OVERVIEW

Danilo Santini
Center for Transportation Research
Argonne National Laboratory

Ken Kurani
Institute for Transportation Studies
University of California, Davis

In the movie, *City Slickers*, there is a scene in the midst of an adventure of discovery in which Mitch and his friends set out to do something they have never done before, guided on their way by Curly, an unlikely sage from an older generation:

> *Curly: None of you get it. You know what the secret to life is?*
> *Mitch: No, what?*
> *Curly: One thing, just one thing...you stick to that.*
> *Mitch: That's great, but what's the one thing?*
> *Curly: That's what you gotta figure out.*

An ensemble of researchers, analysts, regulators, policymakers, as well as energy and transportation industry representatives have come together at conferences in Asilomar, Calif., every two years for the past decade to attempt to write a real-life story of energy, transportation and the environment. Their efforts face several difficulties, including the inescapable fact that neither the end of the story nor the full description of the world it will inhabit are known to either the characters or storytellers.

This uncertainty arises because it is a story about the future that is being drafted. It is a story of how socio-technical systems of energy and transportation should be constituted to achieve certain goals, not simply a history of how those systems have come to be currently constituted. At best, the participants of each conference sift through evolving drafts of the script, casts of potential characters, and possible scenes. In so doing, they participate in the construction of the story. That is, the story of the future is not a forgone conclusion for which they are searching, but is to some extent a product of their searching.

Their difficulty is compounded by the fact that the motive force to the story, that is the goals that this socio-technical system are supposed to facilitate, include an idea only loosely shared by members of the ensemble—sustainability. The 1997 conference "Policies for Fostering Sustainable Transportation Technologies" is not a complete draft of their story. The 1997 conference was about the best policies to cause a change in direction—to cause reduction of greenhouse gases, oil use, and pollutants in the air by choosing among technologies discussed at prior conferences in the series. It and the conferences of the 1990s which preceded it have come to represent a body of work with which not all readers of this volume may be familiar. In this summary, we draw upon both the past conferences of the 1990s and this conference, to attempt a synthesis.

The 1997 conference attendees examined three broad categories of policy—pricing, regulation, and land-use planning. Responses to the questionnaire at the end of

the conference indicated that the conference attendees regarded three areas to be most important to fostering sustainable transportation technologies. These were:
Industry research, development, demonstration, and *marketing* of appropriate transportation technologies. (67% of respondents indicated this has high importance).
Federal regulatory programs requiring (1) reduced greenhouse gas emissions (2) reduced oil use, and (3) changes in emissions which result in better air quality. (59% of respondents indicated this has high importance).
Education about characteristics of appropriate transportation technologies, and about oil imports, greenhouse gas emissions, and air pollution. (57% of respondents indicated this has high importance).

The questionnaire itself did not include a question on the importance of land use planning. The lesson advocated at the 1997 conference, by G. Giuliano, was that one should only expect measurable impact from land use planning on transportation energy consumption and emissions if consistent policies can be maintained for long periods of time.

The conference attendees, by relative absence of support, did not seem to believe that use of federal taxes on fuels or on gas guzzling vehicles or the use of subsidies from revenues raised by such taxes, represented likely policy instruments. It should be mentioned, though, that if we had listed the four most important categories above, federal fiscal policies would have been the fourth. However, in discussion sessions, those participants who recommended fiscal policy—such as C. Nash—got little support. The greatest support seemed to be for regulation—with industry left to determine the best way to implement the goals of the regulation. According to the questionnaire responses, education was seen to be an important part of the package. We presume the purpose of education would be to achieve and maintain support for the need for the regulations and the promotion of their benefits.

As editors and interpreters of the meaning of the events of the 1997 conference, we have chosen to go beyond a description solely of this conference, as has been provided in the proceedings of prior conferences in this series. The Asilomar conferences have been conducted periodically since the late 1980s. Many of those in attendance at the 1997 conference had attended and participated in one or more of the prior conferences, and were aware of many of the arguments in the presentations and papers of the past. One of the purposes of these conferences is to educate, while another is to share information between the scientists, policy makers, and representatives of the transportation and energy industries on what it is thought can and should be done.

We therefore have taken the liberty of incorporating material from proceedings of the prior three conferences (1991, 1993, and 1995) in this review. We choose to let the authors and speakers from those conferences speak in their own voices by selecting quotations from papers of those conferences. In this way, we hope to help inform the reader on the background that influenced the participants in the 1997 conference. In doing so, we have developed some opinions of our own which are clearly different from the sense of the 1997 conference. Readers should easily judge the differences.

Contrary to the focus of our presentation herein, the Asilomar conferences have not exclusively examined the gasoline fueled light duty vehicle. Heavy-duty truck, rail, and air transportation have all been examined in prior conferences. The 1997 conference, however, did almost exclusively focus on the light duty vehicle (passenger cars and light trucks). Accordingly, only quotations from past Asilomar papers examining this part of the transportation system have been included here.

As these quotations below will show, there are several candidate technologies to replace or modify present automotive technology in such a way that U.S. oil imports and light duty transportation greenhouse gas (GHG) emissions could be reduced. Criteria pollutant reducing technologies for gasoline vehicles appear to have moved forward more rapidly than even some at the prior conferences had anticipated, so this consideration is given less attention here. Regulations to force feasible emission control technology appear to be in place in California and on the way nationally, as of the writing of this introduction. There is concern by some that the diesel engine will see a revival of use in the light duty sector, leading to an increase in health damages from fine particulate emissions. Those who are concerned anticipate that such damages would exceed the GHG and oil use reduction benefits obtainable with advanced diesel technology. Even if the diesel engine does not expand its market share in the light duty sector, it will undoubtedly remain dominant in the heavy duty sector for years, so diesel emissions control technology R&D needs to be undertaken in any case.

It will be clear below that there are many technological options, some of them very exciting. None can presently compete on a one-to-one, trip-by-trip basis with a gasoline vehicle, taking into consideration vehicle and fuel costs and consumer preferences revealed by their choices from the existing set of gasoline vehicles. Given current growth of travel—absent changes in technology that improve efficiency faster than the growth rate of travel—total transportation energy consumption will continue to rise. To make explicit that which we have just implied, without technology forcing regulation, taxes on gasoline or on low efficiency vehicles, and/or subsidization of these new technologies, the trend toward increasing gasoline consumption, GHGs, and oil imports will continue. Reasons for the reluctance to use fuel taxes to force the desired change are evident, given the magnitude of the taxes needed (as revealed below) and the attitude that the public has shown in the past toward increased fuel taxes. (Though in the matter of public attitudes, there is some indication that citizens are more likely to support increases in gasoline taxes if they believe the additional tax revenues will be used to address specific transportation related problems and not to augment "general funds.") While we concede that widespread land use planning may be as difficult to sell to the public as would fuel taxes, we add to the discussion at the conference here to argue that there should be some synergism of land use planning with the possible technology packages that appear to be very slowly but very surely on the way. These include: (1) more efficient advanced electric drive vehicles, (2) more direct and indirect use of natural gas feedstocks rather than crude oil feedstocks to provide fuels for advanced and conventional vehicles, and (3) expanded use of ethanol fuel from biomass.

Next, we present our synthesis of the Asilomar conferences of 1991, 1993, and 1995. This synthesis is presented as a sketch, drawing together comments across the years into thematic sections. The first theme is technological choices and policies that promote specific technologies. Next, we highlight some of the commentary on the use of land use and tax policy to manage energy consumption. We close our review with an attempt to articulate some promising, and some not so promising, pathways that emerge from our synthesis.

