Texas Public Policy Foundation

CLEARING HOUSTON'S AIR: An Economic Evaluation of Clean Air Act Compliance Strategy Alternatives

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with a foreword by Dr. Wendy Gramm

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Foreword

by Dr. Wendy L. Gramm

The Clean Air Act requires the EPA to set National Ambient Air Quality Standards (NAAQS) for a number of substances, including ground-level ozone, which the EPA links to increased risk for asthma and other respiratory concerns. While the EPA sets the standards that must be adhered to, it is often up to state and local governments to design and implement plans to meet the standards. Despite the efforts of Congress to limit the ability of executive branch agencies to impose these costs on state, local, and tribal governments through the Unfunded Mandates Reform Act, the practice continues. The imposition of costly regulations that must be met by state and local governments is the hidden tax of regulation, ultimately borne by residents of the state or locality where the regulation applies. The Mercatus Center is particularly interested in the analysis and measurement of the costs of these hidden regulatory taxes. This study of ozone abatement in the Houston-Galveston area, sponsored by the Texas Public Policy Foundation, demonstrates how important a more focused analysis of the costs and economic impacts of a regulation on a region are for determining a proper compliance plan.

A 1997 Mercatus Center public interest comment examined EPA's proposed ozone standard, revealing that the economic analysis prepared by the agency seriously understated total costs by ignoring the additional costs that attainment of standards would impose on states and localities. Additionally, the health benefits that the EPA links to ground-level ozone reduction are drastically overstated. In fact, even using the EPA's own understated cost figures the rule does not pass a cost-benefit test. Despite these shortcomings the rule was finalized and most of the compliance burden has been passed on to the state and local levels. Although ultimately costly, this raises an interesting opportunity for state and local governments to introduce new market-based compliance plans and to utilize proper cost-benefit studies and economic impact analyses to choose among regulatory regimes. It is important that information relevant to each state or region be used in developing these plans at the state and local level, even when the plan must meet federally mandated enforcement goals determined through a one-size-fits-all approach.

The Texas Natural Resources Conservation Commission (TNRCC), drawing heavily upon prescriptions from the EPA, devised a State Implementation Plan (SIP) for achieving ground-level ozone compliance in the Houston area. The Houston region of Texas has been cited by the Foundation for Clean Air Progress as one of the most improved regions in the U.S. with respect to ground-level ozone and other pollutants. The TNRCC SIP proposes to supplement existing measures that have been working for the past 20 years to reduce ozone hazards in and around Houston with top-down mandates.

The value of this study backed by the TPPF is that it fully utilizes cost-benefit analysis to analyze the options in the TNRCC SIP, and more importantly to propose an alternate SIP that maximizes benefits while minimizing costs. By incorporating detailed information about the economic conditions of the region, the study takes into account the full effects of regulatory action on employment, state and local government finances, consumer welfare, and demographics. The results of this study include a demonstration that a dramatic reduction in costs with only a minor reduction in benefits is possible when a rigorous cost-benefit analysis is applied to all aspects of a regulatory plan and its effects.

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Abstract

During the past year, Professor Barton Smith of the University of Houston and Professor George Tolley of the University of Chicago have been conducting a study examining the impacts of the State Implementation Plan (SIP) proposed by the Texas Natural Resources Conservation Commission (TNRCC) for the Houston area economy. The TNRCC SIP is a group of air pollution control measures designed to bring the eight county Houston-Galveston area into compliance with the federal ozone standard by 2007. The study examined the costs and benefits of the TNRCC SIP in reducing air pollution, and the short-run and long-run impacts of the TNRCC SIP on the Houston area economy.

Houston exceeds federally allowed levels of air pollution only for ground-level ozone. Houston meets the federal standards for the other criteria pollutants (particulate matter, carbon dioxide, sulfur dioxide, nitrogen dioxide, and lead). Because Houston exceeds the federal standard for ground-level ozone under the federal Clean Air Act Amendments of 1990, it may be subject to sanctions from the federal government, such as withholding of highway funds. To avoid this, the proposed TNRCC SIP would limit emissions of nitrogen oxide (NOx), which (in conjunction with VOC's, or volatile organic compounds) lead to the formation of ground-level ozone. To reach compliance, Houston must reduce its emissions of NOx significantly.

To ascertain the economic effects of adopting the TNRCC SIP, costs were estimated for the 38 proposed measures within it. The costs of these 38 measures from 2001 to 2020 were used as inputs into the most sophisticated regional economic model available. This model contains multiple sectors consisting of individual industries, such as utilities, refineries, trucking, electrical equipment, retailing, wholesaling and a host of others. Ripple effects and multiplier effects can be estimated, showing how the direct costs are magnified, and in some cases shifted to other industries or households. Control measures placed only on industries in a region will have lower output because production will be shifted to other regions where the costs of the controls can be avoided. This in turn causes employment to shift, reducing both population and the tax base.

It was determined that implementing the TNRCC SIP would significantly reduce job growth, resulting in 103,000 fewer jobs in the Houston area in 2010 and nearly 140,000 fewer jobs in 2020 than without the TNRCC SIP. Total income, or gross regional product, would be $12.6 billion less in 2010 and $21 billion less in 2020 than without the TNRCC SIP. Tax receipts to state and local governments would be $860 million less in 2010 and more than $1.5 billion less in 2020 than without the TNRCC SIP. This represents 3.7 percent of Houston area's 2010 jobs, 5.5 percent of gross regional product, and 4.2 percent of revenues to state and local governments.

An alternative SIP proposal was evaluated, eliminating high cost measures that achieve little NOx reduction and providing for emissions trading and market incentives to promote least cost NOx reductions. The alternative SIP achieves more than 85 percent of the NOx reduction of the TNRCC SIP at just over 40 percent of the costs, with an employment effect of fewer than 40,000 jobs.

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EXECUTIVE SUMMARY

1. Purpose and Major Findings

- During the past year, two professors of economics have been examining the impacts on the Houston area economy of the State Implementation Plan (SIP) proposed by the state agency, Texas Natural Resources Conservation Commissions (TNRCC). This plan was designed to bring the eight county Houston-Galveston area into compliance with the federal ozone standard as defined by the USEPA and in compliance with the 1990 Clear Air Act Amendments. Dr. Barton Smith of the University of Houston and Dr. George Tolley of the University of Chicago conducted the study.

- The proposed measures of the TNRCC SIP were designed to control the nitrogen oxide (NOx) emissions that lead to ozone formation. The impacts of the direct control costs on the Houston area economy were estimated using the most sophisticated regional economic model available. The model contains multiple sectors, enabling estimation of effects on individual industries and Houston area households. The model examines the direct effects of the proposed TNRCC SIP on the Houston metropolitan area, as well as the substantial multiplier or ripple effects that will be inevitable as the impact works its way throughout the entire regional economy.

- The SIP measures are estimated to significantly slow job growth within the Houston metropolitan area. They would result in nearly 103,000 fewer jobs by the year 2010 and nearly 140,000 fewer jobs by 2020.

- The study evaluates an alternative SIP that would achieve nearly as great a NOx reduction at a much lower cost and with much less severe effects on the Houston area economy.

2. Control Costs

- Control costs were estimated for each of the 38 measures in the proposed TNRCC SIP. The annualized costs were obtained by multiplying all capital cost by an amortization factor to yield yearly operating costs.

- The total annualized control cost, summing over all the measures proposed in the TNRCC SIP, increases steadily through the federal compliance year 2007, at which time it reaches $4.1 billion per year.

3. Direct Impacts on Businesses and Households

- $3.8 billion of the 2007 annualized control costs fall directly on Houston area businesses, increasing the cost of doing business in the Houston area.

- Nearly $300 million of these annualized control costs fall directly on households in the Houston area. These direct costs are only partially offset by $40 million in annual benefits from improved air quality, leaving a direct increase in the (effective) cost of living of $260 million.

4. The Regional Model

- The direct control costs that fall on businesses and the direct increases in the cost of living that fall on households were fed into the regional input/output model to obtain total effects on the Houston area economy.

- The model takes account of inter-industry relations by which direct impacts on businesses and households affect purchases from other businesses in the Houston area. For example, a decline in household income leads households to demand fewer retail services and fewer goods produced in Houston for local consumption, causing declines in employment in these industries, even though no control costs are imposed directly on them.

- The model also predicts effects on industry location. Part of the direct business costs fall on Houston area businesses producing for national and international markets, making Houston area businesses less competitive in these markets. Houston industries will lose market share to industries in other regions not encumbered by such strict measures.

- Part of the direct business costs fall on Houston area firms that produce goods and services for local consumption. These costs will be largely passed on to consumers in the Houston area. The rise in prices of local goods and services contributes to further increases in the cost of living. These are added to the $260 million increase in the cost of living noted above. The overall rise in the cost of living leads to wage raises needed to recruit labor to work in the Houston area.

- These higher wages, in turn, generate further rounds of cost of living and wage increases, exacerbating the disadvantage Houston businesses face in national and world markets.

5. Results for Employment, Gross Regional Product and Tax Receipts

- Applying the regional model predicts that, by 2010, employment is 103,000 less than it would be without the TNRCC SIP. By 2020, it is 140,000 less.

- The reduction in the region's growth will leave the economy with a real gross regional product that is $12.6 billion per year less by 2010 than it would be in the absence of the measures, and $21 billion per year less by 2020. This, in turn, will reduce state and local tax receipts by $860 million in 2010 and by $1.5 billion in 2020.

- Table 1 shows the effects on employment, gross regional product and tax receipts for individual years from 2001 to 2020. The table compares the baseline without the TNRCC SIP to a scenario reflecting the presence of the proposed TNRCC SIP. To provide a graphical comparison, Figure 1 compares employment by individual years in the baseline situation, with employment under the TNRCC SIP control scenario. With the TNRCC SIP scenario, employment falls progressively farther behind baseline employment.

6. Household Income and Wages

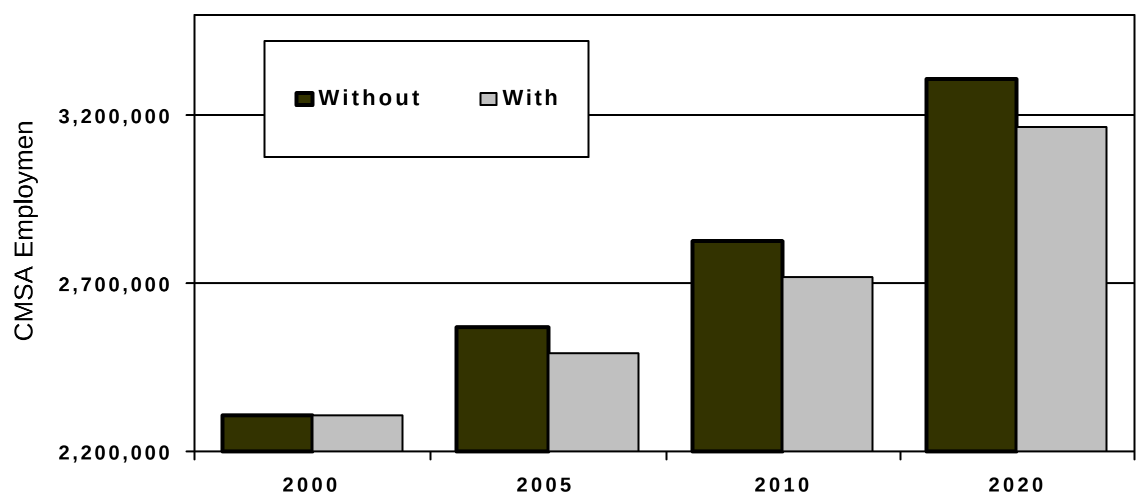
- The impact to the regional economy will reduce Houston area household well-being. The regional model predicts that the combined direct and indirect costs of the proposed TNRCC SIP measures will reduce real disposable income within the region by almost $1.5 billion annually.

Table 1-Time Profile of Economic Impacts With and Without TNRCC SIP[a]

	2001	2003	2005	2007	2010	2020
Employment (Thousands of Persons)						
Without TNRCC SIP	2,360.3	2,432.8	2,575.7	2,677.0	2,826.3	3,311.1
With TNRCC SIP	2,360.7	2,403.2	2,491.3	2,579.4	2,723.1	3,170.8
Difference	0.4	-29.5	-84.4	-97.6	-103.2	-140.3
Gross Regional Product (Billions of Dollars)						
Without TNRCC SIP	163.9	174.1	192.2	207.3	229.9	318.0
With TNRCC SIP	163.0	170.2	183.6	196.7	217.3	297.0
Difference	-0.9	-3.9	-8.6	-10.5	-12.6	-21.0
Tax Receipts to State and Local Governments (Billions of Dollars)						
Without TNRCC SIP	16.8	17.3	18.2	19.1	20.5	26.9
With TNRCC SIP	16.7	17.1	17.7	18.4	19.6	25.5
Difference	-0.1	-0.2	-0.5	-0.7	-0.9	-1.5

[a]Year 2000 prices

Figure 1-Area Jobs With and Without TNRCC SIP



The effect on local wages is mixed. The weakening economy will reduce the demand for labor and hence reduce both jobs and wages. The higher cost of living, however, will also reduce the supply of labor requiring higher wages to recruit skilled labor to the region. This will reduce employment further, though it will mitigate somewhat the decline of wages in dollar terms. Nonetheless, real wages (wages in dollar terms adjusted for the cost of living) will decline.

7. Construction Stimulus

- During the initial four years while measures are phased in, there will be an economic stimulus to the region associated with the implementation of the TNRCC SIP. Positive job impacts will be felt in sectors such as engineering services, construction, and manufacturing during the installation of the pollution control equipment. These job gains, however, do not fully compensate for job losses experienced elsewhere in the regional economy.

8. Unequal Effects of Control Measures

- Not all elements of the proposed TNRCC SIP impact the economy equally. The study found that just a few elements of the plan account for the largest portion of the losses imposed on the regional economy.

- The most onerous elements of the proposed TNRCC SIP include:

  The mandate of 90% reduction in point source emissions of NOx from large industrial facilities, as opposed to the 75% to 80% NOx reductions mandated for these sources elsewhere in Texas and the country.

  The requirement to use special boutique diesel fuel in Texas.

  The requirement to adopt federal engine standards earlier than other parts of the country.

  Time of day limitations on construction activities.

- The mandated 90% NOx reduction for point sources is particularly damaging to the Houston economy because, independent of costs, it leaves little room for growth in such industries as refining and petrochemicals. As a result, the proposed TNRCC SIP actually entails a no-growth mandate for about one fourth of Houston's economic base.

- Smaller firms with less access to financial capital will have the greatest difficulty in achieving the TNRCC SIP mandates. Some firms will also encounter technological challenges that may make achievement within four years impossible. The study optimistically assumes that the vast majority of area firms will, in fact, be able to reach NOx reductions to or near the 90% level. Even if achieved, such a tight NOx mandate will leave little flexibility for many industries to grow through emissions trading or offset provisions.

9. Sensitivity Analysis

- A conservative approach to estimating impacts was followed in the study so as to avoid overestimating negative effects on the regional economy.

- A great deal of sensitivity analysis was conducted, testing the effects of changes in assumptions on the results. Using assumptions leading to less severe impacts, such as low estimates of control costs, the least differences in jobs between the TNRCC SIP and no TNRCC SIP are still almost 62,500 in 2010 and 42,500 in 2020 as compared to the approximately 103,000 jobs by 2010 and nearly 140,000 jobs by 2020 presented as most likely in the study. It should be noted that the assumptions used to generate this scenario is extremely conservative; any one of its provisions is highly unlikely to occur.

- Actual job losses could far exceed those presented in the study. For example, the TNRCC SIP calls for greater reductions in emissions than have been accomplished in other areas, including Southern California. In addition to the optimistic assumption already noted for the 90% emission reductions, the results presented in the study use conservatively low estimates of costs. Higher cost estimates would lead to greater job losses, as would a variety of other possible negative effects not included in the study results.

10. An Alternative Plan

- The research evaluated the impact of an alternative SIP plan that would achieve nearly as large an ozone reduction, but at a greatly reduced cost. In the alternative plan:

  Industrial point sources are allowed to reduce NOx emissions by 79% instead of 90% percent, which would permit trading of emission rights between sources with high and low costs of emissions reductions. In addition, a NOx reduction incentive measure is included, under which revenues from motorist fees and other levies would be used to pay sources to reduce emissions.

The phase-in time to reach compliance is increased from four to seven years.

The requirements to use boutique diesel fuel especially designed for Texas is dropped because it adds very little beyond that already expected to be achieved by federal standards.

The requirement for earlier adoption of federal low emission engines is dropped on similar grounds.

The requirements to limit construction hours and to refrain from lawn mowing in the morning during the ozone season are dropped.

