STRATEGIES FOR REDUCING ENERGY CONSUMPTION IN THE TEXAS TRANSPORTATION SECTOR

Mark A. Euritt, Mike Martello, Jiefeng Qin, Angela Weissmann, Center For Transportation Research, University of Texas at Austin
Stephen Bernow Mark Fulmer, Irene Peters, Tellus Institute[1]

ABSTRACT

Texas is the nation's highest energy consumer, as well as its highest emitter of carbon dioxide. The Texas transportation sector consumes 1.95 quadrillion Btu, 20 percent of the state's energy consumption (111 million Btu per capita, versus the US average of 90 million Btu per capita). Thus, the state's contribution to global climate stabilization and local environmental quality will require a re-examination of its transportation system. In this study, four alternative scenarios were constructed, reflecting different energy strategies that Texas could pursue to address these issues. These alternative scenarios were then measured against a reference scenario, which reflects current regulations and trends in transport policy. The first alternative, a "Roll-Back" Scenario, examined the consequences of revoking the current alternative fuels programs. Moderate, Aggressive and Visionary scenarios were also developed, consisting of increasingly aggressive policies to reduce energy consumption and emissions. Included in the analyses are various transportation control measures, employee trip reduction programs, broader use of telecommunications technologies to replace person and freight movement, accelerated vehicle scrappage, "feebates," mode shifts from automobile to various public transit alternatives and from truck to rail freight, and fuel taxes. We discuss the impacts of these measures, identifying the ones that have the greatest impact. Our scenarios suggest that only if very aggressive policies are adopted--such as those modeled in our Visionary Scenario--will transport energy use and greenhouse gas emissions in Texas stabilize, let alone decline. We also find that the major stumbling blocks to implementing such an aggressive suite of transportation policies is the long time-frame required for the impacts to come to full fruition and conclude that the political difficulties in taking a long-term perspective will need to be overcome.

---

[1] Assisted and advised by Sreedhar R. Varada (CTR), Robert Harrison (CTR), and Jeffrey Hall (Tellus).

CONTEXT

Texas is the highest state consumer of energy; as a political entity itself, Texas has the fifth highest energy consumption in the entire world.* Texas is the nation's largest consumer of natural gas, petroleum, and electricity, and the fourth largest consumer of coal (Ref. 1). Twenty percent of the state's energy is used for transportation, virtually all of which comes from petroleum. As Figure 1 illustrates, two-thirds of this energy is for highway use-- passenger vehicles and road freight.

This dependence on highways and fossil fuels has led to worsening air quality, greater dependence on imported petroleum, and more rapid depletion of domestic fossil fuel resources. The motivation for this study is to explore alternatives aimed at promoting greater efficiency in the Texas transportation sector, reducing energy consumption and associated pollutant emissions. It is important to note that air quality concerns drive the majority of current efforts to develop and implement alternative transportation policies. This being the case, this study has a double perspective: not only are measures to control energy consumption analyzed, but so are methods to reduce pollutant emissions

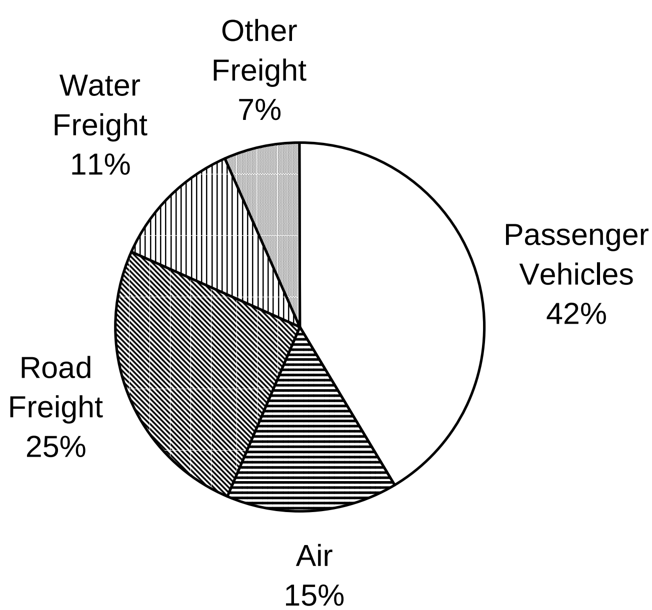

Figure 1: 1994 Texas Transportation Energy Use by Mode.

APPROACH

Scenarios

We used a scenario approach to analyze suites of policies that could be implemented at the state level. First, a Reference Scenario was created and calibrated to existing forecasts of Texas transportation parameters such as new car sales, aircraft seat miles, and freight ton-miles, auto vehicle miles traveled (VMT) and energy consumption by fuel. Reference case data was taken from such sources as EIA *State Energy Data Book* (Ref. 1), EIA *Annual Energy Outlook* (Ref. 2), and *the Texas Transportation Energy Data Book* (Ref. 3). Four alternative scenarios were then created to assess the impacts of different sets of transportation-energy polices. Policies were grouped so as to present different levels of aggressiveness the state could take in reducing transportation energy use and emissions.

Structure of Transportation Demand

We disaggregated the state's transportation demand into nested categories and classifications, as shown in Figure 2. This model structure was devised to capture four issues:

(1) Baseline vehicle miles traveled (VMT), energy, and emissions, identifying large contributors to each.

(2) Disaggregation of Texas into geographical regions that capture specific types of demand that, in turn, call for specific measures for energy savings in transportation.

(3) Capturing specific demand categories that are targets for policies.

(4) Availability and accuracy of technical and cost information about alternative fuels, vehicle-miles-traveled (VMT), ton-miles, and technologies within each demand category.

Each type of demand depicted in Figure 2 demonstrates unique characteristics and is amenable to different policies. Greater urban concentrations such as the Texas Triangle (Dallas/Fort Worth to Houston to San Antonio) are attractive candidates for policies that address transportation demand. Thus, for both personal and freight transportation, the "Urban" category was further divided into "Large Urban" (200,000 or more inhabitants) and "Small Urban" (less

---

* Calculated from the "State Energy Data Report 1991," Energy Information Administration, Washington DC, May 1993, p. 297, Table 276, and "World Resources 1994-5," World Resources Institute, New York, 1994, pp. 334-335, Table 21.1.