A synthesis of proceedings to date:

Technology Choices and Technology Promoting Policies

"Technology is still the answer" (C. Lave, 1997). Professor Lave's comment was directed at the thematic question for the 1995 conference—is technology enough to achieve that conference's stated sustainability goals?

"Designing a radically improved car is a difficult challenge and a dangerous game: If customers don't like your eco-righteous car, you are out of the market ... or out of business"(D. Drake, 1995), quoting J. Baldwin. "One of the big fears of many, including those that believe the electric vehicle has a future, is that the early introduction of an uncommercial product forced by unrealistic mandates will poison the market for an improved product later on." D. Drake (1995) (at the 1993 Asilomar Conference on Strategies for Sustainable Transportation. The California zero emissions vehicle (ZEV) mandate [seen by industry as designed to force the introduction of electric vehicles] has since been delayed from 1998 to 2003).

"The first experimental FFV [flexible fuel vehicle] was built in 1983. Production started in 1993, although still in limited quantities, because Ford wanted to be sure that all of the technical issues had been resolved" (R. Nichols, 1997).

"In the midterm (1996-2000) EVs [electric vehicles] with advanced batteries might appear, perhaps in some hybrid configuration" (J. J. Brogan and S. R. Venkateswaran, 1993). [Editors' note: This quote is from a published presentation given in 1991 at the Asilomar Conference on Transportation and Global Climate Change. Both Honda and Toyota have stated that in the year 2000, they will be selling one hybrid-electric vehicle (HEV) model each, totaling a few thousand HEVs in the United States. Neither of the models can be driven solely in an all-electric mode under realistic driving conditions. The HEVs envisioned by Brogan and Venkateswaran assumed at least 50% all-electric operation, using "electrical outlet power."]

Development of technology is relatively easy compared to development of the market" (R. Nichols, 1997).

Worsening traffic congestion has pushed upward on the actual fleet fuel intensity of the automobile fleet in most OECD countries. In the early 1980s, the U.S. Environmental Protection Agency (EPA) determined that vehicles in use achieved 15% lower fuel economy than the nominal vehicle rating based on the driving cycle test ... Some observers believe that the discrepancy has grown to as much as 25% as a result of increasing urban congestion, increasing share of urban driving ... higher speeds on open highways, and higher levels of acceleration in actual use than in the test" (L. R. Schipper, R. Steiner, and S. Myers,1993).

"The analysis points to an array of options available for the future, with each option providing different tradeoffs in technology risks and emission benefits. Hence, there may be market niches for all these vehicle types" (K. G. Duleep, 1997) [in reference to advanced conventional (gasoline and diesel), electric, and hybrid-electric vehicles].

"One conclusion to draw is that the best vehicle for the urban driving cycle (which in many locations is becoming the gridlock style) may be a rather different vehicle from one used primarily for high speed driving with few stops.... The customer will be offered choices that emphasize one type of driving more than the other, but the vehicle will handle the other type adequately… The net consequence is that, from a fuel economy standpoint, the hybrid looks attractive for low speeds and stop and go driving, and moderately attractive even at higher speeds." (MacReady, 1993). (Editors' note: According to Toyota estimates, their Prius HEV, when compared to a similarly performing Toyota gasoline model, obtains 100% higher fuel economy in the Japan 10-15 mode cycle, a stop and go cycle which averages 14 mph. However, according to EPA estimates, it will exceed the fuel economy of a performance comparable gasoline vehicle by 45% on the U.S. Corporate Average Fuel Economy Test. Compared to the 1998 Toyota Corolla with a four speed automatic transmission, it obtains about a 60% mpg increase in city driving, and about 15% in highway driving. [Toyota, 1997; K. Hellman, M. R. Peralta, and G. K. Piotrowsky, 1998; U.S. Department of Energy, 1997]. Fuel cell HEVs appear to be likely to have the same property—i.e. a larger jump in city fuel economy than highway fuel economy in comparison to conventional gasoline vehicles. While the ratio of the city to highway test fuel economy for the Toyota Corolla is 67% [U.S. Department of Energy, 1997]; for simulated fuel cell vehicles, the ratio varies from 80% to 96%. [E.D. Doss, R. Ahluwalia, and R. Kumar, 1998, and Oei et al, 1997]). Lovins characterized the "Ultima" hypothetical ultralight HEV to be introduced in the "late 1990s". It was projected to be more than twice as efficient as the U.S. 1990 average car, perhaps as much as three times as efficient—in city driving—but this car was characterized to have efficiency (relative to its own city driving) fall in highway driving "because there is far more irrecoverable loss to air drag … and less recoverable loss to braking." (Lovins, 1995). The Partnership for a New Generation of Vehicle's "Goal 3" is to produce a vehicle which can triple fuel economy on the Corporate Average Fuel Economy cycle, which combines city (55%) and highway driving (45%) fuel consumption. Thus, the PNGV goal exceeds the fuel efficiency gain implied by example (in Lovins' Fig. 5-1) to be possible. However, it does allow a few more years to reach that goal (2004). In 1998, Car and Driver, perhaps misusing the existing EPA-based gasoline car on-road vs. dynamometer test discount factors, published a so-called EPA rating of the Toyota Prius HEV of 43 mpg in the city, and 41 mpg on the highway. (P. Bedard, 1998). C. E. Thomas et al (1998) also recently estimated lower highway than city mpg for three simulated HEVs operating on city and highway cycles designed to be 25% more aggressive than the present EPA test cycles (thereby presumably more closely replicating "real world" on-road behavior).

"In the long run, I think electric drive hybrid cars will win because they are likely to be better all around for the customer … Achieving a reasonable transportation energy/environment goal … requires a mixture of strategies that include (1) attention to both gasoline and alternative fuels—especially methanol, ethanol, CNG, and hydrogen—with consideration given to domestic sources, replenishability, CO2 benefits, and local pollution benefits … Harnessing the combined consumer-government-automobile manufacturer-energy industry into a team to use these technologies represents the much greater part of the challenge" (MacReady, 1993).

In his table 7-5, K. G. Duleep (1997) estimated the cost to achieve fuel consumption of 64 to 65 miles per gallon (CAFE combined city/highway) in a mid-size passenger car using gasoline in a conventional vehicle technology package. He estimated that it would cost slightly more than obtaining the same fuel consumption using hybrid-electric technology. As we have seen above, an HEV with the same CAFE rating as a conventional vehicle package would have much higher city fuel economy, and somewhat lower highway fuel economy. Duleep estimated that an advanced diesel could obtain fuel consumption of about 59 mpg, at about half the incremental cost of the 64-65 mpg HEV or conventional gasoline vehicle.

M. A. Delucchi (1998) coined the acronym NPGV—negative population growth vehicle—to show his concern with a focus on diesel technology to improve fuel economy and reduce greenhouse gas emissions. His concern is due to the likelihood of increased direct and indirect fine particulate emissions if diesel technology is adopted in light duty vehicles. Lovins (1995) and Kinsey (1997) did include diesel vehicles on their list of candidate high-fuel-efficiency technologies.