A 65 mph speed limit replaces the proposed 55 mph speed limit.

- The analysis compared the costs of the TNRCC SIP with the alternative SIP. The costs of the alternative SIP are less than half the costs of the TNRCC SIP. The lower costs are due to the elimination of several of the most expensive measures, including the lowering of the point source reduction requirement from 90% to 79%, the use of emissions trading, and the use of market incentives to purchase emissions reductions.

- Even under this alternative plan, the Houston area is still estimated to lose jobs, income, and tax revenues, but the losses are substantially less than under the TNRCC SIP. Job losses in 2010 are reduced from more than 103,000 to a little more than 38,000. Losses in 2010 real gross regional product are cut to $3.5 billion. State and local revenue losses are cut by almost two thirds.

- Table 2 shows effects of the alternative SIP on employment, gross regional product and tax receipts for individual years from 2001 to 2020. Compared with Table 1, the effects are much smaller than under the TNRCC SIP.

- Figure 2 presents a graphical comparison of job losses under the alternative SIP and the TNRCC SIP. Under the alternative SIP, job effects remain low and are only about 40,000 from 2010 onward, while under the TNRCC SIP, job losses continue to climb and reach almost 100,000 in excess over the alternative SIP by 2020.

- In summary, by eliminating measures with very low cost effectiveness and introducing emissions trading and purchase of emissions reduction, the alternative plan greatly reduces both the direct costs and the further deleterious effects on the Houston area economy.

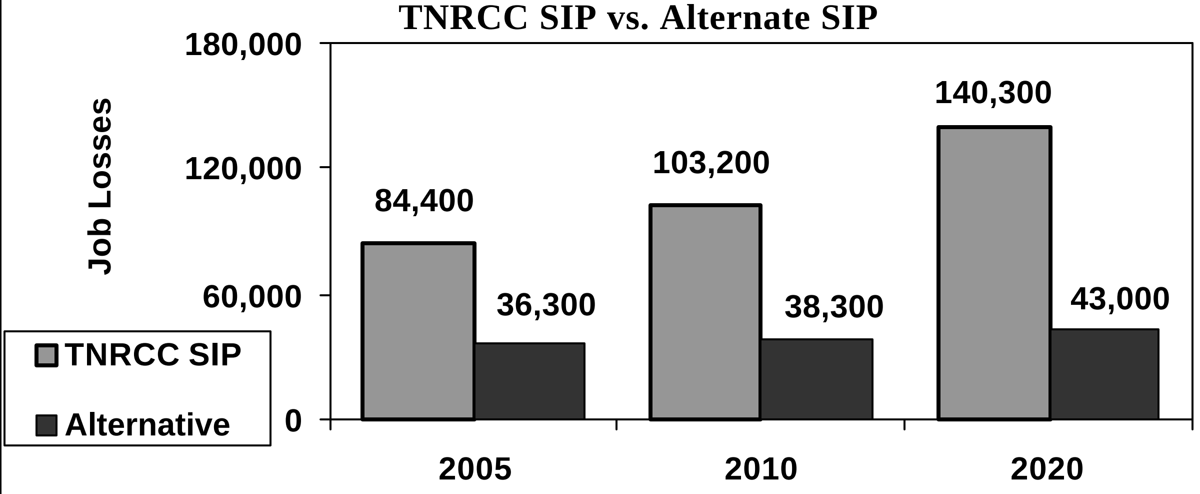
- This study has assumed that the National Ambient Air Quality Standards (NAAQS) for ozone can be achieved by a slightly lower reduction in NOx tons per day than envisaged in the TNRCC SIP. At this writing, the precise reduction in NOx tons per day is not yet settled. Even if a reduction in tons per day as great as that proposed by TNRCC were to be required, the present study makes clear that the results could be achieved at greatly reduced direct costs and greatly reduced regional effects. This is due to the fact that the alternative SIP emphasizes measures with greater cost effectiveness than those proposed by the TNRCC SIP.

Table 2-Time Profile of Economic Impacts With and Without Alternative SIP[a]

	2001	2003	2005	2007	2010	2020
Employment (Thousands of Persons)						
Without Alternative SIP	2,360.3	2,432.8	2,575.7	2,677.0	2,826.3	3,311.1
With Alternative SIP	2,366.8	2,425.8	2,539.4	2,633.5	2,788.0	3,268.0
Difference	6.5	-6.9	-36.3	-43.5	-38.3	-43.0
Gross Regional Product (Billions of Dollars)						
Without Alternative SIP	163.9	174.1	192.2	207.3	229.9	318.0
With Alternative SIP	164.1	173.3	189.5	203.8	226.4	313.0
Difference	0.2	-0.8	-2.7	-3.5	-3.5	-4.9
Tax Receipts to State and Local Governments (Billions of Dollars)						
Without Alternative SIP	16.8	17.3	18.2	19.1	20.5	26.9
With Alternative SIP	16.8	17.2	18.0	18.7	20.1	26.4
Difference	0.0	-0.1	-0.2	-0.3	-0.3	-0.5

[a]Year 2000 prices

Figure 2-Job Impacts of Alternative Plans: TNRCC SIP vs. Alternate SIP



I. INTRODUCTION: FINDING THE RIGHT BALANCE

A. The Balance In Nature

Environmental issues involve questions of balance. What is typically called pollution today usually has its counterpart in nature. For example, while world leaders argue about reducing industrial carbon emissions, human life (as well as all animal life) are natural sources of carbon dioxide which is balanced by vegetation that reverses the carbon/oxygen cycle. The emissions of most other pollutants also have their natural counterpart. The current threat to animal and plant species stems from alternations in this environmental balance within the earth, water, and air to which species have adapted. To this extent, environmental concerns appear to focus on the status quo - the maintenance of an environmental balance most conducive to the prosperity of the current mixture of species occupying the earth. While policy emphasis focuses to a large extent upon the prosperity of humanity, there is a growing consensus that this prosperity is linked to the well-being of the rest of nature, both as co-habitants of the planet earth and as barometers of impacts potentially threatening to mankind.

A proper environmental policy will seek to achieve a balance. Pollution properly defined becomes any man-made activity that would destroy this balance. For example, the emission of carbon dioxide then does not necessarily entail pollution. Pollution is the emission of too much carbon dioxide or even too little. To some extent pollution is related to the notion of what is and is not "natural". It is also known that the earth itself emits enormous amounts of volatile organic compounds (VOCs) into the air. The policy question becomes whether the additional VOCs created by man-made processes is large enough to threaten the balance in nature in such a way that it is deleterious to mankind and other living things.

One problem is that this natural balance has never been static or fixed. Instead, the balance regularly undergoes significant variations, both random and cyclical. Environmentalists, therefore, must struggle with questions of reasonable bounds instead of absolute targets. The predicament is particularly relevant with respect to global warming. Are averaging temperatures rising *outside the bounds of normal cyclical patterns*? Key words within environmental science become crucial, such as "natural", "normal", and "co-dependence".

As in many fields of research, the more we come to understand the complexities of this balance, the more we realize how much is left to learn. Scientific understanding of interdependencies in nature, of the chemical processes that create nature's balance, and of the optimizing levels of these processes is still in its infancy. Do we have too much or too little atmospheric carbon dioxide? Are man-made contributions creating non-optimal levels of CO_2 or are these contributors insignificant in comparison to what is termed natural processes within the earth? What, in fact, is the optimal level of CO_2? Could it be that industrial emissions are actually improving the environment in the sense of making mankind better off? Answering such questions requires a framework from which the term optimal can be better defined. This, in turn, requires a broader perspective on natural processes that takes into account the relation of all species to man's interventions. Unfortunately, the needed framework is far from being realized. As a result, policy makers are often left to make environmental decisions with less than perfect information.

B. Economic Analysis of Environmental Issues

Economists' interest in the environment bloomed in the 1960s and focused upon the reasons for market failures that keep societies from achieving optimum utilization of resources. From this analysis evolved a more precise definition of "externalities," a term that has become an increasingly important part of neoclassical micro economics. Externalities are essentially spillover effects emanating from economic activities where the decision makers ignore the positive or negative consequences of their actions. In the case of pollution that imposes costs upon other members of society, the polluters do not have to pay for the external costs they impose on others. As a consequence, they do not have the incentives to modify the extent or manner in which their economic activities are conducted. The end result is too much pollution and perhaps too many goods whose production generates pollution.

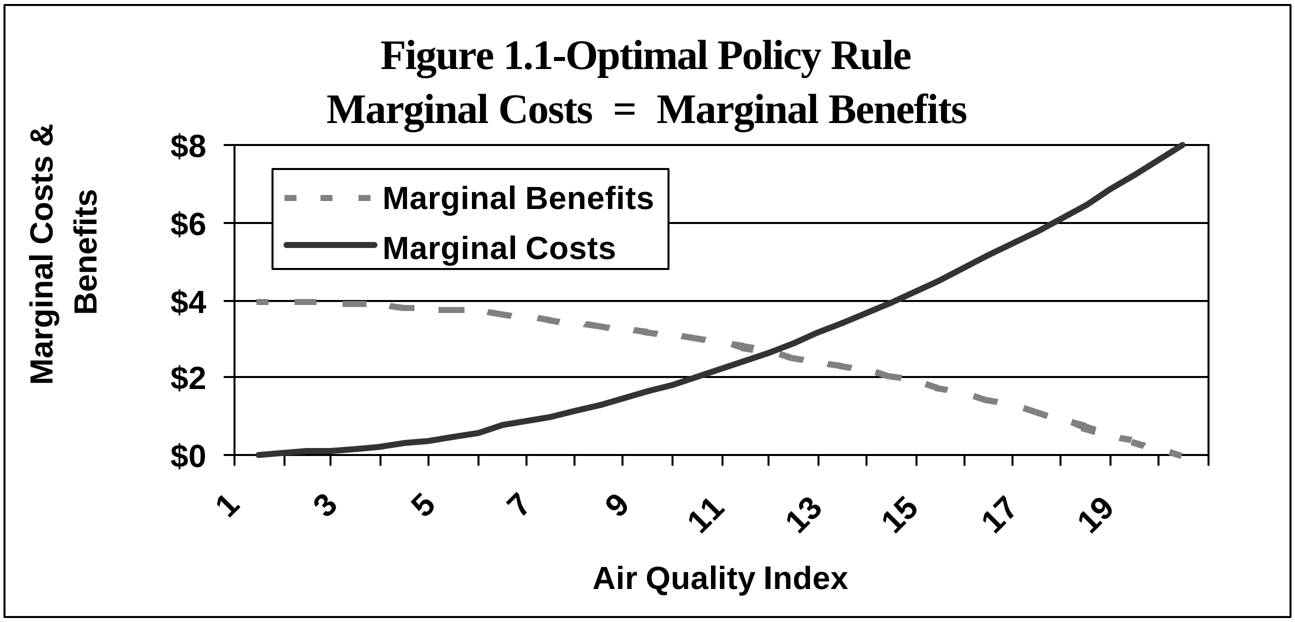
Researchers have refined the notion of externalities by identifying primary causes. Most externalities occur where property rights are inadequately defined. In the absence of laws explicitly assigning property rights to the air, air resources become available to all at zero cost, despite that fact that one economic agent's use of the resource might well diminish the value of the resource to others. This latter phenomenon is the basis for the economist's definition of opportunity costs. If one entity's utilization of a resource diminishes the utilization of that resource to others, there is an *opportunity* cost associated with that use. Where property rights are ill defined, economic agents do not have to pay this opportunity cost and basically treat the resource as a free good. As a result, the resource will be over-utilized and social well-being will be diminished.

Documentation of such market failures help form the basis of policy prescriptions to remediate the problem of environmental degradation. The economist's solution to this type of externality problem is to internalize the external costs to the decision maker. This can be done through the creation of explicit property rights, through optimal taxation of pollution activities, or through regulations that mimic such taxation. Such policies make explicit the external costs and give economic agents incentives to weigh the external costs against the costs of reducing them.

However, as has often been pointed out, the idealized outcome is difficult to achieve. Politically, laws have been passed which attempt to regulate pollution and hopefully approximate the idealized outcome. The idealized outcome (however impractical) is recognized as the benchmark from which any alternative set of policies can be evaluated. Just as balance is the key issue in scientific notions of the environment, balance is the key to the economic analysis of environmental policy. Given the objective of maximizing society's well-being, taking account of interconnections with all other species, the primary goal of policy becomes finding the correct balance between the environment and all other goods which provide social well-being. The economist does not see the primary issue as eliminating all pollution, but rather of finding the optimal reduction in pollution and the optimal (cost effective) way of achieving that reduction. While the notion of the optimal level of pollution may seem to run counter to the naturalist view of many environmentalists, it is quite similar to the notion of optimal levels of carbon dioxide or nitric oxides that the scientific community must also grapple with.

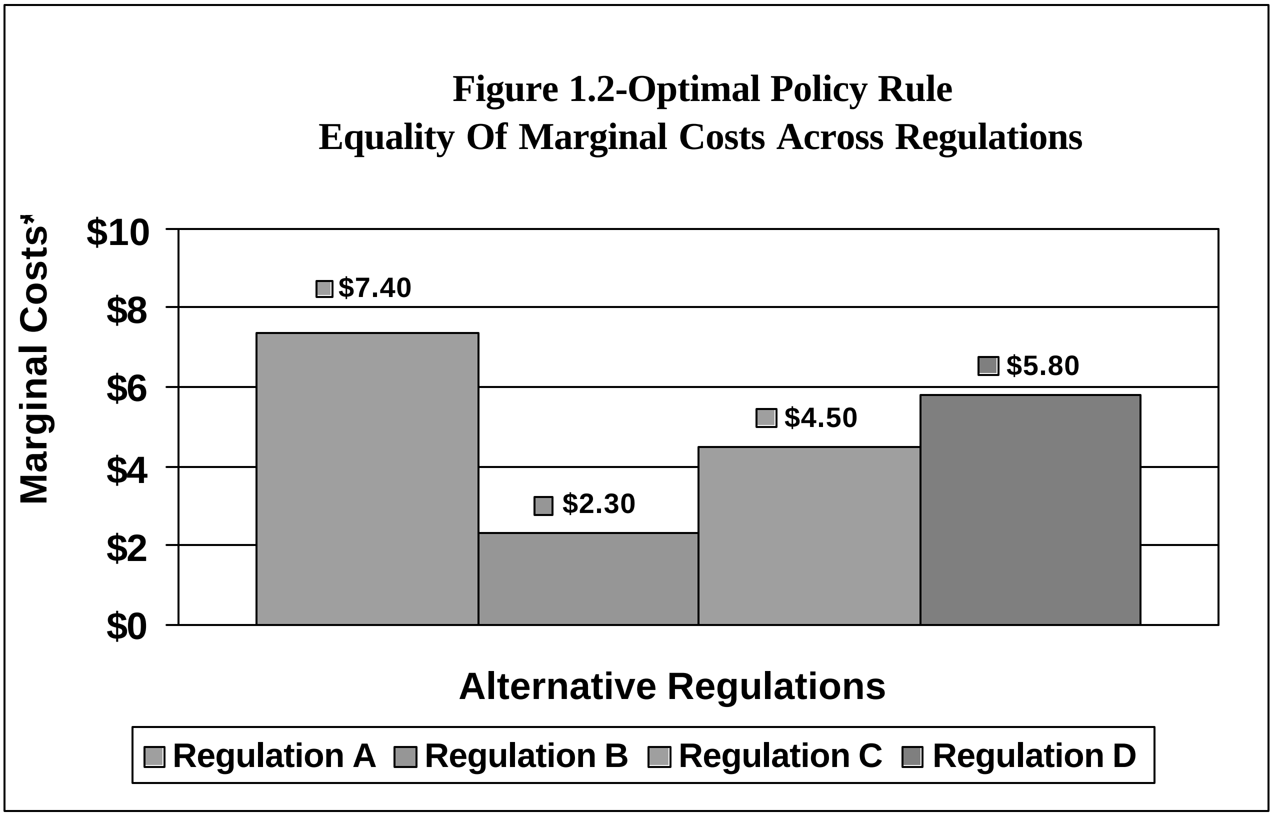
C. Basic Rules of Optimality

This notion of optimality in environmental decision making has led to a large economics literature involving more than four decades of both theoretical and empirical research. From this literature a general consensus has evolved regarding ingredients of optimal policy. First, optimality requires that pollution abatement efforts should increase until the marginal social costs of abatement come to exceed the marginal benefits, as shown in Figure 1.1. Beyond that point society is made worse off. This rule explicitly recognizes the fact that, while there are social spillover costs associated with pollution, there are also social costs associated with pollution abatement. Policies that cost more social resources than the benefits generated actually make society worse off.