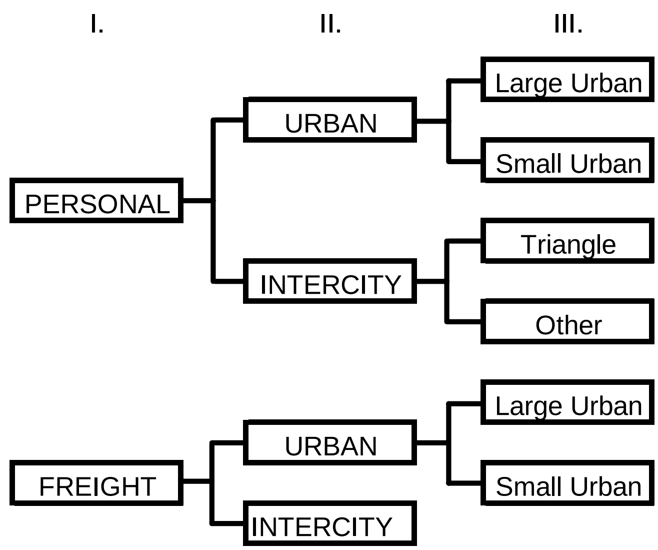

Figure 2: Major Categories of Texas Transportation Demand

than 200,000) subcategories (column III). The "Intercity-Other" category represents all trips between cities that are not part of the Texas Triangle, as well as those trips which use Texas infrastructure but have origins and/or destinations outside the state.

In order to achieve greater specificity, each category depicted in column III of Figure 2 was further disaggregated by transport mode (e.g., transit, personal vehicle, air, rail non-motorized), trip purpose (work, non-work), vehicle type (automobile, light truck), and fuel type (gasoline, diesel, CNG, LPG, electricity, alcohols, other). Thus, specific policies could be evaluated, such as transportation control measures (TCMs) that target exclusively work-related trips on large urban areas, or alternative fuel mandates that target specific vehicle types.

Analysis tools.

Energy consumption and the emissions under each scenario were calculated using the Long-Range Alternatives Planning/Environmental Data Base (LEAP/EDB). LEAP/EDB is a computer model and data base system developed to estimate energy use and emissions of an energy system (Ref. 4). Emissions factors specific for Texas, both at the present and projections into the future were used throughout this study.

Since LEAP/EDB is an energy accounting tool, the actual impacts of the different policies being considered were calculated "off-line." Impacts on light duty vehicle energy use were calculated using a stock turnover model, whose output was linked to separate efficiency and emissions modules. Impact in the freight sector were similarly constructed off-line using spreadsheet analysis.

POLICY SCENARIOS

Motivation.

The primary concerns that motivated this study are high and increasing energy use (petroleum use in particular), carbon dioxide emissions, and threatened local and regional air quality, from the transportation sector in the state. Related secondary concerns include congestion and other environmental impacts. The development of policies to address these concerns is based on the technical and behavioral relationships that inhere in the current transportation system, and the degree to which changes can be made both to and within those relationships.

Energy consumption is based on fuel-efficiency and vehicle miles traveled which, in turn, is based on person (or ton) miles of personal or freight movement. Thus, to reduce energy demand one could design policies that improve vehicle efficiencies, reduce overall demand for travel, shift modes or improve load factors in transport. For reducing petroleum use and carbon dioxide emissions, an additional factor would shifting to other, less carbonaceous fuels. Emissions of pollutants that affect local and regional air quality—fine articulates, oxides of nitrogen, volatile organics, carbon monoxide—are based primarily on vehicle miles traveled, fuel choice and tailpipe emissions controls; these could be reduced by some of the measures listed above, but not fuel-efficiency improvement. Finally, congestion could be reduced by reducing overall travel demand and vehicle miles traveled, as well as by improving traffic flow; these, in turn, could have beneficial effects in energy use and pollutant emissions.

Policies must be tailored to address each of these technical and behavioral relationships—overall demand, mode choice and load factor, fuel-efficiency, fuel choice, emissions factors, and traffic flow—in order to effectively reduce energy consumption, petroleum use, carbon emissions, pollution, congestion and other environmental impacts. Policies would include standards or requirements, incentives, pricing, land-use, infrastructure and systems management.

Description of Scenarios.

We developed five hypothetical transportation scenarios: Reference, Moderate, Aggressive, Visionary, and Roll-Back. The Reference Scenario reflects the expected business-as-usual development of the Texas transport sector, The next three consist of increasingly aggressive policies and measures to reduce energy consumption and emissions. The Roll-Back Scenario represents the consequences of revoking the current alternative fuels program. The proposed scenarios include a number of alternative transportation policies and pricing strategies to modify travel behavior, and new vehicle and infrastructure technologies.

The specific policies for the Moderate, Aggressive, and Visionary scenarios were selected based on their potential effectiveness for reducing energy use, cost and cost-effectiveness, and their feasibility in the short- and intermediate-terms.. A matrix of the policies assumed in each and their area of influence are summarized in Table 1 (Ref. 5). A discussion of the impact of these policies and how their impacts were estimated follows.