"… the tailpipe of a hypercar would emit less pollution than the powerplants needed to recharge a battery-electric car. Hypercars would therefore be cleaner, even in the Los Angeles airshed, than so-called zero emission vehicles (ZEVs) (actually, 'elsewhere' emission). Ultralight hybrids should therefore qualify as 'virtual ZEVs' and probably will" (A. Lovins, 1995). In fact, the California Air Resources Board did introduce an "equivalent ZEV" (EZEV) category in subsequent regulation, but did not abandon the ZEV requirement altogether. Note that the hypercar conceptually was a petroleum-fueled car (though Lovins mentioned fuel cell versions in passing), while electric power uses very little petroleum, and electric vehicles have no tailpipe emissions control equipment failure due to malfunction and deterioration. Honda has since announced that it expects to produce a relatively conventional gasoline-powered Accord that will meet the EZEV regulation. The Toyota Prius HEV tested by EPA is not yet an ultra low emissions vehicle (ULEV)—a category much less strict than the EZEV category. As of this writing, several conventional gasoline vehicles already meet the present California Ultra Low Emissions Vehicle (ULEV) emissions requirements.

"The analysis indicates a substantially large potential for reducing automobile energy use and related CO_2 emissions through improvements to the conventional four-stroke SI engine, introduction of advanced heat engine, electric, and electric-hybrid alternatives, combined with reduction in the weight of vehicle structures … and vehicle design improvements. In the best case, the fuel energy use … and CO_2 emissions … for a … mid-sized automobile … could be potentially reduced (in the long term) to as low as 2300 Btu/mi … with a PEM fuel cell battery hybrid vehicle fueled by hydrogen" (J. J. Brogan and S. R. Venkateswaran,1993).

"Current gasoline engines operate at only about 32 percent peak efficiency, whereas 4SDI [Editors' note: 4SDI is four stroke direct injection—presumably meaning an advanced diesel here] engines operate at about 43 percent peak efficiency…. Important PNGV goals for the 4SDI engine are to increase peak thermal efficiency to about 46 percent and to reduce NO_2 and particulate matter emissions to Tier II levels…. Fuel cells using stored hydrogen potentially have high vehicle efficiency; full-cycle efficiency still needs to be assessed. Fuel cells currently have vehicle peak thermal efficiencies of 52 percent and are expected to achieve efficiencies greater than 55 percent in the 2004 time frame. Fuel cells with an on-board methanol reformer have 35 percent peak thermal efficiency today and are projected to improve to 37 percent. With a petroleum reformer, the efficiency is 30 percent today, with improvement to 32 percent projected" (D. Kinsey, 1997). The PNGV, due in part to pressure from Chrysler and to a desire to avoid costs of switching fueling infrastructure, included fuel cells using gasoline as the hydrogen carrier on its list of candidate technologies. When DaimlerBenz bought Chrysler, the new DaimlerChrysler's research on the use of gasoline for fuel cell vehicles was dramatically de-emphasized in favor of methanol and/or hydrogen, both presumably produced from natural gas.

"For the initial tests of FCEVs [fuel cell electric vehicles], hydrogen could come from the most convenient and lowest cost source, which probably would be natural gas... Hydrogen fuel cell vehicles could become an important part of a strategy for reducing greenhouse gas emissions and improving urban air quality" (Ogden and Delucchi, 1993).

"The estimated emission control cost effectiveness of ten alternative fuel vehicle (AFV) types shows that compressed natural gas vehicles (CNGVs) are the most cost effective AFV type in regulating air pollutant emissions; vehicles using ethanol and gasoline in a variable proportion from 0/100 up to 85/15 [85 flexible fuel vehicles (FFVs)] are the least cost-effective AFV type; methanol vehicles, liquid petroleum gas vehicles (LPGVs), and EVs fall in between" (Wang, 1995). [Editors' note: Wang examined no HEVs in this analysis, emissions of "criteria" pollutants, by vehicle type were based on real data.]

"In the early years of a transition to AFV use, transition costs will be greater than the near-term benefits of AFV use" (M. K. Singh and M. Mintz, 1997).

"When the power supplying an EV is generated with existing, relatively dirty coal powerplants, then the externality costs of the sulfur emissions add significantly to the cost of EVs. If new, clean burning gas combined cycle (or renewable) technology is applied, the reduced externality values relative to the internal combustion engine alternatives provide electric vehicles a significant savings" (M. Fullmer and S. Bernow, 1995). [Editors' note: The EIA (1998) study "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity" simulated a massive switch to combined cycle gas-fired power plants in the event of adoption of carbon taxes sufficient to meet Kyoto goals in the U.S.]

"In the case of the heat engine/battery hybrid vehicles ... it is assumed that 50% of the driving energy to the wheels comes from electrical outlet power (through charging the batteries) and 50% from the heat engine generator. In the mid to long term... the contribution of electrical outlet power is increased to 60%" (J. J. Brogan and S. R. Venkateswaran, 1993). California Air Resources Board LEV II regulations allow scaled "partial ZEV" credits for hybrid vehicles with 20 or more miles of all electric range. Between 20 and 30 miles of all electric range, assuming vehicle recharging every night, could lead to 50% of energy provided by the electric grid. The concept for the Partnership for a New Generation of Vehicles (PNGV) is for an HEV with no recharging from the grid, like the Lovins "hypercar" and the Toyota Prius.

"[For] Synthetic fuels from wood or other low input biomass feedstocks... Production processes are not yet technically demonstrated, but the fuels could offer 60 to 80 percent life-cycle greenhouse gas emission reduction... The externalities that have been identified with car use probably do not justify the level of fiscal intervention that appears to be necessary to introduce alternative fuels requiring substantially different car technology" (Michaelis, 1995)

"... We first apply cellulosic ethanol... in blends... once a 10 percent level is reached nationwide, additional capacity is assumed to go to dedicated- or flexible-fuel vehicles...accelerated biofuel production capacity expansion would yield a renewable share of nearly 10 percent by 2015 and a substantial share in later years, nearly 30 percent by 2030. Even in this more ambitious scenario, the renewable share is just starting to rapidly climb in 2010, and widespread use of dedicated vehicles only begins in 2013" (J. DeCicco and L. Lynd, 1995). DeCicco and Lynd recommended an extension of the then current ethanol subsidy, to be phased out by 2010, and capped at $650 million. Criteria pollutant emissions from present ethanol fueled vehicles match those of average gasoline vehicles at best. While some of the numerous gasoline vehicles sold today have very low emissions, this is not the case for the few ethanol vehicles sold today. Use of ethanol in FFVs (many of which are being sold) in nonattainment areas which need significant emissions reductions is therefore likely to be limited.

"In 1996... there was a ramp-up in the number of units produced because the market now sees the FFV as a reliable product. In 1997 Ford will build as many units as anyone orders, with shipment anywhere. One of the key events that brought the FFV out of research and development and into the production development process was the passage of the Alternative Motor Fuel Act (AMFA) of 1988.... it provides the auto industry the opportunity to comply with CAFE with new product whenever some of the cost of that new product can be justified by the offsetting CAFE benefit" (R. Nichols, 1997).

"...Given the limited experience with market mechanisms and the large uncertainties in response to pricing changes, only fuel economy standards, or equivalent approaches such as a regulatory cap on GHG emissions, are likely to provide the certainty needed to reach particular sustainability targets ..." (DeCicco and Lynd, 1997).

"Current programs and policies will not bring these technologies into use to the degree needed to achieve the goals....we do agree on these directions:

- reducing greenhouse gas emissions
- reducing criteria pollutants
- reducing oil imports
- increasing renewable fuels" (B. McNutt, L. Fulton, and D. Greene, 1997).