The notion of optimality includes the issue of optimal timing. Since the costs and benefits of environmental policies can be affected by the speed of implementation, optimal environmental decision making requires that implementation occur as rapidly as possible, consistent with the condition that the marginal costs of quicker implementation are not greater than the marginal benefits of the added swiftness.

Where alternative strategies are available, all alternatives that are not mutually exclusive should be pursued as long as the marginal costs per unit of clean up is equated across alternatives. For example, if there exist two alternative strategies to reduce carbon monoxide from the air and if one strategy costs twice as much per ton of reduced CO, then policy should be restricted to the alternative strategy. However, most empirical studies show that marginal costs of clean up increase with the level of abatement for each strategy. As one strategy is pursued more and more fully, a point may eventually be reached where the alternative strategy becomes equally cost effective. Alternative strategies include not only different policies but similar policies applied to different industries or in different locations. If it costs twice as much to remove a ton of CO emitted by industry A than industry B, then more emphasis should be placed upon B's emissions than A's. Similarly, if one abatement technology entails twice as much cost to reduce CO emissions as another technology, the less costly technology ought to be applied. Figure 1.2 illustrates an example of a non-optimal strategy where alternatives measures vary significantly in their marginal costs. Whereas Rule One is summarized by the statement that marginal costs should equal marginal benefits, Rule Two can be characterized as marginal cost equalization.



Finally, most analysts of environmental issues recognize that information regarding costs and benefits is far from certain. In a world of uncertainty, policy makers must equate expected costs and benefits. Policy makers should weigh the risks associated with the uncertainty and must include in their analyses such procedures as the application of risk premiums to social discount rates or the application of sensitivity analyses in cost-benefit calculations.

D. Environmental Regionalism

The wave of new environmental policies of the 1960s and 70s was largely implemented at the national level. Federal policy mandated specific strategies which were, for the most part, universally applied across the nation. One of the major exceptions actually had perverse effects, namely the prevention of significant deterioration (PSD) provisions militating against expansion of industries in some areas regardless of the costs and benefits of dealing with the environment. During the 1990s, federal policy began to shift towards "environmental regionalism", where regulations and abatement strategies were specifically formulated to regional circumstances. States were allowed some flexibility in the measures adopted to meet federal standards. This approach is not to be confused, however, with state or local environmental policy, since the USEPA both mandates the creation of these regional regulations, sets the standards to be met, and approves the strategic mix ultimately implemented. What is different about this policy is that it creates unique regional policy mixes which can and do vary substantially across regions within the United States.

The notion of environmental regionalism makes sense in terms of the two basic rules of environmental decision making discussed above. Given that industry mix and environmental circumstances vary across regions, it is highly unlikely that the optimal policy mix is the same in every region. Some regions may be dominated by industries that have low costs of pollution abatement. Hence in those regions, the optimal level of pollution abatement is likely to be greater. Other regions may have natural environmental conditions that exacerbate the impact of pollutants, making for greater social payoffs to environmental clean up than elsewhere. In such cases, optimal abatement efforts should also be more extensive.

Environmental regionalism allows for another avenue to minimize the social spillover costs of pollution. To the extent that differential regulations transfer economic activity from one region where marginal costs and benefits of abatement are high to regions where marginal costs and benefits are low, then additional social efficiencies will be achieved through the mobility of capital and labor.

While environmental regionalism allows for these additional efficiencies, it also creates the risk of exacerbating the social costs of environmental policy mistakes. That is, while the efficiency gains of implementing optimal environmental policy are enhanced by optimally differentiating across regions, the potential social loss associated with non-optimal rules and regulations can also be magnified.

It should be emphasized that even nationally implemented environmental policy can have differential economic impacts upon regions because of differences in the industrial mix that exists across regions. Environmental regionalism will increase the differentials in economic impacts, but these impacts will only be nonoptimal to the extent that the regional policies themselves are nonoptimal. Where policy regulations are not optimal, the distortions associated with the inequality of costs and benefits at the margin are magnified because of greater than optimal private sector response that is differently magnified across regions. This principle is akin to a principle of tax policy. The loss associated with an equal tax across all goods is minimal. Differential taxes across individual goods or locations results in significant social losses.

It is this aspect of regional environmentalism that has stimulated the research of this report. Analyses of direct impacts upon individual industries fill the literature. That same literature also contains theoretical and empirical environmental cost-benefit analyses and to a lesser extent analyses of the incidence of environmental regulations. On the other hand, differential regional economic impacts of environmental regulations are just now gaining attention. With the expansion of environmental regionalism, these considerations have become more important. Regional economic impact analysis does not focus on the optimality issue per se, but on the impact on regional economic growth in terms of such variables as jobs, incomes, and regional output. This does not mean that questions of optimality are not relevant as explained above, but in the presence of optimal or non-optimal policies, impact analyses examines the regional outcomes associated with environmental regulations. As these outcomes are better understood, the regional response to the current approach of forced uniformity of standards across regions may also be better understood, and law makers may wish to reevaluate the wisdom of unfettered environmental regionalism.

E. Current National Air Quality Policy

Current federal air quality policy is established by the Clean Air Amendments Act of 1990. This Act gives the USEPA broad discretionary powers to establish standards for key pollutants consistent with Congressional mandates. It also requires an inventory of the nation's status in meeting environmental objectives, and this inventory is conducted at a regional level. This process has resulted in a list of regions that are not in compliance with the federal legislation and the USEPA's interpretation of the requirements necessary to meet the spirit of Congress' intent. Current federalism links the USEPA to regions through state governments. Each state containing areas that are not in compliance with USEPA standards is required to develop a plan to assure compliance by a specified deadline. Failure to satisfy the USEPA with a plan deemed sufficient to guarantee compliance in the future places the entire state at risk of losing federal highway dollars and perhaps other federal monies.

While the notion of individualized state implementation plans sounds appealing on the surface, the current arrangement immediately violates the rules of efficiency by mandating equal standards across all regions. To the extent that environmental regionalism makes sense, its great advantage would be in establishing different standards for different regions based upon variations in marginal costs and benefits. Establishing a fixed standard applicable to all regions violates the basic principle of equating marginal benefits and marginal costs. Furthermore, while individualized regional plans offers the possibility of satisfying Rule Two of optimality (marginal cost equalization), practical experience is that the choice of regulatory mix is never required to meet that standard. To the extent that the USEPA demands plans that greatly violate the rules of social efficiency, then such a policy will also have the effect of generating substantial unwarranted relocations of economic activity that will add to the social losses. It is the extent of these relocations and the subsequent impact upon local incomes that this study focuses upon. While such impacts are likely to be felt to some degree or other in all cities where this type of policy is being implemented, this study focuses upon the likely impact of just one such plan in Houston area of Texas.

F. Outline of the Study

This study was commissioned by the Greater Houston Partnership. Most of the work was carried out at RCF Economic & Financial Consulting, Inc. where Brian Edwards, Charles Parekh, Craig Koerner, and Joon Kang made significant contributions. Following this introduction, chapter II sets the stage for the study by elucidating the basic background of environmental economics as applicable to ozone and Houston's air quality problems. Chapter III presents the direct capital, operating and annualized costs for the 38 federal, state, and local control measures formulated by the Texas Natural Resources Conservation Commission (TNRCC) to meet the federal standards. The cost per ton of NOx reduction, or cost effectiveness, of the measures to reduce ozone, is contrasted, as is the allocation of costs of the measures between households and businesses. Chapter IV describes the estimation of benefits from ozone reduction resulting from the TNRCC SIP. Results from a rollback model of air quality effects are presented. Estimates of the effects on health symptoms are presented. These are monetized using USEPA willingness to pay figures. The results are used to estimate direct effects on cost of living and wages in the Houston area. Chapter V first describes the regional model used in the study. Results are then presented using the model to estimate the impacts on the local economy in the form of lost jobs, lower gross regional product, lower tax receipts, and household incomes and wages. Chapter VI presents a proposed alternative to the TNRCC

SIP that achieves a similar reduction in NOx at greatly reduced direct costs and greatly reduced regional impacts. Chapter VII describes the sensitivity analysis undertaken in light of the scientific and technological uncertainties that exist. Chapter VIII provides a brief conclusion highlighting the study's major findings.

II. HOUSTON: THE ECONOMY, THE ENVIRONMENT, AND PUBLIC POLICY

A. Houston's Environment

Despite its dependency upon the automobile and the heavy concentration of refining and petrochemicals, Houston is in compliance with federal standards for all pollutants except ozone. Ozone is unique in that it is not directly emitted into the air by industry or households, but is created in the atmosphere from other pollutants that are man-made. Ironically, Houston is in compliance with federal standards regarding levels of NOx which plays such a crucial role in ozone creation.

The possible negative effects of ozone have received considerable attention, though at present there is considerable research left to be done. It is known that the costs of ground level ozone are incurred in the form of increased health costs such as respiratory symptoms, emergency room visits and decreased work productivity. Each additional ton of NOx released into the air results in additional health costs. Present evidence suggests that the health costs of excessive ozone are substantially less than for other pollutants such as particulates.

It has been hypothesized that, for the Houston area to reduce ozone levels to the federal standards, NOx emission within the region must be reduced dramatically. At the same time, cleaning the environment also has opportunity costs, and this is particularly true of NOx. These include the costs of implementing the technologies to prevent or remove the NOx which require foregoing useful production elsewhere in the economy. Because meeting the federal ozone standards requires such substantial reductions in NOx, a host of regulatory strategies must be employed. Costs of the TNRCC SIP measures also include the extra commuting time due to lower speed limits and the additional cost of cleaner diesel fuel.

Since Houston is not in compliance with federal ozone standards, the State of Texas through its environmental agency, the Texas Natural Resources Conservation Commission (TNRCC) has been required to submit to the USEPA a plan that will bring Houston in compliance by 2007. This plan includes nearly 40 separate regulatory provisions. To understand both past and proposed pollution abatement strategies, the regional chemical processes which produce ozone need to be understood.

B. The Origins of Regional Ground Level Ozone

Many different pathways exist by which NOx emissions lead to the formation of ground level ozone. While the reactions that take place are extremely complicated, some common elements may be noted.

Essential compounds in the reaction are nitrogen oxides (NOx) and hydrocarbons, which are part of the group of pollutants known as volatile organic compounds (VOCs). Also needed is sunlight, which provides energy for the reaction, and water, in the form of humidity. Relatively still air, which is often caused by temperature inversions of the air during time of high heat, allows the reactants to stay together rather than dispersing into the atmosphere. This last phenomenon causes the ozone season to be concentrated during the summer months, which in Houston last from May through September. This process is illustrated in Figure 2.1.

The beginning of the process occurs during internal combustion. Combustion exhaust from industrial point sources, cars and trucks, boats, airplanes, and air conditioners (to name a few sources) release NOx and unburned fuel in the form of VOCs into the air. The NOx and the hydrogen and carbon from the VOCs react with sunlight and water to eventually form ground-level ozone. Ozone levels in Houston are due to human activities plus background levels due to natural conditions along with the transport of ozone into the region from elsewhere. Problems are exacerbated in Houston as compared to other cities due to its industrial mix, the dominance of the automobile, the summer weather and the rapid growth of the city.

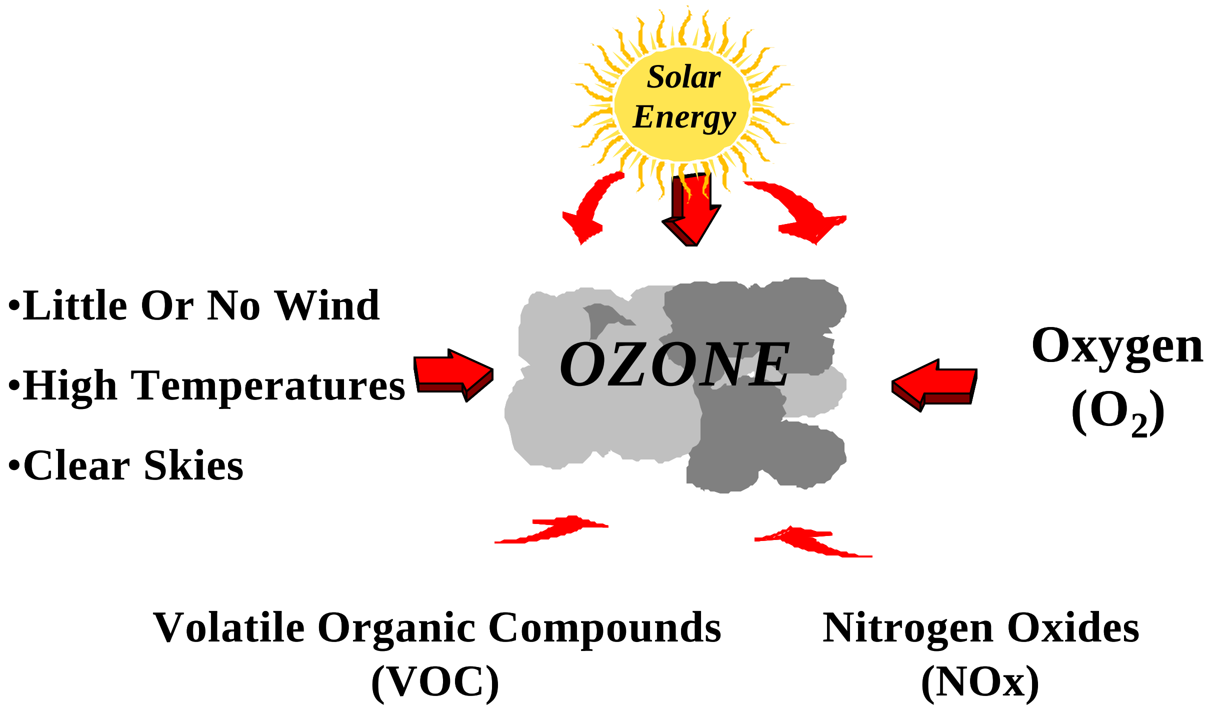


Figure 2.1-The Process of Ozone Formation

C. Past Efforts to Ameliorate Houston's Ozone Problem

Originally, measures taken to reduce ground-level ozone in Houston concentrated on reducing VOCs. While reductions could be made in the VOC emitted from industrial point sources, non-mobile area sources, and both on-road and off-road mobile sources, the background level of VOCs remained essentially constant. Between 1970 and 2000, significant progress was made, with VOC emissions declining by approximately one third. Progress has also been made in reducing NOx emissions, with essentially no growth from on-road and point sources from 1990 to 2000 and a substantial decline in NOx from the area and off-road sources over the same period.

Despite progress, Houston is still not fully in compliance with the federal Clean Air Act amendments of 1990. Houston is out of compliance, or in "non-attainment," with respect to the USEPA's ground-level ozone standards. Table 2.1 shows how Houston compares to other major U.S. cities. Los Angeles, a frequent source of comparisons to Houston, is out of compliance not only for ozone, but also for particulates and carbon dioxide, as are New York and Phoenix. Table 2.1 presents other examples demonstrating that Houston is not an unusual case with respect to compliance with the USEPA rules and in fact, when considering all pollutants, compares favorably to most other cities listed.

Table 2.1-Non-Attainment of USEPA Standards

City	Ozone	Particulates	CO_2	SO_2
Chicago	X	X		X
Cleveland		X		X
Denver		X	X	
HOUSTON	X			
Los Angeles	X	X	X	
New York	X	X	X	
Phoenix	X	X	X	
Seattle		X		

D. The Next Round of Air Quality Regulations: The TNRCC SIP

Just as Houston has made progress in reducing its air pollution, other cities have reduced their air pollution. Figure 2.2 shows how Los Angeles, Houston, New York, Chicago, and Milwaukee have reduced NOx emissions over the past 10 years. The reductions have not been as large in Houston as in the other cities. Houston's non-compliance with the federal ozone standard raises at least two questions. First, what is the optimal policy mix, balancing the ill-effects of air pollution against the costs of reducing them? Second, what can be done to satisfy the USEPA and bring Houston back into compliance, and at what cost?

The Houston region has until 2007 to meet the federal ozone standard. The TNRCC was required to submit a plan by December 2000, under the threat of significant consequences if it failed to do so. Without further progress and an acceptable plan in place, Houston would continue to be in non-attainment of the ozone standard, its residents would suffer health consequences from the ozone, and the state could lose its federal highway funds. There would be restrictions on new or expanding businesses, with consequent impacts on economic development.

The SIP, created by TNRCC, must be approved by the USEPA and submitted for approval to the state legislature. The 38 different measures of the TNRCC SIP directly affect both households and businesses. The measures apply to a large number of emission sources, broadly categorized into point sources, on-road mobile sources, and area plus non-road mobile sources. The reductions in NOx emissions from the major sources under the TNRCC SIP are shown in Figure 2.3. Total NOx emissions in 2007, in the absence of adopting the TNRCC SIP are estimated to be 1,001 tons per day (tpd). If the TNRCC SIP is adopted, 2007 emissions are estimated to be 414 tpd.