Table 1: Policies Included in Each Scenario

<table>
<tr><th rowspan="2">SCENARIO</th><th colspan="2">PASSENGER</th><th colspan="2">FREIGHT</th></tr>
<tr><th>URBAN</th><th>INTER-CITY</th><th>URBAN</th><th>INTER-CITY</th></tr>
<tr><td rowspan="2">MODERATE
Incentives only
No pricing strategies</td><td colspan="2">1) Revenue neutral feebates
2) Accelerated retirement of vehicles</td><td rowspan="2"></td><td rowspan="2">1) Truck size & weight increases</td></tr>
<tr><td>1.ETRP*
2.System optimization
3.Telecommuting
4) Improved public transit</td><td></td></tr>
<tr><td rowspan="3">AGGRESSIVE
Pricing Strategies Utilized</td><td colspan="4">1) More aggressive non-revenue neutral feebates, applied only to gasoline and diesel vehicles
2) Other pricing strategies
3) Vehicle technology options, including alternative fuels</td></tr>
<tr><td colspan="2">1) Mode shift to HOVs **
2) Teletransporting</td><td colspan="2">1) Telefreight</td></tr>
<tr><td>1) ETRP
2) Improved public transit</td><td></td><td>1) Alternative fuels requirements to private fleets in large urban</td><td>1) Mode shift truck to rail</td></tr>
<tr><td rowspan="3">VISIONARY
More aggressive pricing</td><td colspan="4">1) Technology options, including ZEVs *** and fuel cells</td></tr>
<tr><td colspan="2">1) Greater development/use of HOVs than in Aggressive Scenario
2) More significant teletransporting</td><td rowspan="2"></td><td>1) Higher mode shift truck to rail</td></tr>
<tr><td>1) Land use
2) ETRP
3) Intensive public transit</td><td>1) Mode shift to HOVs, including high speed rail</td><td>1) Alternative rail fuels</td></tr>
</table>

*Employer trip reduction programs

**High-occupancy vehicles
***Zero-emissions vehicle

The objective of the **Moderate Scenario** was to investigate the potential impact of policies that do not require drastic changes in established travel behaviors, and as such are suitable for short-term implementation. The **Aggressive Scenario** included transportation pricing policies as wells as the TCMs in the Moderate Scenario. Alternative fuels are also required for all large urban freight transportation movements. The **Visionary Scenario** represented what can be accomplished in Texas with more aggressive pricing policies, as well as more fundamental changes in the urban transportation environment and utilization of anticipated technological changes (e.g., transit-friendly land development, promotion of telecommuting, teleconferencing, teleshopping, etc.).

Policy Analysis and Implementation.

Feebates. These are fees or rebates levied on personal vehicle sales. Refunds (fees) apply when fuel efficiency is higher (lower) than a reference point. In the Moderate and Aggressive Scenarios, we impose gallon-per-mile (GPM) based revenue-neutral feebates for cars and light trucks separately; i.e. the reference points are sales-weighted fleet averages. In addition, the car feebate is size-based in the Moderate Scenario, i.e. is revenue neutral within a size class. The rationale is that relatively little seems to be sacrificed in effectiveness, but much gained in political feasibility of the policy (because larger, domestic automobiles are not taxed "unfairly"). We rely on the study of Davis et al., 1995 (Ref. 6) which estimates consumer response with a logit choice model that accounts for several vehicle characteristics, including price and operating cost; manufacturers are assumed to respond to consumer preferences. We use two of their policy scenarios and adjusted the effects they predicted to fit our fleet fuel efficiency profile.

The feebates in the Moderate and Aggressive Scenarios correspond to $50,000 and $100,000 per GPM, respectively. In the Moderate Scenario, they range from $580 rebates to $980 fees for cars and $720 rebates to $880 fees for light trucks in the first year of the policy (which is announced with five years lead time). At the end of the study period (15 years after implementing the policy), Moderate feebates result in a new vehicle fuel efficiency increase of 12 percent for cars and 11 percent for light trucks.

Aggressive feebates range from $880 rebates to $1,480 fees for cars and from $1,500 rebates to $1,740 fees for light trucks. At the end of the study period, they result in new vehicle fuel efficiency increases of 18 percent for cars and 13 percent for light.

New Car Fuel Efficiency Standards. In the Visionary Scenario, a Corporate Average Fuel Economy (CAFE) standard supersedes the feebate scheme. This policy decrees what the feebate policy attempts to achieve through behavioral incentives. We impose a standard of 40 MPG by 2000, increasing at about 0.1 MPG annually thereafter.

Accelerated Vehicle Retirement (AVR). We rely on the results of two demonstration projects: The 1993 "SCRAP^R II" project by the California petrochemicals manufacturer UnoCal and the 1992 Delaware Vehicle Retirement Program, organized mainly by U.S. Generating Company and analyzed by Resources for the Future (Ref.s 7,8). Both programs targeted vintages of 1979 and older; we do the same. Our AVR programs are implemented in three successive years: 1995, 1996, and 1997. By the end of that period, the target vehicle population will have shrunk significantly.

We assume that half of the qualifying owner population is contacted. For the Moderate Scenario, we impose an offer price of $500 and a participation rate of four percent; for the Aggressive and Visionary Scenarios, an offer price of $700 and a participation rate of 12 percent. (The participation rates stem from a response curve estimated by the RFF researchers).

In the Moderate Scenario, we assume AVR programs are implemented in Serious and Severe Ozone Non-Attainment Areas: Beaumont/Port Arthur, El Paso, and Houston/Galveston/ Brazoria. In the Aggressive and Visionary Scenarios, we additionally include Dallas/Ft. Worth, which is only in Moderate Ozone Non-Compliance.

In the Moderate Scenario, 44,600 cars are scrapped over the span of three years. The effect on fuel economy is negligible, but the fleet average emission factors in Urban Areas are reduced by 4 to 5 percent, compared to the Reference Scenario. In the Aggressive and Visionary Scenarios, a total of 224,700 vehicles are scrapped. Impacts on average fuel economy are still very small, however, the Urban fleet average emission factors are reduced by 12 to 15 percent.

Pricing Policies. The pricing policies we model in our Aggressive and Visionary Scenarios are an incremental gasoline tax of $0.40 and $1.00 per gallon, phased in between 1996 and 2000. The $1.00 tax corresponds to estimates of the air externalities caused by the combustion of gasoline (Ref. 9); the $0.40 tax was assumed as a reasonable intermediate value. Given current fleet fuel efficiencies, this corresponds to a VMT fee of 2c and 5c per mile for cars in the Aggressive and Visionary Scenarios, respectively, and 2.7c and 6.7c per mile for light trucks. Focusing on a fuel tax does not imply we preclude other pricing policies such as VMT charges, Pay-As-You-Drive Insurance, or congestion pricing. We would account for the *short run* effect of all these policies by the same technique: translate each policy into an equivalent increase in vehicle operating cost, find the gasoline price increase which is equivalent to this increase in operating cost, and apply an estimate for the short-run price elasticity of gasoline demand. We can do this because a gasoline price increase translates into an equiproportional increase in the cost of VMT (abstracting from the fact that a vehicle's fuel efficiency slightly varies with driving conditions).