Of the four goals above, criteria pollutants are being reduced, and corn ethanol use is being maintained and perhaps expanded slightly, if only because of the federal ethanol subsidy. E85 FFVs are being sold, and numerous CNG light duty vehicle models are now available, but the use of ethanol and CNG in light vehicles is not increasing rapidly enough to offset growth in demand for gasoline. HEVs and EVs will be available in the U.S. in the next century, but their cost may be too high to result in enough sales to reverse growth in GHGs and oil imports. Though real oil prices were projected in a 1991 presentation by Miles-McLean, Haltmaier, and Shelby (1993) to increase, with new light duty vehicle fuel economy increasing, light truck shares decreasing, and vehicle imports increasing, the opposite happened. Gasoline consumption and GHGs have risen (U.S. Department of Energy, 1998) and seem destined to continue to do so. In the meantime, advanced drilling technology kept the rate of decline in U.S. oil production from worsening, but production did relatively steadily decline nevertheless, so oil imports also rose and continue to rise (U.S. Department of Energy, 1998). Where regulations have been tightened (criteria pollutant emissions) or fiscal incentives maintained (potentially renewable ethanol), progress toward the above goals has been realized. Where neither has been used (GHG emissions and oil imports), progress has been absent.

This tells us where we have been lately (last decade), more or less where we are at the moment and where we are going for the time being. It does not tell us where we are going for the next decade or for the next three decades. Though petroleum consumption is on the rise, it is about the same as in the late 1970s, despite a far larger economy, and because of a couple of multi-year drops in oil consumption in that interval. Technology to allow a jump in vehicle fuel economy or a sharp reduction in petroleum use (by use of alternative fuels) appears to be technically feasible now, though not economically feasible at present retail gasoline prices (including all taxes).

Reducing Fuel Use of Vehicles through Land Use and Taxation

"Gordon suggests that shorter-term solutions are likely to focus on pricing and educational policies, that mid-term solutions will be premised on technology, and longer-term solutions will focus on changed land-use patterns and life styles" (D. Sperling and S. A. Shaheen, 1995).

"The biggest concern in most metropolitan areas include equity, quality of local services, and habitat loss. The issues are not air quality and global warming" (B. Johnston, 1997).

"Land-use policy would not be a promising strategy to achieve environmental or sustainability objectives.... Sustainability is more about pricing than it is about land use" (G. Giuliano, 1997).

Giuliano (1997) suggested two land-use proposals for the future. First is an urban design policy based on transit oriented development (TODs). The idea is to make walking and transit use more attractive. Second is an increase in development density—the "compact city" proposal. In this way, automobile use would become less attractive.

"The evidence is much more positive and complete concerning density increase ... relatively high densities and relatively high clustering reduced gasoline consumption, whereas a concentration of jobs in the urban center increased consumption... higher *residential* densities reduce VMT per capita. An empirical study in Toronto found that an increase in residential units in the downtown area reduced commute trips to the center by 240 trips per work day per 100 units built. Reducing sprawl at the edge with urban growth boundaries was also seen to reduce VMT in conjunction with pricing and transit improvements" (B. Johnston and R. Ceerla, 1995).

"... auto costs had to rise by 300 percent to reduce VMT by about 33 percent...." (B. Johnston and R. Ceerla, 1995).

"... [I]t would roughly take a tripling of gasoline prices to yield a 40 percent increase in new-vehicle fuel economy (to an average of 35 mpg for new cars and light trucks)" (J. DeCicco and D. Gordon, 1995). According to DeCicco and Lynd's paper, such an increase in fuel economy, accomplished steadily over a decade's time, would not lead to a reversal of growth of U.S. gasoline consumption. Note that, in light of declining domestic oil production, a reversal of gasoline consumption growth would certainly be necessary to begin to reduce the importation of oil, or even to hold the quantity imported constant.

"...The U.S. Department of Energy... projects production costs comparable to those for corn—on the order of 1.20/gallon" (L. Lynd, citing a 1993 study on the costs of biomass ethanol, 1997). [Editors' note: Assuming that this is "ex tax" cost per gallon of ethanol, the gasoline-equivalent cost per gallon, based on specific energy and allowing for a 10% octane-based in-use efficiency gain, would be about $1.65/gallon. Assuming a retail price of about $1.00/gallon gasoline (slightly low, but close to the price for unleaded regular in the twelve months ending in June 1999), with 65¢ represented by "ex tax" price, the "ex tax" price increase per gallon-of-gasoline-equivalent for ethanol would be $1.00. Holding the taxes constant at 35¢/gallon, and adding a dollar to the ex-tax price of gasoline, to make the ex-tax price equivalent to that of ethanol on an energy equivalent base, we obtain an estimate that a doubling of retail gasoline price from a $1.00/gallon base would be needed before ethanol could be directly competitive with gasoline, at the pump.]

These last three citations, taken together, give us a rough idea of possible ethanol costs vs. gasoline tax levels that might be needed to bring forth enough improvement in light duty vehicle efficiency to begin reduction of gasoline use and GHGs from light vehicles within the next decade or two.

Multiple Strategies—Accounting for Technology Strengths and Weaknesses

Some suites of actions appear to offer potentially mutually reinforcing benefits. Still, even if promising suites of actions can be constructed, the timing of the different actions within each suite, and the stream of costs and benefits associated with each suite may render the suites infeasible, or at least unlikely, given current technological and regulatory conditions. We offer the first suite as an example—under what conditions might we initiate large-scale use of cellulose ethanol?

Increasing land use density, tapping hybrid vehicle efficiency, and reserving land for ethanol production. We note that increasing residential density tends to reduce annual vehicle VMT and average vehicle speed. Lower average speed, due to congestion, and more frequent stops, may improve the absolute efficiency of hybrids and will certainly improve the efficiency of hybrids relative to comparably performing gasoline vehicles. Urban growth boundaries, mentioned by B. Johnston and R. Ceerla, if maintained for decades, would undoubtedly increase population density and thus decrease VMT per individual. It should also thereby increase in-use efficiency of hybrid cars relative to gasoline cars, and increase the amount of walking and biking in place of use of motor vehicles. In a world where cellulosic ethanol is one of the key options for GHG reduction, limitation of encroachment into cropland at existing urban boundaries would help assure adequate land area to produce the ethanol (given certain assumptions about the specific nature of competition for which crops are grown on what land). To the extent that biodiversity in habitat adjacent to urban areas is desired, annexation of the land for such purpose might lead to needed support for an explicit urban boundary.

But what of the transition path to ethanol? Ethanol, at this time, does not appear to offer criteria pollutant benefits relative to gasoline. Accordingly, it is presently difficult to argue that ethanol refueling stations should be introduced into those metropolitan areas that violate ozone air quality regulations (nonattainment areas). HEVs do appear to be able to match the criteria pollutant performance of low emissions gasoline vehicles. Ethanol is not regarded as a prime fuel cell vehicle fuel (though it has been advocated by some for such a possibility), and would be less efficient than methanol in such an application. In any case, if one cannot now promote a requisite ethanol fueling infrastructure within ozone nonattainment areas, a prerequisite for ethanol fuel cell vehicles would be missing.

