 33% increase in gasoline price. Using Duleep's vehicle sales vs. fuel price elasticity estimate of -0.34, this implies a more dramatic, industry-wide sales drop of 11%. Using an immediately imposed fuel price increase of the magnitude recommended by L. Lave (he did not recommend that it be used alone) would thereby lead to an initial loss of vehicle sales and profits. After automakers developed new models efficient enough to offset the fuel price increase, sales would rise; however, they would not return to original levels, because vehicle costs and prices would be higher (total auto industry revenues might, however, recover to original levels). A several-year increase in taxes to the level recommended by L. Lave would probably still not lead to increases in fuel economy as rapidly as would a CAFE regulation.

There would be a "you first" mentality among automakers, in view of the potential sales losses associated with being the first to proceed alone with a costly technology and commensurate price increase (in which case, they face an elasticity of demand of -5). Using only a fuel economy regulation would lead to quicker introduction of new vehicles and a greater increase in fuel economy, at a lesser cost. Except for money spent to determine the best form of regulation and governmental administration and policing, all the money would stay in the private sector, and the allocation mechanisms for spending the required dollars would stay in the "economically efficient" private sector rather than be allocated by the government.

Note that a group of automakers faced with increasing fuel taxes but not with fuel economy regulations could achieve the same ends as a fuel economy regulation by adopting a "voluntary agreement." All would be better off if they were to reach such an agreement. Faced with the most rapidly rising gasoline taxes on the European continent from 1990 to 1996 (67%), German automakers have adopted such an agreement (IEA 1997).

On the basis of this "back of the envelope" examination of the implications of the numbers presented by the participants at Asilomar, if one were asked whether to recommend only a transportation fuel tax or only a fuel economy regulation, it is clear that a regulation would be recommended.

The remaining question is whether or not a tax would also be recommended. If so, what level of tax would be recommended, and how would the tax revenues be used? With respect to air quality regulation, conference participants have suggested (or conceded) that the regulatory process has worked. According to presentations made at the conference, the issue is not one of whether or not regulation should be used (instead of a tax), but rather how the regulation can be made to be efficient. Cackette emphasized that his experience as a regulator was that, over time, industry demonstrated that it could do more than had been anticipated before it was forced to work on the problem. By this logic, technological discoveries and breakthroughs are to be expected, if only industry is directed to address the proper problem. The conference participants' retrospective on CAFE indicated that it worked.

The PNGV program may lead to many technologies that can in the future push the cost for fuel efficiency down below its present levels, though there is no tax or regulatory mechanism in the United States to ensure that those technologies are "spun off" into the U.S. market. Nevertheless, each of the three companies involved is a world producer of automobiles, and tax-related pressures do exist in Europe to cause introduction of more efficient vehicles. A part of the process that Cackette described was that technologies were forced into the market by regulation, though it was conceded that government should set flexible regulations and allow industry to use a menu of technologies. Industry requested even more flexibility in regulations, and many non-industry participants suggested that regulations needed to be written both in a coordinated fashion and in a fashion that allows trade-offs to be made. In pointing out that industry occasionally came to CARB with information on a new technology that would allow a

tightening of the regulation (to their advantage), Cackette implicitly acknowledged that there was an attempt by CARB to be realistic -- that is, to set achievable requirements. The selected values discussed in the "holding action" proposal here also represent an attempt to be realistic.

New U.S. air quality regulations have been set. Debate on the continuation of Congestion Mitigation and Air Quality (CMAQ) funds, which allow gasoline taxes to be spent on a variety of projects that do not support highways, is ongoing. It appears that the flexibility in the program or its nominal replacement will stay in place. CMAQ funds can be used very flexibly by states and localities to reduce travel on highways, as long as the end result is to reduce congestion or improve air quality.

Doug Howell (Environmental and Energy Study) proposed a penny a gallon tax be used to develop, test, and demonstrate transportation technologies that would provide considerable net benefits. Trade-offs would be allowed among oil use reduction, air quality improvement, and greenhouse gas reduction, so long as significant net benefits were achieved (taking all three effects into account). If a 20% increase in fleet on-road fuel economy were achieved by 2005-2010, such that, taking account of net effects of income and population growth, a reduction of a few percent in U.S. gasoline consumption were achieved with respect to 1997 values, then gasoline consumption in the 2005-2010 interval might be estimated at about 7.5 million barrels per day. This would represent a savings of about 1.5 million barrels per day over an assumed 9 million barrels per day that would otherwise be consumed: at $1.20 per gallon, a savings of $27 billion. Howell's proposed 1¢/gallon tax would take back a little more than $1 billion of that.