A recent comprehensive survey of estimates for gasoline demand price elasticities suggests a short-run value for the U.S. of -0.18 (Ref. 10), which we apply this figure to car and light truck VMT. For Urban Areas, we assume that one half of this effect comes about through a shift of personal travel (measured as Person-Miles-Traveled, PMT) to public transit (recall that in our Scenarios, public transit is improved), and one quarter each through an increase in vehicle occupancy and a genuine reduction in PMT (i.e. people avoiding travel through trip chaining, omission of trips, etc.). In Intercity and Triangle travel, we assume that one half of the effect comes about through a reduction in PMT, and one quarter each through increased occupancy and a shift to rail and bus.

In the *long run*, we draw on "Cost-of-Saved-Energy (CSE) Curves" developed in Reference 11 to estimate the effect of the tax on vehicle fuel efficiencies. A CSE curve describes which fuel efficiency technologies are cost-effective, given fuel prices and an assumption about the amount of miles a vehicle travels over its lifetime. We increase fuel efficiency when the curve dictates that it is cost-effective to do so, given the increased fuel cost. (This assumes that automobile markets are competitive, consumers are rational, and that manufacturers smoothly respond to consumer purchasing decisions). These values are roughly consistent with the long run price elasticities shown in Reference 10.

Land Use Changes. Land use, the spatial pattern of human settlement and economic activity, is rediscovered as a target for public policy, especially in the context of transportation planning. Land use policies, presumably most effective when targeted at growth areas, can be a means to contain the growth in transportation demand. Attempting to account for specific characteristics of Texas Urban Areas was far beyond the scope of our study. Instead, we draw on a detailed land use and transportation planning study for Portland, Oregon (Ref. 12) to find a plausible reduction in VMT growth that could be achieved through active Land Use policies. This study suggests that the ratio of VMT *growth* to population *growth* can be reduced by a factor of one-third. In our Visionary Scenario, we apply this factor to large urban areas and thus reduce the VMT growth projected in the Reference Scenario.

Light Duty Alternative Fuel Vehicles (AFVs). In the Reference and Moderate Scenarios, the penetration of AFVs into the light-duty vehicle market was taken from EIA 1994 (Ref. 2) up to 2010, and linearly extrapolated beyond 2010. These data show about 7.5 percent of the light vehicles in 2010 running on alliterative fuels, primarily natural gas, with modest penetration of LPG, alcohol fuels and electric and electric hybrids. By 2020, the overall AFV penetration increases to about 14 percent, with similar numbers of CNG, LPG, alcohol and electric/hybrid vehicles.

AFV penetration was accelerated in the Aggressive and Visionary scenarios, where 2020 AFV penetrations were assumed to be 24 percent and 35 percent, respectively. In these scenarios, the electric and hybrid vehicles play a larger role, exceeding the penetration of CNG vehicles in around 2010. Fuel cell vehicles also begin to make significant penetration in the 2010 to 2020 time frame, up to about five percent by 2020 in the Visionary scenario. These high penetration rates require from 20 percent to over 50 percent of the new vehicles sold after 2005 to be AFV.

Because of the great uncertainties surrounding AFV market penetration and acceptance, no analytical relationships were developed connecting AFV purchases to specific policies, such as a logit vehicle choice model. The penetrations were estimated by the team based on the projected fully developed costs of the different vehicle types, along with their emissions characteristics (Ref. 9).

Transportation Control Measures. A broad suite of transportation control measures were considered the three main alternative scenarios (Ref. 13). They include Employee Trip Reduction Programs (ETRPs), encouragement of telecommuting and teleconferencing, improved public transit, parking management, work schedule changes, and the encouragement of non-motorized transport (e.g., bicycle lanes). The impacts of each of these broad categories were taken from the literature, concentrating on studies of Texas cities or other western urban areas with similar geography and development patterns (e.g., significant suburanization).

The assumed impacts of the TCM suite were phased in over ten years. In the Moderate Scenario, the TCMs were assumed to decrease intra-urban travel in large metropolitan areas (population >200,000) by 6.5 percent. The bulk of the savings, 5.5 percent, result from telecommuting. The remaining two percent reduction is split evenly between improved public transit and various ETRPs. In the Aggressive Scenario, the TCMs reduced urban VMT by 10.5

percent. The bulk of the savings (7.5 percent) result from telecommuting and teleconferencing, with the remainder split between improved public transit (one percent) and ETRPs (two percent).

Freight Measures. A suite of policies addressing energy used for moving freight was also included. In the Moderate Scenario, we assume a revision of the truck size and weight limitations (the Turner Proposal). The new truck configurations decrease pavement wear through better weight distribution, increase productivity by allowing larger loads, but increase bridge wear. We assume that 55 percent of the projected heavy truck payload is diverted to the Turner trucks. We assume this diversion is in effect by 2000, and remains at the same fraction of road freight movement (55 percent) throughout the study period.

In the Aggressive Scenario we additionally introduce “telefreight,” road to rail mode shifts, and mandatory light urban freight alternative fuels use. Telefreight—more extensive use of telecommunications in place of paper documents—applies to paper shipments by overnight and local courier services. We assume a 0.52 percent reduction in intra-urban VMT for a 6.6 percent reduction in inter-urban air cargo. (Ref. 12)

The degree of truck-freight to rail-freight mode shift in the Aggressive Scenario is based upon our estimate of charging trucks the “full-cost” of their use of roads: introducing a explicit road consumption fee, air pollution fee and congestion fee. These fees would increase the cost of trucking 32 percent relative to rail. Based on the American Association of Railroads’ cross elasticity, we estimated that this increase would results in a diversion of 16.6 percent (13,265 billion ton-miles) of truck freight to the rail.