Outside of larger metropolitan areas, average vehicle speeds are higher. At higher speeds the relative advantage of HEVs, EVs, and fuel cell vehicle technology (ethanol, or otherwise) is or would be considerably less. Therefore, use of ethanol in conventional vehicles outside of major urban nonattainment areas seems like a best, if not compelling, use of ethanol to displace oil use and reduce GHG emissions. In fact, the existence and sales of ethanol FFVs may be premature, since ethanol, as "gasohol" in a 10% blend, can be blended into a much larger percentage of that share of the conventional gasoline market outside of ozone nonattainment areas. However, those ethanol FFVs sold now will have the ability to use ethanol for as long as they exist, up to a decade and a half for many vehicle models. Thus, large percentage increases of ethanol through cellulosic ethanol production in a few years could be nicely enabled by present sales of ethanol FFVs that may use only gasoline for several years.

No methanol-to-fuel-cell pathway? Methanol was the alternative fuel that caused introduction of reformulated gasoline. The State of California pursued methanol in the 1980s, for emissions reduction purposes. Initial Ford FFV work mentioned above by R. Nichols focused on the use of methanol and gasoline, only later switching to ethanol and gasoline after interest in methanol faded. Reformulated gasoline for summertime ozone reduction uses methanol as a feedstock for MTBE, a chemical blended into the gasoline to provide emissions advantages. The introduction of MTBE led the methanol industry to lose interest in selling and promoting FFVs capable of using methanol. Only California established any refueling infrastructure; the number of stations was small, and is now diminishing. The number of methanol FFVs being sold by the auto industry is minimal——far fewer than ethanol FFVs. Any "momentum" toward development of either a methanol fueling infrastructure or a representative group of methanol FFVs has been lost. Incremental supplies of methanol for MTBE are foreign-sourced, so it is argued that replacement of gasoline with methanol will simply switch one fuel import problem for another. There are no appreciable GHG effects of introducing methanol in conventional vehicles. Reformulated gasoline allows emissions as low or lower in conventional vehicles as does methanol. Methanol from natural gas (the method of production used by the industry) is not renewable. Accordingly, there is no short-term justification for methanol fuel as a means of reaching any of the four goals addressed by the Asilomar conference participants. (Editors' note: We may perhaps be reading the oil import goal more broadly than did conference participants.)

Methanol is probably the cheapest way to convert offshore natural gas into a fuel for shipment by tankers and use in slightly modified conventional vehicles. So it could provide greater price competition for oil (gasoline) than the other alternatives examined here, and keep oil prices down. However, for GHG reduction a higher fuel price is better than a lower price (to encourage increases in efficiency). Much of the U.S. population now lives near the coasts. Methanol shipments to coastal areas and relatively short infrastructure links might be constructed, allowing fuel cell vehicles to efficiently use the methanol in dense metropolitan areas near the U.S. coastline. This end result seems very unlikely, since there is no short-run reason among the four above to pursue methanol.

Natural gas vehicles—a possible pathway from conventional to fuel cell vehicles. Natural gas ICE vehicles are presently quite clean, and the net emissions reductions costs are not as high as for other alternative fuel and advanced vehicle types, due to the usually low cost of natural gas. 1999 model year CNGVs are consistently being certified to the ultra-low emissions vehicle (ULEV) category, or better (SULEV). When dedicated to CNG only, they have less driving range than otherwise comparable gasoline vehicles. In dense urban areas, trips are shorter and speeds are slower. So distance traveled per day will on average be less, and range perhaps less likely to be a constraint. Natural gas refueling infrastructure is most often available in metropolitan areas. One option being considered for fuel cell vehicles is conversion of natural gas to hydrogen at refueling stations. A switch to hydrogen fuel cells making use of previously implemented natural gas refueling facilities is one possible pathway to a hydrogen fuel cell vehicle future. Accordingly, introduction of ICE CNG vehicles now in major nonattainment areas may be a good short-term emissions and oil use reduction strategy (though GHG emissions are little affected), and perhaps a good long-term strategy for introduction of extremely clean hydrogen fuel cell vehicles which would have relatively high fuel efficiency in the urban driving conditions existing in major nonattainment areas.

Vehicles using electric drivetrains. The introduction of electric drivetrains creates the long-term opportunity to use natural gas fuel in several ways. First, electric drive for hybrid vehicles can be seen as setting up production and technology for a switch from conventional engines to fuel cells. The fuel cells could use hydrogen converted at the station from natural gas or methanol in a conventional station set-up, with the methanol produced from natural gas. Second, batteries in electric drive vehicles could allow charging by combined cycle power plants fueled by natural gas, or by stationary fuel cells using natural gas. In the near-term, hybrid vehicles capable of connecting to the grid have the potential to reduce oil use by switching to electricity. During peak ozone episodes, running a hybrid on grid electricity (in ZEV "mode") in the morning and afternoon hours could result in nearly all of the air quality benefits of an electric vehicle. In the longer term, if combined cycle natural gas power plants or fuel cell power plants replace contemporary steam generating plants and fuels, the full pathway efficiency from the use of grid electricity by electric and hybrid electric vehicles could be quite high, and the GHG reductions significant. Research on grid connectable hybrids should continue and best applications carefully examined.

Hybrid vehicles such as the Toyota Prius and Honda VV, in compact and smaller sizes, appear most attractive as high utilization urban vehicles. Use as the urban car in multi-vehicle households which put a lot of miles on their vehicles would appear to be the most likely initial market. Significant reductions in both oil consumption and GHG emissions could be realized by such applications of hybrid vehicles.

General observations. Absent fiscal policies to increase gasoline costs and decrease the costs of consumer use of alternative vehicle propulsion technologies, expansion of use of these alternative technologies will be inadequate to reverse growth of GHGs and oil imports. Regulation of fuel efficiency could accelerate the introduction of HEVs and high efficiency conventional ICE vehicles, and could lead to reduced gasoline use, oil imports, and GHGs. Further AMFA type exceptions to tightened fuel economy regulations—but tied to documented alternative fuel use—could accelerate implementation of natural gas and ethanol refueling stations, and the vehicles to purchase fuels from those stations. Expansion of ethanol use outside of ozone nonattainment areas could reduce gasoline use, oil imports and GHGs in both the near and long-term. Expansion of natural gas use within ozone nonattainment areas could improve urban air quality in the near term, and could help lead to hydrogen fuel cell vehicles in the long term, then reducing gasoline use, oil imports, GHGs, and criteria air pollutants. Electric utilities might find ways to promote the introduction and sale of grid connectable variants of hybrid vehicles, by continuing and adapting programs originally intended to promote electric vehicles.

The 1997 Asilomar Conference

These proceedings differ from past proceedings in that these include both papers prepared by some of the speakers, as well as a summary of the entire conference. Individual papers are presented first; the final chapter contains the extended review.

As noted earlier, the papers and the 1997 conference addressed the importance and potential value of three different government policy instruments—transportation fuel taxes, regulation, and research and development programs. The discussion involved the relative desirability of applying these policy instruments to three different objectives: reduction of (a) petroleum-based transportation fuels consumption, (b) criteria pollutant emissions, and (c) net greenhouse gases.

Taxation—Transportation pricing

Ken Button's paper addressed the "rational" use of pricing. He nominally provided a European perspective. His title is telling—he used the term "more" rational pricing, thereby implying a great deal of respect for the existing pricing system, indicating a need for improvement, not radical change. An emphasis was the need for and emergence of coordination and balancing of tax and emissions regulation policies among European nations. He indicated that coming waves of privatization of transport seemed likely to decrease the cost of transport, and noted the potential for higher use of transport and higher social costs due to that higher use. One feature highlighted by Button was the need to prevent creation of an effective barrier to trade which could be a side effect of emissions control measures that might be adopted due to high volume throughput in the Alps.