Figure 2.2-Reductions in Ozone Over Past 10 Years Based on USEPA Design Values

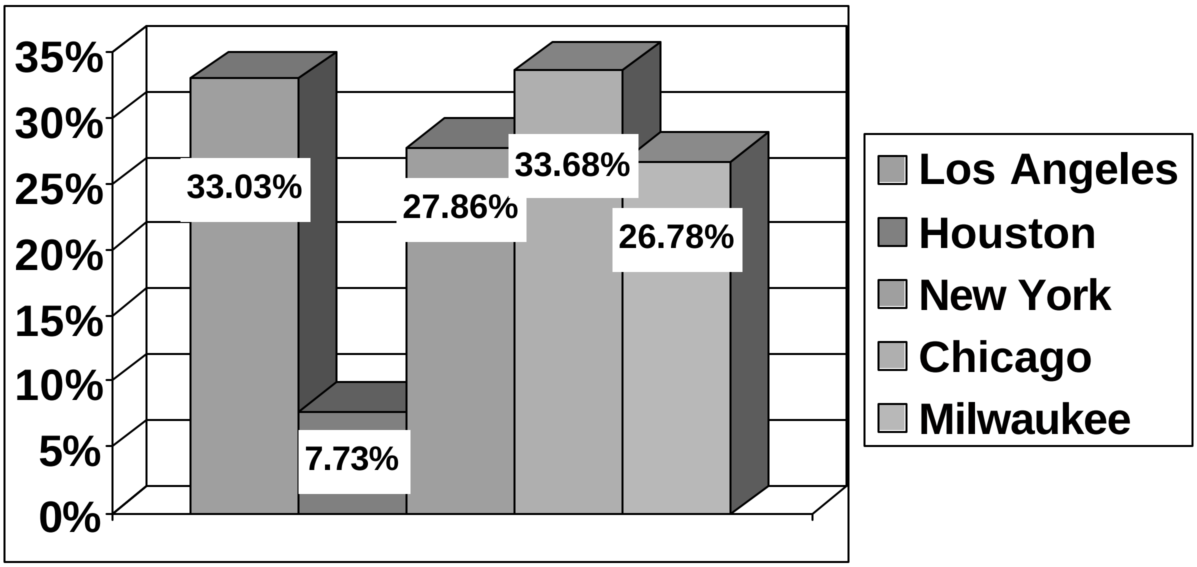
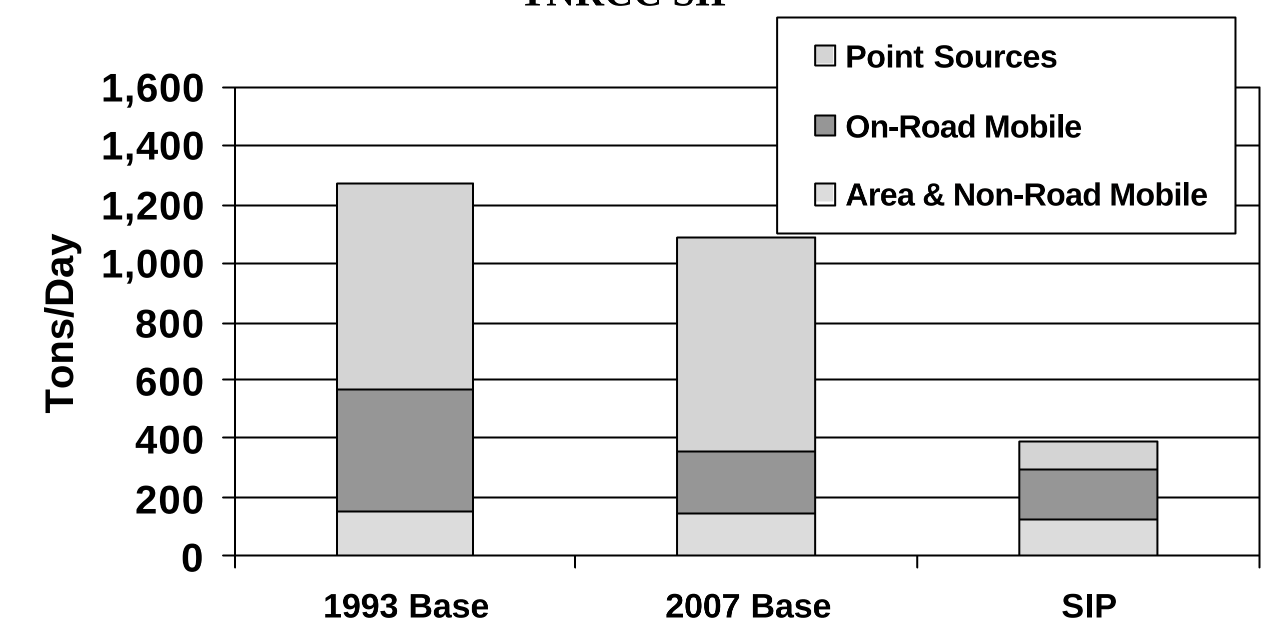


Figure 2.3-Reduction in NOx Emissions Under Proposed TNRCC SIP



III. DIRECT COSTS OF IMPROVING AIR QUALITY

A. The TNRCC SIP

As has been noted, the SIP is a proposal by the TNRCC to reduce pollution in Texas. The aim of the parts of the TNRCC plan applicable to the Houston area is to reduce the emissions of NOx and bring the area into compliance with the federal one hour ozone standard by 2007 set in the Clean Air Act Amendment of 1990. The TNRCC SIP contains 38 different measures (plus two other projects that had already been implemented, and two "cap and trade" emissions trading measures that were judged to be irrelevant, as it was assumed that there would be no reductions below the NOx caps to trade and therefore no costs to estimate). The version of the TNRCC SIP analyzed in this study is the August 2000 version with some modifications resulting from community discussions and public hearings after its release. These include modifications to the Texas boutique fuels measure (eliminating the requirement for Texas low sulfur gasoline) and to the lawn equipment operating restrictions (which now only apply to firms, as opposed to applying to all equipment users). The version analyzed in this study is close to the December version adopted by the TNRCC.

As a result of the December 6, 2000 meeting of the TNRCC, the final adopted TNRCC SIP was different from that considered in this report in a few ways. The measures mandating new air conditioner standards, diesel emulsion fuel, and NOx reduction systems (heavy-duty vehicle tailpipe systems) were eliminated. The bans on using diesel construction equipment and on using light gasoline-powered lawn care equipment from 6:00 AM to noon during daylight savings time were eliminated from the rural counties of Chambers, Liberty, and Waller. For all remaining counties in the case of construction equipment operating restrictions, for the entire HGA subject to the requirement for the accelerated purchase of Tier 2/Tier 3 heavy diesel equipment, and for the Inspection/Maintenance requirements for motor vehicles in the rural counties, the plan stipulated by the TNRCC may be replaced by a different plan if this new plan gives the equivalent NOx reduction. Specific acceptable alternatives, however, were not described. The major provisions leading to the high cost of the TNRCC SIP remain.

B. Estimation Methods

Considerable effort had to be devoted to developing cost estimates. Cost estimates published in the TNRCC SIP document were fragmentary and insufficient for completing an economic evaluation. The information used to construct the cost estimates for the various NOx control measures was obtained from a number of sources. These included (TNRCC), the Business Coalition for Cleaner Air (BCCA), various sources within the specific industries affected by the measures, the United States Environmental Protection Agency (USEPA), and RCF. TNRCC did not report costs for seven measures. For some measures, TNRCC cost estimates were, at best, only partial, and for others the interpretation of the numbers was not clear. For instance, it was not always clear whether capital costs or annualized costs were being reported. In some cases, detailed work drawing on industry information led to revisions of TNRCC estimates for use in the present study.

In cases where no explicit monetary costs were involved, such as the costs of waiting in line for motor vehicle inspections, dollar equivalent costs were assessed for the time and inconvenience involved. This was especially important in assessing the costs of the 55 mph speed limit, in which the only apparent costs were negative, i.e., fuel savings, until time costs were taken into account. Implicit costs were also important in assessing the impacts of other measures, such as motor vehicle inspection and maintenance, and vehicle engine idling restrictions.

Measures with significant capital costs required particular care. Capital estimates from different sources were frequently not in agreement. When this occurred, RCF paid particular attention to estimates with the most detailed considerations of the costs involved. In the evaluation of the costs of restricting NOx from the major industrial point sources, significantly different estimates were received from the TNRCC and the BCCA. RCF chose the estimates derived from the more detailed consideration of costs. For example, the BCCA noted that, in some cases, the examples used by the TNRCC relied on isolated instances of new technologies, experience with industrial apparatuses used differently from what would be necessary in Houston, or technologically optimistic extrapolations from currently existing technology. It should be emphasized that, due to the nature of the study, the costs presented in this chapter are subject to some uncertainty. No city has been asked to achieve as much as Houston in such a short period of time. When figures were available from different sources, an attempt was made to arrive at a consensus figure. If a consensus figure was unclear, the philosophy was to choose a conservative estimate. A conservative number is defined as a number that will not overstate the costs but may understate them.

Virtually no available cost estimates gave figures for different years. Cost estimates usually pertained to only one year. Since a complete time series of costs was needed for use in the modeling of the Houston economy, RCF estimated time series of the costs of the proposed measures. In measures with significant capital costs, it was often unclear whether the given costs were yearly amounts of total investment, or were instead the annualized expenditures for these measures. Smaller individual expenditures, such as those for NOx reduction systems (such as tailpipe antipollution systems), are capital expenditures in that they last for years and their costs may be distributed over these years. Yet it was sometimes not clear whether the cost estimate was for buying the systems, or for the amortization of the total capital purchased. RCF evaluated the figures to determine how to properly categorize the costs.

Measures involving the phase-in of capital investments over time required a separate cost calculation for each year's investment. As the precise timing of these investments by year was seldom provided by the TNRCC, an estimated phase-in reference was worked out by RCF in consultation with industry experts. For some of the larger capital measures, particularly those applying to industrial point sources, Texas cleaner diesel fuel, and the accelerated purchase of diesel equipment meeting the federal Tier 2/3 standards, a phase-in was employed, in which the costs were built up over 4 years.

While the views of industry personnel on interest payments and depreciation rates were taken into account, RCF employed its own amortization procedures to develop final cost estimates. The annualized cost of the capital was calculated as the total capital expenditure multiplied by the capital amortization factor, which was 0.180622 in most cases. This number was calculated by determining how much must be paid every year over an assumed 10-year life of the equipment to pay off the amount of the equipment's original cost, assuming the risk-adjusted discount rate for this type of industrial investment is 12.5 percent per year.

The calculation is:

$$R = \frac{1}{\sum_{t=1}^{T} \left(\frac{1}{1+r} \right)^t}$$

where R is the amortization factor, r is the real interest rate, and time goes from t to T. In the case of this calculation, T=10, r=0.125, and R=0.180622.

C. Control Cost Summary

Capital costs, operating costs, and annualized total costs are shown for the major cost components of the TNRCC SIP in Table 3.1. The combined cost of all measures proposed in the TNRCC is approximately $4.1 billion in 2007, the year in which Houston must meet the federal ozone standard to comply with the Clean Air Act Amendments.

Table 3.1-Control Costs for the Houston Area (Millions of Dollars)[a]

Measure	Capital Cost	Operating Cost[a]	Annualized Costs[a]
Federal Measures Total	$658	$21	$140
State Measures			
Point Source	$7,236	$277	$1,446
Construction Restrictions	$419	$1,436	$1,512
Texas Cleaner Diesel Fuel	$300	$26	$75
Lawn Service Restrictions	$1	$6	$7
Accelerated Tier 2/3 Equipment	$2,541	$0	$341
55 Mph Speed Limit	$0	$196	$196
Other State	$1,783	$74	$396
Local Measures Total	$470	$41	$126
Totals	$13,408	$2,079	$4,239

[a]Year 2000 Prices

The NOx control measures are divided into federal, state (i.e. overseen by state agencies), and local (i.e. overseen by local governments) level measures. The federal measures are not subject to approval by any state, and do not affect incentives for interregional re-allocation of people or resources. The costs of all federal measures are given in Table 3.2. (Costs are for the year 2007 deflated to be expressed in year 2000 prices). Federal measures total $140 million, including a $39 million low-sulfur gasoline measure, a $35 million measure for Phase II reformulated gasoline, a $26 million measure for the national low emission vehicle measure, a $5 million measure to comply with new standards for heavy-duty diesel engines, and lesser costs for new standards for off-road diesels and previously unregulated engines such as those of low power locomotives and marine vessels.

Table 3.2-Federal Components of Costs (2007 Annualized Costs, Millions of Dollars)[a]

On-Road Mobile	
Federal Low-Sulfur Gasoline	$39
Heavy-Duty Diesel Standards	$5
Phase II Reformulated Gasoline	$35
National Low Emission Vehicles	$26
Tier II Standards	$23
Off-Road Mobile Sources	
Heavy-Duty Diesel Standards	$5
Small Engine Standards	$4
Locomotive Standards	$1
Combined Commercial and Recreational Marine Standards	$0.49
Total Federal	$140

[a]Year 2000 Prices

State measures constitute by far the largest component of costs, totaling $3,973 million. As shown in Table 3.3, the most expensive state measure is the ban on heavy diesel use in construction from 6:00 A.M. until noon during daylight savings time, which would cost $1,512 million per year. The measure to achieve the 90 percent NOx reduction from point sources is next in expense, with an annualized cost of $1,446 million. These two measures alone account for 74 percent of the total costs of NOx control in the TNRCC SIP. The purchase of diesel equipment to comply with the federal Tier 2 and Tier 3 standards is accelerated as part of the TNRCC SIP, at an annualized cost of $341 million. Other major measures include motor vehicle inspection and maintenance checks for compliance with automobile pollution standards ($52 million), Texas cleaner diesel fuel with its reduced sulfur content ($75 million), new standards for air conditioners ($204 million), speed limit reductions to 55 mph ($196 million), and a diesel emulsion measure in which water and emulsifier is added to diesel fuels to burn with less pollutant output, but at a cost in output per gallon of fuel ($72 million). Other measures are included which propose such measures as to how long trucks may idle, when lawn care firms may mow the lawns, and what kinds of small gasoline-powered engines may be used. Finally, local measures to control NOx have a total cost of $126.1 million per year.

Table 3.3-State Components of Costs (2007 Annualized Costs, Millions of Dollars)[a]

Point Source NOx Controls	$1,446
Inspection/Maintenance	$52
Construction Work Day Restriction	$1,512
Texas Cleaner Diesel Fuel	$75
Lawn Service Operating Restrictions	$7
Accelerated Purchase of Tier 2/3 Equipment	$341
Residential & Commercial Air Conditioners	$204
NOx Reduction Systems	$17
55 Mph Speed Limit	$196
Diesel Emulsion Fuels	$72
Airport Ground Support Equipment	$28
California Spark-Ignition Engines	$12
Vehicle Idling Restrictions	$11
Total State	$3,973

[a]Year 2000 Prices

As shown in Table 3.4, the most costly measure, at $63.4 million per year, is a series of construction projects, which calls for both road improvement and creation of bicycle paths, entitled "Transportation Control Measures." Energy efficiencies for buildings are mandated at $7.3 million per year. All other local measures fall under the "Voluntary Mobile Emissions Reduction Measure." This includes a number of separate measures, including replacing current busses with electric or hybrid-electric busses, buying older and more polluting vehicles and replacing them with newer, less polluting ones, increasing public transportation, and measures to change driving patterns.

Table 3.4-Local Components of Costs (2007 Annualized Costs, Millions of Dollars)[a]

Voluntary Mobile Emission Reduction Measure	
Electric Airport Shuttle Buses	$1.2
Scrappage	$9.8
Smoking Vehicle Measure	$0.004
Purchase of Hybrid Electric Buses	$1.6
Shuttle for Hire Fleet Controls	$0.3
Non-Road Spark-Ignition Three-Way Catalyst Retrofits	$0.4
Reduce Tug/Push Boat Activity	$0.7
Pricing Measures	$34.3
Commute Solutions Measure	$1.2
School Year Schedule Change	$1.0
Transtar Expansion	$1.5
Expanded Transit Services	$1.4
Clean Air Action	$0.4
Land Use Measures	$1.7
Energy Efficiencies for Buildings	$7.3
Transportation Control Measures (TCMs)	$63.4
Total Local	$126.1

[a]Year 2000 Prices

D. Cost Effectiveness of Different Measures

The control measures were analyzed for their cost-effectiveness. Estimates of NOx reductions in tons per day were given in the August 2000 TNRCC SIP proposal. These were compared with the annualized costs to yield an annual cost of reducing NOx by 1 ton per day, or cost effectiveness, for each different measure. Results are shown in Table 3.5. The federal measures, in some cases regulating previously unregulated sources of pollution, had an average cost effectiveness of $2,306 per ton-per-day reduction in NOx. For the local measures, this value was $15,572.