The Aggressive Scenario also mandated the use of alternative fuels in all light and medium fleet freight trucks in the large urban areas. As with the light vehicles, the AFV trucks were primarily natural gas and LPG in the early years, with electric technologies gaining shares in the latter years.

Freight measures in the Visionary Scenario were generally more aggressive versions of those in the Aggressive Scenario: telefreight and truck-to-rail mode shifts were doubled, the urban freight AFV mandates were maintained, and modest penetration of LNG rail freight is introduced.

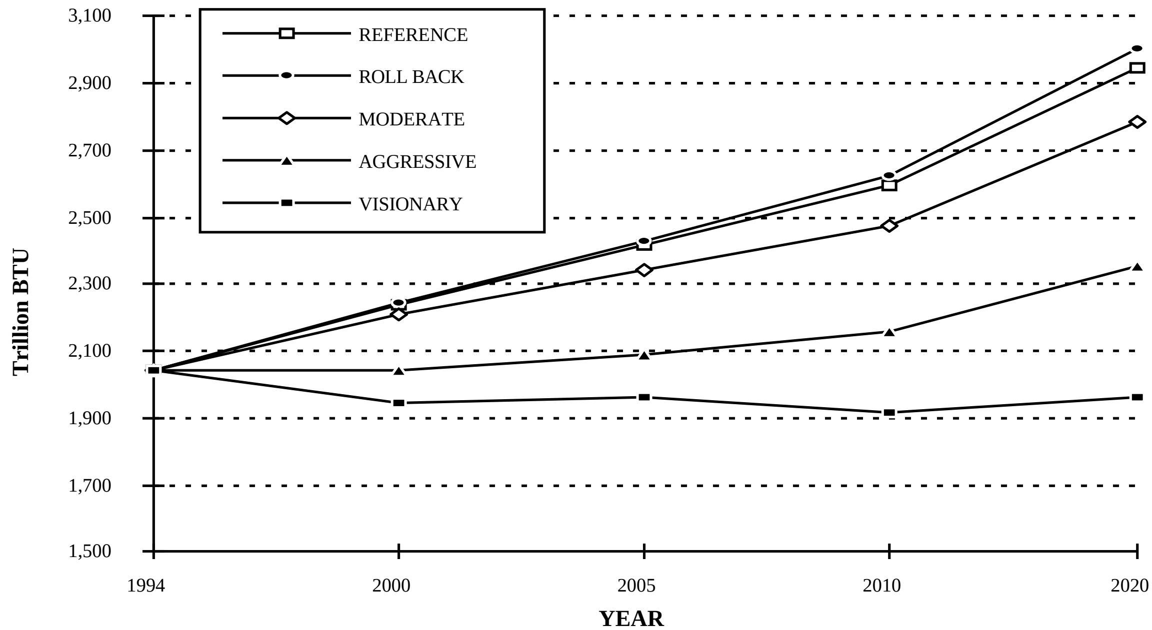

Figure 3: Total Transport Sector Energy Use.

RESULTS

Energy.

The Reference Scenario projects a steady increase in energy use through the year 2020 owing primarily to population growth and associated increases in personal driving and economic activity. By 2020, energy use in the transportation sector will have increased by 44 percent to almost 3,000 trillion Btu. Energy consumption continues to be dominated by petroleum-based fuels, although alternative fuels are assumed to increase steadily during this period. The highway surface transportation system remains the major mode of operation for passenger and freight transportation in terms of energy use.

Figure 3 illustrates the impact total on energy consumption in the Texas transportation sector of the various scenarios. By the end of the analysis period, the energy consumption under the Roll-Back Scenario is one percent higher than the Reference Scenario, due to the cancellation of the alternative fuel policies. The Moderate, Aggressive, and Visionary scenarios progressively reduce energy consumption in the state's transportation sector. By the year 2020, the energy consumption decreases 5.5 percent under the Moderate Scenario, over 20.1 percent under the Aggressive Scenario, and over 33.5 percent in the Visionary Scenario.

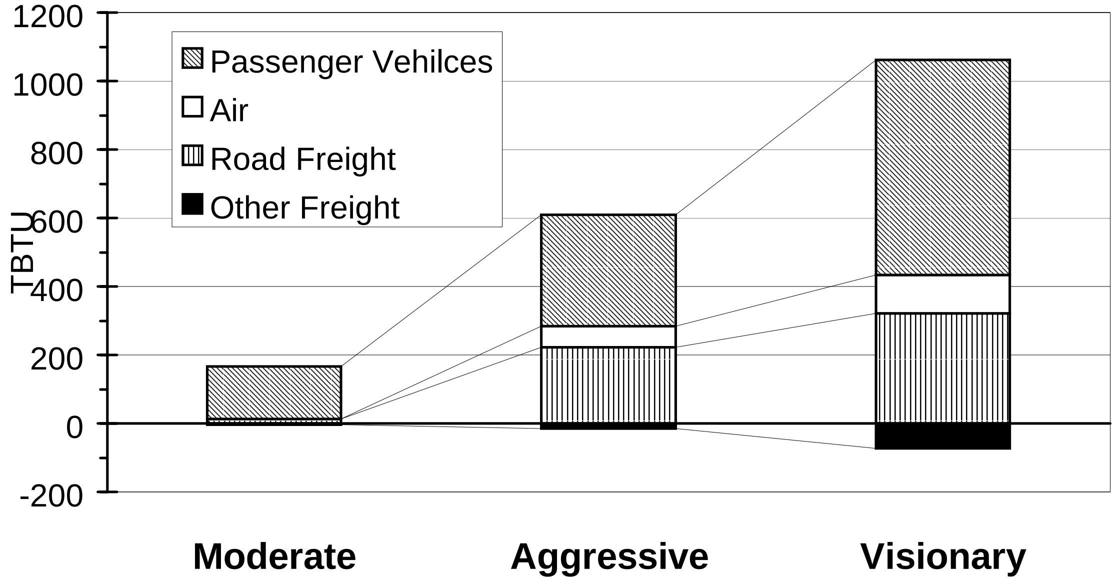

Figure 4: Savings from Alternative Scenarios

The energy savings in the three policy scenarios come primarily from passenger vehicles (Figure 4). In the Moderate Scenario, passenger vehicle energy savings result primarily from feebates, which increased new car fuel economy in 2020 from 32.5 mpg in the Reference Scenario to 36 mpg. VMT reductions from ETRPs also contributed to the energy savings, along with the VMT reduction in road freight from the use of Turner trucks.