Button's paper was the only one to attempt to provide information on the current status of transportation taxes in various political units (the nations of Europe and the U.S.). His illustration (his Table 2) showed, to us, a surprising characteristic of several nations, including the U.S. For the U.S., the amount of revenue raised by fuel taxes, vehicle taxes, and tolls is only 63 percent of the amount of revenue disbursed to support transportation services. The mean in Europe was estimated to be 124 percent, but half of the ten nations for which Button had estimates raised less money than they expended on transport. We checked on the ratio of the tax on gasoline to the price of gasoline in the European nations in Button's table, vs. that of the U.S. The mean for the European nations was 0.67, with a standard deviation of 0.067, compared to a value of 0.33 for the

U.S. So, assuming that retail gasoline can be produced for similar real costs in Europe and the U.S., the level of taxation in Europe is about twice that in the U.S. This method does not match up to results obtained when using real dollars and exchange rates, but it does provide an indication independent of highly variable exchange rate effects. So, in the aggregate, it appears that Europe in the mid-1980s taxed gasoline about twice as heavily as in the U.S. Europe also raised about twice the revenue needed relative to transport infrastructure expenditures through fuel and vehicle taxes as did the U.S. (124% vs.63%).

As Button points out, many of the nations of Europe put revenues from fuel and vehicle taxes into the general fund, rather than earmarking those revenues for transportation infrastructure, as is done in the U.S. Interestingly, Button contended that the approach of the U.K. is that "prices should reflect broad costs and demand conditions". Yet Button's Table 2 indicated that the U.K. raised 180 percent of the public expenditure on transportation infrastructure, essentially tied for the high position with Italy. Button cited adoption of a 3 percent per annum fuel tax increase by the U.K for the purpose of addressing carbon dioxide emissions. Examination of gasoline price trends and inflation in the U.K indicated that, over the time that this tax has been in effect, it merely allowed the tax on gasoline to increase with inflation. Policy critics should take care to examine proposed global warming taxes carefully, to determine whether they are real taxes (i.e. adjusted for inflation), or nominal taxes that only keep real revenues at about the same level (i.e. in real terms the tax declines but fuel use rises, thereby holding real revenue about the same).

Unfortunately, Button was not able to present his paper at the Conference itself, so the differences between European tax policy and that in the U.S. were not part of the discussion. Recommendations for specific levels of taxation for the U.S. came from Nash, whose paper is included in this volume. Nash's recommendation was for gasoline taxes near the level of taxation in Europe. According to Nash's estimates, this would result in revenues adequate to replace social security taxes and a significant portion of the income tax. Under Nash's proposal, the U.S. would become like Europe in the sense that fuel tax revenue would now go into the general fund and we would expect to raise more in fuel and vehicle tax revenue than would be spent on transportation infrastructure. Note that, if the U.S. were to desire to double real fuel taxes by adopting the UK's nominal carbon tax strategy, a *real* tax rate increase of 3% per year would require 23 years to double real fuel taxes. Further, if inflation were 2% per year for this entire period, the nominal rate of increase in fuel taxes would have to be 5% per year. Nash does not provide information on the method he used to develop his revenue estimates. The reader might examine the numbers in Lee Schipper's paper herein regarding fuel use and travel per vehicle in Europe.

Our point here, however, is that if Nash's recommendation is taken at face value, we have a recommendation for a level of taxation of transportation fuels well in excess of that necessary to support investment in the transportation infrastructure itself.

The paper by Leiby and Rubin essentially examined the concept of taxing or subsidizing alternative fuels, based upon their life cycle greenhouse gas emissions. Six alternative fuels were examined. The analysis suggested subsidy of $0.80 per gallon of gasoline equivalent (GGE) for E85 fuel produced from biomass, and $0.16 per GGE for LPG. Other subsidies or tax levels for other fuels varied. Leiby and Rubin estimated that E85

from biomass and LPG were the two fuels whose subsidization would be both well justified and effective. Vehicle attributes and consumer responses to those attributes were included in the modeling. In one scenario, Leiby and Rubin projected that ethanol fuel production would rise to 20 percent of the gasoline market by 2010, and LPG about 15 percent. Such fuel production levels, at the subsidies proposed, would lead to a need for an additional gasoline tax of 28¢/gallon, if the revenues for the ethanol and LPG subsidy were to be paid by gasoline fuel users. This would increase the rate of taxation of gasoline from 40¢ to 68¢, or 70 percent, an amount in the neighborhood of the Nash proposal. However, given that the revenue base is itself depleted by the subsidy, the light duty vehicle fuel tax revenues raised per GGE of fuel sold (including ethanol and LPG in the average) would be about 44¢, so the tax and subsidy, as of 2010, would be approximately "revenue neutral". In any case, this computation puts the Leiby and Rubin proposal into perspective relative to the others, using admitted approximations. Leiby and Rubin do not discuss how the money for their presumed subsidy is to be raised .
One contribution that Leiby and Rubin highlight is the development of solid evidence that "transitional barriers" act to prevent alternative fuels from entering the market, even though those fuels could retain a significant share once those barriers had been successfully negotiated. The key barriers include high cost of vehicles and fuels at low production volumes, and consumer dissatisfaction with few fuel and vehicle choices early in the process of introduction.

Given Button's estimate that U.S. citizens presently do not pay high enough petrofuel taxes to allow transportation tax revenue to support transportation investment, we argue that a proposal that was missing at the Asilomar conference was that such an increase in petrofuel taxation is logical to support. This is an intermediate proposal that would raise fuel taxes less than Nash proposed, less than are in effect in Europe, and less than necessary to overcome the transitional barriers identified by Leiby and Rubin to cause a 20% reduction in Greenhouse Gases by subsidized adoption of biomass ethanol and LPG fuels. It would sharply raise taxes relative to a "seed money" proposal offered from the floor by D. Howell (see the summary at the close of this document). Howell's proposal dealt with both collection and disbursement of gasoline tax funds from a 1¢/gallon gasoline tax. In Howell's case, the funds were to be used to promote the introduction of new transportation technology that might succeed on its own after the seed money had laid the foundation for its success.

The "fairness" of user taxes on services received is more popular and commonly accepted now than in prior years, so this argument has the advantage of being philosophically consistent with the views of many of the policy makers in power today. Its implementation would simply be an extension of existing direction in a successfully evolving tax structure (success in the sense that deficits have been eliminated). If the policy had the side effect of making other funds available for diversion to other purposes (such as Social Security or tax cuts elsewhere), so be it. The point here is that this is philosophically consistent with present nominal practice in the U.S. as a way of funding transportation services.

We do note that there was absolutely no enthusiasm for proposals for national taxes on the part of the U.S. attendees, aside from Nash and S. Wallman of Volvo. Wallman, an invited commentator in the conference closing session, expressed amazement at the unwillingness of participants to even discuss tax proposals.