The state measures had an enormous variance in cost-effectiveness. The ban on using diesel engines in construction during the early day would cost $618,220 per ton-per-day reduction. The accelerated purchase of new diesel equipment to meet the federal Tier 2/Tier 3 standards would cost $76,672 per ton-per-day. To achieve the final 1 percent of the 90 percent reduction in NOx output from the point sources would cost $58,924 per ton-per-day. The air conditioner standards would cost $43,063, and the 55 Mph speed limit $29,460, per ton-per-day. Other measures were significantly more cost-effective. Inspection and maintenance requirements for motor vehicles would be the most cost-effective, at $3,400 per ton-per-day.

Table 3.5-Policy Cost Effectiveness TNRCC SIP

	Annualized 2007 Cost ($Millions)[a]	**NOx/Day Reduction (Tons)**	**Cost Effectiveness ($/Ton)[a]**
Federal	140	166	2,306
State			
Point Source	1,446	599	58,924[b]
Inspection/Maintenance	52	42	3,400
Construction	1,512	7	618,220
Texas Cleaner Diesel Fuel	75	7	29,989
Lawn Service	7	1	16,627
Accelerated Tier 2/3	341	12	76,672
Air Conditioners	204	13	43,063
55 Mph Speed Limit	196	18	29,460
Diesel Emulsion Fuel	72	11	18,487
Vehicle Idling Restrictions	11	1	32,676
Other State	56	24	6,388
Local	126	22	15,572

[a]Year 2000 Prices

[b]Cost of an additional ton of NOx reduction at 90 percent control

E. Allocation of Capital Costs to Businesses and Households

In assessing the impact of the TNRCC SIP on businesses and households in Houston, only the state and local measures were explicitly considered. Federal measures are beyond the legislative authority of both the state and local legislatures and do not differentially impact different regions and their economies.

As shown in Table 3.6, more than $3.8 billion of the annualized costs of the TNRCC SIP fall directly on businesses in the Houston area. The majority of the costs, 76 percent, are in two measures, the 90 percent NOx reduction by industrial point sources, and the ban on using diesel engines in construction from 6:00 A.M. until noon during daylight savings time. Nearly $300 million of the annualized TNRCC SIP costs fall directly on Houston area households. More than one third of this is due to the proposed speed limit reduction to 55 Mph alone. These costs to households are offset by a reduction in ground-level ozone, but the benefits from this reduction are only $40 million per year, as will be discussed in chapter VI. This means that the net direct increase of costs to Houston households is over $260 million.

Table 3.6-Allocation of State and Local Costs to Businesses and Households (Millions of Dollars)[a]

	Annualized 2007 Cost	Borne by Businesses	Borne by Households
State			
Point Source	$1,446	$1,446	$0
Construction Work Day	$1,512	$1,427	$85
Texas Cleaner Diesel Fuel	$75	$75	$0
Lawn Service	$7	$1	$6
Accelerated Tier 2/3	$341	$341	$0
55 Mph Speed Limit	$196	$93	$104
Other State	$396	$320	$76
Local	$126	$102	$24
State & Local Totals	$4,099	$3,805	$294

[a]Year 2000 Prices

To compensate for this cost of living increase to Houston households, wages in Houston will have to rise by 0.32 percent, or by $262 million. If they do not, workers would be expected to migrate out of Houston until the resulting labor shortage causes the wages to rise by this amount. This wage increase is not a benefit to the Houston workers. Rather, it is a necessary compensation for the losses due to higher taxes and other costs (such as motorists' fees and the time costs of taking longer to commute at lower speeds).

IV. BENEFITS OF IMPROVING AIR QUALITY

A. Introduction

The air quality benefits of ozone controls enter the estimation of regional economic impacts because air quality influences the willingness of people to live and work in Houston. As just noted in the previous chapter, the benefits of the TNRCC SIP offset some of the costs imposed on households in arriving at the net wage compensation needed to make workers indifferent to living in Houston and elsewhere.

To evaluate the benefits, a model of the effects of local NOx emissions on Houston area air quality was needed. We utilized a rollback air dispersion model to estimate potential effects of SIP controls on ozone levels for each day of the year, using 1999 as a prototype year. The fourth highest ozone day in a three year period is the design day that determines the reduction in emissions required to meet the federal standard of 124 parts per billion (ppb). The rollback model posits that reductions in ozone levels in excess of the background ozone level are proportional to changes in Houston area NOx emissions. According to the rollback model, the SIP reduces the excess of the ozone level over the background level on every day of the year by the same percentage it is reduced on the design day. Assuming that the SIP control measures reduce Houston's contribution to local ozone by 59.4% on the design day, Houston's contribution is reduced by 59.4% on all other days of the year. Houston's contribution on each day of the year in the absence of the SIP is measured as the excess of Houston area daily ozone concentrations in 1996, when there was no SIP, over the background ozone level. More complex air quality modeling techniques may yield different benefit values, but because in the end the estimated benefits were very small compared to costs, the basic conclusions of the study should not be affected.

The health symptom effects of the changes in ozone due to the SIP were estimated drawing on epidemiological studies reviewed by USEPA. The agency's estimates of the most likely effects of a one ppb reduction in ozone were used. The health symptom effects were, in turn, monetized using USEPA estimates of willingness to pay for symptom relief. The monetized value of a one ppb reduction per person in ozone was translated into Houston area benefits for each symptom considered in a study by multiplying by the number of persons in the Houston area and then by the reductions in ozone levels added over all days of the year as estimated from the rollback model. Non-overlapping scenarios from the studies were constructed. The benefits from each study included in a scenario were added. The scenarios gave a range of total benefit estimates. The most likely scenarios gave total benefits to Houston households of $40 million per year.

The organization of this chapter is as follows. The analysis of effects of benefits of improved air quality is carried out in three major steps. The first major step is to estimate changes in air quality brought about by the proposed TNRCC SIP. This step is carried out in Section B. Using the rollback model, order of magnitude estimates are developed for reductions in average daily ozone concentrations in the Houston area that would be brought about by adoption of the proposed TNRCC SIP.

The second major step, carried out in Section C, is to estimate the value of the ozone reductions to Houston residents, which involves a series of substeps. The improvements in health symptoms per person resulting from a one ppb daily average ozone change are first estimated drawing on USEPA reviews of epidemiological studies. Then the monetary values of improvements in health symptoms per person from a one ppb change in ozone are estimated, again drawing on the USEPA. The monetary values of the health improvements per person are combined into symptom scenarios and multiplied by the Houston area population to obtain total benefits of a one ppb ozone reduction to the Houston area. Finally the benefits of a one ppb reduction in ozone are multiplied by the total change in ozone concentrations resulting from the proposed TNRCC SIP as derived from the rollback model in section B.

The third major step, carried out in Section D, is to compare the benefits of the ozone reductions with the costs of control measures borne by Houston area households, in order to obtain the net effect of the proposed TNRCC SIP on Houston area households. The difference between the benefits and costs borne by Houston area households determines the change in money wage necessary to attract labor to the Houston area.

B. Rollback Model of Air Quality Effects

The design day, or day used to determine the ozone reduction necessary to bring the Houston area into compliance with the National Ambient Air Quality Standards (NAAQS), is the day on which the fourth highest hourly ozone reading within a three year period occurs. For the 1997-1999 period, the indicated design day is August 25, 1999 when the maximum hourly reading was 203 ppb. Since the one hour NAAQS for ozone is 124 ppb, the indication is that TNRCC SIP controls must be sufficient to reduce the maximum hourly reading on the design day by 203 minus 124, or 79 ppb.

Conversations with TNRCC suggested using a maximum background level of ozone of 70 ppb due to natural conditions and transport of ozone into the area from elsewhere. The Houston area contribution to maximum hourly ozone on the design day is then estimated as 203 minus 70, or 133 ppb. Dividing the 79 ppb required reduction by Houston's contribution of 133 ppb gives a required reduction in Houston's contribution of 59.4 percent. The TNRCC SIP control measures will contribute to reductions in ozone concentrations on other days of the year as well as on the design day. The estimated reduction in maximum daily ozone reading is $(X_{Mt}-X_{MB})P$ where X_{Mt} is the maximum hourly ozone reading in the absence of the TNRCC SIP on the t^{th} day of the year, and the assumed background maximum is X_{MB}. P is the proportionate reduction in Houston's contribution brought about by the TNRCC SIP. P equals $(X_{MD}-X_{MS})/(X_{MD}-X_{MB})$ where X_{MD} is the maximum on the design day and X_{MS} is the NAAQS standard. The numbers presented so far are $X_{MD}=203$, $X_{MS}=124$, $P=.594$ and $X_{MB}=70$.

The benefit estimation to be considered below relates health symptoms to average daily reading rather than maximum daily reading. Figure 4.1 shows daily values of the maximum and average for each day of 1999 and indicates that, while the average is of course less than the maximum, the two measures vary together. On the design day August 22, 1999, the average hourly ozone reading taking the mean of the eight monitors with useable data was 27.05 ppb. The ratio of average to maximum was 27.05/203, or .133. Applying this ratio to the assumed background maximum of 70 gives a background average of .133 times 70 or 9.33. The estimated reduction in average daily ozone reading is $(X_{At}-X_{AB})P$ where X_{At} is the average hourly reading on the t^{th} day of the year without the TNRCC SIP and X_{AB} is the average background reading assuming no contribution from the Houston area. Letting $R=X_{AB}/X_{MB}$ be the ratio of background average to background maximum, the estimated reduction in average daily ozone reading due to the TNRCC SIP is $(X_{At}-X_{MB}R)P$. With the assumption of a given ratio of average to maximum reading, the proportionate reduction P is the same whether averages or maximums are considered since the ratio enters the numerator and denominator of P and cancels. In the numbers given so far, P remains .594, and R equals .133.

Figure 4.1-Hourly Maximum and Daily Average Ozone Levels

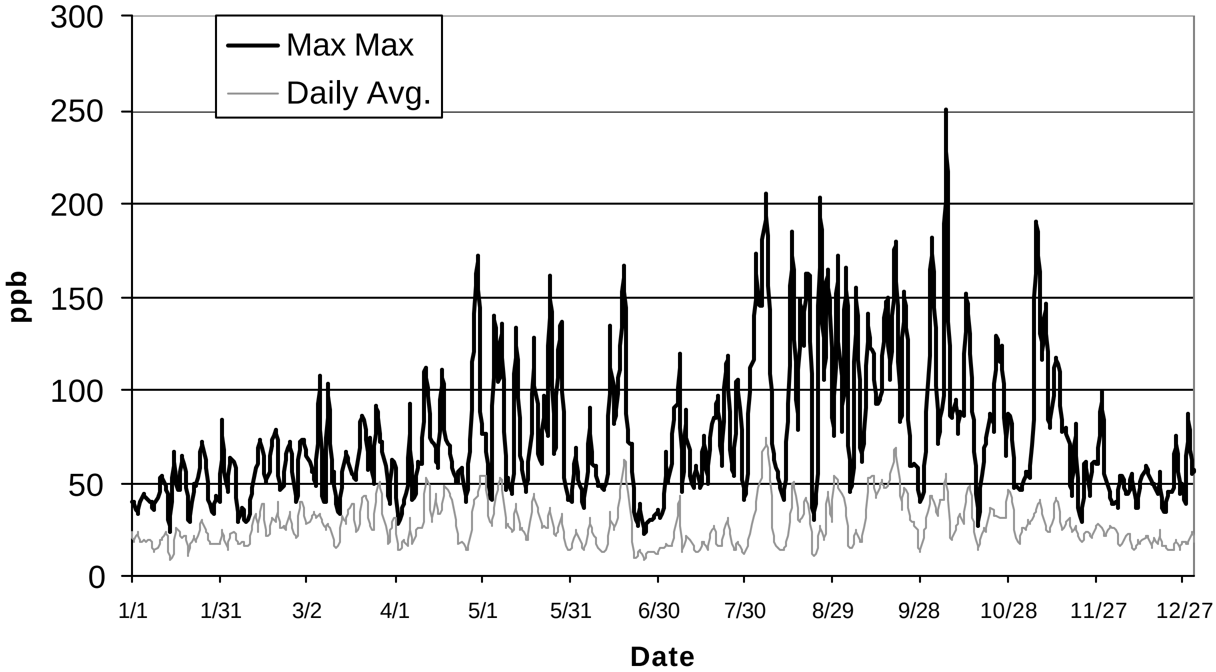
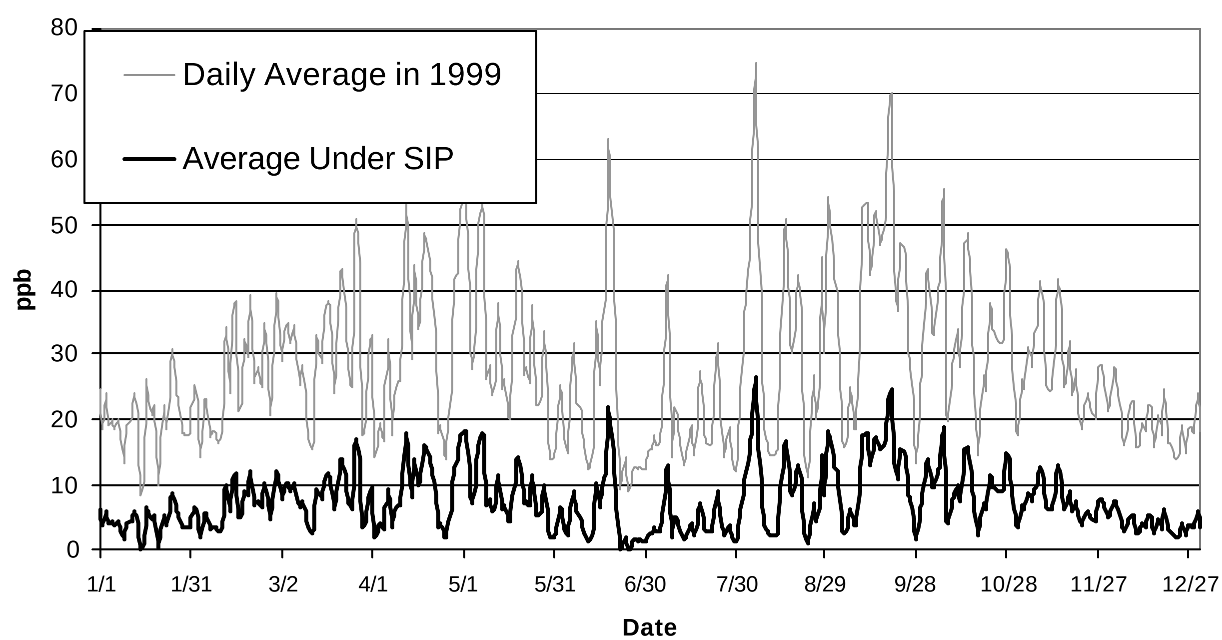
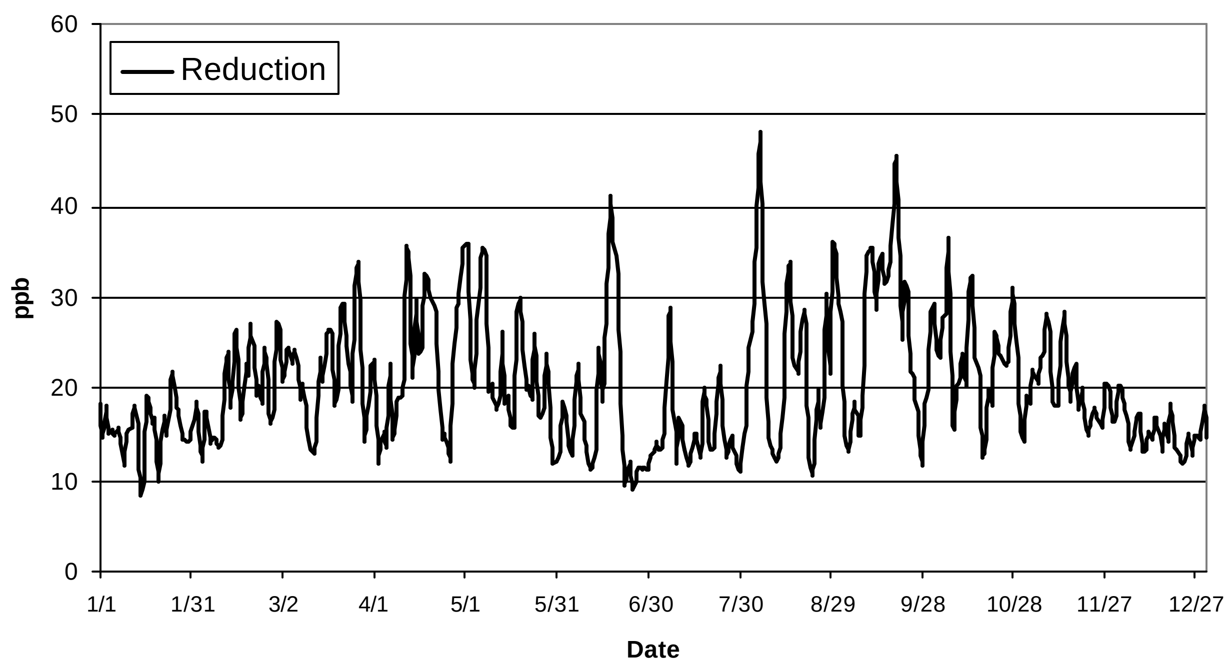


Figure 4.2-Daily Average Ozone With and Without SIP



The top line in the Figure 4.2 gives average daily ozone reading for each day in 1999, repeating the figures plotted earlier. The lower line gives estimated average readings under compliance with the TNRCC SIP. It is obtained by subtracting the reductions due to the TNRCC SIP (X_{At}-X_{MB}R)P from the top line values. The estimated reductions (X_{At}-X_{MB}R)P are plotted in Figure 4.3, "Reductions in Average Ozone Due to the TNRCC SIP." These average daily ozone reductions are used below as the starting point for estimating physical symptom reductions.