In the Aggressive Scenario, energy savings are split equally between passenger vehicles and freight. The passenger vehicle energy savings results primarily from the more aggressive feebates (43 mpg new car mpg in 2020), along with reduced VMT from the ETRPs (primarily telecommuting), and responses to the fuel taxes. In the freight sector, savings occur from road to rail mode shifts from and a shift from tonnage shipped to telefreight. The shift from road to rail is seen in the slight increase in the “other freight” category. Air transport energy savings result from better airport management (e.g, fewer minutes at idle on the ground), and the use of larger, more efficient (on a seat-mile basis) aircraft, and some teleconferencing reducing air travel demand.

A majority of the Visionary Scenario energy saving are from passenger vehicles. Most of the savings result from the aggressive fuel economy standards (44.6 mpg by 2020), with significant contributions coming from VMT reductions induced by the $1.00 per gallon fuel tax and increased telecommuting teleshopping. The savings in the road freight sector energy demand result from mode shifts to rail, reduced ton-miles shipped, more efficient heavy trucks, and the accelerated use of telecommunications substituting for document shipping. Air savings come from more of the same as done in the Aggressive Scenario, plus some diversion to high speed rail in the Texas Triangle (Dallas-Houston-San Antonio).

Petroleum Use. Another important issue is the dependence on petroleum-derived fuels. Figure 5 illustrates the changes in petroleum-based energy use (gasoline, diesel, jet fuel, aviation gas, and residual fuel oil) under the different scenarios.

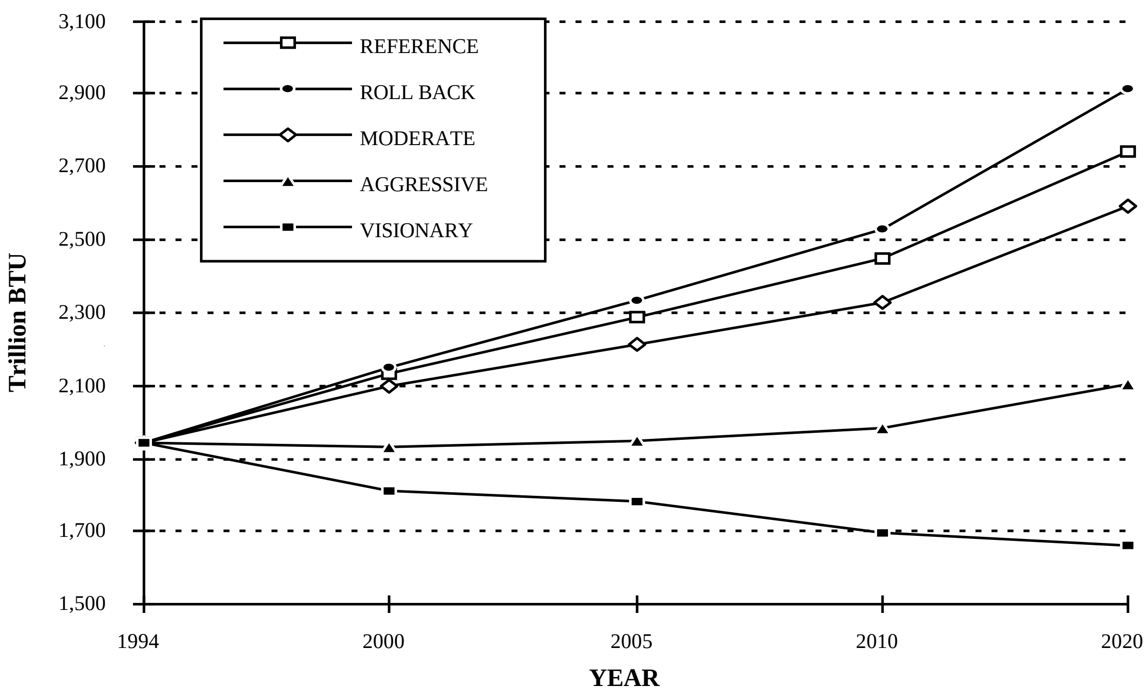

Figure 5: Petroleum Energy Use

Under the Reference Scenario, in the year 2020 petroleum-based fuels will provide approximately 2,700 trillion Btu, or almost 93 percent of the state's transportation energy needs. This petroleum-based energy share increases to over 97 percent in the Roll-Back Scenario (2,900 trillion Btu). The 93 percent Reference Scenario share is maintained in the Moderate Scenario, though actual petroleum use is almost six percent less than the Reference (2,600 trillion Btu).

The Aggressive and Visionary scenarios show the more significant change. In the year 2020, total petroleum-based energy use drops to 2,100 trillion Btu in the Aggressive Scenario, and to 1,700 trillion Btu in the Visionary. This corresponds, respectively, to petroleum-based fuel shares of 89.4 percent and 84.8 percent. Due to the use of vehicles running on electricity and renewable fuels, the petroleum-based energy consumption in Visionary Scenario has a continuous downward trend after the year 2005.

Emissions.

The primary focus of this study is energy use, but we also developed estimates of emissions under each scenario, since most policies that have the potential to decrease energy consumption are used today almost exclusively for air quality purposes. We considered the following pollutants: total suspended particulates (TSP), carbon monoxide (CO), volatile organic compounds (VOCs, or HC), nitrogen oxides (NO_X), and carbon dioxide (CO_2). The latter is the most important greenhouse gas emitted by the transportation sector; the others are among the criteria pollutants for which EPA has promulgated standards for point sources, mobile sources, and ambient concentrations.