The paper of Cameron, which analyzes the implementation of congestion taxes, includes an example of the problem of revenue allocation, which is addressed in different ways by Nash, by Howell, and by our extension of Leiby and Rubin's analysis. To obtain support of a tax, Cameron shows that the question of allocation of revenue becomes important. In Cameron's examples, public support for a proposed congestion reducing bridge toll never materialized because there was no plan for use of the revenue that could be accepted by those who would essentially be asked to pay or to give up the service. In Nash's proposal, one must assume that the judgment is that the nature of the proposal will make it palatable to the citizenry and therefore to the Congress and President. There clearly was no bandwagon of support for Nash's proposal at the conference itself. In fact, audience reaction indicated that the notion of any tax was not likely to be accepted by the public or by the Congress—even a one penny a gallon tax. Yet the two lonely proponents of particular taxes recognized well the importance of the tax and revenue package—that is that the support of a tax requires the approval of the plan of use of the revenue. Nash's idea featured considerations of equity and of the possible coming self interest voting effects of the members of the baby boom. He suggested that revenues be used to reduce income taxes of the lowest income individuals, and that the anchor of retirement income for aging baby boomers (Social Security) be supported. In Nash's thinking it is important to develop a proposed use of increased gasoline taxes which is palatable to the citizenry and therefore to the Congress and President. There clearly was no bandwagon of support for Nash's proposal at the conference itself. In fact, audience reaction indicated that the notion of any tax was not likely to be accepted by the public or by the Congress—even the one penny a gallon tax suggested by Howell. Yet the two lonely proponents of particular taxes recognized well the importance of the tax and revenue package—that is that the support of a tax requires the approval of the plan of use of the revenue.

Leiby and Rubin's analysis considers an objective, and tries to develop a path to that objective. It uses a subsidy to reach that objective, but ducks the issue of a tax to raise the revenue for the subsidy.

We note that several past papers in the Asilomar series have examined the use of taxes and subsidies. In the 1993 volume, Miles-McLean, Haltmaier, and Shelby examined such options ("Designing Incentive-Based Approaches to Limit Carbon Dioxide Emissions from the Light Duty Fleet"). They examined a gasoline tax offset by payroll tax reductions, a gas guzzler/gas sipper rebate, and an oil import fee, finding the gasoline tax to be the best of the three. The federal gasoline tax increase that they simulated increased from 9¢/gallon in 1989 dollars to 50¢/gallon by 2010. Their projection assumed an increase in before tax gasoline prices, and essentially a net doubling of real gasoline costs over a 20 year period. This increase was simulated to result in the same gasoline consumption at the end of the 20 year period as at the beginning, and a new car fleet fuel economy increase of about 30% (from 28 to 36 mpg). Truck share was projected to decline. However, the policy itself only caused a fuel economy increase of 8% relative to the reference case. The "reference case" in fact showed *increases* in fuel economy due to *presumed* increases in oil and gasoline costs. Thus, an increase of federal taxes of over five times was projected to only increase new car fleet fuel economy by 8%. The gas guzzler/sipper tax and rebate resulted in a slightly more efficient fleet, but higher vmt, thereby differing little in overall effect. Note that no technological breakthroughs were assumed—increases projected were from "econometrically simulated" improvement based on history for conventional gasoline vehicles, and are not technically challenging. This small increase in new car mpg as a function of gasoline price increase is perhaps pessimistic, as DeCicco and Gordon (1995), in the 1995 Asilomar Proceedings estimate that "it would take roughly a tripling of gasoline prices to yield a 40 percent increase in new-vehicle fuel economy." In any case, the increases in gasoline price to bring about increased new vehicle fuel economy are large indeed. Note that this combination—a 40% increase in mpg combined with a tripling of fuel cost—would lead to an increase in cost per mile of 80%. According to MacReady (1993), such a change would be like going from 1989 real cost per mile levels nearly back to 1969 real cost per mile levels (MacReady estimated 1969 costs to be double those of 1989).

A problem that inhibits the ability to make decisions is the opinion of conference participants concerning whether a given proposal will get close enough to the objective that they have in mind. Thus, when the participants examine the probable effects of taxation on petrofuel consumption, they have serious doubts that the effect of any possible tax will be large enough to realize the petrofuel, greenhouse gas, and/or criteria pollutant emissions reductions that they have in mind. When and if one reaches the conclusion that a tax cannot be implemented, or if implemented just cannot politically be large enough to provide reductions that a conference participant has in mind, then thoughts turn to technological innovation. The sense of this and prior conferences is that behavior change promoted by taxes is not likely to reduce oil use and emissions enough, even if some taxes could be implemented.

Regulation—of vehicles and/or land use

Schipper's paper seems to imply that the nation that achieved the greatest percentage reduction in fuel use after the oil price shocks of the 1970s was the U.S., and the only reason that the U.S. was able to do so was the adoption of technology forcing regulation. Nash has looked at the history of transportation and seen the long term benefits of technological innovations in transportation. Apparently, he has concluded that regulation similar to that used by the U.S. in the past is not politically feasible. The organization that he retired from—the National Highway Traffic Safety Administration—has been proscribed by Congress from even spending any funds to analyze changes in the existing Corporate Average Fuel Economy regulation. We speculate that Nash, seeing technology "revolutions" in transportation as highly desirable, and seeing the resistance to technological change as being strong, has concluded that the only way to cause such a revolution is through a very high petrofuel tax. Accordingly, he has tried to develop a justification for use of the revenues of the tax to garner support for it.

Others at the conference come from organizations not proscribed from considering the use of regulation to force the introduction of new technology. Greene is one of those. He has provided an analysis of the economic value of a tightened fuel economy regulation, while not dismissing the value of petrofuel taxes as well. He has provided illustrations indicating why a regulation of passenger car mpg to the mid 30 mpg range might be desirable, with a commensurate change for light trucks. He has developed an argument, ignoring criteria emissions and greenhouse gases, that the economy would be better off with a tightened improved fuel economy regulation alone than without it. He has asserted that a combination of regulation and taxation would be even better, but regulation alone—of the specified magnitude—would be better than none at all. Greene's arguments are based on a trade-off analysis of costs and benefits of varying levels of fuel economy in the light duty vehicle fleet, not on a specified goal for reduced petrofuel use or greenhouse gas emissions. In effect Greene says we have too little fuel economy in our light duty motor vehicle fleet and we should be smart enough to do something about it.

What are the equity consideration's in Greene's proposal for tightened regulation? Who pays, and who benefits ? It was estimated(see discussion in the summary) from K.G. Duleep's presentation and Greene's paper that the automobile industry would realize the same amount of revenue, while the owners of vehicles would use less fuel. Those who pay higher prices for more efficient new cars first tend to be higher income individuals, while used car purchasers have a lower income level. The fuel use reduction benefits would trickle down over time from higher income new car buyers to middle income used car buyers.

Greene's proposal is essentially based on the world the way it is. That is, he looked at available fuel efficiency technologies using existing fuels. He did not consider the potential benefits of research and development designed to create more options and to increase the percentage reduction in fuel economy for a given amount of incremental dollars of expenditure. Nor did he discuss what would be done with the revenues from a fuel tax that might accompany the regulation revisions that he proposed. Our earlier discussion covers the question of fuel tax revenue allocation.

Giuliano reviews evidence for the potential of land use policy to affect energy consumption. She concludes that land use policy alone cannot be relied on to provide reductions in energy use. Her research indicated that worldwide demographic and economic factors indicate continued consumption of land for urban expansion at the extensive margin of cities, motor vehicle use, and traffic congestion. These arise from forces that she sees as difficult to counter. While largely conceding her point, the other presenter in her session, Robert Johnston, stated his belief that in the long run, land use can have significant effect, if consistent policies can be maintained.