Figure 4.3-Reduction in Average Daily Ozone Levels Due to the TNRCC SIP



As a sensitivity check, calculations were done using other values of X_{MB} and R. As noted, the maximum background X_{MB} of 70 used in the calculations presented here was suggested in conversations with TNRCC personnel. A perusal of the observed X_{MB}'s revealed a number of values as low as 50, which was tried as an alternative value. The value of R of 0.133 used here was obtained as the ratio of the average to the maximum on the design day. The average of the ratios for all days of the year is 0.364, which was tried as an alternative. The alternative values all led to lower estimates of benefits than the numbers presented here.

C. Value of Ozone Reductions

1. Morbidity Responses to Ozone in Houston

Descriptive medical literature exists suggesting that ozone may have physical effects, such as cellular and molecular changes in the lung resulting from inhalation of ozone. This descriptive medical literature is non-quantitative. Another type of evidence is animal chamber studies with controlled levels of high doses of ozone. The animal chamber studies find evidence of temporary effects, while the evidence on long term effects is not conclusive. Still another type of evidence is human chamber studies. These also find temporary effects, but dosage levels are too low and too short lived to test for long term effects. Finally, epidemiological studies consider correlations between symptoms observed in non-experimental populations and monitored ozone levels. These range from diary studies to time series studies of hospital admissions and self-reported symptoms over a number of years in particular cities. Increasing effort has been devoted to these latter studies. The USEPA has reviewed them thoroughly. Major reliance in the present study is placed on the USEPA review of epidemiology studies.

A variety of epidemiological studies have attempted to quantify various physical effects that atmospheric ozone can have on human populations. These studies make it possible to estimate health improvements expected to result from reductions in atmospheric ozone concentrations. The USEPA publication, "The Benefits and Costs of the Clear Air Act: 1990-2010" (November 1999), was relied upon for their selection of studies upon which to base benefits estimates. The USEPA publication is particularly useful because it develops a set of functions that are computationally convenient and that estimate the likely health effects of ozone in multi-pollutant settings. USEPA's selection of studies examines a wide variety of health effects. This has two major advantages. One is that it permits different aggregation paths that can be compared as checks against each other. Another is that a number of studies measure the same, or nearly the same, health effects, and can be compared to each other as a partial validation procedure.

USEPA selected 21 studies of morbidity effects of ozone. Four studies examined all respiratory symptoms, two examined combinations of some respiratory symptoms , three examined pneumonia, three examined chronic obstructive pulmonary and obstructive lung diseases, six examined asthma, two examined cardiac and dysrythmia symptoms, and one examined minor restricted activity days.

Reference numbers that we have assigned to the studies are listed in column 1 of Table 4.1. Full bibliographic identifications of the studies are given at the end of this chapter. The symptom considered in each study is shown in column 2 of Table 4.1. A typical study regressed hospital admissions for a certain type of symptom, such as hospital admissions for respiratory ailments each day, on ozone concentrations in parts per billion that day or lagged. The typical study pertained to a particular city using observations over several years. Various additional explanatory variables were used, including concentrations of other pollutants, season, and day of week.

Cases per person due to a one ppb change in average daily ozone concentration are shown in column 3. The original studies were not uniform in measurement of ozone. Most used average daily concentrations, that is, daily 24 hour averages. Other measures, including maximum daily one-hour concentrations and daily 5, 8 or 12 hour averages, were also used. These differences required that ozone concentrations as measured in the studies be re-expressed in different units so that the functions could be applied to the Houston data on average daily concentrations. These conversions affect the cases per person in column 3.

To elucidate the conversions, let x be the daily symptom per person. Then the USEPA publication gives dx/dZ_i for each study, or change in symptom per person in response to a change in Z_i, where Z_i is ozone measured in the units used in a study reviewed by USEPA. The ozone unit used for our ozone concentration effects for Houston estimated above in Section B is average daily ppb which may be denoted Z_A. To find the health effects in Houston, we need to multiply the estimated effects of the SIP on Z_A by the health effect per unit change in average daily ppb dx/dZ_A. To convert dx/dZ_i from one of the studies to dx/dZ_A, we use the relation $dx/dZ_A=(dx/dZ_i)(dZ_i/dZ_A)$ which multiplies the coefficient from the study by dZ_i/dZ_A, the change in ozone measured in the units of the study with respect to a change in average daily concentration.

The unit used in studies 1, 2, 6, 7, 8, 9, 10, 11, 12, 13 and 20 is average daily ozone concentration giving dx/dZ_A directly. The unit used in studies 4, 5, 14, 15 and 21 is the daily maximum. Regressing the daily value of maximum on daily average concentration in Houston for 1999 gives an estimate of the value needed for conversion of the units of these studies dZ_i/dZ_A of 2.24. The maximum is more variable than the average and goes up by 2.24 times the average when the average is observed to change. The remaining studies use daily 5-hour (studies 16, and 17), 8-hour (study 18) and 12-hour (studies 3 and 19) averages. The daily average Z_A changes by y/24 for every unit change in the y-hour average Z_i, that is by the change in the restricted hour average as a fraction of the total number of hours in the 24-hour daily average period. Thus, $dZ_A/dZ_i = y/24$, or taking the reciprocal, the value needed for conversion of units is $dZ_i/dZ_A=24/y$.

Continuing with the explanation of Table 4.1, "Relevant population" in column 4 multiplies the cases per person in the preceding column by the number of people in the Houston population to whom the cases refer, i.e. total Houston population of 4,218,139 for studies applicable to the total Houston population and Houston population in particular age groups for studies confined to an age group. For example, the study minor restricted activity days (MRADs) in the last row pertains to ages 18-65. The respiratory studies in rows 1 and 2 pertain to persons age 65 and older. "Number of Cases" in column 5 is the product of columns 3 and 4. In row 1, for example, Houston would expect 0.48 respiratory cases in response to a 1 ppb increase in ozone, according to study number 1.

Table 4.1-Values of Symptom Changes in the Houston Area from a One ppb Change in Average Daily Ozone Level

Study	Symptom§	Cases/Person	Relevant Pop	Number of Cases	EPA Value/Case°	EPA Total*
1	All Respiratory Conditions > 65	852.0E-9	330,218	0.2813	$ 8,500	$ 2,391
2	All Respiratory Conditions > 65	315.0E-9	330,218	0.1040	$ 8,500	$ 884
3	All Respiratory Conditions < 65	259.8E-9	3,887,921	1.0101	$ 8,500	$ 8,586
4	All Respiratory Conditions < 65	37.5E-9	3,887,921	0.1457	$ 8,500	$ 1,238
5	19 Acute Respiratory Symptoms 18-65	156119.3E-9	2,626,213	410.0025	$ 22	$ 9,020
6	Respiratory Infection all ages	30.9E-9	4,218,139	0.1303	$ 8,500	$ 1,108
7	Pneumonia > 65	271.0E-9	330,218	0.0895	$ 8,500	$ 761
8	Pneumonia > 65	196.0E-9	330,218	0.0647	$ 8,500	$ 550
9	Pneumonia > 65	149.0E-9	330,218	0.0492	$ 8,500	$ 418
10	COPD > 65	168.0E-9	330,218	0.0555	$ 8,500	$ 472
11	COPD > 65	103.0E-9	330,218	0.0340	$ 8,500	$ 289
12	Obstructive Lung Disease all ages	17.5E-9	4,218,139	0.0738	$ 8,500	$ 627
13	Asthma all ages	11.9E-9	3,887,921	0.0463	$ 8,500	$ 393
14	Asthma self-reported asthmatics	108410.0E-9	236,638	25.6539	$ 39	$ 1,001
15	Asthma all ages ER visits	3.7E-9	4,218,139	0.0157	$ 238	$ 4
16	Asthma all ages ER visits	47.9E-9	4,218,139	0.2021	$ 238	$ 48
17	Asthma all ages ER visits	134.4E-9	4,218,139	0.5669	$ 238	$ 135
18	Asthma < 65 chronic onset	504.0E-9	1,128,357	0.5687	$ 37,000	$ 21,042
19	Cardiac all ages	403.2E-9	4,218,139	1.7008	$ 11,700	$ 19,899
20	Dysrythmia all ages	10.9E-9	4,218,139	0.0460	$ 11,700	$ 538
21	Minor Restricted Activity Day 18-65	7535.8E-9	2,626,213	19.7905	$ 47	$ 930

§ Daily hospital admissions rate unless stated otherwise

° Year 2000 prices

* The value to Houston of a one ppb reduction in ozone for a particular disease per day

2. Monetary Values Attached to Symptom Reduction and Combining of Studies to Estimate Total SIP Benefits

Column 6 of Table 4.1 gives dollar values per case assigned by the USEPA to the symptoms based on a comprehensive survey of the literature on health values. The values in column 6 are those reported in USEPA 1999, p.70 inflated to 2000 prices from the USEPA values given in 1990 prices. Column 7 gives dollar values of symptom reduction to Houston for a 1 ppb reduction in ambient ozone concentration, as calculated for each study by multiplying column 5 by column 6.

The 21 ozone morbidity studies reviewed by the USEPA cover a variety of non-comparable situations. Some of the studies refer to broad categories of symptoms, while others pertain to individual symptoms. Some cover all age groups, while others cover subgroups. The next task is to combine the results of the studies into coherent scenarios. Combining the studies requires that care be exercised to avoid double counting of benefits while obtaining measures that are as inclusive as possible. The ICD–9 (International Classification of Diseases–9th edition) is available for each of the conditions appearing in the 21 ozone morbidity studies reviewed by USEPA. The classification was consulted during the adding-up phase of the analysis. Table 4.2 shows the definitions of each scenario.

Table 4.2-Definition of Health Benefit Scenarios

SCENARIO	COMPONENT STUDIES
One	5, 20
Two	Average of 1 and 2, Average of 3 and 4, 20
Three	6, 12, 13, 20
Four	6, 12, 14, 20
Five	6, 12, 20, 21
Six	6, 12, 18, 20

One basic type of scenario (aggregate type) combines studies pertaining to largely non-overlapping broad categories. The other type of scenario (disaggregate type) builds up a set of values from more detailed studies again chosen to be as non-overlapping as possible. Scenario One is an aggregate scenario combining studies 5 and 20. It adds estimated health effects (study 5) pertaining to all respiratory symptoms to cardiac health effects using an adjustment to dysrythmia (study 20) as an estimate of cardiac effects. The respiratory symptoms in study 5 cover all the component respiratory symptoms in the other studies, which are therefore not used in this scenario. The other type of symptom in this scenario is cardiac, which is not covered by the respiratory symptoms. Study 19, pertaining to cardiac all ages, gave such extremely implausible results as to preclude its use. The assumption that one third of cardiac patients have dysrythmia led to multiplying the dysrythmia estimate of study 20 by 3 as the estimate of cardiac effects of ozone. Adding the monetary values for study 5 and three times the monetary value for dysrythmia shown in column 6 of Table 4.1 for a one ppb change in ozone, multiplying by the total hours of ppb reduction due to the SIP of 4,011 as estimated from the rollback model in Section B, gives 2007 benefits of the SIP to the Houston area of $44 million.

Scenario Two is also an aggregate scenario. It adds the average of studies 1 and 2 pertaining to all respiratory symptoms of persons 65 and over to the average of studies 3 and 4 pertaining to those under 65 to obtain estimates for respiratory symptoms in place of study 5 used in Scenario A. Three times the effects of dysrythmia is again used for cardiac effects. Following the same calculation procedure, the total benefits for this scenario are $34 million.

The remaining scenarios are disaggregate, using specific types of respiratory symptoms instead of aggregates of all respiratory symptoms combined. Each of the disaggregate scenarios is identical except for the treatment of asthma. They all use study 6 for respiratory infections of persons of all ages, study 12 for obstructive lung diseases of persons of all ages, with different measures in each case for the remaining respiratory category of asthma. As before, three times the effects of dysrythmia is used for cardiac effects. Scenario Three adds to this basic disaggregate set study 13 pertaining to hospital admissions for asthma of persons of all ages. Total benefits for Scenario Three are $15 million. Scenario Four replaces study 13 with study 14 which is for self reported asthma. Scenario Four gives benefits of $18 million. Scenario Five uses study 21 pertaining to minor restricted activity days as a surrogate for asthma symptoms. While the effects of ozone on minor restricted activity days are due to more conditions than asthma, some asthma is not severe enough to cause activity restriction, so the effects are to some extent offsetting. Study 21 gives results similar to study 14 and is suggestive that much of the effects of ozone on restricted activity days may be due to asthma. Scenario Five benefits are $18 million. Finally, Scenario Six uses, as the asthma effect , study 18 for effect of ozone on onset of chronic asthma. Scenario Six gives benefits of $101 million.

The remaining studies listed in Table 4.1 may be viewed as corroborative but are not used because they pertain to incomplete subsets of the symptoms covered in the scenarios. Studies 10 and 11 on chronic obstructive pulmonary disease(COPD) for person 65 and over are primarily for a subset of study 12 on obstructive lung disease for persons of all ages. As expected they give lower health benefits. Studies 15, 16 and 17 are for emergency room visits for asthma and as expected give low benefits in relation to the other asthma studies which cover the great amount of discomfort from asthma that does not require emergency treatment.

Considering all the scenarios, the aggregate Scenarios One and Two merit greatest consideration. They are the most comprehensive in coverage of symptoms, and they give benefits that are similar in order of magnitude. The average for these two scenarios is close to $40 million, which is used as the most likely estimate in the present investigation. Among the disaggregate scenarios, Scenarios Three, Four and Five are in the narrow range of $15 million to $18 million. These estimates may be low because in their attempt to aggregate from individual symptoms, they exclude some of the health effects of ozone. The remaining scenario, Scenario Six, gives the high benefit estimate of $101 million because of the high value attributed to onset of chronic asthma by study 18. Study 18 is for a relatively small sample and anomalously finds that there is an estimated effect for adult males, but no effect for females. If one were to give a reduced weight to this study of one third, the estimated total benefits would be in the vicinity of $40 million, similar to favored scenarios One and Two.

3. Additional Considerations

Most of the epidemiology studies are for northern cities where time spent outdoors during the daytime is greater than in Houston, because temperatures in Houston are higher and air conditioning is heavily relied on. This consideration would make the health benefits for the Houston area less than estimated here, in view of less exposure to ozone than in northern cities.

A previous study , "Assessment of the Health Benefits of Improving Air Quality in Houston, Texas, Draft Final Report" (Sonoma Technology, Inc., April 1999) also presented estimates of health effects of ozone in Houston based on indoor-outdoor considerations and bringing in many epidemiological studies. The estimate of health values from meeting the one hour ozone standard in the Houston area for 2007 was $73.6 million (p.6-38), apparently in 1997 prices. Inflating to 2000 prices for comparability with the present study, the benefits would be $74.3 million. While somewhat higher than the benefits estimated in the present study, use of the Sonoma result would not affect the basic conclusions of this study, since the benefits still remain an extremely small influence on wages and have an essentially negligible effect on the regional economy. Commendable painstaking work was reported in the Sonoma study, whose general order of magnitude corroborates the benefits estimated in the present study. The estimates used in the investigation are based on USEPA were chosen for three reasons. First, insufficient information is given in the Sonoma study to replicate its results and therefore to fully evaluate it. Second, $36.8 million, or half of the estimated benefits were due to relief from eye irritation. The reasonableness of this figure may be questioned since eye irritation has figured at best only in a minor way in the literature on possible symptom effects of ozone. Third, the USEPA study of the benefits and costs of the Clean Air Act has been widely read and peer reviewed.