The results include only emissions from vehicle tailpipes and other energy combustion processes for the propulsion of the transportation modes. Other important sources of pollution are: upstream energy sources, evaporative emissions and spills of toxic materials at filling stations, and runoff of tire materials left on the road. This additional pollution has not been included in this analysis, but if included, would have decreased in the Moderate, Aggressive, and Visionary scenarios because of reductions in VMT and energy use.

With the exception of carbon dioxide, emissions of all air pollutants shown in Figure 6 show the same basic shape in all five scenarios considered: flat or slightly decreasing total emissions through the first years of the study period, followed by increasing emission in the latter years. The early declines reflect the ongoing efforts in criteria pollutant reduction, and more importantly, the retirement and repair of the older, most polluting highway vehicles. Eventually, however, the most polluting vehicles will be off the road, and increases in VMT with population and economic activity will again drive emissions upward.

CO_2 emissions are also effected by this retirement and repair of older, more polluting vehicles, but to a much lesser degree. The difference in emissions of criteria air pollutants (NO_X, HCs, CO, TSP) between a new, cleanly running car and an older, dirty one can be literally orders of magnitude, and thus cleaning up or removing from service the dirty cars makes a discernible difference. The difference in energy efficiency, and hence CO_2 emissions, between the new car and the dirty one is much less—20 to 50 percent.

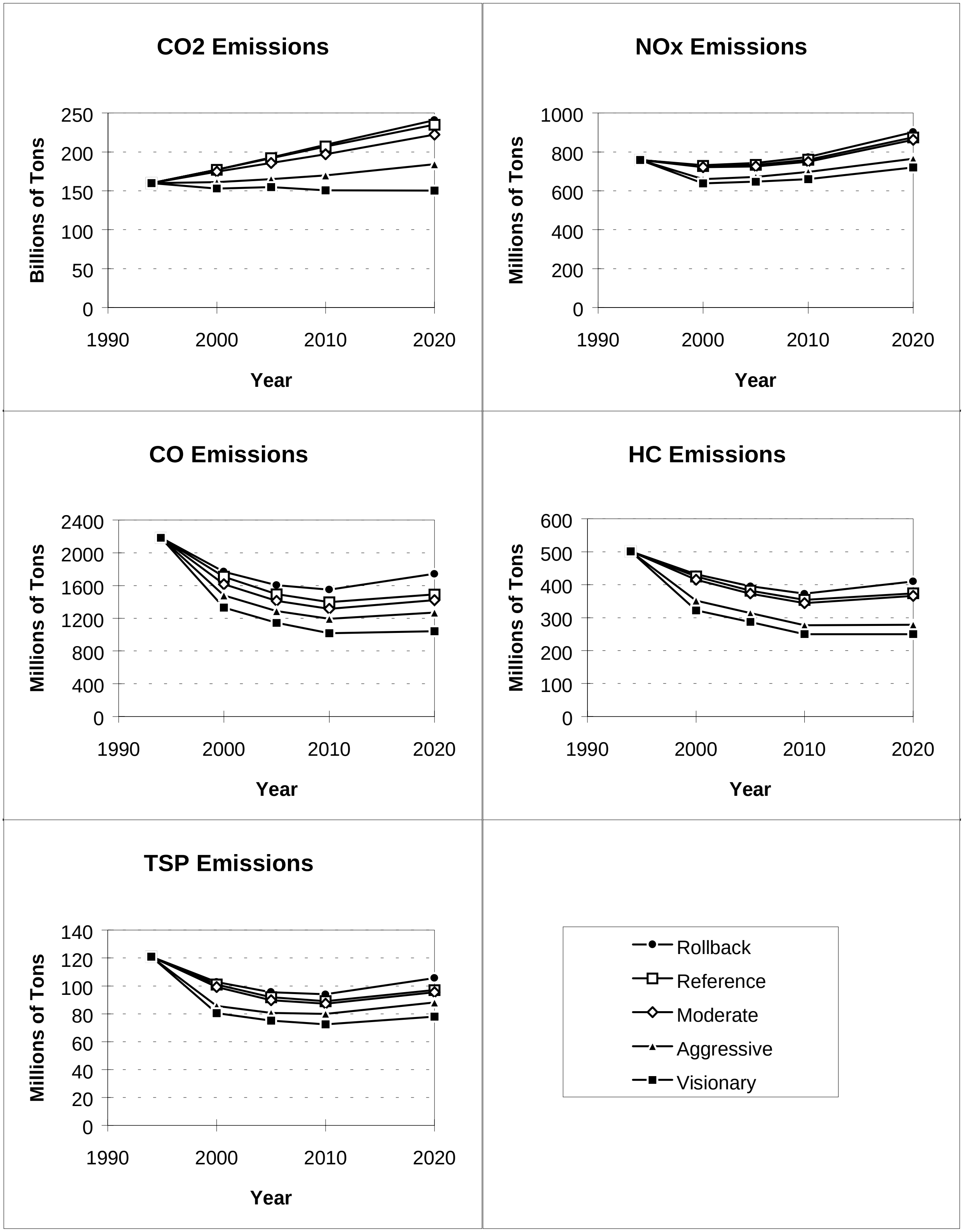

Figure 6: Scenario Emissions

All four alternative scenarios impact air emissions relative to the Reference Scenario. The negative air quality implications of a reversal in the alternative fuels program (Roll-Back Scenario) are clearly reflected in the emissions estimates. The Moderate Scenario has the potential to decrease CO_2 emissions by 5.4 percent, and all other pollutants also decrease, albeit by a lesser amount.