The one drawback to using a fuel economy regulation alone is that it will not cause a shift in allocation of resources from fuel efficiency, either to air quality or toward experiments on the most bedeviling of the problems in achieving sustainability goals, human behavior. One of the appropriate goals of government is the reallocation of resources for social goals agreed to by voting. In order to allow for such reallocation, a tax is recommended. Only Howell's proposal was specific in this regard. Given that there was only this proposal, it is accepted and recommended, in part because, as described, it primarily supports the development and demonstration of technology, not the alteration of behavior. It complements the technology-promoting PNGV research effort and is a legitimate part of a diversified government portfolio of sustainable transportation technology development efforts.

A position has been developed from the Asilomar conference material that emphasizes technological optimism, combined with technological goals, as the best means of moving toward sustainability. Consistent with Peake's "technological optimism vs. behavioral doom" statement, our assessment of the likely behavioral responses to taxes is that there would be very little response, and whatever response there was would come at a far higher cost than simply improving light duty vehicle transportation technology. The costs of a new-vehicle fuel economy standard would first fall on higher income households, which also tend to be older, more mature, and better educated households. This would represent a transfer of technology from the older to

the younger generation, setting an example of commitment to that younger generation. The fuel economy gains would actually reduce the demand for gasoline, first by higher income vehicle owners. Lower income owners would benefit first through a reduction in fuel demand, which should "trickle down" as a slight reduction in fuel price, and therefore in costs to provide a relatively fixed demand for service (miles of travel). Later, as more efficient used cars became available, further benefits would be realized. The alternative, a 40¢/gallon fuel tax, would represent a greater initial imposition on the young and less capable. One of Nash's two proposals for allocation of gasoline tax revenues -- to support Social Security and Medicare -- would clearly transfer funds from the young to the elderly. The other -- to reduce income taxes for those with less than $100,000 of income -- would have complex, but certainly more equitable, transfer effects. Despite the concerns expressed here over choice of a high tax to cause improvements in vehicle fuel economy, a small symbolic increase in taxes on fuel (Howell's 1¢/gallon) to cause some sharing of the costs across nearly all segments of the population would be entirely reasonable; the revenue could be used to foster experimentation with locally appropriate technologies and with transportation system modifications that could achieve significant sustainability benefits per dollar of investment. A 40¢/gallon ultimate tax increase might be more readily acceptable if it were scheduled to be imposed over a period of years and only initiated after some of the regulation-promoted fuel economy gains had reduced the cost of driving.

That, in C. Lave's words, "technology is still the answer" is implicitly accepted by the government-industry Partnership for a New Generation of Vehicles. Also, the Energy Policy Act of 1992, written after what Nash would call a "cleansing storm" (Desert Storm, in this case), is only the latest example showing that action will be taken to get technology into the market. In advanced industrialized nations, it is not a matter of whether, only a matter of when. The process of getting technologies into the market as well as keeping them out when they do not belong is promoted by research and development, demonstration, and evaluation. When implementation of available technology seems desirable, education becomes necessary. If education is not sufficient, then events will run their course -- a "cleansing storm" will occur -- and regulation or taxation (or both) to promote the technology and/or control its negative side effects will follow. In some respects, this exercise will be a failure. If taxes are used to promote the technologies of interest, subsidies are highly likely, because those promoting change through taxation realize that the use of the tax revenue has to be acceptable to those taxed. Experimentation and subsidization of technologies left waiting at the door is a very likely outcome of this sequence of events. Those technologies will then be researched, developed, demonstrated, and evaluated. The worthy ones will remain "on the shelf" until the need to educate the population about their value (or lack thereof) emerges again.

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The material presented here represents the author's attempt to reflect, but also to extend and interpret, a "sense of the conference" summary of participants' research or views. The material

also develops several implications of numbers presented by participants but not discussed at the conference. The views and interpretations are not necessarily those of the sponsors of this review, nor of any conference participant. This work was supported by the U.S. Department of Energy, Office of Transportation Technologies (DOE-OTT), under contract W-31-109-Eng-38. The support of Dr. Phil Patterson (DOE-OTT) is gratefully acknowledged. Comments by Phil Patterson, Barry McNutt (DOE-PE), Douglas Eisinger (Sonoma Technologies), Dan Sperling (U. of Calif. at Davis), and Carl Nash (George Washington U.) are appreciated. The author, however, is solely responsible for the contents.

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1. L. Lave's role was that of a discussant. Owing to the nature of his comments, it would be very difficult to isolate his personal opinions from his professional judgments concerning the best way to accomplish a given social (or corporate) goal that might be inconsistent with his own views. Of course, the same may be said of others, especially those responsible for presenting corporate positions.

2. In this paragraph, an extension of the material presented at the conference is developed.

3. In this paragraph, an extension of the material presented in the conference is developed.