Closing Thoughts

In the 20th Century, the "one thing" in light duty personal transportation has been the gasoline fueled, spark-ignition-engine powered passenger car, and lately, light truck. This is easy to see now, looking back. At the onset of the century, the journey of discovery of that "one thing" had just begun, and the end result was hardly predictable. Perhaps any conferences sponsored by governments and industry at that time were about rail travel. At the turn of the past century the horse had not been replaced in rural areas, while novel electric, gasoline, and steam automobiles provided a tiny portion of personal travel needs in urban areas. The railroad, both intercity and intracity, provided most of the powered transportation services. For a few decades, all of these technologies competed until a winner emerged.

Based on the many technologies that have been advocated and discussed at Asilomar, the challenge at the beginning of the next century is also daunting, and the future uncertain. We presume, as Asilomar participants have, that the light duty motor vehicle using a paved highway will still be dominant in that century (but even that assumption may be wrong). However, the best fuels and motive power for such vehicles are certainly a subject of considerable debate, and the number of options to consider is great. The proposal that we have made is that we recognize that we "gotta" begin to figure out the best options, learning by doing. Let's make more use of the policy levers that have been discussed, to promote more use of alternative technologies to obtain the benefit of experience and, in a few decades, 20/20 hindsight. Perhaps all but one of the options offered at Asilomar conferences will drop by the wayside, but we certainly can't predict which one will remain in the end. It is true that the journey has begun, but there is far more of that journey ahead than behind.

References

U. S. Energy Information Administration (1998). *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity.* U. S. Energy Information Administration Report SR/oIAF/98-03. USGPO, Pittsburgh, Pa. (Oct.)

Bedard, P.(1999). Road Test: Toyota Prius Hybrid. *Car and Driver.* (Feb.) pp. 63-68.

Brogan, J.J. and S. R. Venkateswaran (1993). USDOE Vehicle Propulsion Research and Development Program. In *Transportation and Global Climate Change*, D. L. Greene and D. J. Santini, (eds). American Council for an Energy Efficient Economy, Washington, DC., pp. 159-187.

Delucchi, M.A. (1998). NPGV. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary.* T. Lipman, D. Santini, and D. Sperling, (eds.). University of California at Davis Institute of Transportation Studies report UCS-ITS-RR-98-8 (May) p. 88.

Doss, E.D., R. Ahluwalia, and R. Kumar (1998). Hydrogen-Fueled Polymer Electrolyte Fuel Cell Systems for Transportation. Argonne National Laboratory Report ANL-98/16. Argonne, Il. (Aug.)

DeCicco J.M., and D. Gordon, (1995) Steering with Prices: Vehicle and Fuel Taxation as Market Incentives for Higher Fuel Economy. In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 177-215.

Drake, D. A. (1995) Technology, Economics, and the ZEV Mandate: A Vehicle Manufacturer's Perspective. In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 243-254.

DeCicco, J. and L. Lynd (1997). Combining Vehicle Efficiency and Renewable Biofuels to Reduce Light-Vehicle Oil Use and CO2 Emissions. In *Transportation, Energy, and Environment: How Far Can Technology Take Us?* J. DeCicco and M. Delucchi, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 75-108.

Duleep, K.G. (1997). Evolutionary and Revolutionary Technologies for Improving Automotive Fuel Economy. *In Transportation, Energy, and Environment: How Far Can Technology Take Us?* J. DeCicco and M. Delucchi, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 157-178.

Giuliano, G. (1998). Land Use Policy and Transportation: Why We Won't Get There From Here. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary.* T. Lipman, D. Santini, and D. Sperling, (eds.). University of California at Davis Institute of Transportation Studies, Report UCS-ITS-RR-98-8 (May), pp. 78-81.

Hellman, K., M.R. Peralta, and G. K. Piotrowsky (1998). *Evaluation of a Toyota Prius Hybrid System (THS).* U.S. Environmental Protection Agency Report EPA420-R-98-006. Office of Mobile Sources, Ann Arbor, Mich. (August).

Johnston, B. and R. Ceerla (1995). Land Use and Transportation Alternatives. In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 13-44.

Johnston, B. (1998). Comprehensive Urban Modeling. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. T. Lipman, D. Santini, and D. Sperling, (eds.). University of California at Davis Institute of Transportation Studies, Report UCS-ITS-RR-98-8 (May), pp. 81-84.

Kinsey (1997). Potential of Leap-Forward Vehicle Technology: Automotive Industry Perspective. In *Transportation, Energy, and Environment: How Far Can Technology Take Us?* J. DeCicco and M. Delucchi, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 229-241.

Lave, C. (1998). Technology is still the answer. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary.* T. Lipman, D. Santini, and D. Sperling, (eds.). University of California at Davis Institute of Transportation Studies, Report UCS-ITS-RR-98-8 (May), p. 96.

Lovins, A. (1995). Hypercars: The Next Industrial Revolution. In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 77-96.

L. Lynd (1997). *Cellulose Ethanol: Technology in Relation to Environmental Goals and Policy Formulation. In Transportation, Energy, and Environment: How Far Can Technology Take Us?* J. DeCicco and M. Delucchi, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 109-133.

MacReady (1993) Vehicle Efficiency and the Electric Option. In *Transportation and Global Climate Change*, D. L. Greene and D. J. Santini, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 147-158.

Michealis, L. (1995). Alternative Fuels and Greenhouse Gas Emission Policy. In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 97-115.

Miles-McLean, R. M., S.M. Haltmaier, and M. Shelby (1993). Designing Incentive-Based Approaches to Limit Carbon Dioxide Emissions from the Light Duty Fleet. In *Transportation and Global Climate Change*, D. L. Greene and D. J. Santini, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 109-126.

Nichols, R. (1997).Transition to New Sources of Energy Using Sustainable Energy Strategies. In *Transportation, Energy, and Environment: How Far Can Technology Take Us?* J. DeCicco and M. Delucchi, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 243-250.

Oei, D. et al (1997). *Direct-Hydrogen-Fueled Proton-Exchange-Membrane Fuel Cell System for Transportation Applications*. U.S. Department of Energy Office of Transportation Technologies Report DOE/CE/50389-503. Ford Motor Co. Dearborn, Mich. (July).

Ogden, J. M., and M.A. Delucchi (1993). Solar Hydrogen Transportation Fuels. In *Transportation and Global Climate Change*, D. L. Greene and D. J. Santini, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 189-241.

Schipper, L., R. Steiner and S. Myers (1993). Trends in Transportation Energy Use, 1970-1988: An International Perspective. In *Transportation and Global Climate Change*, D. L. Greene and D. J. Santini, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 51-89.

Singh, M. K. and M. Mintz (1997). Alternative Fuels and Vehicles: Transition Issues and Costs. *In Transportation, Energy, and Environment: How Far Can Technology Take Us?* J. DeCicco and M. Delucchi, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 135-156.

Sperling, D., and S. A. Shaheen (1995). *Preface.* In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. vii-xii.

Toyota (1997). *Toyota Hybrid System*. Toyota Press Information `97, Tokyo, Japan.

Thomas, C.E., et al. (1998). *Integrated Analysis of Hydrogen Passenger Vehicle Transportation Pathways*. Presented at the U.S. DOE Annual Hydrogen Program Review, Alexandria, Va. (April 29).

U.S. Department of Energy (1998). *Gas Mileage Guide: EPA Fuel Economy Estimates,* Oct.

Wang, M. Q. (1995). Emission Reductions of Alternative Fuel Vehicles: Implications for Vehicle and Fuel Price Subsidies. In *Transportation and Energy: Strategies for a Sustainable Transportation System*, D. Sperling and S. A. Shaheen, (eds.). American Council for an Energy Efficient Economy, Washington, D.C., pp. 117-138.