The Aggressive Scenario indicates a stronger potential for significantly improved air quality as an added benefit. Criteria pollutant emissions drop dramatically during the first years of the scenario, followed by continued either a continuing gentle decrease or slight a increase CO_2 emissions decrease over 21.5 percent by 2020 relative to the Reference Scenario, but are nonetheless still increasing in absolute terms. The Visionary Scenario represents the potential changes that are possible with more aggressive use of advanced technologies, pricing, and land-use policies in the transportation sector. By the year 2020, CO_2 emissions are 36 percent less than the Reference Scenario, and are actually slightly less than in 1992. Criteria pollutants are also reduced from 17 to 33 percent relative to the Reference Scenario in 2020.

While some of the these reductions may appear modest, it is worth noting that our results represent total statewide emissions. For example, the 4.6 percent decrease in CO under the Moderate Scenario may not seem dramatic, and could be regarded as so if these 68,410 metric tons were uniformly emitted over the entire state. In practice, however, these thousands of additional tons of CO are concentrated in urban areas, especially in large cities, many of which have already been classified as non-attainment areas for several years. Analogous reasoning is applicable to other pollutants considered in our analysis.

DISCUSSION AND CONCLUSIONS.

The analysis of the four alternative transportation policy scenarios developed in this study indicate that relative to business-as-usual (Reference Scenario), there is potential for a one-third reduction in both energy use and air emissions by the year 2020 (Visionary Scenario). Our assumed suite of “Moderate” polices can decrease such energy use by over five percent in the year 2020, while our suite of “Aggressive” policies can reduce transport energy use by over 20 percent.

Two of the four alternative scenarios effectively reduce the rate at which transportation energy consumption grows. For example, in the year 2020 under the Aggressive Scenario 2,354 trillion Btu are projected to be consumed, while under the Reference Scenario this amount of energy would have already been consumed by year 2005. In other words, the Aggressive Scenario would not consume the year 2005 Reference Scenario's amount of energy until 15 years later. The Moderate Scenario shows a much more modest deceleration of transportation energy growth, achieving 2015 Reference Scenario energy consumption in 2020. CO_2 emissions in these two scenarios follow this same general trend of lowering but not reversing growth rates.

The Roll-Back Scenario-- reversing the alternative fuels programs-- results in a two-year *acceleration* in the energy use. In other words, the Roll-Back Scenario would mean that the levels of energy use and expected for the year 2022 under the Reference Scenario would occur in 2020.

The Visionary Scenario is the only one in which *absolute* reductions from current energy consumption occur, not simply reductions relative to the Reference Scenario. Transport energy in this scenario dips to the 1990 level and effectively remains there throughout the study period. Its policy impact on petroleum use and carbon dioxide emissions is even more pronounced, offering a steady decrease in these variables throughout the study period, with policies in place to continue that decline in years beyond 2020.

Therefore, if greenhouse gas emissions are to be held at 1990 levels, or reduced below that, very dramatic polices such as those assumed in the Visionary Scenario are needed; including aggressive CAFE standards for light-duty vehicles, incentives and policies to increase truck efficiency and move freight using more efficient carriers such as rail, policies to reduce VMT, and initiatives to redesign our cities. The greatest challenge is not in achieving the technologies needed to successfully reach these goals, but rather having the political will to carry them out to fruition.

REFERENCES

1. Department of Energy, Energy Information Administration. *State Energy Data Report 1992 Consumption Estimates*. DOE/EIA-0214(92), Washington, D.C, May 1994.

2. Department of Energy Energy Information Administration, Annual Energy Outlook 1995, DOE/EIA-0383(1995), Washington DC. 1995.

3. Zane A. Goff and Kent Steffel. *Texas Transportation Energy Data Book: Edition 2*. SWUTC/91/60014-2, Texas Transportation Institute, Texas A&M University System, 1994.

4. SEI-B (1993) "Overview and User Guide for LEAP." Stockholm Environment Institute—Boston (SEI-B), Tellus Institute, Boston, USA.

5. The University of Texas at Austin's Center for Transportation Research and the Tellus Institute. *An Assessment of Transportation Control Measures, Transportation Technologies, and Pricing/Regulatory Policies*. Research Report SEDC-2, Texas Transportation Study for the Texas Sustainable Energy Development Council, June 1995.

6. Davis, William B., Mark D. Levine, and Kenneth Train, in association with K.G.Duleep, 1993. *Feebates: Estimated Impacts on Vehicle Fuel Economy, Fuel Consumption, CO2 Emissions, and Consumer Surplus,* Draft, Lawrence Berkeley Laboratory, LBL-34408, August.

7. Tatsutani, Marika, 1991. *UNOCAL Corporation's SCRAP: An Experiment in Corporate Environmental Initiative*, Energy and Resources Group, University of California at Berkeley, June.

8. Alberini, Anna, David Edelstein, Winston Harrington, and Virginia McConnell, 1994. *Reducing Emissions from Old Cars: The Economics of the Delaware Vehicle Retirement Program,* Discussion Paper 94-27. Washington, D.C.: Resources for the Future, April.

9. Fulmer, Mark and Stephen Bernow, "A Social Cost Analysis of Alternative Fuels for Light Vehicles," *Transportation and Energy: Strategies for a Sustainable Transportation System*, American Council for an Energy-Efficient Economy, Washington DC. 1995.

10. Dahl, Carol A., and Thomas Sterner, 1991b. "A Survey of Econometric Gasoline Demand Elasticities", *International Journal of Energy Systems*, Vol. 11, No. 2, pp. 53-76.

11. DeCicco, Johm M and Marc Ross, "An Undated Assessment of the Near-Term Potential for Improving Automotive Fuel Economy," American Council for an Energy-Efficient Economy, Washington DC. 1993.

12. *Mixed-Use Urban Centers: Economic and Transportation Characteristics. Literature Review*, 1993. Prepared for Metropolitan Service District, Portland, Oregon, by Cambridge Systematics, Inc., and Parsons Brinckerhoff Quade and Douglas, Inc., February.

13. The University of Texas at Austin's Center for Transportation Research and the Tellus Institute. *Strategies for Reducing Energy Consumption in the Texas Transportation Sector*. Research Report SEDC-2, Texas Transportation Study for the Texas Sustainable Energy Development Council, June 1995.