In accordance with the USEPA (1999, p. D-19), we chose as a most likely estimate that ozone control has no discernible mortality benefits. We agree with USEPA's cautionary note regarding the possibility of spurious correlations if attempts are made to relate ozone to mortality. Problems include difficulties in measurement of fine particulate matter and other confounding pollutants, as well as problems of correct functional form and omitted variables generally.

The benefit estimates are needed for the present study of SIP effects on the Houston area economy as an impact on wages needed to attract labor to Houston. The impact is, strictly speaking, a perceived impact on the part of those marginal to living in Houston. As will be brought out in the next section, the estimated effect on wages is essentially negligible. The perceived impact on the part of people deciding whether to live and work in Houston could be zero, or it could be many fold the amount estimated here, without affecting the conclusions of the present study of effects of SIP benefits on the Houston economy.

D. Effects of TNRCC SIP on Cost of Living and Wages

Houston area households will be impacted both positively and negatively by the proposed SIP. Health benefits of reduced ozone concentrations would be expected to result in lower wages, since the Houston area would be more desirable, leading to an increase in the supply of labor. However, the controls giving rise to those benefits are likely to result in undesirable cost-of-living effects that would reduce the supply of labor resulting in higher wages. The net effect is *a priori* ambiguous, depending on the relative magnitudes of the cost-of-living effects and the benefits received.

An estimate of the 2007 health benefits expressed in year 2000 prices, as developed in the preceding section, is $40 million. If one is interested in whether the attainment of benefits is justified in the view of total costs of the SIP, one may compare the relatively small $40 million in benefits to the large 2007 total annualized cost of $4,239 million for the TNRCC SIP as given in Table 3.1. The purpose of the present study, however, is not to question whether the SIP is justified. Rather, the purpose is to estimate the regional impacts if a SIP is adopted, regardless of whether it is justified. In estimating regional impacts, the role of the benefits is as an influence on wages needed to attract labor to the Houston area.

To investigate wages, the $40 million benefit may be compared with the share of 2007 annualized costs falling directly on the households of $294 million as given in Table 3.6 for the TNRCC SIP. The $40 million of benefits amount to 0.025 of one percent of projected personal income in 2007 of $150 billion. The costs of the TNRCC SIP falling directly on households are 0.2 of one percent of personal income, and the costs of the alternative SIP are approximately 0.1 of one percent. These percentages approximate the direct percentage effects on wages necessary to attract labor to Houston and give an idea of their extremely small relative magnitude. In the regional modeling, the impact of the direct wage effect was captured by using as one of the inputs the net effect, or difference between the total costs falling directly on households and the total benefits. This difference was incorporated into the regional model in the calculation of cost of living change to which labor responds.

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V. EFFECTS OF THE TNRCC SIP ON THE HOUSTON ECONOMY

A. The Regional Model

The regional economic impacts of the TNRCC SIP were estimated by simulating the Houston regional economy. The direct cost and benefits described in the preceding chapters were used as inputs into an adaptation of the well known REMI model, and simulations were conducted for the Houston area economy for each year from 2001 to 2020. These results were compared to the results under a scenario that assumes no additional environmental control options, other than those that are currently in place (the without-controls scenario). The regional economic impacts of the TNRCC SIP are the differences between the results of the simulations under the with-controls scenario and the simulation under the without-controls scenario. Comparing the results of the policy simulations reveals differences in population, employment, output, and other regional economic performance measures of interest that constitute the regional economic impacts of the ozone control measures.

The version of the REMI model adapted for use in this report breaks the regional economy into 53 sectors (49 private nonfarm industries, 3 government sectors, and the farm sector), and divides the Houston regional economy into the eight counties that make up the Houston-Galveston nonattainment area (Harris, Brazoria, Galveston, Chambers, Liberty, Montgomery, Waller and Fort Bend counties). Overrides of the standard REMI model were used to take account of special features of the Houston area economy.

One of the principal advantages of using a regional economic model is that the model preserves the linkages between sectors of the economy, captures the impacts that wages and prices have on businesses and consumers, and calculates major regional economic variables. The use of a regional economic model captures how the costs of the TNRCC SIP controls affect measures of regional economic performance, including unemployment rates, Gross Regional Product, government expenditures, state and local tax receipts, and measures of wages, prices, and income. Many of the regional economic impacts are broken down by industry, so that one can, for example, compare how the refining, petrochemical, and construction industries fare under the TNRCC SIP controls and how induced effects on retailing and other local industries compare with the direct effects.

The costs imposed on businesses, consumers, and government affect industry location since many Houston area businesses produce goods and services for national and international markets. To the extent that these control costs fall solely on Houston based businesses, Houston area businesses become less competitive in national and international markets. Houston industries will lose market share to industries in other regions not encumbered by such strict measures. Over a period of years, many firms in these industries will be forced to locate elsewhere, and firms outside of Houston will be discouraged from either establishing new businesses in Houston or relocating to Houston from outside the region. As a result, the potential for future economic growth and development of the Houston regional economy is impaired by the imposition of the controls. To the extent that the imposition of these measures reduces the rate of long term economic growth, erosions to the tax base occur so that state and local government agencies are less able to maintain infrastructure that serves citizens and encourages the continued longer term economic development of the Houston regional economy.

Many of the measures considered in the TNRCC SIP impose costs on businesses producing local goods. To stay in business, they respond by passing the additional costs to other businesses, consumers, and government entities, in the form of higher prices. The use of regional economic modeling allows measurement of these cost increases and traces how they filter through all sectors of the Houston area economy. Higher prices will be manifested in higher rates of inflation, nominal wage rates, interest rates, and reduced real wages, incomes, and profits. By taking into account inter-industry relations, by which direct impacts on businesses and households affect purchases from other businesses in the Houston area, the resulting decline in household income leads households to demand fewer retail services and fewer goods produced in Houston for local consumption. As a result, the use of the regional model captures impacts on employment and output in nearly all industries, many of which had no direct control costs imposed directly on them. A simplified version of this process is presented in Figure 5.1.

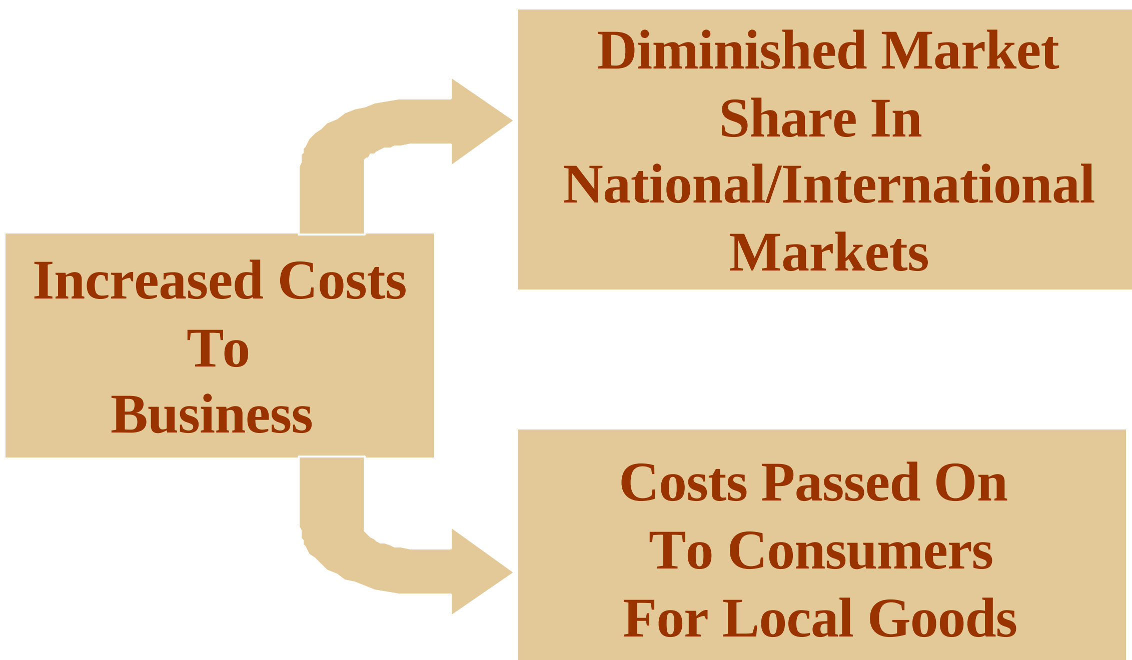

Figure 5.1-The Impact of TNRCC SIP Measures

The resulting higher prices for local goods and services contributes to increases in the cost of living. These are added to the direct effects on the cost of living from the $300 million of cost of living increase that fall directly on households. Second, the rise in prices forces Houston area firms to raise wages to recruit new and retain existing workers. These higher wages generate further rounds of cost of living and wage increases, exacerbating the disadvantage Houston businesses face in national and world product and labor markets. The effects on households are diagramed in Figure 5.2.

B. Results for Employment, Gross Regional Product, and Tax Receipts

The measures proposed by the TNRCC to meet the ozone standards under the Clean Air Act will reduce employment and output in virtually all sectors of the regional economy of the Houston nonattainment area. The time profile of effects on the Houston area economy can be found in Table 1 presented earlier in the Executive Summary section. By the year 2007, the year in which the Houston nonattainment area will have to be in compliance, there will be approximately 98,000 fewer jobs than would have occurred had the proposed measures not been implemented. This amounts to a 3.7 percent effect on total employment. By 2010, the job effect increases to 103,000, which represents 3.7 percent fewer jobs than would occur if the proposed measures had not been implemented. The Houston economy does not recover from these costs. By the year 2020, the job effect is 140,000, which amounts to 4.2 percent fewer jobs than under the baseline scenario without controls.

Figure 5.2-The Impact of TNRCC SIP Measures

The effects on employment are accompanied by effects on output, measured by real Gross Regional Product (GRP). By 2007, the Houston regional economy will have $10.5 billion (in 2000 prices) less in output than without the TNRCC SIP controls, which amounts to 5.1 percent of total output. By 2010, the output difference increases to $12.6 billion, which amounts to 5.5 percent of output. The effects on GRP follow the pattern of employment effects and continue to increase into the future. By the year 2020, GRP is $21.0 billion below the baseline, which amounts to 6.6 percent less output than would have occurred if the TNRCC SIP measures were not implemented.

The deleterious effects on economic performance, as measured by employment and output, erode the tax base of the Houston regional economy. By the year 2007, the state of Texas and local governments will have $676 million less in tax receipts than without the TNRCC SIP. The relative erosion in the tax base will continue throughout the forecast period, reaching $860 million by 2010, and continuing to increase out to the year 2020, when tax receipts are $1.5 billion less, or 5.5 percent less than without the TNRCC SIP.

Table 5.1-Sector Breakdown of Economic Impacts of TNRCC SIP in 2010

Industry	Without	With	Difference	% Difference
Durables Manufacturing	154.6	152.7	-1.9	-1.2%
Non-Durables Manufacturing	118.1	104.0	-14.1	-12.0%
Mining	83.4	79.9	-3.5	-4.2%
Construction	204.9	192.8	-12.0	-5.9%
Transportation, Public Utilities	195.5	187.6	-8.0	-4.1%
Finance, Insurance, Real Estate	153.6	149.3	-4.3	-2.8%
Retail Trade	456.4	441.2	-15.2	-3.3%
Wholesale Trade	171.6	166.2	-5.5	-3.2%
Services	944.2	914.6	-29.6	-3.1%

The TNRCC SIP affects employment in virtually every sector of the Houston regional economy, as shown in Table 5.1. The hardest hit sector, services, loses almost 30,000 jobs, relative to the no TNRCC SIP situation, accounting for nearly one third of the total 103,000 job effect that occurs in 2010. Other notable job reductions from the baseline in 2010 are: retail trade- 15,200 jobs nondurables manufacturing- 14,100 jobs, and construction- 12,000 jobs. When combined, these industries account for more than 71 percent of the total job effect in 2010. Of the nearly 14 thousand job effect in nondurable goods manufacturing, more than 5 thousand occurs in industrial chemicals, while an additional 2.5 thousand occurs in plastic materials and synthetics. Petroleum refining accounts for an additional 3 thousand job effect. Real private output is reduced by $28 billion below the no TNRCC SIP situation by 2010. The largest effect on output is for nondurables manufacturing, and is nearly $16 billion (in year 2000 prices) in 2010. Significant effects also occur in transportation, public utilities, services, mining, and construction, which together account for an $8 billion effect on output.

C. Results for Household Income and Wages

The costs passed on to local residents by businesses, along with less rapidly growing job opportunities, will reduce Houston area household well-being. The costs imposed on industry, consumers, and the government increase prices which result in a higher cost of living, and a lower real income (adjusted for inflation). By the year 2010, the local cost of living, as measured by the price index for personal consumption expenditures, increases by 0.32 percent. By reducing the purchasing power of money, this reduces the real value of earnings. Wage and salary income is $92.3 billion without the TNRCC SIP as compared to $87.5 billion with the TNRCC SIP in 2010, a 5.2 percent effect on wage and salary income. Real disposable per capita income, a measure of after-tax income per person, is reduced from $30,800 to $30,500, a reduction of 1.1 percent. See Table 5.2 for these impacts.

Table 5.2-TNRCC SIP Impacts[a] (8-County Houston Area, 2010)

Local Cost of Living	
Without Scenario	100
With Scenario	100.10
Difference	0.10
Percent Difference	0.10%
Wage and Salary Income (Billions of Dollars)	
Without Scenario	$92.30
With Scenario	$87.50
Difference	-$4.80
Percent Difference	-5.2%
Real Disposable Per Capita Income (Thousands of Dollars)	
Without Scenario	$30.8
With Scenario	$30.5
Difference	-$0.3
Percent Difference	-1.1%

[a]Year 2000 Prices

D. Construction Stimulus

During the initial years while measures are phased in, there will be an economic stimulus to the region associated with the implementation of the TNRCC SIP. This stimulus will largely be due to the fact that pollution control equipment will have to be designed, built, installed, and maintained. The result is that initially positive job impacts will be felt in sectors such as engineering services, construction, and manufacturing during the installation of the pollution control equipment. This gain is, however, temporary and will fade. By 2003 these job gains do not fully compensate for job losses experienced elsewhere in the regional economy. See Table 1 in the Executive Summary.

E. Unequal Effects Within Regions

Not all elements of the proposed TNRCC SIP impact the economy equally. Just a few of the control measures account for the largest portion of the effects imposed on the regional economy. These few measures drive up the cost of the TNRCC SIP while accounting for relatively meager NOx reductions. The mandate of 90% reduction in point source emissions of NOx from large industrial facilities, compares to the 75 to 80% NOx reductions mandated for these sources elsewhere in Texas and the country. Because of diminishing returns to measures armed at reducing NOx emissions, the last 10 to 15% reduction is by far the most costly.

The requirement to use special boutique diesel fuel in Texas results in great cost compared to the benefit in NOx reduction. The requirement to adopt federal engine standards earlier than other parts of the country and time of day limitations on construction activities also fall into this category of costly measures that result in relatively small NOx reductions.

The mandated 90% NOx reduction is especially damaging to the Houston economy because, independent of costs, it leaves little room for growth in such industries as refining and petrochemicals. As a result, the proposed TNRCC SIP actually entails a no-growth mandate for about one fourth of Houston's economic base.

Smaller firms will be unequally affected by the TNRCC SIP as compared to larger firms. Because smaller firms have less access to financial capital, they will have greater difficulty in achieving the TNRCC SIP mandates. Many of the TNRCC SIP controls require significant capital investments in equipment and services. For larger firms, the capital may come from cash reserves, loans, or other means of raising cash. Many small firms will not have access to such large sums within the four year phase in period required for many of the TNRCC SIP measures.

Some firms will encounter technological challenges that may make achievement within four years impossible. The present study optimistically assumes that NOx reductions to or near the 90% level will be possible for all point sources. Even if achieved, such a stringent NOx mandate will leave little room for many industries to grow through emissions trading or offset provisions. If each point source is forced to adhere to a 90% reduction, many firms will not be able to expand further, which could seriously affect the future of the Houston economy. Further, if every source is required to achieve a 90% reduction, the ability of some firms to more easily reduce NOx is ignored. A lower required reduction threshold allows for the ability to trade emissions between sources with lower marginal control costs and those with high marginal control costs.

VI. AN ALTERNATIVE TO THE TNRCC SIP

A. Description of the Alternative SIP

The impacts of an alternative SIP have been estimated. This alternative SIP would achieve nearly the same reduction in NOx emissions at a far lower cost. The alternative SIP should make it possible to achieve the mandated NOx standard, in view of slightly lowered required NOx reductions resulting from air quality measurement considerations not dealt within the present study. The choice of which measures to include or modify in the alternative SIP was based in part on considerations of cost effectiveness. Under this alternative plan, industrial factories and refineries that are point sources of pollution would reduce NOx emissions by 79%, instead of the 90% in the original TNRCC SIP, which would permit trading between high cost and low cost NOx point sources. In addition, a NOx reduction incentive measure is included, under which revenues from motorist fees and other levies would be used to pay sources to reduce their emissions. The phase-in time for the industries to reach compliance with the federal standards is increased from 4 to 7 years. The TNRCC SIP requirement to use boutique low-sulfur diesel fuel is dropped because of high cost and minimal improvement over the already-mandated federal fuel standards. The requirement for early adoption of federal low-emission engines is dropped for the same reasons. The bans on construction work and commercial lawn care, between 6:00 A.M. and noon during daylight savings time, are dropped. Finally, the proposed 55 mph speed limit is replaced with a 65 mph limit.

Table 6.1 Comparison of Annualized Costs (Millions of Dollars)[a]

	TNRCC SIP	Alternative SIP
Federal	$140	Same
State		
Point Source	$1,446	$994
NOx Reduction Incentives	$0	$17
Construction Work Day	$1,512	$0
Texas Cleaner Diesel Fuel	$75	$0
Lawn Service	$7	$0
Acc Tier 2/3	$341	$0
Speed Limit	$196	$62
Other State	$396	Same
Local	$126	Same
Totals	$4,239	$1,734

[a]Year 2000 Prices

The estimated costs of the two versions of the SIP are compared in Table 6.1. The cost of the alternative SIP is only 40 percent of the cost of the TNRCC SIP. The large reduction in costs, achieved at the price of a small reduction in NOx prevention with the alternative SIP, is due to the elimination of some of the least cost-effective measures in the TNRCC SIP. The cost estimates do not take account of gains from trading among point sources under the alternative SIP, which would make the costs of the alternative SIP even lower.

B. Cost Effectiveness of the Alternative SIP

Under the alternative SIP, the elimination of some of the most onerous NOx control measures and the modification of others greatly increases the cost effectiveness of the entire plan. See Table 6.2. The cost of each ton-per-day reduction for the plan as a whole is $12,582 under the TNRCC SIP, but only $6,011 under the alternative plan. The provision in the alternative SIP for a 79% reduction from the point sources, instead of the 90% in the TNRCC SIP, yields a cost effectiveness of $13,222 for each ton-per-day reduction, instead of $58,924 in the original. The measures banning construction activity before noon, mandating accelerated purchase of heavy diesel engines meeting the federal Tier 2/Tier 3 standards, and reducing NOx from point sources by 90%, were the three most costly measures per ton-per-day reduced. In the alternative SIP, the first two are eliminated and the last is modified to lower its costs per ton-per-day to less than a quarter of its value in the TNRCC plan. These three modifications, the elimination of the pre-noon lawn service equipment use restriction, and the change from a 55 mph to a 65 mph speed limit, are the only alterations made TNRCC plan to achieve this greater cost-effectiveness. The majority of measures are unaltered. The NOx reduction changes from 923 to 790 tons per day. In short, the alternative SIP achieves over 85% of the NOx reduction at just slightly over 40% of the costs.

Table 6.2-Cost Effectiveness of Alternate SIP

	Cost Effectiveness ($/Ton)[a]
Federal	2,306
State	
Point Source	13,222[b]
NOx Reduction Incentives	15,000
Inspection/Maintenance	3,400
Construction	0
Texas Cleaner Diesel Fuel	0
Lawn Service	0
Accelerated Tier 2/3	0
Air Conditioners	43,063
65 Mph Speed Limit	18,602
Diesel Emulsion Fuel	18,487
Vehicle Idling Restrictions	32,476
Other State	6,388
Local	15,572

[a]Year 2000 Prices

[b]Cost of an additional ton of NOx reduction at 90 percent control

C. Direct Impacts of the Alternative SIP on Businesses and Households

Under the alternative SIP, $1,466 million in annualized costs fall directly on Houston area businesses, which is 38% of the $3,805 million that impacts businesses in the TNRCC plan. $128 million fall on households, which is 44% of the $294 million that they bear in the TNRCC SIP. Table 6.3 gives the allocation of the costs of all the individual measures to businesses and households.

Table 6.3-Allocation of State and Local Costs to Businesses and Households Alternative SIP (Millions of Dollars)[a]

	Annualized 2007 Cost	Borne by Businesses	Borne by Households
State			
Point Source	$994	$994	$0
NOx Reduction Incentives	$17	$11	$6
Construction Work Day	$0	$0	$0
Texas Cleaner Diesel Fuel	$0	$0	$0
Lawn Service	$0	$0	$0
Accelerated Tier 2/3	$0	$0	$0
65 Mph Speed Limit	$62	$39	$23
Other State	$396	$320	$76
Local	$126	$102	$24
State & Local Totals	$1,594	$1,466	$128

[a]Year 2000 Prices

D. Comparison of Employment, Gross Regional Product, and Tax Receipts Under the TNRCC SIP and the Alternative SIP

The alternative plan results in less severe regional economic impacts than those that occur under the TNRCC SIP. Instead of 103,000 fewer jobs in 2010 than without NOx controls as occurs under the TNRCC SIP, the effect under the alternative SIP is approximately 38,000 in 2010. Over the remainder of the forecast period, the job effects increase but less than under the TNRCC SIP. By 2020, the alternative SIP sees a job effect of 43,000, as opposed to the 140,000 job effect that occurs in 2020 under the TNRCC SIP. A graphical comparison of job losses under the TNRCC SIP and the alternative SIP, as compared to no controls, can be found in Figure 2 presented earlier.

The Houston regional economy also suffers less of an effect on economic output under the alternative SIP than under the TNRCC SIP. See Table 2 in the Executive Summary. Under the alternative plan, the reduction in output, relative to no control, is smaller than under the TNRCC SIP by almost a factor of four. Instead of having $12.6 billion less in output (measured in year 2000 prices) in 2010 than without controls, as occurs under the TNRCC SIP, the figure is $3.5 billion for the alternative SIP. The effects that occur under the alternative SIP increase rather slightly throughout the remainder of the forecast period, but only reach $4.9 billion by 2020, as opposed to the $21 billion in 2020 under the TNRCC SIP.

As expected, the tax base effect is much smaller under the alternative plan than under the TNRCC SIP. Instead of $860 million dollars less in tax receipts in 2010 than without the TNRCC SIP, as occurs under the TNRCC SIP, the combined effect for state and local governments is $339 million in 2010. By 2020, the figure increases to $506 million, but is small in comparison to the $1.5 billion effect on tax receipts that occurs under the TNRCC SIP in 2020.

Table 6.4 gives summary comparisons showing the dramatic differences in effects on employment, regional product, real per capita income, direct costs to households and businesses, and tax revenues, under the TNRCC SIP and the alternative SIP.

Table 6.4-Summary Comparison TNRCC SIP Vs. Alternative SIP[a] (2010 Comparisons)

Category	Differences	% Reduction in SIP Effects
Employment Loss	-64,900	-62.92%
Regional Product Loss	-$9.15 Billion	-72.43%
Real Per Capita Income Loss	-$226	-69.10%
Direct Costs to Households	-$166 Million	-56.52%
Direct Costs to Businesses	-$2.3 Billion	-61.47%
Tax Revenues Loss	-$521 Million	-60.57%

[a]Year 2000 Prices

VII. SENSITIVITY ANALYSIS

The study was designed to give an accurate picture of the costs to the Houston economy in achieving the measures given in the TNRCC SIP, taking care not to overstate the effects. In order to do this, a conservative approach to estimating impacts was followed, in order to avoid overestimating negative effects on the regional economy.

To examine the sensitivity of the empirical results for the TNRCC SIP for alternative assumptions regarding direct impacts, we carried out a series of sensitivity simulations designed to determine how much the results would change under alternative sets of model input assumptions. In many cases the direct impacts of TNRCC SIP measures were so small that they did not merit detailed sensitivity analyses. On the other hand, there are three areas of possible disagreement regarding the magnitude of the direct impacts, which could have a sizeable impact upon the regional economy. These include the extent to which the TNRCC SIP would allow key industries to expand in the future; the magnitude of the total costs of meeting 90% point source reductions in NOx, and the magnitude of the social benefits accruing because of reductions in regional ozone levels. As a consequence, four sensitivity analyses were run. The first sensitivity simulation relaxed the assumptions on the growth constraints imposed on the petrochemical and refining industries. The second sensitivity simulation reduced the direct costs of the point source controls by 50 percent. The third sensitivity simulation reduced the direct costs of the household measures to zero. The fourth sensitivity simulation combines all three sensitivity assumptions together. These alternative assumptions are extremely conservative. It is felt that these sensitivity simulations indicate an absolute bottom line to the economic impact of the TNRCC SIP. Table 71compares the results for employment between the current TNRCC SIP and the four sensitivity simulations.

Table 7.1-Comparison of Employment Impacts
(Deviations from Baseline: Thousands of Persons)

	2001	2003	2005	2007	2010	2020
Current TNRCC SIP	0.4	-29.5	-84.4	-97.6	-103.2	-140.3
Sensitivity 1: Less Severe Caps	0.4	-29.5	-84.4	-89.5	-73.4	-54.9
Sensitivity 2: Reduced Point Source Control Costs	-7.1	-34.3	-78.4	-91.0	-96.8	-134.8
Sensitivity 3: 0 Household Costs	0.5	-28.5	-81.7	-93.6	-98.6	-133.4
Sensitivity 4: All Sensitivities Combined	-7.0	-33.3	-75.7	-78.9	-62.5	-42.5

The various changes in assumptions gave similar results. Using assumptions leading to less severe impacts, such as low estimates of control costs and more favorable effects on households, the least difference found for jobs under the TNRCC SIP as compared to no controls is still almost 62,500 in 2010 and 42,500 in 2020, as compared to the approximately 103,000 jobs in 2010 and 140,000 jobs in 2020 presented as the most likely results in the study.

On the other hand, it is possible that actual job losses could far exceed those presented in the study. For example, the TNRCC SIP calls for greater reductions in emissions than have been accomplished in other areas, including Southern California. In addition to the optimistic assumption already noted, for the 90% emission reductions, the results presented in the study as most likely use conservatively low estimates of costs. Higher cost estimates would give greater job losses, as would a variety of other possible negative effects not included in the study results.

VIII. CONCLUSION

Most of the $4.1 billion direct annual costs of the TNRCC SIP fall on businesses, reducing the competitiveness of Houston in national and world markets. The direct costs falling on households are only partly offset by benefits of ozone abatement. Wages necessary to attract people to live and work in Houston are raised, further reducing competitiveness. The effects of the direct costs on overall Houston area economic development and well being have been estimated using regional modeling. We estimate that the plan will cost 103 thousand jobs by 2010 and nearly 140 thousand jobs by 2020, with accompanying effects on gross regional product, tax revenues and overall well being. We also examined an alternative SIP plan having greatly reduced effects. The direct annual costs of the alternative SIP are $1.7 billion. The job losses are only 38 thousand by 2010 and 43 thousand by 2020.

At first glance the extent of dislocations of economic activity away from the Houston area due to the TNRCC SIP seem surprisingly large. During the first 10 years the Houston economy gives up nearly two years of economic growth. Some growth continues due to the strength of the non-energy and upstream energy portions of the region's economic base. However, the consequences of the TNRCC SIP are not merely diminished economic performance in Houston. The region has a clear and dominant comparative advantage in refining and petrochemical production. The shifting of production away from Houston to more expensive areas will act to raise nation-wide prices of fossil fuel products at a time of increasing worry about the adequacy of U.S. energy supplies. To the extent that production is shifted outside the United States, foreign energy dependence is increased.

A feature of the TNRCC SIP that is particularly costly to the Houston economy is the built-in no-growth bias against refining and petrochemical portions of the region's economic base. There is some argument whether mandated 90% NOx reduction by all major Houston point sources is achievable. However, serous argument is not heard that further reductions beyond the 90% goal could be accomplished. Given that the plan pushes industry to it technological limits, it is unlikely that many, if any firms, in the region will achieve levels in excess of the requirements and thus have excess emission credits to sell. As a consequence, new permits for expansion, especially in petrochemicals and refining, may be virtually impossible to obtain. Because these two sectors make up about one quarter of Houston's economic base, the resultant limitation on Houston's growth will remain substantial well into the future. Indeed, of the 140,000 job loss by 2020, nearly one third is attributable to this de facto no-growth feature of the TNRCC SIP, and this feature is primarily responsible for extending job losses beyond 2010.

On the other hand the impacts documented in the above chapters may not seem particularly surprising given the gap between annual costs of over $4 billion and estimated annual benefits of only $40 million. Due to the paucity of the benefits, the net hit on the Houston economy is large. Furthermore, the estimated impact documented in this study may actually be too conservative. Great care was taken in this study not to over-estimate direct costs. Thus, the disparity between Houston area costs and benefits may even be greater than what is reported above. For example, in the tables of this report, only local Houston costs are included. A neglected part of the direct costs reported here are those costs associated with the *spatial distortions*. Of course, if the marginal costs equaled the marginal benefits of controls in each locality, then industry would be given incentives to locate so as to achieve the greatest well being from the nation's resources. However, the potential for spatial distortions resulting from Houston area ozone controls is particularly great in view of the severity of Houston controls relative to controls in other areas of the country.

A consequence of imposition of high costs in the Houston area is to shift production to other areas less efficient in producing the nations chemical and energy supply. The nation will not only lose because economic activity is displaced from Houston to higher cost locations, but accompanying the shift in location of production will be an increase in pollution in the areas to which production is shifted. In other words, the TNRCC SIP will export pollution from Houston to other regions of the country. The increase in pollution in other areas is a further loss to the nation from excessive controls in Houston. Expanding the scope of the study to a national perspective, would require adding these costs of producing in other locations and the increase in pollution costs to the rest of the nation.

In this study, we have accepted the mandated federal ozone standard, eschewing concern with Rule One of environmental policy which requires controls to be carried to the point where the benefits justify the costs. The major focus of the present study has been on Rule Two of optimality requiring a policy to be carried out at as low a cost as feasible. The many measures in the TNRCC SIP exhibit substantially differing cost effectiveness, which is to say differing marginal costs per ton of NOx reduction. Redirection toward measures that have lower costs per ton of NOx reduction away from the higher cost measures would greatly reduce the burden of controlling ground level ozone.

One of the contributions of this study is to provide needed systematic quantification of the direct costs of the SIP measures recommended by TNRCC. If this information had been available when the plan was formulated, the unevenness of the measures would have been apparent. Choice of a plan with less deleterious effects would have been aided. This approach is followed in the alternative SIP examined in this study. It eliminates the least cost-effective measures and further reduces burdens by allowing an expanded role of market based incentives by which emissions are reduced by sources having the least costs. As compared to the TNRCC SIP, the alternative SIP accomplishes a 60 percent reduction in direct costs and in 2010 job losses. Job losses peak around 2010 and then gradually decline as the Houston economy adjusts to the new regulatory environment, whereas they continue to increase under TNRCC SIP..

The justification of the TNRCC SIP depends on answers to two questions: (1) Is *the degree* to which ozone is being reduced socially efficient? And (2) Is *the way* ozone is being reduced socially efficient? From the present analysis, the answer to both questions appears definitely to be no. However, the Houston area may have no choice other than to conform to the federal standard. The primary consideration in developing a regulatory plan becomes how to achieve the standard in the most cost effective way. Unfortunately the TNRCC plan fails this test as well. There are apt to be many alternative plans that are more cost effective than that proposed by the TNRCC. This study has given a demonstration of one such plan. This alternative plan, which still violates Rule One, entails lower costs to society. It more closely approximates Rule Two at the local level and, in view of its lower shortfall of benefits over costs at the local level, is accompanied by less cost-raising economic dislocation.

This study has assumed that the federal one hour standard for ozone can be achieved by a slightly lower reduction in NOx emissions under the alternative SIP than under the TNRCC SIP. At this writing, the precise reduction in tons per day that would meet the standard is not yet settled. Even if a reduction as great as proposed by TNRCC were to be required, the present study makes clear that the results could be achieved at greatly reduced direct costs and greatly reduced regional effects, as compared to the TNRCC proposal, by choosing acceptable measures with greater cost effectiveness and more reliance on market incentives than proposed by TNRCC.